Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future

Executive Summary

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Jointly prepared by:

Energy+Environmental Economics

ENERGY FUTURES INITIATIVE

Project Team

This report was produced in collaboration between E3 and EFI and sponsored by Calpine Corporation. While Calpine provided input and perspectives regarding the study scope and analysis, all decisions regarding the analysis were made by E3 and EFI. Thus, this report solely reflects the research, analysis, and conclusions of the E3 and EFI study authors.

Energy and Environmental Economics, Inc. (E3) is a leading economic consultancy focused on the clean energy transition. E3's analysis is utilized by the utilities, regulators, developers, and advocates that are writing the script for the emerging clean energy transition in leading-edge jurisdictions such as California, New York, Hawaii and elsewhere. E3 has offices in San Francisco, Boston, New York, Calgary, and Raleigh.

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The Energy Futures Initiative, Inc. (EFI) is a nonprofit clean energy think tank dedicated to harnessing the power of innovation–both in technology and policy–to create clean energy jobs, grow economies, enhance national and global energy security, and address the imperatives of climate change. EFI was founded in Washington, DC by former Energy Secretary Ernest Moniz. The EFI team and its global network of experts provides policymakers, industry leaders, NGOs and other leaders with analytically based, unbiased policy options to advance a cleaner, safer, more affordable and more secure energy future. The majority of project funding is derived from charitable and educational nonprofit institutions. EFI maintains editorial independence from its public and private sponsors.

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The report authors greatly benefited from the advice and feedback of an Advisory Group comprising a diverse group of stakeholders with relevant expertise for this project and chaired by former energy secretary Ernest Moniz. Participation on the Advisory Group does not imply endorsement of any of the report's conclusions.

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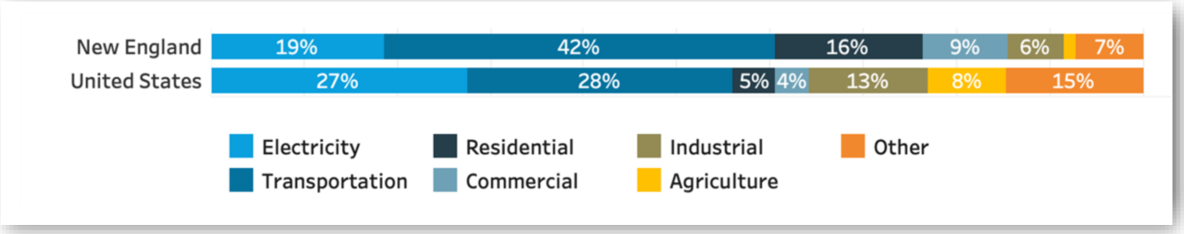
The six New England states have adopted economy-wide greenhouse gas (GHG) reduction targets of at least 80% economy-wide emissions reductions by midcentury, with Massachusetts recently adopting a net-zero commitment. The electricity system will play a key role in achieving these targets through near-complete decarbonization of electricity supply and supporting the electrification of transportation, buildings, and industry. To date, there has been limited research on how the New England electricity system can reliably accommodate this dual challenge of growing electricity demand—increasingly characterized by peak winter heating demand—and reducing emissions to nearly zero. This study shows that cost-effectively meeting this dual challenge will involve the addition of large amounts of wind, solar, and battery storage resources, complemented by firm capacity to provide generation during extended periods of low wind and solar availability. Firm capacity includes natural gas power plants, nuclear, hydrogen generation, or other yet-to-be commercialized options such as long-duration storage. Achieving carbon goals with natural gas generation will require operating natural gas power plants at suitably low capacity factors, capturing their emissions, and/or utilizing low/zero-carbon fuels such as hydrogen.

E3 and EFI conducted this study to fill this research gap by evaluating net-zero economy-wide decarbonization pathways that meet New England's long-term goals while maintaining electric system reliability. Reliable electricity supplies are critical to the functioning of the modern economy and for the health and safety of people everywhere. This will increasingly be true in an electrified future in which New Englanders rely at least in part on electricity for heating and mobility on the coldest winter days. At the same time, decarbonizing the electricity system will require New England to deploy significant quantities of wind, solar, and energy storage resources. While these intermittent and/or energy-limited resources can make significant contributions to reliable electric system operations, numerous studies in other regions have demonstrated that complementary resources will continue to be needed to provide essential grid services and to generate electricity during extended periods of low wind and solar generation. This study assesses in detail the resources needed to maintain reliable electric service in a New England electricity system with high penetrations of renewable energy resources.

