Forecasting and Electric Demand Assessment Methodology

Eversource Energy

Advanced Forecasting and Modeling – Distribution System Planning

April 11th, 2023

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INTRODUCTION

Climate change is one of the most pressing issues of our time, and one of the main drivers of this global problem is the use of fossil fuels for energy. As a result, there is an urgent need for cleaner and more sustainable sources of energy. Clean energy, such as solar, wind, and hydropower, can help reduce greenhouse gas emissions and mitigate the effects of climate change. Furthermore, clean energy is becoming increasingly cost-effective and accessible, making it a viable alternative to fossil fuels. The transition to a clean energy future is not only necessary for the environment but also for the health and wellbeing of people and communities around the world.

All assumptions in this document are valid as of January 2023 and are based on the then most current policy objectives by state.

Electric vehicles (EVs) and air sourced heat pumps (ASHP) are the two dominant examples of clean energy technologies that can help reduce carbon impact. EVs are powered by electricity rather than fossil fuels, which makes them much cleaner to operate than traditional gasoline-powered vehicles. Heat pumps, on the other hand, are an energy-efficient alternative to traditional heating and cooling systems that directly use fossil fuels. By adopting these clean energy technologies, states in Eversource Energy (the Company) territory can make significant strides towards reducing our carbon footprint and mitigating the effects of climate change.

The transition to renewable generation resources like solar, the use of electric vehicles, and the introduction of heat pumps represent significant changes to the way we consume and produce energy. To fully realize the benefits of these technologies, a transformation of the power grid is necessary. The increased demand for charging electric vehicles requires infrastructure changes to support charging stations, and the widespread adoption of heat pumps requires upgrades to the distribution network to handle the increased load. In addition, the reliance on distributed generation from wind and solar increases the installed generation capacity on the distribution system by an order of magnitude in regions dissociated from most of the load growth. Figures 1a) and 1b) highlight the expected New England Peaks[1] over the next decades.

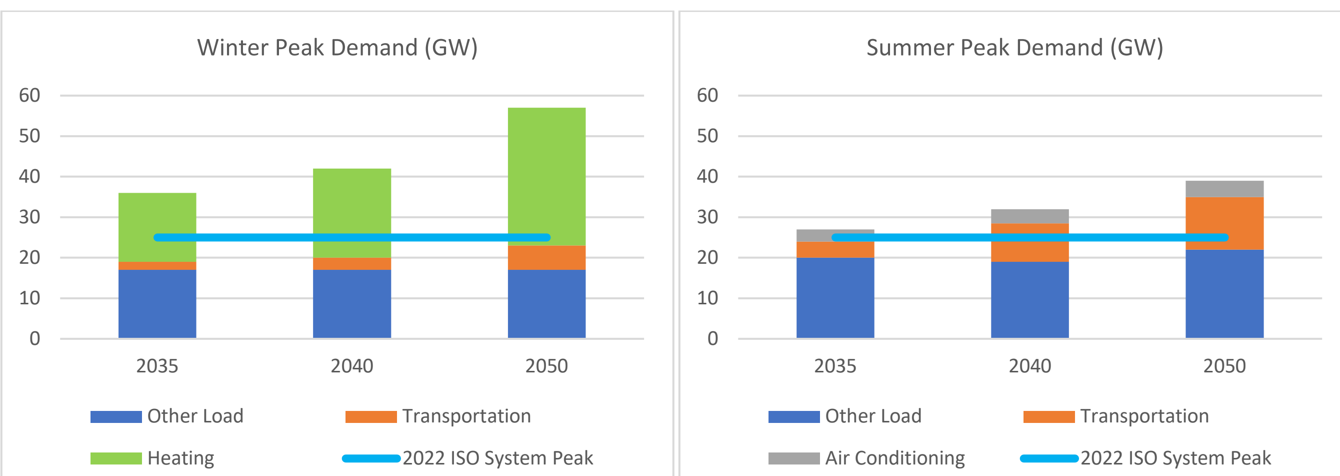

Figure 1: NE ISO System Peak Projections

[1] ISO New England. (2022). 2022 CELT Report: 2022-2031 Forecast Report of Capacity, Energy, Loads and Transmission. https://www.iso-ne.com/system-planning/system-plans-studies/celt

To address this generational challenge, Eversource has developed a first in the nation approach for forecasting and assessing electric demand to inform the Company's capital investments into its distribution and transmission system. This white paper describes Eversource Energy's (the 'Company') approach to forecasting electric demand across its service territory in Massachusetts, Connecticut, and New Hampshire. The objective of this document is to describe the efforts to date the Company has made and outline methodology and considerations for long-term forecasts. Eversource Energy has established a new "Advanced Forecasting and Modeling Team" within System Planning, to develop detailed long-term demand assessments and models to inform distribution and transmission infrastructure system needs and associated solutions.

The Company deploys a two – pronged approach to addressing the challenge of optimizing its capital investments; a 10-year forecast to determine prioritization in the company's capital plan, and a 2050 electric demand assessment which informs size and scale of investments prioritized in the 10-year forecast. The Company conducts the long-term electric demand assessments on a regional basis as the challenges of electrification far exceed any single substation or distribution circuit, and in most cases will require rebuilds of the power system from transmission downwards.

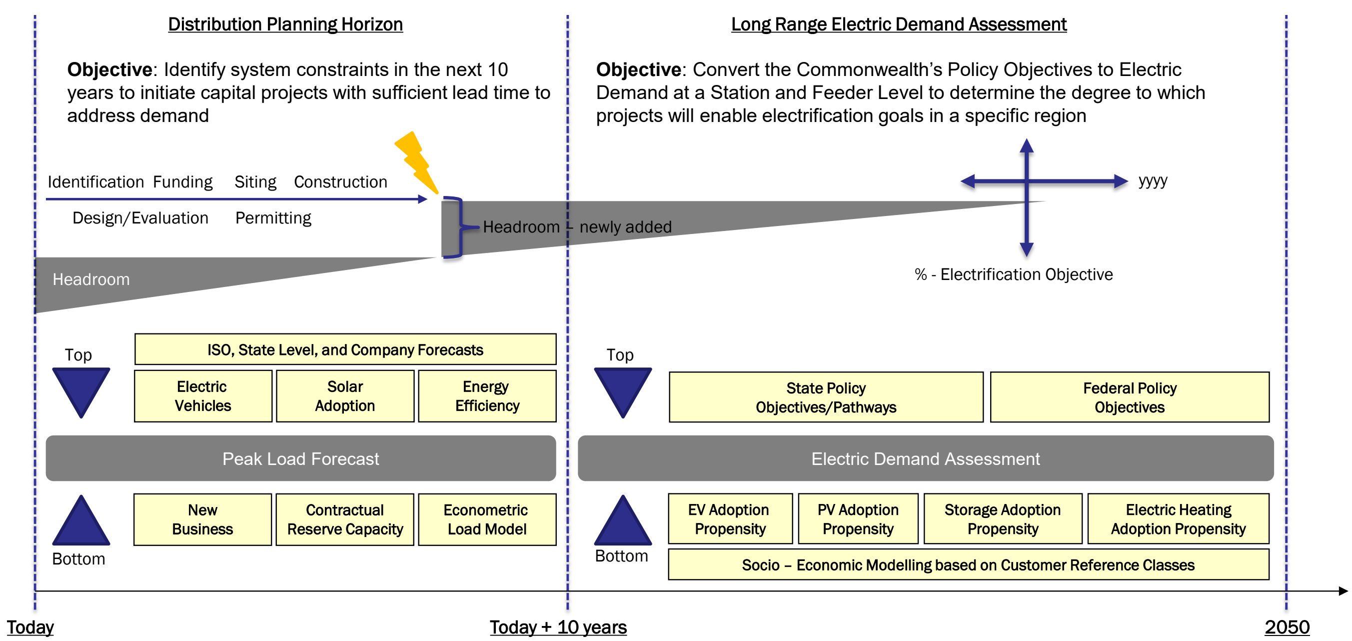

Figure 2: The Company's Approach to Forecasting and Electric Demand Assessment

REGULATORY OBJECTIVES

Regulatory goals play a crucial role in driving the transition to a clean energy future. As the world grapples with the challenges of climate change, governments must set ambitious targets for reducing carbon emissions and incentivizing the adoption of clean energy technologies. By setting regulatory goals, such as renewable energy standards, carbon pricing, and energy efficiency standards, policymakers can create a level playing field that encourages innovation and investment in clean energy. Additionally, regulatory goals can drive improvements in energy infrastructure, including the power grid and transportation networks, making it easier and more affordable for households and businesses to adopt clean energy technologies. Ultimately, a regulatory framework that supports the transition to a clean energy future will help mitigate the worst effects of climate change, create new economic opportunities, and foster a more sustainable and equitable society.

