THE ENERGY IS ABOUT TO *SHIFT*

Pathways to a Community-Centered, Resilient, and Decarbonized Grid for New England

CATF

Acadia Center

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ACKNOWLEDGEMENTS:

Acadia Center and Clean Air Task Force (CATF) would like to thank many partners for their review and insights in developing this report, especially organizations associated with the studies citied in the decarbonization pathways literature review section of this report, including E3, Brattle Group, Princeton's Net Zero America Study project team, and the Massachusetts Executive Office of Energy and Environmental Affairs, and case study interviewees, including interviewees Meg Sheehan (Community Land and Water Coalition); Mary Dormer (Carver Concerned Citizens); and John Walkey (GreenRoots), along with other interviewees who were willing to speak off the record.

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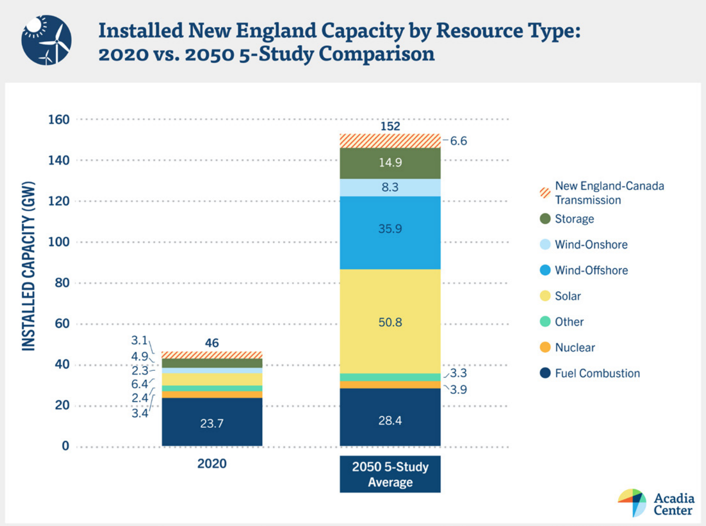
The Energy is About to Shift: New England's 2050 Clean Energy Transition

Executive Summary

New England has set itself apart as a region committed to climate action and clean air. Today, that commitment to spurring clean energy and combating climate change is reflected in the laws and policies of most New England states, which generally target 80 to 100% emissions reductions below 1990 levels by 2050. In order to dramatically reduce greenhouse gas (GHG) emissions and achieve these climate targets, the region's energy systems are in the early-to-mid stages of a massive evolution—a transition away from a reliance on aging, polluting fossil fuel infrastructure and toward a future that is increasingly efficient, electric, and dynamic. That is where New England finds itself in its energy transition: the energy, simply put, is about to shift. The forces behind this shift have been forming for years, but it is about to reach an inflection point that significantly ratchets up the deployment of clean energy.

At the center of New England's journey to reduce emissions and address climate change is the region's electricity grid—the network connecting power generation, transmission lines, local utility wires, and customer demand for electricity. The grid is important to New England's energy transition, since an increasingly decarbonized grid will be the primary means by which we can reduce emissions from important sectors, like residential and commercial buildings and transportation. For this to happen, the region will need significant investments that grow the grid to make it stronger, less carbon intensive, more efficient, more affordable, more intelligent, more distributed, and more resilient. This investment is also needed to meet significant rising demand for electricity: by the 2030s, peak demand for electricity in the region will shift from summer to winter, and by 2050, it will double from roughly 27 gigawatts (GW) to 55 GW, driven primarily by the electrification of vehicles and proliferation of heat pumps. To meet this demand, clean energy generation capacity is also projected to increase significantly by 2050, as shown below in five well-regarded deep decarbonization pathways studies investigating a high electrification future (see Section 2 for details).