New England's GHG emissions in 2016 (the latest year with published estimates for all states) equaled 170 million metric tons of CO_2-equivalent (MMT CO_2e), roughly 3% of the U.S. total. Massachusetts accounts for roughly 44% of total New England emissions, primarily due to its larger population. Every state besides Vermont has seen gross emissions reductions since 1990, aided by the power sector transition from coal to natural gas. In 2017, all six New England states had lower per-capita energy consumption than the national average, with Rhode Island having the lowest in the country.[1] Figure ES-1 provides a comparison of 2016 emissions profiles for New England and the United States. Transportation is the largest source of carbon emissions in New England (42%) while electricity accounts for approximately 20%. New England will not be able to attain its GHG reduction goals with an exclusive focus on electricity production; it will be necessary to implement aggressive decarbonization on an economy-wide basis.

Figure ES-1. 2016 Greenhouse Gas Emissions Profile of New England and United States



Notes: Other includes waste, non-combustion, and industrial processes and product use (IPPU). Transportation, electrical generation, building heat, and industry account for nearly all of New England's emissions. Source: EIA, 2016; state emissions inventories, 2016.

New England's unique economy, resource availability, and geography will shape its path to decarbonization. The proportion of emissions attributable to transportation is higher than the national average, while the emissions from industrial sources are lower. Fossil fuel use for residential and commercial heat contributes a quarter of New England's emissions, and New England is the only region in the country where oil is the most common heating fuel. A successful clean energy transition will require sector-specific solutions that navigate a thicket of difficult issues related to planning, financing and siting of electricity transmission and other new energy infrastructure, while at the same time protecting environmentally-sensitive lands, preserving natural landscapes and alleviating the environmental burden on disadvantaged communities.

New England's electricity supply is already less carbon-intensive than much of the rest of the country. Natural gas fuels 40% of the region's electricity generation today, and its displacement of oil and coal over the past decades has contributed to halving power sector emissions since 2005. Nuclear generation is currently New England's largest source of carbon-free power, producing over seven times as much electricity as all the region's wind and solar combined. Prospectively, solar represents a relatively low-cost source of clean electricity in New England, despite capacity factors roughly half of those in the Southwestern United States. Solar can be complemented by high-quality offshore wind resources that are available in significant quantities, and New England states are already in the process of procuring significant amounts of offshore wind through long-term contracts. As prices fall, batteries also provide a useful complementary resource by shifting generation.

To map out plausible pathways toward economy-wide deep decarbonization in New England, E3 and EFI assess two "bookend" scenarios that achieve net-zero GHG emissions reductions by midcentury. The two scenarios are distinguished by their assumptions about the level of electrification in the building and transportation sectors as well as the availability of low-carbon fuels for transportation, buildings and industry. The results of this economy-wide analysis are used to develop corresponding electricity resource portfolios that meet New England's greenhouse gas and reliability needs, including new requirements imposed by electrification. Estimates of effective capacity needed to ensure resource adequacy are derived, as well as contributions toward those needs from renewable resources and batteries, across thousands of simulations based on 40 years of weather conditions. The computer modeling is complemented by a systematic assessment and prioritization of emerging innovations that could support the region's carbon neutral emissions goals and address the reliability challenge.

More specifically, this study evaluates a series of study questions in New England, including:

+ What decarbonization technologies and strategies are most likely to be successful in New England given its geography, weather, policy, economics, and other regional considerations?
+ How much must electricity sector emissions fall by 2050 to support economy-wide net-zero emissions goals?
+ How much additional electric load will materialize due to electrification of end-uses between now and 2050?
+ What is the cost-optimal electricity resource mix, subject to reasonable limitations on resource availability, to meet New England's energy and resource adequacy needs through 2050 while achieving economy-wide GHG goals?
+ What roles do various electricity supply resources play in achieving resource adequacy?
+ What are critical areas for innovation breakthroughs that can contribute to deep decarbonization and maintaining electric reliability?

Key Findings

The following key findings provide insight into how New England can provide affordable and reliable electric power under future scenarios that achieve net-zero economy-wide GHG emissions by 2050.