As New England states start to transition towards a decarbonized future, it is imperative to have an integrated planning process that accounts for state and federal policy objectives. Massachusetts leads this charge with the most comprehensive plan for electrification and a decarbonized future out of the three states in Eversource territory[2]. The Massachusetts plan addresses the concerted effort needed across the Northeast region, neighboring states, Canada, and beyond to ensure a clean energy future. Thus, the Commonwealth strategy is considered a model for the region; some assumptions may be applied for Connecticut and New Hampshire.

MASSACHUSETTS

Massachusetts' primary energy consumption is mainly driven by the state's transportation, residential, and commercial sectors. In 2020, the state's total primary energy consumption was about 1.6 quadrillion British thermal units (Btu), which was primarily composed of natural gas (46%), petroleum (25%), and electricity (23%). Renewable energy sources, including solar, wind, hydropower, and biomass, accounted for about 6% of the state's total energy consumption. In terms of end-use sectors, transportation was the largest energy consumer, accounting for 38% of the state's total energy consumption, followed by the residential sector (27%) and the commercial sector (21%). The industrial sector accounted for 14% of the state's energy consumption.

The Commonwealth developed a decarbonization roadmap ('2050 Roadmap') in 2020 describing eight pathways[3] to reach net zero emissions by 2050. An independent assessment for the pathways in the 2050 Roadmap was conducted as part of the Massachusetts Department of Public Utilities (or "D.P.U.") Docket 20-80, and the 'Future of gas' report[4] was released

[2] Commonwealth of Massachusetts. (2022). House Bill No. 5060: An Act Driving Clean Energy and Offshore Wind. https://malegislature.gov/Bills/192/H5060

[3] Massachusetts Executive Office of Energy and Environmental Affairs (EEA). (2020). Energy Pathways to Deep Decarbonization. https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/

[4] Energy Environmental Economics (E3). (2022). The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals: Technical Analysis of Decarbonization Pathways. https://thefutureofgas.com/content/downloads/2022-03-21/3.18.22%20-%20Independent%20Consultant%20Report%20-%20Decarbonization%20Pathways.pdf

in March 2022. The 2022 Massachusetts Clean Energy and Climate Plan ('CECP') for 2025 and 2030[5] further expands on the 2050 Roadmap and includes 5 clean heat pathways. All three pathways' studies (2050 Roadmap, CECP, and E3) analyze similar pathways and share analytical methods and data.

The DPU Future of gas ('E3') report is the primary resource used to inform the current Eversource analysis for transportation and building electrification. At the time of 2022 forecast development, the E3 report contained more updated data and assumptions compared to the 2050 Roadmap study. The 2050 Roadmap study solar generation projections are used in the Eversource analysis since the E3 report did not analyze solar generation, and the CECP study did not offer a breakdown between ground mounted and rooftop solar. Table 1 lists the pathways in the E3 report. Each pathway contains technology specific adoption targets necessary to achieve decarbonization goals.

The Company evaluates the impact of these top-down targets on the long-term electric demand assessment. The 'High Electrification' pathway is akin to the 'All Options' pathway in the 2050 Roadmap and the 'High Electrification' pathway in the 2022 CECP report. The current Eversource analysis prioritizes the 'All Options' (or 'High Electrification') scenario since it is the "baseline analysis - model [that] select[s] most economic resources to meet emissions limits using baseline cost assumptions" (Table ES1, Energy Pathways to Deep Decarbonization). For the purpose of this document, this scenario shall be described as the 'Baseline Scenario'. Table 1 on the following page describes the eight Massachusetts Energy Pathways analyzed in the DPU 20-80 Technical Analysis of Decarbonization Pathways report (2022). The eight scenarios were developed with stakeholder input to achieve the Commonwealth's net zero goals under varying assumptions for industrial and transportation electrification, building electrification and shell retrofits, the availability of networked geothermal, and makeup of the renewable gas supply. In all scenarios, electric vehicle penetration is assumed to be high.

Different pathways, such as the 'Hybrid Electrification' Pathway have the potential to reduce the impact on the electric power grid through reducing peak heating demand by retaining gas burning capabilities to supplement heating during the worst conditions of the year.

The Baseline Scenario calls for 26 GW of solar, 20 GW of wind power, and 3 GW of storage capacity by 2050 on the energy supply side. Figure 3 show the transition over time in these 3 sectors from 2020-2050[6]. Clean energy generation capacity increases significantly, with most of the growth from installed solar capacity. On the demand side, more than 5 million EVs (nearly all light duty vehicles) are expected to be on the road in 2050, including public transit buses and heavy-duty trucking. Building electrification, most notably for space heating, aims to reduce dependence on pipeline gas and liquid fuels. By 2050, building energy consumption is significantly reduced from 2020 levels, with the demand remaining mainly for electricity, which makes up 41 TBTU or nearly 50% of the total building heating demand.

[5] Massachusetts Executive Office of Energy and Environmental Affairs (EEA). (2022). Massachusetts Clean Energy and Climate Plan (CECP) for 2025 and 2030. https://www.mass.gov/doc/clean-energy-and-climate-plan-for-2025-and-2030

[6] Data from DPU 20-80 Technical Analysis of Decarbonization Pathways (2022) and MA CECP study (2022).

Figure 3a) Massachusetts Energy Generation

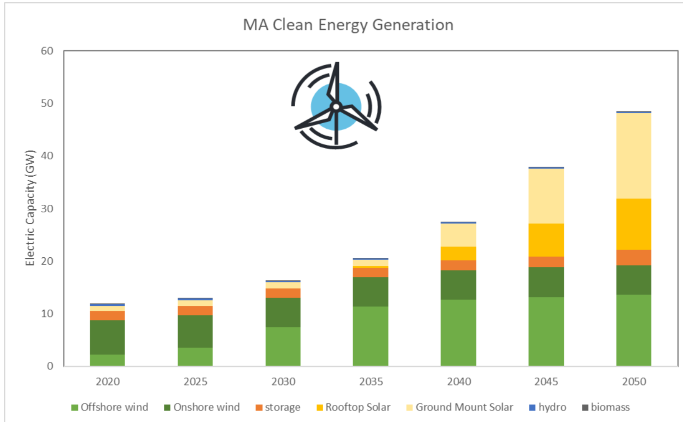

Figure 3b) Massachusetts Transportation Sector Objectives

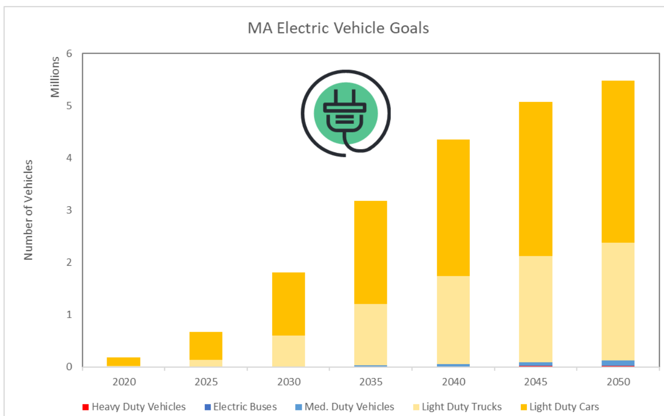

Figure 3c) Massachusetts Building Heating Composition

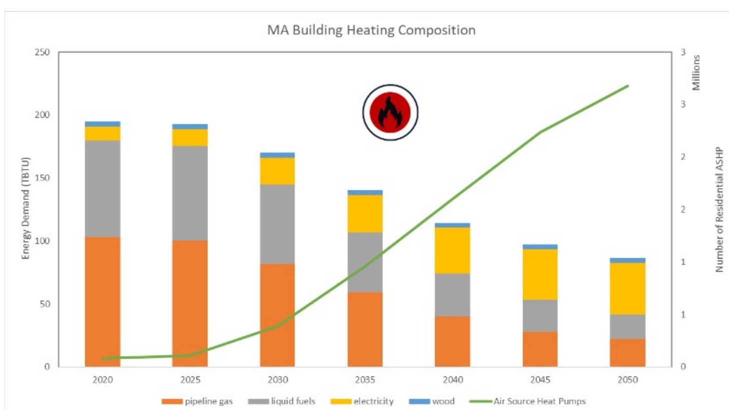

Figure 3: Massachusetts Energy Generation, Transportation, and Building Sector Objectives

Table 1 Massachusetts Energy Pathways – DPU Future of Gas Report[7]