But more important than what is at the center of the region's energy transition journey (i.e., the grid), is who: the region's communities; its people. For New England to build out its infrastructure at the speed and scale needed to unlock a local energy transition, it will take buy-in, acceptance, and trust from the communities that will host these clean energy resources. Communities take many forms, from the 1,300+ cities and towns in New England, to informal groups such as local business districts and regional organizing networks all the way to local libraries, community centers, and sports and recreation groups. Whether large or small, rural or urban, every community—including environmental justice communities and un-

The Energy is About to Shift: A Fitting Rallying Cry for Basketball and the Energy Transition

When it comes to basketball, New England is Celtics country. In Boston, Massachusetts, and across all the six New England states, green runs deep. When the Boston Celtics secured their record 18th World Championship in the 2024 NBA Finals this past June, it was the culmination of a multi-year journey through adversity, setbacks, and scrutiny.

It was also, in many ways, the fulfillment of Finals MVP Jaylen Brown's now iconic prediction in 2022 that "the energy is about to shift." This catchphrase is also a fitting moniker for the subject of this report, capturing both the changing energy mix for the region and the shifting posture around the priority of improved community engagement and acceptance for infrastructure siting and permitting. With the approval of Jaylen Brown's 7uice Foundation, The Energy is About to Shift has been repurposed as a title for this report and a rallying cry for the imperative of a community-centered approach to decarbonizing the grid.

derserved populations—must be able to use their voice and have it heard as states and the region make decisions about the unfolding energy transition. This is for good reason, as the stakes of siting, permitting, and grid-planning have important repercussions for how land-use is prioritized, where clean air is enjoyed, who pays what, and how other benefits and burdens are distributed—all outcomes that matter to local communities.

The need for community engagement around infrastructure siting and decision-making is precisely why Acadia Center and Clean Air Task Force (CATF) undertook this report. Community engagement means developing a system designed for the urgency of the climate crisis that values community access and standing in meaningful ways, including by offering them the tools needed to provide input, express preferences, and participate.[1] New England's track record around community engagement for clean infrastructure has been lacking—with a trail of failed projects and lawsuits to show for it. Thankfully, recently enacted policy reforms, most notably in Massachusetts, offer a promising new model for modernized, streamlined siting, permitting, and community engagement policies.[2] So, "the energy is about to shift": the region's energy systems must rapidly shift from fossil fuel to clean, renewable energy, and the region's policies and processes for siting, permitting, and community engagement must be improved and strengthened to unlock a clean energy transition with community involvement.

Through this report, Acadia Center and CATF ("the Project Team") set out to describe and analyze the many components of this unfolding transition for New England, and to understand the implications of the transition on infrastructure siting and community acceptance. This includes a data-focused, *quantitative* literature review of electrification-focused, cost-effective 2050 decarbonization pathways from five prominent recent studies. The review finds the region will have to significantly increase deployment of clean energy generation to keep pace with growing peak demand and annual load, and anticipates substantial growth in generation capacity and energy demand—by orders of magnitude—between now and 2050 (see **Table 1** and Section 2 of the report):

Table 1: 2020 vs. 2050 Summary of Key Energy System Changes in New England Based on 5-Study Electrification-focused Decarbonization Pathway Literature Review

ENERGY SYSTEM FEATURE	"TODAY": NEW ENGLAND'S GRID IN 2020 (REAL-WORLD FIGURES)	"TOMORROW": NEW ENGLAND'S GRID IN 2050 (FIVE-STUDY AVERAGE)
Installed electric generation capacity	43 GW	145 GW (+237%, or >3x)
Share of renewable energy generation	7.1% of TWh	84% of TWh (up 75%)
Annual end-use electric load	117 TWh	241 TWh (+106%, or >2x)
Electric peak demand	27.3 GW	55 GW (+101%, or >2x)
Interregional transmission capacity	5.13 GW	23.74 GW (+360%, or >4.5x)
Annual net electricity imports from neighbors	15.1 TWh (2023*)	22.1 TWh (+46%, or ~1.5x)[3]

Table 2: Project Case Studies		
PROJECT CASE STUDY	**STATE/LOCATION**	**TECHNOLOGY FOCUS**
Vineyard Wind	Massachusetts & federal offshore lease area	Offshore Wind
King Pine Wind and LS Power Grid MaineAroostook Renewable Gateway	Aroostook County, ME	Electricity Transmission and Onshore Wind
East Eagle Substation	East Boston, MA	Electric Substation
Cranberry Point Energy Storage	Carver, MA	Battery Energy Storage
Johnston Winsor Solar III	Johnston, RI	Solar
Twin States Clean Energy Link	New Hampshire & Vermont	Electricity Transmission