1. **Decarbonizing New England requires transformational change in all energy end-use sectors**. New England has long been an environmental policy leader, with progress in recent decades aided by the region's transition from oil and coal to natural gas. Today, direct energy use for transportation and buildings makes up two-thirds of the region's emissions. Key strategies for mitigating economy-wide greenhouse gas emissions are: (1) aggressive deployment of energy efficiency; (2) widespread electrification of end uses in the building, transportation and industrial sectors; (3) development of low-carbon fuels; and (4) deep decarbonization of electricity supplies.

2. **Electricity demand will increase significantly in New England over the next three decades under the net-zero scenarios studied.** In the two primary bookend scenarios, annual electricity demand grows by 70 to 110 Terawatt-hours (TWh), roughly 60 to 90% from today. Electric peak demand reaches 42 to 51 Gigawatts (GW) as the system shifts from summer to winter peaking in the 2030s. This demand growth is primarily due to electrification of transportation, building and industrial end-uses that currently rely on direct combustion of fossil fuels. This large increase in electricity demand occurs despite significant energy efficiency included in the scenarios. Absent energy efficiency, demand growth would be even higher.

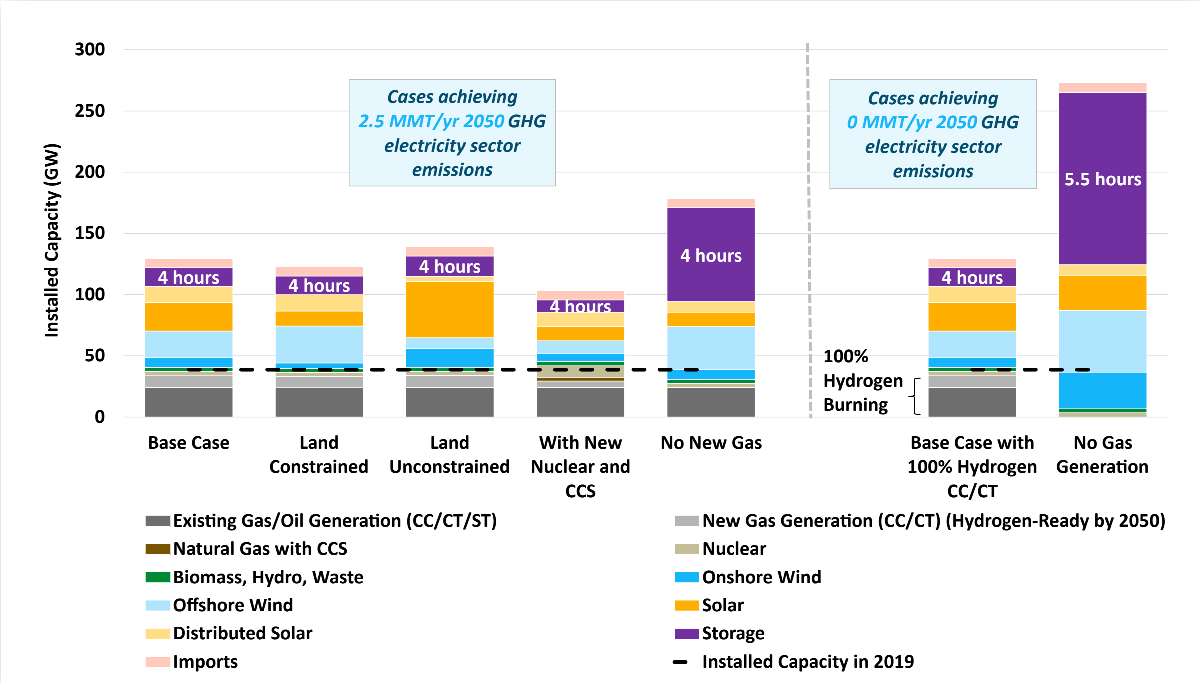
3. **Renewable electricity generation will play a major role in providing zero-carbon energy to the region.** The Base Case scenarios select a diverse mix of 47 to 64 GW of new renewable generation capacity by 2050, including land-based solar and wind, offshore wind, and distributed solar, along with 3.5 GW of incremental Canadian hydro. Renewable generation is needed to displace fossil fuel generation in the electricity system and to provide zero-carbon energy for vehicles, buildings and industry. Greenfield development will be required to reach adequate scale, even if opportunities to develop brownfield sites, rooftops, and marginal lands are maximized, notwithstanding the region's limited availability of land for renewable energy development. New England's constrained geography, slow pace of electric transmission planning, and historical difficulty siting new infrastructure are significant challenges that the region must overcome.