Scenario	Summary narrative	Building Electrification	Industrial Electrification	Transportation Electrification	Networked Geothermal	Building Shell Retrofits	Renewable gas Supply[8]
High Electrification (**Baseline Scenario**)	(Roadmap study "All Options" Scenario) Building sector electrifies >90% of buildings, primarily through the adoption of Air Source Heat Pumps.	High	Medium	High	None	High	~5% by 2030, 35% by 2050
Low Electrification	(Roadmap study "Pipeline Gas" Scenario) Building sector electrifies 65% of buildings through the adoption of ASHPs; gas customer count declines by 40% compared to today.	Medium	Medium	High	None	High	~10% by 2030, 70% by 2050
Interim 2030 CECP	(2020 version of Interim 2030 CECP) Building sector electrifies at an accelerated pace following goals outlined in the Interim 2030 CECP.	High	Medium	High	None	High	~5% by 2030, 35% by 2050
Hybrid Electrification	>90% of buildings electrify through ASHPs paired with renewable gas back-up (hybrid heat pumps) that supply heating in cold hours of the year.	High	Medium	High	None	Low	~10% by 2030, 75% by 2050
Networked Geothermal	LDCs evolve their business model and convert +/-25% of the building sector to networked geothermal systems. Remaining gas customers use renewable gas as their main source of heating by 2050.	Medium	Medium	High	High (+/- 25% of building by 2050)	High	~10% by 2030, 80% by 2050
Targeted Electrification	>90% of buildings are electrified through a combination of technologies. LDC customers converting to ASHPs do so in a "targeted" approach.	High	Medium	High	None	High	~10% by 2030, 75% by 2050
Efficient Gas Equipment	Building sector largely adopts high-efficiency gas appliances supplied by a combination of renewable gases by 2050. The industrial sector converts to dedicated hydrogen pipelines.	Low	Low (converts to 100% hydrogen)	High	None	High	~15% by 2030, 100% by 2050
100% Gas Decommissioning	Building and industrial sectors fully electrify by 2050. +/- 25% of the building sector converts to networked geothermal systems.	High	High	High	High (+/- 25% of buildings by 2050)	High	0% by 2030, 0% by 2050

[7] Energy Environmental Economics (E3). (2022). The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals: Technical Analysis of Decarbonization Pathways. Table 2 and table 3. https://thefutureofgas.com/content/downloads/2022-03-21/3.18.22%20-%20Independent%20Consultant%20Report%20-%20Decarbonization%20Pathways.pdf).

[8] As % of Total Pipeline Gas Throughput

CONNECTICUT

Connecticut's primary energy consumption is mainly driven by the state's industrial, transportation, and residential sectors. In 2020, the state's total primary energy consumption was about 634 trillion British thermal units (Btu), which was primarily composed of petroleum (47%), natural gas (28%), and electricity (23%). Renewable energy sources, including hydroelectric power, solar, wind, and biomass, accounted for about 2% of the state's total energy consumption. In terms of the end-use sectors, transportation was the largest energy consumer, accounting for 43% of the state's total energy consumption, followed by the residential sector (24%), and the commercial sector (20%). The industrial sector accounted for 13% of the state's energy consumption[9].

Connecticut has implemented various policies to promote energy efficiency and renewable energy. The state's energy efficiency programs have helped to reduce energy consumption and costs for households and businesses. In addition, Connecticut has set a target of sourcing 40% of its electricity from renewable sources by 2030, and has implemented various policies, such as a renewable portfolio standard, to promote the use of renewable energy in the state. The state of Connecticut developed an integrated resource plan (IRP) in 2020 describing five scenarios to meet Regional Emissions Target; to reduce economy wide emissions 45% by 2030 and 80 percent by 2050. The goals require the state to achieve a 100% Zero Carbon Target (100% zero carbon electric supply) by 2040. The state's study applies two forecasts of electricity demand:

- Base case: existing electricity consumption trends continue based on the ISO-NE Capacity, Energy, Loads and Transmission (CELT) Forecast
- High Electrification case: rapid adoption of electric vehicles and building heating (triple from 2020 to 2040)

Table 2 provides an overview of the targets described in the state's plan, which includes policies and initiatives to promote renewable energy, energy efficiency, storage, and electrification.

Table 2 Connecticut Decarbonization Initiative Targets

Focus Area	Target
Energy Supply	40% electricity from renewable sources by 2030, 100% by 2040
Energy Efficiency	Reduce building energy consumption by 40% by 2030
Building Electrification	3 million air source heat pump (ASHP) installations (in all New England in the Electrification Case)
Transportation Electrification	500,000 EVs by 2030 60 % LDEV New Sales Penetration Rate in 2040[10]
Storage	Deploy additional 580 MW by 2030, 1000 MW by 2040

[9] U.S. Energy Information Administration. (2022). Connecticut State Profile and Energy Estimates/ https://www.eia.gov/state/?sid=CT#tabs-4

[10] Connecticut Department of Energy and Environmental Protection. (2020). Electric Vehicle Roadmap for Connecticut: A Policy Framework to Accelerate Electric Vehicle Adoption. https://portal.ct.gov/-/media/DEEP/air/mobile/EVConnecticut/2020-04-22---EV-Roadmap-for-Connecticut---FINAL.pdf

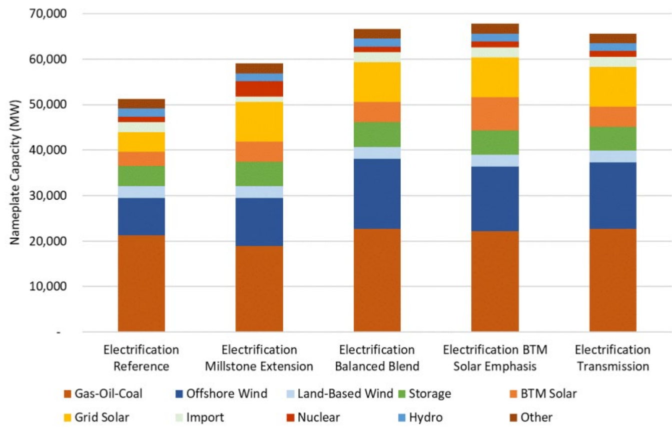

Figure 4: Connecticut 2040 Regional Capacity by Fuel Type, Electrification Load Scenarios[11]

The CT IRP provides the total energy plans for the state over the next decades; with a lag of more clear policy objectives for individual components, such as EV sales numbers, information provided in the Massachusetts analysis is used to inform technology specific adoption until such time Connecticut is able to issue similarly detailed policy objectives.

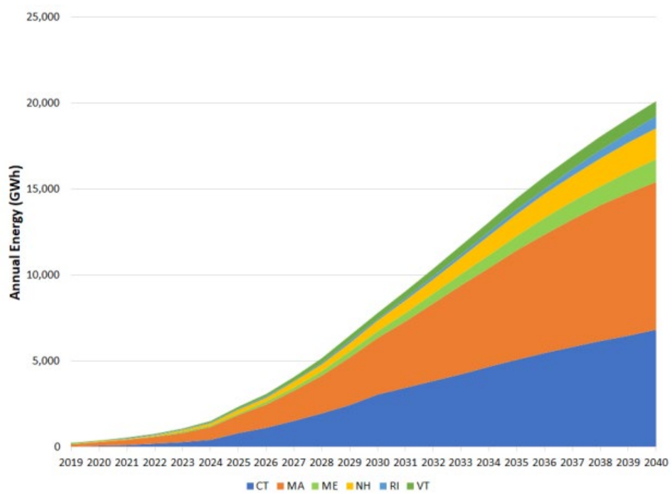

Figure 5: EV Projections by State, Electrification Load Scenario[12]

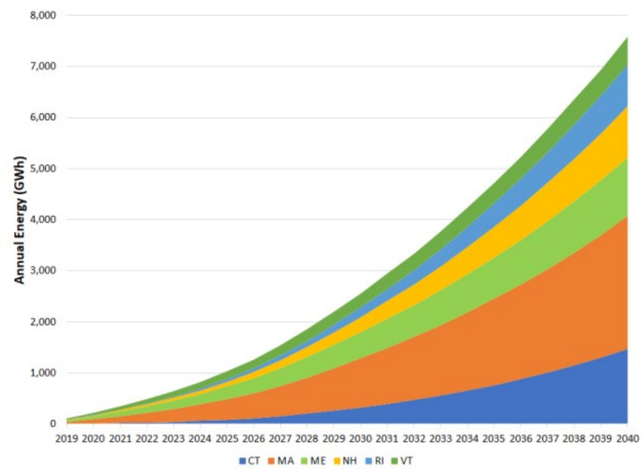

Figure 6: ASHP Projections by State, Electrification Load Scenario[13]

[11] Connecticut 2020 Integrated Resources Plan Appendix A3. Results. Figure 2.