The Project Team also conducted a qualitative examination of the barriers, challenges, and points of friction that currently stymy positive project development and community acceptance and engagement, informed by interviews with first-hand participants and real-world case studies across solar, offshore wind, transmission, battery energy storage, substations, and other projects. Case studies (see **Table 2**) documented several notable and high-profile siting and community engagement examples in the region, capturing community dynamics not always portrayed in media coverage. Our research and conversations with renewable energy developers, state agency staff, and community leaders show opposition can snowball when community concerns are not taken seriously and go unaddressed. This often increases development timelines and costs, while potentially poisoning the waters for future development in neighboring communities. Sections 3 and 4 and the appendix include deep insights and lessons learned through case studies of the following projects.

While these analyses and case studies help us understand the region's energy system starting point and its destination, the future is not yet carved in stone and the roads to get there are myriad. This report highlights numerous opportunities—from energy efficiency and flexible demand as system resources, to transmission reconductoring and grid-enhancing technologies—to manage and minimize grid build-out costs, land-use impacts, and siting requirements. And despite how much new clean infrastructure the region will need to build, building trust with communities will require demonstrating effort to maximize the use and efficiency of existing infrastructure—a concept that deserves more refinement and attention in future studies.

This report presents the results of this year-long assessment and puts forth recommendations and takeaways for the region, both at the state and local government level and at the community- and project-level. This first set of recommendations, discussed in detail in Section 3, is derived from the Project Team's analysis of regional decarbonization studies in Section 2, and focuses on addressing technical challenges (grid reliability and affordability) posed by the region's energy transition. The highest order recommendation is that the region must adopt a diverse, clean energy portfolio approach to achieve decarbonization goals while keeping the lights on and heat pumps running.

OPTIONS AND OPPORTUNITIES
CORE APPROACHES TO RIGHT-SIZE THE ENERGY SYSTEM

- **A clean energy portfolio approach:** To achieve the decarbonization pathways, New England must deploy a portfolio of clean energy resources, including both supply- and demand-side solutions, to support resource adequacy, affordability, grid flexibility, stability, and resilience. A diversified portfolio of resources will 1) ensure a cost-effective mix of energy resources, 2) balance the benefits and drawbacks of resource types vis-à-vis energy contributions and land-use impacts, and 3) allow the region to tap into natural seasonal synergies between variable resources, balance their output with "clean firm" resources, and prevent overbuild.

- **Get more out of what is already built:** Upgrade existing infrastructure wherever possible, such as by rebuilding and upgrading transmission and distribution lines in existing rights of way (ROW), bringing offshore wind transmission onshore at decommissioned fossil fuel plant connection points, and by deploying technologies like high performance conductors and other grid-enhancing technologies (GETs) – to avoid the risk of over-building infrastructure and incurring needless additional siting pressures.

- **Not just generation:** A truly diversified clean energy portfolio approach optimized for cost-effectiveness, land-use impact, and achievability will look beyond just clean generation resources, and will include other vital resources to transfer and store energy while reducing demand: energy efficiency as a competitive resource that can be acquired and deployed to shift the entire demand curve down; interregional transmission expansion to enable greater two-way power flow between neighboring control areas (New York and eastern Canada, plus PJM); and energy storage capable of storing and reinjecting surplus clean generation over daily and seasonal timescales, including via aggregations of electric vehicles or electric hot water heaters.

- **Align regional planning with state vision:** The region's grid operator, ISO New England (ISO-NE) and its stakeholder advisory group. the New England Power Pool (NEPOOL), must improve existing planning frameworks to reflect state policies and partnerships and keep pace with rapidly evolving technologies and market conditions. To optimize the build-out of the grid, ISO-NE and interested stakeholders must have the full set of tools to study and ultimately deploy. This includes incorporating medium and long-duration energy storage resources now beginning to come to market, and a dramatically stronger embrace of interregional grid coordination and planning with neighboring balancing authorities on both the U.S. and Canadian sides of the border (which NE States are undertaking on their own devices).