4. **A cost-effective, reliable, and decarbonized grid requires firm generating capacity.** Firm capacity is capacity that can provide electricity on demand and operate for as long as needed; today, natural gas and nuclear generation are the primary sources of firm capacity in the region. While today's renewable generation and battery storage technologies will play large roles in the future New England system, relying on these resources alone would require very large quantities of renewables and storage (Figure ES-2) and would be extremely costly (Figure ES-3). In practice, as much as 46 GW of firm capacity could be needed in 2050 to ensure resource adequacy; our Base Case includes about 34 GW of gas generation, 3.5 GW of nuclear, 8 GW of imports and 1 GW of biomass and waste (under High Electrification loads). Significant gas capacity is retained even though the gas plants operate far fewer hours and contribute less energy (and emissions) to the region than today. New resources may be developed and deployed in the future to provide low-carbon firm capacity such as advanced nuclear, natural gas plants with carbon capture and sequestration (CCS), long duration energy storage, or generation from carbon-neutral fuels such as hydrogen. These resources would require significant investments in supporting infrastructure; for example, natural gas with CCS or hydrogen would require dedicated pipeline infrastructure connecting New England to regions with suitable geology for carbon sequestration or hydrogen storage. Until one or more of these technologies is widely and commercially available, natural gas generation is the most cost-effective source of firm capacity, and some reliance on gas generation for resource adequacy is consistent with achieving a 95% carbon-free electricity grid in 2050 as long as the generation operates at a suitably low capacity factor.

5. **A broader range of technology choices lowers costs and technology risks.** The availability of low-carbon firm generation technologies – such as advanced nuclear or natural gas with CCS – could provide significant cost savings and reduce the pressure of renewable development on New England's lands and coastal waters. The 2050 incremental cost to achieve an electricity sector target of 2.5 million metric tonnes (MMT CO_2e) relative to a Reference Case (50% renewables) falls roughly in half when natural gas with CCS is made available, assuming technology cost declines are achieved. When advanced nuclear technology is also available at scale, the cost of decarbonization declines further (Figure ES-3). In addition to reducing direct costs, a portfolio approach for ensuring the availability of low-carbon firm generation resources mitigates the risks associated with the possibility

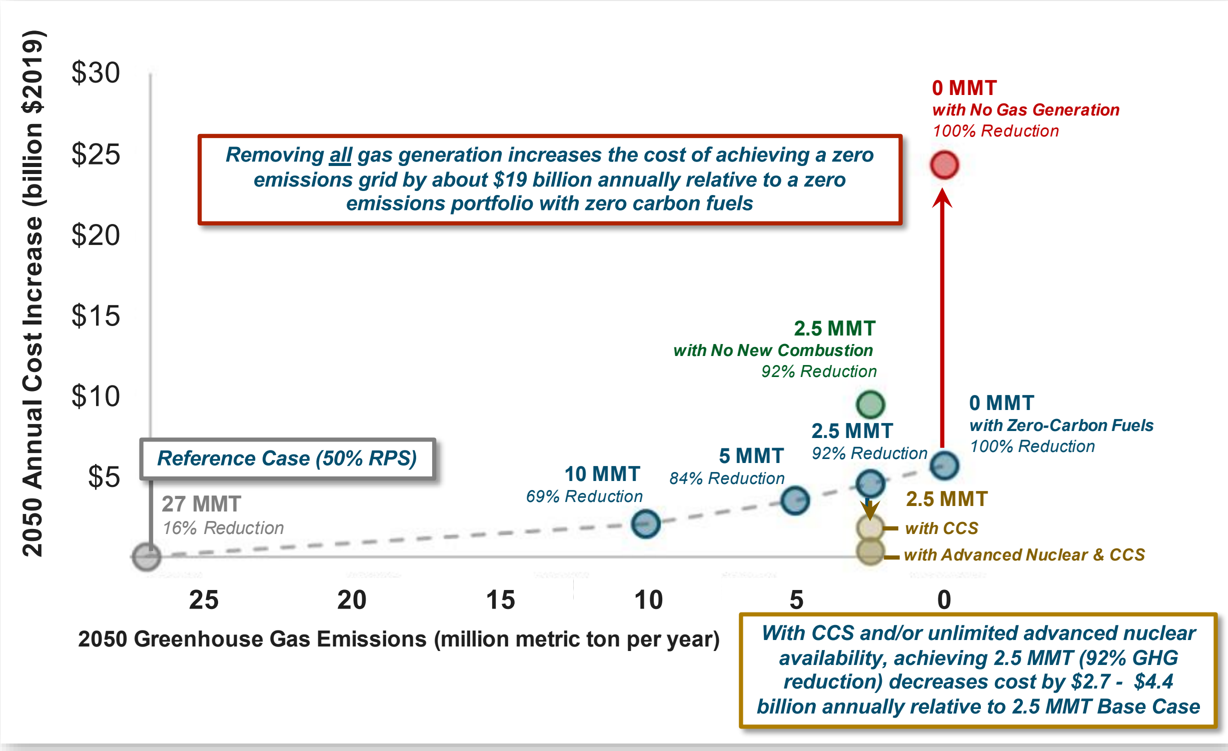
that one or more technology options does not materialize as expected. Issues including uncertain innovation time horizons, difficulty building supporting infrastructure, incompatibility with other policy goals, or alignment with the decisions of neighboring regions may limit the role of some technologies in helping meet New England's climate goals.