[12] Connecticut 2020 Integrated Resources Plan Appendix A1. Factor Input. Figure 9.

[13] Connecticut 2020 Integrated Resources Plan Appendix A1. Factor Input. Figure 11.

NEW HAMPSHIRE

New Hampshire's primary energy consumption is primarily driven by the state's residential, commercial, and transportation sectors. In 2020, the state's total primary energy consumption was about 131 trillion British thermal units (Btu), which was primarily composed of petroleum (51%), natural gas (29%), and electricity (19%). Renewable energy sources, including biomass, hydropower, wind, and solar, accounted for about 1% of the state's total energy consumption. In terms of end-use sectors, the residential sector was the largest energy consumer, accounting for 34% of the state's total energy consumption, followed by the commercial sector (29%) and the transportation sector (25%). The industrial sector accounted for 12% of the state's energy consumption. [14]

Due to the lack of a detailed policy objective in New Hampshire, the Company solely relies on the development of 10-year forecasts to determine infrastructure needs in the service territory. Hereby, forecasts for the 10 -year horizon are modified and do not include a policy top-down component but are solely based on historical models and local data to determine adoption

New Hampshire issued the New Hampshire 10-Year State Energy Strategy in 2022. The report outlines 10 state energy policy goals oriented to better meet consumer needs[15][16]. Compared to other New England states, New Hampshire does not have a state policy to reduce greenhouse gas emissions to net zero by 2050. Eversource will not conduct a long-term forecast for 2050 driven by top-down regulatory goals due to the lack of a detailed policy objective. A 10-year forecast based on current policy initiatives, historical models, and local data will be used to inform infrastructure needs.

[14] U.S. Energy Information Administration. (2022). New Hampshire State Profile and Energy Estimates/ https://www.eia.gov/state/?sid=NH#tabs-4

[15] New Hampshire Department of Energy. (2022). New Hampshire 10-Year State Energy Strategy. https://www.energy.nh.gov/sites/g/files/ehbemt551/files/2022-07/2022-state-energy-strategy.pdf

[16] New Hampshire Saves. 2022-2023 New Hampshire Statewide Energy Efficiency Plan. (2022). https://www.puc.nh.gov/Regulatory/Docketbk/2020/20-092/LETTERS-MEMOS-TARIFFS/20-092_2022-03-01_NH_UTILITIES_NHSAVES-PLAN.PDF

FORECAST OVERVIEW

To enable a clean energy future, there is a shared vision for a gradual shift in focus for the Electric Distribution Companies ("EDCs") as all forms of energy consumption are supported by a single infrastructure. Understanding the transition of two main forms of energy delivery today (liquid fuels and pipeline gas) to the electric distribution infrastructure is key to understanding the future challenges and required investments.

To ensure that the electric distribution and transmission system does not inhibit New England's clean energy objectives, Eversource Energy has established a new "Advanced Forecasting and Modeling Team" group within System Planning. The Advanced Forecasting and Modeling Team serves all three states in which Eversource operates and provides detailed long-term demand assessments and models to inform distribution and transmission infrastructure system needs and associated solutions. The primary focus of the Advanced Modeling and Forecasting Team is to ensure that electric infrastructure is planned in alignment with emerging needs, prevailing trends and long-term state and federal policy objectives, goals, and mandates.

As New England and specifically the Commonwealth start transitioning towards a decarbonized future, it is imperative to have an integrated planning process between Distributed Energy Resources (DER) Planning, Distribution and Transmission Planning, Gas and Electric, that accounts for state and federal policy objectives. To ensure that the Commonwealth's Net Zero Emissions Future is accounted for in every large capital project the Company plans and constructs, the Advanced Forecasting and Modeling group Team is charged with translating policy objectives into Electric Demand Assessments – and in-turn to determine infrastructure capacity deficiencies where applicable and build or expand infrastructure solutions where necessary.

In that regard, the Company has identified three main drivers for the capacity need of the electric distribution infrastructure: (a) electrification of heating; (b) electrification of vehicles; and (c) distributed (primarily solar) generation. Both heating and vehicle electrification pose a significant challenge as these end-uses transition existing infrastructure capacities to the electric power system. Distributed solar generation transitions bulk generation assets to the distribution system while significantly increasing the overall amount of installed generation capacity. Between the increase in load and the dissemination of distributed generation the Company expects to see bifurcation of regions into two camps (See Figure 7), infrastructure driven almost exclusively by distributed generation, and infrastructure driven by load growth. Early trends and recent studies have shown that these will be, in most cases, geographically separate infrastructure sets as we see rural areas built to match generation and urban areas matching load growth.

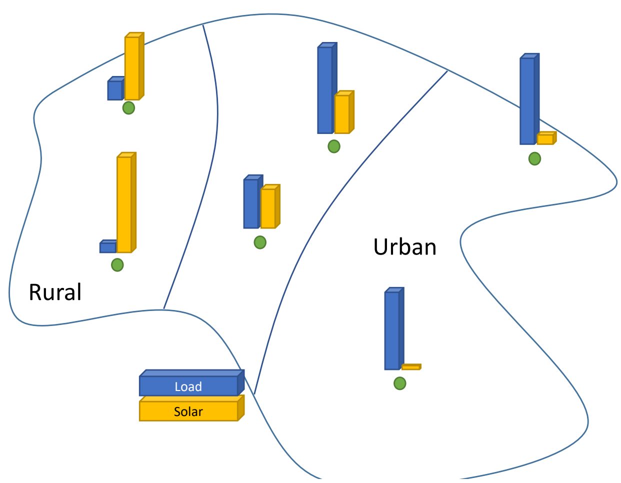

Figure 7: Schematic of Regional Load and Generation Discrepancy

Each state's climate impact and decarbonization objectives as it pertains to the long-term electric supply and demand forecasts are reviewed. Eversource interpretates the state's strategy as top down, exogenous pressures that will be applied to enable successful decarbonization. The realization of these decarbonization objectives means a certain level of adoption of key technologies, and a certain strain on the existing electric grid. Models are developed to assess the load impact of technology disruptions to the following sectors:

- Generation (primarily renewable resources such as solar, wind, and associated storage)
- Transportation (primarily electric vehicles)
- Buildings (primarily electric heating)

The forecast methodology addresses how Eversource seeks to assess the distribution of these load impacts on its system. The methodology does not address development of forecasts outside of the regulatory objectives, nor does it seek to validate these objectives. The long-term forecast does not change existing capital plans based on the Company's ten-year forecast. The long-term demand assessment, with a span of 30 years or until 2050, is intended to be dynamic rather than static, and informative rather than prescriptive to accommodate variables that will surely change across the coming decades.

APPROACHES TO FORECASTING

The Company develops a ten (10) year forecast ('forecast') as well as the 2035/2040/2045/2050 long term electrification demand assessment ('demand assessment'). Both approaches serve specific and dedicated purposes with one relying heavily on the other. Table 3 shows a comparison of the two types of forecasts.

Table 3 Overview of Eversource 10 year and long-term forecasts

	10-year Forecast	**Long Term Demand Assessment**
Time Period	10 years	To 2050
Approach	Analyzing historical trends and near-term projects	Translating top-down objectives to system level load impacts using bottom-up adoption models
Base load	weather normalized load, economic growth	weather normalized load, economic growth, climate impact
Contributions	Energy Efficiency Business growth Distributed Generation Electric vehicles Heating electrification	Energy Efficiency Business growth Distributed Generation Electric vehicles Heating electrification

TEN YEAR PLANNING FORECAST

The current 10-year forecast process begins by forecasting peak demand at the Eversource system level. The Eversource system level peak demand is forecasted using an econometric model that evaluates historical peak demand as a function of peak day weather conditions and the economy. The econometric model utilizes two different weather variables in forecasting summer peak demand: a three-day weighted temperature humidity index and cooling degree days. The forecast assumes typical weather conditions based off the most recent 10-year period. Eversource produces a "50/50" and a "90/10" peak demand forecast. The 50/50 forecast is based off normal 10-year weather and has a 50 percent chance of being exceeded. The 90/10 forecast is the extreme weather scenario that has a 10 percent chance of being exceeded. The economic history and forecast are provided by Moody's Analytics, an international economic consulting company.