- **Reform interconnection alongside permitting:** Policymakers can integrate interconnection reform, both at the wholesale and distribution level, into siting and permitting and land-use planning efforts, to move projects more quickly from interconnection queue to operation.

This second set of recommendations is derived from the Project Team's qualitative examination of renewable energy development in the New England region, including interviews, research, and case studies of specific projects. These recommendations focus on addressing the sociopolitical barriers to achieving equitable decarbonization in New England, and are further categorized by theme. These recommendations are contextualized alongside our research in Section 4 of the report. Ultimate siting and permitting reform improvements should be tailored to and influenced by direct input from communities about their needs.

ADDRESSING BARRIERS TO ACHIEVE EQUITABLE DECARBONIZATION

POLICY, PROCESS, AND CAPACITY CHALLENGES

- **Pass comprehensive permitting reform:** Policymakers can act swiftly to develop and enact statewide permitting reforms for clean energy and grid infrastructure that balance urgency and clear, consistent non-discretionary standards with early and robust community input—focusing both on local siting standards as well as policies governing state-level energy facility siting boards and councils.

- **Improve siting and permitting processes:** State policymakers can update siting policies to improve clarity in decision-making processes, create avenues to expedite permit approvals, streamline appeals processes, require early and meaningful community engagement, and increase coordination and communication across state agencies, and between state agencies and local governments.

- **Increase government capacity:** State policymakers can make durable commitments to increase state and local government capacity, through added staff with technical expertise at permitting entities, financial resources for technical consultants, and state-local liaisons to ensure adequate bandwidth for timely review and permitting decisions of many gigawatts per year of new project capacity across the region.

- **Provide technical support to local governments:** State agencies can provide robust technical assistance, guidance materials, financial incentives, and education to local governments, updated frequently to stay abreast of changing market trends. This should include robust outreach and engagement to communities to not only provide them with guidance materials but walk them through the process of adopting and tailoring zoning ordinances to meet both community needs and state policy goals.

- **Facilitate peer-to-peer knowledge sharing:** Non-profit organizations can engage elected and de facto community leaders in peer-to-peer knowledge sharing through facilitated workshops. Workshops can bring together diverse leaders from communities with experience siting projects and communities new to renewable energy siting to share best practices, technical resources, and fill knowledge gaps. Workshops can create a virtual network across New England of informed, resourced local leaders to accelerate renewable deployments while improving siting outcomes for their communities.

LAND USE AND SITING CHALLENGES

- **Integrate clean energy into land use planning:** States and non-profit organizations can create programs to proactively engage communities in combined land use and clean energy planning to provide opportunities for self-determination, align development with the long-term goals of the community, and reflect the tradeoffs of siting energy resources. State energy planning processes should include cross-sectoral stakeholders from resource conservation, agriculture, and local governments to account for competing land use priorities and coordinate with adjacent state energy planning.

- **Prioritize low-impact development and account for cumulative impacts:** Policymakers can incentivize siting and development standards that promote low-impact development practices. Such standards should also encourage siting on disturbed lands (brownfields, reclaimed mine lands, etc.) in rural areas, and maximize rooftop and solar canopy deployments in urban areas, while also not arbitrarily limiting greenfield development through acreage caps.

- **Balance farmland and wildlife protections with energy deployment:** Address concerns regarding the conversion of agricultural and forested land by proactive state-and-local planning and decision-making to reflect the tradeoffs of siting energy resources, ultimately developing policies that balance protection of the most productive lands with the need for responsible energy deployment of a significant magnitude. State agencies should provide developers with best management practices to minimize impacts to wildlife and policymakers should consider adoption of mitigation hierarchies to limit impacts to high-quality agricultural land and wildlife habitat. Policymakers should encourage developers to maximize co-benefits and minimize agricultural and environmental impacts by incentivizing dual-use solar, including agrivoltaics, floating solar, and pollinator-friendly solar.