Figure ES-2. Installed Capacity Across Base Case and Key Sensitivities in 2050 (High Electrification)



Notes: In the 0 MMT Base Case, all existing and new gas units, when dispatched, burn 100% hydrogen in 2050. In 2.5 MMT model runs, hydrogen is available as a drop-in fuel and blended in at varying percentages with natural gas in order to meet the 2.5 MMT electricity sector target in 2050 only. The existing fossil capacity includes units burning natural gas, oil or coal today in combustion turbines (CT), combined cycles (CC) or steam turbines (ST), but only natural gas and hydrogen are burned by 2050. Our Base Case assumed modest land use constraints for renewable energy resources, nuclear capacity limited to about 3.5 GW, and hydrogen blending available when the model finds it economic to meet resource needs subject to constraints. New natural gas units can be equipped with Carbon Capture and Storage (CCS) in one of the sensitivities, but gas with CCS is not available in the Base Case. Annotations for storage represent average duration across the fleet.

Figure ES-3. Increase in Electricity System Modeled Costs Relative to Reference Case Across Selected Set of Scenarios in 2050 (High Electrification)



Notes: Cost increases are reported relative to the hypothetical Reference Case (50% RPS), which has annual costs in 2050 of $20.7 billion. Emissions reductions relative to 2016 emissions of 32 MMT estimated based on EPA SIT database and import emissions for all New England States. The "No Gas Generation" Case removes all fossil and hydrogen/zero-carbon fuel generation (CC/CT/ST) from the portfolio.

6. **Achieving net-zero GHGs requires carbon dioxide removal (CDR), and New England's extensive stock of healthy forests and local forest management expertise provide an ideal local opportunity for CDR.** While CDR alone will not be enough to achieve economy-wide decarbonization or meet the region's policy targets, it supports achieving full carbon neutrality and potentially net-negative emissions in New England and beyond. The lack of suitable geology for carbon sequestration make direct air capture and bioenergy with carbon capture and storage poorly suited to the region, but a large stock of forests provides a good opportunity for in-region CDR. A more purposeful and explicit consideration of the carbon sequestration potential of New England's forests would help the region better manage tradeoffs between preserving forest land and new greenfield renewable energy development. Policymakers should consider incorporating practices that promote CDR across its forest lands, as well as other natural CDR options, which are the best candidates for near-term deployment.

7. **Achieving the commercialization of emerging technologies can be aided by leveraging regional innovation capacity.** New England's innovation ecosystem is one of the most robust in the world. Local policymakers can increase the likelihood of commercializing emerging technologies by orienting the homegrown efforts of private, public, and academic researchers already developing science and business innovations relevant to decarbonization. Specifically, advanced nuclear, long-duration storage, and renewable fuels are innovation areas that have tremendous regional potential and could play a role in supporting a low-carbon power sector, especially when local innovation efforts are coordinated with federally-funded programs.

[1] https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/rank_use_capita.html&sid=US