Once the Eversource system level forecast is finalized, the bulk substation level forecasts are developed. Each bulk substation is forecasted using an econometric model that evaluates substation historical demand as a function of the Eversource system peak demand history and forecast. The substation econometric models measure how each substation performed relative to the Eversource system and then projects that relationship into the future. After a trend forecast is produced for each substation, the forecast is adjusted for energy efficiency, DER, large customer projects, or other material changes in load or supply. Company sponsored energy efficiency and behind-the-meter solar are proportionally applied to each substation in proportion to historical peak demand at each substation. Specifically identified large development projects or expected changes in system operations that could not otherwise be predicted by the econometric forecasts are applied to the affected substation. In addition, capacity reserves are held for customer owned co-generation units which hold Standby Delivery Service Contracts.

2050 ELECTRIFICATION DEMAND ASSESSMENT

There is no Electrification Demand Assessment for New Hampshire at the time this paper's development due to a lack of state policy

The 2050 long range electrification demand assessment begins with an evaluation of policy objectives for the respective region/state the assessment is created for. State and local government expectations are applied directly where available. The system level objectives often translate into total installed capacity (gigawatts of distributed generation), number of units of EVs and electric heaters, to assess magnitude of peak loads. Load profiles are developed using various data sets, for example, mobility data for EVs or standard heating profiles from industry studies. Eversource expects a transition to a winter peak between 2030 and 2040 due to heating electrification and will design its system to accommodate both summer and winter peaks. For the summer peak, local climate models will be used in studies to estimate frequency of and duration of extreme events – days requiring high cooling (90th and 95th percentile of the temperature – humidity index).

Once the policy objectives are translated into load and generation at a state level they are broken down by geographic region (typically at a zip code level) using a bottom-up adoption probability model which informs the placement of the policy driven resources across the system. This way, the long-term electrification demand assessment matches state and local policy objectives while ensuring a data driven approach to allocation of the resources on the system.

OBJECTIVES OF FORECASTING AND ELECTRIFICATION DEMAND ASSESSMENT IN PLANNING

The Company is, much like every regulated electric distribution company, constrained by its annual capital plan and must prioritize and optimize its capital plan investments in a prudent manner to ensure system capacity and reliability meet expectations. Capital planning optimization is a critical aspect of financial planning for regulated distribution utilities. Regulated utilities need to invest in infrastructure and equipment to ensure reliable and safe delivery of energy to their customers, and capital planning helps them to prioritize and optimize these investments. To optimize this capital plan, the Company must consider various factors, such as regulatory requirements, customer needs, financial constraints, and specifically state policy objectives.

Effective capital planning optimization requires careful analysis of the Company's asset base and the expected lifecycle of each asset, as well as forecasted system needs and long-term policy objectives to ensure effective deployment of the Company's capital. This analysis enables the Company to make informed decisions about when to invest in maintenance or replacement of existing assets and when to invest in new infrastructure. By optimizing its capital plan, the Company can enhance customer satisfaction, and achieve compliance with regulatory requirements and policy objectives. The Company can also increase its operational efficiency by minimizing the need for emergency repairs and reducing the risk of service disruptions.

With large capital infrastructure projects taking anywhere between 5-10 years, in extreme cases even longer to deploy, it is critical for the Company to forecast its peak electric loads. Without such forecasts, the Company would not be able to ensure that its infrastructure meets future needs and would consistently be behind its infrastructure build-out.

As shown in Figure 8, for the Company to initiate a capital project it must show need in the 10-year forecast. The Company will not initiate projects purely on a potential violation on the 2050 Electric Demand Assessment. Once a project is identified and moves to the design phase the Long-Term Electrification Demand Assessment is pulled in to support the design process and to ensure that infrastructure is built in a manner that ensures the system either has sufficient capacity for the long term or can easily be upgraded in a reliable manner to avoid inefficiencies. The Company evaluates traditional solutions, as well as non-wires alternatives (NWAs) as outlined in its NWA Framework in this manner.

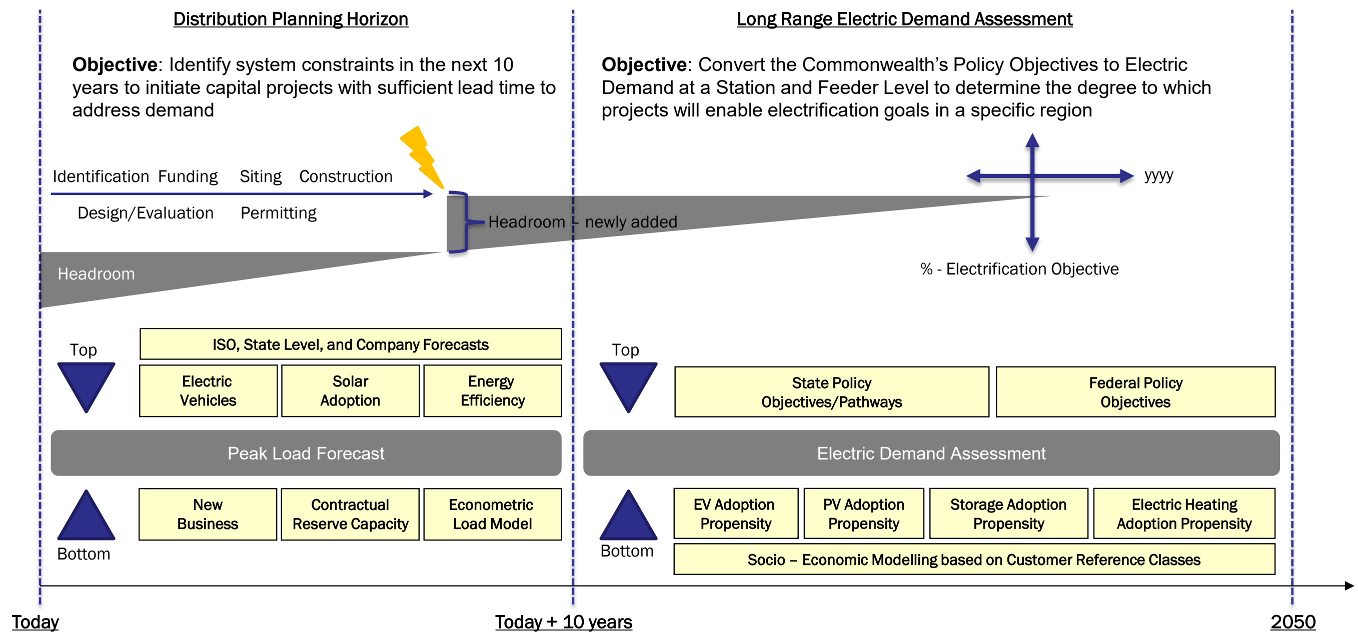

Figure 8: Forecasting Process Overview and Time Horizons

EVALUATION OF CAPITAL PROJECTS FOR THEIR LONG-TERM SUITABILITY

Each capital project initiated in the 10-year forecast horizon is evaluated for its ability to service the long-term electric demand of the region. This electric demand can be either generation or load driven. If projects can be designed to meet the long-term electric demand assessment (barring local constraints, such as siting limitations or technical system constraints), the Company will pursue a comprehensive solution. If the project face design limitations, then each project is evaluated to determine its contribution in enabling long-term electrification. Figure 9 shows the schematic overview of the evaluation of each region. When a station is triggered in the 10-year planning horizon, an electric demand assessment is conducted for the entire region to support a holistic solution design as the most effective solution to the constraint may not be the most straight forward (e.g., a station upgrade).

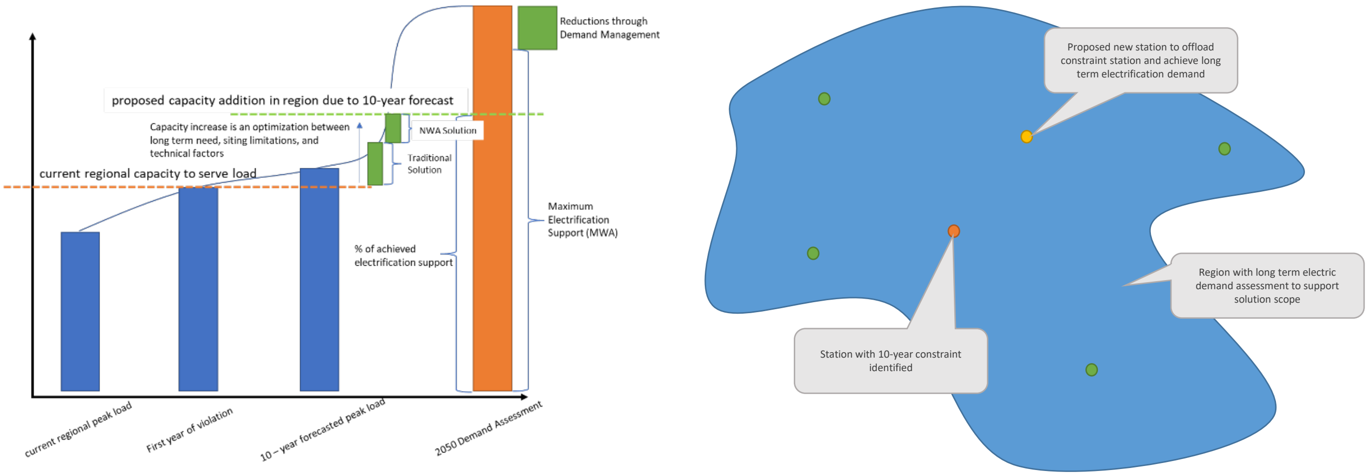

Figure 9: Evaluation of Projects to meet long term electric demand

TEN YEAR FORECAST

The 10-year forecast starts with a Base Load Forecast which represents the development of the current existing load without any additional contributions (or 'adders') considered. This Base Load Forecast, also commonly referred to as a 'Trend Forecast', is then adjusted by a set of components, such as potential impact of solar, energy efficiency, or electric vehicles, to ensure that fundamental changes in the load make up are accounted for by the Company.