REFORMING THE PROCESS OF FACILITATING COMMUNITY ENGAGEMENT

- **Facilitate proactive developer communication and engagement with communities:** Developers can proactively communicate positive and negative impacts (e.g., economic, environmental, health, and reliability) of proposed infrastructure development, as well as opportunities to mitigate impacts through community benefits or design modifications. Developers should increase access to information, promote engagement opportunities, and create procedural opportunities to identify community concerns and incorporate feedback into project siting, design, and decision-making processes.

- **Deliver meaningful benefits for communities:** Developers, communities, and governments can work together to consider additional means to deliver benefits to communities from individual projects. Development of a community benefit should occur through an early, inclusive, community-led process that not only informs the structure of community benefits program, but also incorporates community input into the design of the project itself. Accountability and monitoring metrics should be agreed on to ensure that promised benefits are delivered.

- **Assess and minimize cumulative impacts:** Policymakers can modify permitting standards and processes to account for cumulative impacts that may be created by proposed projects in a community to limit further burden on communities that have historically housed energy or other industrial infrastructure.

The region has work to do, but the benefits to be realized from the impending energy shift are enormous. To unlock those benefits, cities, states, and the region as a whole need to act urgently to update and modernize their siting, permitting, and community engagement policies, so that mutually beneficial, community-supportive infrastructure projects can go forward.

The report is organized as follows:

Section 1: A Brief History of New England's Electrical Grid and the Impacts of Status Quo Decision-making—provides an overview of how the region's grid has operated under a fossil-heavy paradigm and examines recent actions to preserve reliability and resource adequacy in a high-renewable future.

Section 2: Decarbonization Pathways for New England—unpacks the findings of the literature review of five prominent deep decarbonization pathways studies for New England.

Section 3: Opportunities for New England: Achieving a Reliable, Affordable Clean Energy Future—illuminates future pathways and resources with a more granular, descriptive look at how the region can use a portfolio approach to expedite its journey from where it is today to where it needs to be tomorrow.

Section 4: Beyond Infrastructure: Building a Supportive Community and Policy Environment—ties it all together by identifying critical-path roadblocks and impediments to positive project development and community engagement, drawing from project case-study interviews, and recommends actions different stakeholders can take to overcome those barriers.

Section 1

A Brief History of New England's Electrical Grid and the Impacts of Status Quo Decision-making

Section 1: A Brief History of New England's Electrical Grid and the Impacts of Status Quo Decision-making

- New England is heavily reliant on natural gas for electricity and heating, but supply is constrained and demand is volatile, especially in winter months
- Natural gas supply constraints and volatility contribute to high energy prices for the region and are associated with significant greenhouse gas emissions
- The region's grid also faces reliability risks, as demonstrated by recent winter storm events, with the grid operator's interventions falling short

THE OLD PARADIGM FOR GRID RELIABILITY IN NEW ENGLAND

For the last quarter-century, New England has been at the literal and figurative end of the pipeline. Because the region has little to no in-region fossil fuel resources, the legacy New England grid was built around the paradigm of widespread import of fossil fuels, including natural gas by interstate pipeline and liquefied natural gas (LNG) by tanker. Reliance on natural gas in New England, alongside constrained supply, results in higher wholesale electricity prices and presents risks to grid reliability.

In 2000, natural gas accounted for just 15% of the region's aggregate annual electricity generation, but by 2023 that percentage had increased to 49%.[4] Several factors contributed to this increase. First, wholesale electricity markets opened to competition in 1996,[5] with private companies investing billions of dollars in the development of natural-gas-fired power plants.[6] Rising oil prices in the early 2000s, due to soaring demand from China and India, wars in the Middle East, and a decline in U.S. petroleum reserves, among other reasons, accelerated an expansion of natural gas use in New England for electricity generation and heating.[7] In 2008, the advent of hydraulic fracturing (fracking) made previously untapped natural gas sources extractable, causing a natural gas boom in areas like the Marcellus shale region, New England's principal source of fracked natural gas. Moreover, during the last ten years, more than 7,000 MW of mostly oil- and coal-powered generating facilities shuttered and were replaced with natural gas generators, changing the makeup of the region's overall generation portfolio and consolidating natural gas's position as the region's primary fuel for electricity generation.