The overall forecast is composed of three main categories: the underlying base load, generation, and load from electrification. The resulting distribution load shape is an aggregation of load shapes, the drivers and subcomponents of each category are described below:

Table 4 Forecast Components

Category	Driver	Component
Base load	Minimum required demand. Customer growth, economic outlook, weather	Minimum load Step loads (large customer loads) Energy efficiency Climate impact
Generation	Distributed generation	Solar Wind Storage
Electrification Load	Technology adoption	Electric vehicles Electric heating & cooling

Figure 10 displays a sample hourly graph of net load to show the various load forecast components. For simplicity only a typical day with 24 hours, a subset of the annual '8760' hourly forecast is shown. The example shows the timing imbalance between peak demand and solar power generation; a high amount of midday solar generation causes the net load demand to be negative.

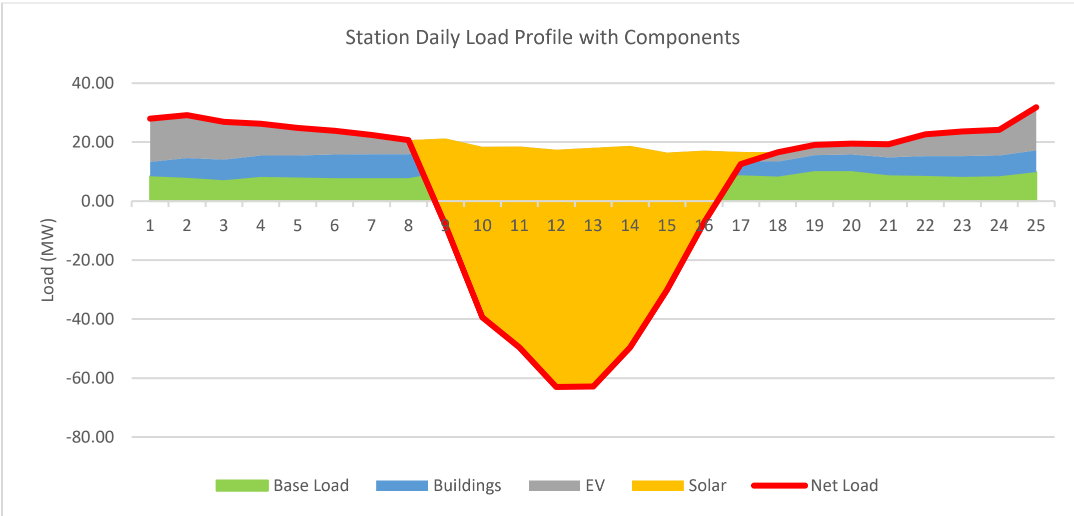

Figure 10 Sample 2050 Station Daily Load Profile with Components

BASE LOAD

The 'Base Load' for the 10-year Forecast represents the underlying load growth, or trend of the existing load to develop over the next 10 years. This process begins by forecasting the peak demand at the Eversource system level. The Eversource system level peak demand is forecasted using an econometric model that evaluates historical peak demand as a function of peak day weather conditions and the economy. The econometric model utilizes two different weather variables in forecasting summer peak demand: a three-day weighted temperature humidity index and cooling degree days. The forecast assumes normal weather conditions, which are based off the most recent 10-year period. Eversource produces a "50/50" and a "90/10" peak demand forecast. The 50/50 forecast is based off normal 10-year weather and has a 50 percent chance of being exceeded. The 90/10 forecast is the extreme weather scenario that has a 10 percent chance of being exceeded. The economic history and forecast are provided by Moody's Analytics, an international economic consulting company.

To ensure that the Company captures the true nature of the load growth, a handful of adjustments are applied to the peak load econometric model – the motivation and approach of each adjustment type is detailed in Table 5.

Table 5 Base Load Adjustments

Adjustment Type	Motivation	Approach
Existing DER	Existing DER, such as solar, can mask the actual load.	The Company backs out generation of every asset from measured peak load data. For that purpose, peak loads are recorded with SCADA readings and for peak days, generation is determined on an hourly interval basis to yield a gross station load
Switching Operations	Switching operations due to maintenance, storms, or other events can temporarily load systems to levels which can induce artificial peaks	Company Engineers review every peak day together with switching logs to ensure that recorded data represents load on that station
Weather Normalization	Weather anomalies might cause load to be higher, or lower, in a specific year and the load correlation to weather (temperature humidity index) must be considered	The Company correlates the past 10-year peaks to the temperature humidity index and generates a 90/10 peak load based on what constitutes the 90th percentile temperature humidity index over the last 30 years on a 3-day rolling basis

Once the Base Load Forecast is complete, additional load contributions from a variety of components are accounted for. Each of the components are predicted individually using historical or known data to inform technology adoption forecasts, which in turn direct the allocation of state level targets for MA and CT. In NH, the forecasts do not allocate using top-down state level targets (beyond the 10-year mark) but rather local trends and variables.

ADOPTION MODELS

The Company applies adoption models for a variety of forecasting approaches, such as ground mounted solar, electric vehicles, and heat pumps. Adoption probability refers to the likelihood that an entity will adopt a new technology (e.g., a customer's likelihood to purchase a new product, or a region's likelihood of adopting solar). It is an important concept in forecasting as understanding adoption probabilities can help businesses identify potential customers and predict demand. A variety of factors may influence adoption probabilities, including socioeconomic variables such as age, income, and education. Innovativeness, or the degree to which an individual is open to trying new products or services, may also be a predictor of adoption. Policy driven variables such as technology incentives, geographic variables such as proximity to infrastructure, and economic conditions may also influence adoption probabilities.

Where local municipal or city policies or ordinances significantly impact the adoption of certain technologies, the Company makes those adjustments on a case-by-case basis.

The Company utilizes, among other data analytics solutions, LoadSEER, a software application funded through the Company's Grid Modernization Program. LoadSEER's adoption probability modeling uses an agent-based forecast which is a type of forecasting model that simulates the behavior of individual agents within a system to predict future outcomes. In this model, agents are typically represented as autonomous entities that interact with one another based on a set of predefined rules or decision-making processes. The behavior of the agents is often based on historical data, and the model is designed to predict how agents will behave in the future based on this data. For example, an agent-based forecast for a stock market may simulate the behavior of individual traders, based on their past trading history, to predict future market trends.

Multiple variables are involved when forecasting future technology adoption and load impact, each come with their own uncertainties and add to the dynamic nature of the forecast. Changes in these dynamic factors may significantly impact or render some predictions obsolete. The long-term forecast is expected to be updated on an annual basis; drastic changes in variables may trigger updates to the forecast methodology. Data for key long term economic, policy, and technology variables will be monitored for update triggers and captured in a timely manner.

The Company utilizes, among other data analytics solutions, LoadSeer, a software application funded through the Company's Grid Modernization Program. LoadSeer's adoption modeling uses an agent-based forecast which is a type of forecasting model that simulates the behavior of individual agents within a system to predict future outcomes. In this model, agents are typically represented as autonomous entities that interact with one another based on a set of predefined rules or decision-making processes. The behavior of the agents is often based on historical data, and the model is designed to predict how agents will behave in the future based on this data.

Table 6 Dynamic Variables with high impact on forecast

Category	Dynamic Factors	Example of trigger (long term)
Economics	Incentives Taxes & Tariffs Capital costs Operating costs	Material changes in tax incentives for EV's Solar panel costs change significantly Interconnection costs for solar projects set at fixed price Rate re-design that materially influences adoption & operation of EVs, heat pumps
Policy	Technology restrictions Energy goals	ICE (internal combustion engine) vehicles restrictions Gas and fossil fuel building heating restrictions Net zero goal timelines change
Technology	Improvements in efficiency/load demand New technology breakthrough	Breakthrough in grid edge technologies, clean energy technologies

Metrics are needed to evaluate the efficacy of the forecasts, validate the forecast, and make sense of the forecasts. Because the forecasts are conducted using top-down regulatory targets and assumes that exogenous shocks will disrupt the 'business as usual' trends, it is important to note that deviation of the forecast from actual recorded values does not singularly invalidate the forecast. Ultimately, the common goal is to reach the net zero by 2050 goals, but the year-by-year projections may vary as a pathway to the goal is being established in the dynamic economic, policy, and technology environment. There is a feedback loop between the metrics and the forecast to optimize the forecast.

FORECAST COMPONENT: STEP LOADS

New Business Growth, known as Step Loads (MA) are large new customer load additions greater than 500 kW. Step loads can be attributed to one large customer or a group of customers in a similar area (e.g., large residential developments). Step loads are incorporated into the load forecast as known entities and are not forecasted using a predictive model. The step loads must be confirmed load additions that have been applied for by customers and approved by System Planning. Currently a standardized step load tracking process that will feed directly into forecast tools is being developed to track the additions across Massachusetts, and later to the entire Eversource territory. The step loads will be added to the overall load forecast based on the distribution feeder it will be located on.

The Company tracks all developments from its 5400+ national accounts and thousands of strategic accounts from early inception stage to final workorder for a new interconnection. As plans progress through certainty, each station is monitored for its total development and adjustments are made, based on the certainty of load being proposed. The Company tracks loads for summer peak contribution, winter peak contribution (electrification of heating), and electrification of transportation. Each load type has profiles the Company can assign to determine their actual impact on the system peak.

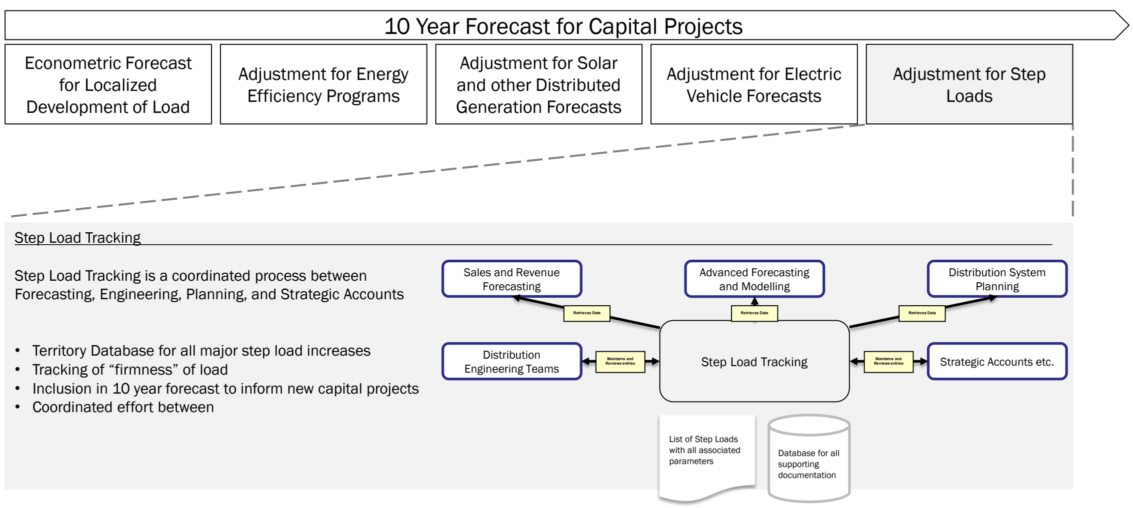

Figure 11: Step Load Tracking

FORECAST COMPONENT: ENERGY EFFICIENCY

Energy efficiency potential currently follows the existing energy efficiency plans in each respective state. In Massachusetts, assumptions follow the Energy Efficiency Advisory Council (EEAC) Three-Year Plan 2022-2024[17], a joint report from the state gas and electric utilities. In Connecticut, assumptions follow the 2022-2024 Energy Efficiency Plan. In New Hampshire, the assumptions follow the 2022-2023 New Hampshire Statewide Energy Efficiency Plan. For long term forecasts beyond the 10-

[17] Mass Save (2021). Massachusetts Joint State Wide Electric and Gas 2022-2024 Energy Efficiency Plan. https://ma-eeac.org/plans-updates

year planning horizon assumptions about energy efficiency potential are not incorporated. As there is a high level of uncertainty regarding implementation of energy efficiency programs and new technology, a conservative base case is applied in order to capture expected electric demand.

Naturally occurring energy efficiency is inherently captured in the Company’s econometric model as the model is based on the last 10 years of peak data, reflecting naturally occurring energy efficiency. This captures any energy efficiency in increased building standards, or efficiency gains through the natural replacement of equipment with more energy efficient versions.

FORECAST COMPONENT: ELECTRIC VEHICLES

Electric vehicles are included in the 10-year forecast with their coincident appearance at time of peak station load. Using a combination of top down and bottom-up statewide EV forecasts based on policy objectives are split between the bulk stations. The Company utilizes a travel model to determine when EV charging hits peak. The Travel Model uses advanced data analytics and GPS tracking data from cellular service and App providers to create travel profiles showing when, how many, and where vehicles terminate a trip. This then allows the creation of charging profiles for the company on a temporal and special resolution. One important consideration – this is done by season and day type (weekdays, Fridays, Weekend Days, and Holidays) to capture dynamics such as holiday travel on Cape Cod. The Company uses the same data vendor as the Massachusetts Department of Transportation (“MA-DOT”) to ensure a consistent data basis for all planning entities within the Commonwealth.

An Adoption Probability Model is deployed to determine which area will see the fastest adoption of electric vehicles. Adoption Probability Models uses socioeconomic data on customers, as well as policy information to derive which customers are most likely to adopt. The EV adoption rate models in Massachusetts are part of a Grid Modernization Project approved by the Department of Public Utilities (the “Department”) Grid Modernization Docket 21-69 in which the company is partnering with a wide variety of vendors to deploy advanced software solutions for the purpose of forecasting EV Adoption.

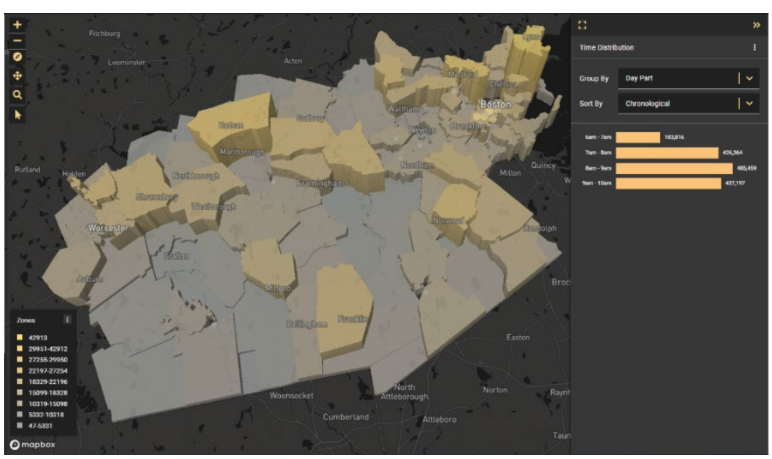

Figure 12: Representative visualization of vehicle arrival volumes during morning hours

FORECAST COMPONENT: HEAT PUMPS

Building energy consumption is primarily expended on space heating and cooling. Air conditioning currently drives the system summer peak, and a winter peak driven by heating electrification is expected to meet or exceed it between 2030 and 2040. Currently, air source heat pumps are the main heating technology that is the focus of building electrification. Eversource Energy has developed a model in Massachusetts to predict zip code level heat pump adoption using Eversource customer attributes and the company's Energy Efficiency heat pump program enrollment data.

In the next stages. the Company seeks to expand the analysis and gather more data on electric heating potential; the analysis is currently limited because the Company does not operate the gas infrastructure in many of its electric coverage areas, in addition many new heating installations are not reported to utilities. To accurately estimate adoption and consumption in a region will depend on whether Eversource has reliable data for that region, for its own customers and the region as a whole.

There are several components that make up the analysis:

Table 7 Heating Electrification Components

Heating Conversion	Electric Impact	Considerations
Electric to electric	Load offset from electric resistive heating to efficient heat pump	Energy Efficiency savings
Gas to electric	100% Load from new heat pumps	Estimating current natural gas consumption Estimating non displaceable gas consumption
Delivered fuels (oil, propane, wood, etc.) to electric	100% Load from new heat pumps	Regions with no reliable consumption information Estimating non displaceable consumption

The Company uses a-5°F design day to evaluate the peak load of heat pumps which face severe challenges during extreme cold snap conditions as the energy demand of buildings skyrockets and the efficiency of the heat pump plummets. The Company operates under the assumption that future heat pump fleets will not have resistive electric elements as those effectively double required system capacity and that air sourced heat pumps will be the dominate technology. The performance of heat pumps depends on the Coefficient of Power (COP) during peak conditions[18]. For air source (ASHP) and geothermal solutions, the Company assumes different performance during the coldest operating conditions. Use of a different underlying scenario could impact these assumptions.

During extreme cold conditions heat pumps will operate at design specifications; this means that heat pumps, when designed, are scaled to allow enough heating output during such a -5°F condition. This, however, also limits the heat pumps for any form of demand side management during these conditions as they will be running 24 hours a day to retain building core temperature and any demand management is equal to a lowering of building temperature.

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[18] Cadmus Group. (2022). Residential ccASHP Building Electrification Study, 2nd Advisory Committee Meeting. https://cadmusgroup.com/wp-content/uploads/2022/06/Residential-ccASHP-Building-Electrification-Study_Cadmus_Final_060322_Public.pdf.

FORECAST COMPONENT: DISTRIBUTED GENERATION & STORAGE

ROOFTOP SOLAR

Rooftop solar projects tend to be smaller in size, with higher residential penetration, therefore different variables are used to assess rooftop solar than ground mount solar. Currently, Eversource applies a system of regression models to predict rooftop solar adoption in Massachusetts. The tool is built on Eversource data including historical consumption and customer load profiles, electric utility rates as well as US census data. The model forecasts rooftop solar in a two-part process; annual solar deployment and regional level adoption. The annual solar deployment is determined based on historical trends, the number of potential adopters and top-level targets. Variables that are considered for solar deployment include installation costs, incentives and expected payback for customers. The regional level adoption considers geography specific (zip code) variables including land cover area, population density, proximity to other adopters and average age of homes.

The company is developing a forecast based on similar principles and data to predict areas of adoption in Connecticut and New Hampshire. In addition, Eversource will incorporate weather and irradiance data to forecast solar generation potential on an hour vs hour granularity. Solar, both rooftop and ground mounted, can offset the peak load in the forecast. Hereby, the installed capacity, as well as the forecasted capacity of solar are considered. The potential power from photovoltaic (PV) installations is modelled using solar irradiance models acquired from Clean Power Research. Using historical weather data to correlate relative irradiance to peak gross station load, the Company developed a probability model to adjust solar output at a 90/10 probability for overcast weather conditions during peak days. This reduces the modeled solar output for load planning purposes.

GROUND MOUNTED SOLAR

Ground mounted solar is expected to comprise 70% of installed solar capacity in Massachusetts by 2050, therefore it is important for identifying and enabling areas of high potential. Ground mount solar projects tend to be exclusively commercial initiatives in more remote areas and as such require a different approach to forecast compared to rooftop solar adoption. Eversource Energy has deployed a software platform that can:

a. Assist solar developers with utility interconnection, mapping, and parcel identification for ground mounted solar projects in Massachusetts, Connecticut, and New Hampshire.
b. Calculate the technically available land for solar and amount of generation potential from this land
c. Forecast the development of solar projects based on project economics

The annual ground mounted solar deployment is determined by state level projections (or historical data for NH), with adjustments in the near term for planned projects. Projects are forecasted to develop in order of high to low rate of return for the customer; the project and its required capacity is assigned to the associated substation if capacity is available. Three main factors affect development of ground mount solar projects: cost, infrastructure capacity, and land use constraints. Land use restrictions depend heavily on regulatory direction. Therefore, in the current forecast, all technically available land is assumed to be developable for solar and included in the forecast. The following scenarios and their assumptions address cost and capacity constraints.

Table 8 Ground mount solar scenarios

Scenario	Status	Assumption
Base Case	Current	No CIP fees at any station – developer project bears cost of all upgrades that is triggered Each substation that requires a capacity increase is enabled in 1 year Multiple upgrades allowed
Substation capacity constraint	Sensitivity	No CIP fees at any station – developer project bears cost of all upgrades that is triggered Each substation that requires a capacity increase is enabled in 1 year Limit to 1 - 2 upgrades
Shared upgrade costs	Sensitivity	Stations have associated CIP interconnection fee ($/kW), anticipated capacity upgrade size, and date of upgrade completion Upgrade cost 50:50 to rate payers: project
No infrastructure constraint	Sensitivity	Deployment driven purely by project economics All stations have enough hosting capacity
All scenarios	N/A	Parcels generate solar at 4 kW/ acre Parcels that are majority wetland and protected under state register are excluded in its entirety Parcels with existing solar are excluded in its entirety Parcels connect to distribution lines, not transmission

LONG TERM ELECTRIFICATION DEMAND ASSESSMENT

The Company's long term electrification demand assessment mirrors the state's clean energy objectives and translates policy objectives into a load and generation demand assessment. It looks at the years 2040 and 2050 to support the planning efforts of projects identified in the 10-year planning horizon. Electric demand assessments are often developed at a regional level to inform comprehensive solution development up to and including transmission design.

The long-term electrification demand assessment does not include an economic forecast (e.g., data from Moody's Analytics) as such predictions on a 20+ year time horizon are extremely vague. The Company assumes some economic growth will increase underlying load by including a continuation of the average CAGR (Compound annual growth rate) of the 10-year forecast. The same applies to the step load forecast.

For the 2035, 2040, and 2045 electrification demand assessments, the Company continues to utilize adoption probability models.

All other forecast components remain the same with the main difference being that in 2050 electrification is assumed to reach saturation, making adoption probability models obsolete thereafter. Therefore, the focus of the long-term electrification demand assessment lies on the modeling of climate impacts which are expected to drive significant change over the next decades, as well as customer behaviors. Figure 13 shows a schematic rendering of the concept with green representing the EV adoption probability, and grey the heating equivalent.

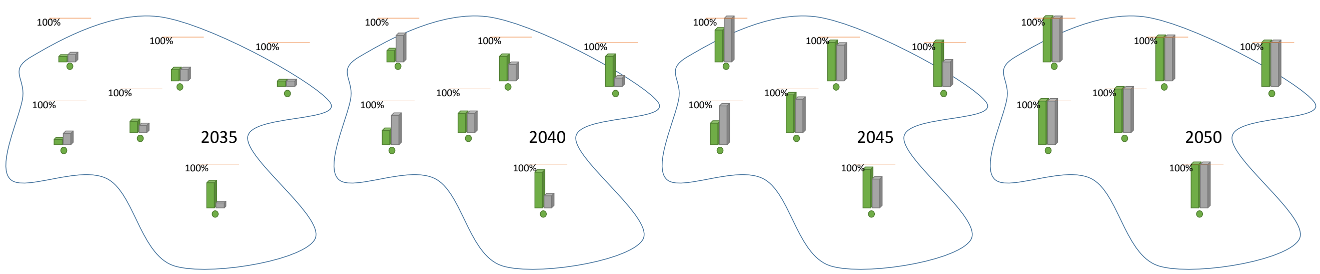

Figure 13: Schematic Overview of Adoption Probability

CLIMATE IMPACT

Fluctuations in climate are currently accounted for using a 30-year weather normalized load distribution with varying percentiles considering high, typical, and low historical weather trends. Climate impact in the form of new temperature extremes, changes to humidity and precipitation is not directly incorporated in the current forecast. Eversource is in the process of conducting a climate impact study and the results of the analysis will be applied in the long-term base load profile. The Company is using result of a Climate Impact Study conducted for the Company by ICF which will show the 95th and 90th percentile of hottest/coldest day per decade using the Temperature/Humidity Index for both the hottest and coldest days, every 5 years from 2030 to 2050, as well as:

- Number of 1-day events at 90th and 95th temperature (humidity) value
- Number of 2-day consecutive events at or above 90th and 95th temperature (humidity) value
- Number of 3-day consecutive events at or above 90th and 95th temperature (humidity) value
- Longest consecutive event at or above 90th and 95th percentile

Using historically weather normalized load with a clear understanding of the load change relative to ambient temperature and humidity, the Company can predict load changes based on climate change, both for cooling and heating events.