NATURAL GAS SUPPLY AND INFRASTRUCTURE CONSTRAINTS

New England's increased demand for natural gas since 2000, however, met with two different supply constraints: one physical, and the other market-based. Physically, the rate of regional natural gas demand increase over the last quarter century consistently outpaced the rate of new pipeline capacity buildout in New England.[8] Incremental natural gas demand not served by domestic sources via pipelines was served primarily by foreign LNG delivered to one of the few active LNG import facilities in the country: the Everett LNG Marine Terminal (EMT) in Everett, Massachusetts.[9]

As global demand for LNG rises and falls, so does its price. Because of the region's reliance on natural gas for electricity generation and on LNG imports, any volatility in global gas commodity markets results in volatility in New England's electricity costs. When Russia invaded Ukraine, for example, Europeans ceased buying Russian natural gas and replaced it with globally-sourced LNG. This increase in LNG demand resulted in higher LNG prices around the world, and higher natural gas and electricity prices in New England. Because the U.S. is now the world's leading LNG exporter, higher LNG prices result in more domestic natural gas being shipped abroad, reducing the supply of natural gas available for domestic consumption. As a result, New Englanders pay a higher price both for natural gas delivered into the region via pipelines and pay higher global prices for LNG delivered to the EMT.[10]

NATURAL GAS DEPENDENCE DRIVES UP ENERGY PRICES AND EMISSIONS IN NEW ENGLAND

Natural gas reliance creates problems during winter months when gas heating customers have priority access to the region's constrained pipeline capacity.[11] The competition between natural gas for heat and natural gas for electricity during the winter leads to spikes in wholesale electricity prices, prompting oil-fired generation dispatch at dual fuel gas/oil generating plants.[12] According to ISO-NE, the current paradigm is unreliable and poses risks for the region, as the age and infrequent operation of oil-fired generators leads to higher outage rates.[13]

The need for oil-fired generation also brings pollution and reliability concerns. The region's seasonal reliance on fuel oil as a source of electricity results in higher aggregate annual carbon dioxide emissions. During the winter cold spell in 2017-2018, for example, an atypically high number of generators resorted to burning fuel oil and more than doubled the region's average daily carbon dioxide emissions.[14]

Natural gas production, distribution, and combustion also have significant climate impacts. Methane, the main component of natural gas, is a greenhouse gas with significant planet-warming potential. The gas is responsible for 0.5 degrees Celsius of global warming experienced to date and a ton of methane traps more than 80 times more heat in our atmosphere relative to a ton of carbon dioxide over a 20-year period.[15] Recent EPA regulations have driven down methane emissions since 2016 even as natural gas production has increased.[16]

However, measuring methane emissions is notoriously challenging, with researchers estimating actual methane emissions three times greater than levels predicted by the U.S. government[17]—and more emerging analysis continuously documents high and varying rates of methane leakage across production areas in the U.S.[18]

The region's energy security vulnerabilities have been observed in stark relief during recent major weather or peak demand events. The grid will need to grapple with and withstand similar future events in the years ahead—and worse, as extreme weather departs further from historical norms.

TABLE 3: RECENT NOTABLE EXTREME WEATHER AND PEAK PERIOD RELIABILITY EVENTS

POLAR VORTEX 2013-2014[19]

In the winter of 2013-2014, the New England region experienced historically cold weather, including during a so-called "polar vortex" event. High natural gas demand for heating resulted in sustained high natural gas prices, and ISO-NE frequently operated the system with little or no gas-fired generation. In some cases, oil-fired generators were economically dispatched. Demand response was the only other major resource solution deployed through ISO-NE's Winter Reliability program. For this winter season, the wholesale cost of electricity totaled about $5 billion in New England.

WINTER COLD SNAP 2017-2018[20]

New England faced another historically cold period during the winter of 2017-2018, specifically: a two-week cold snap in late December and early January that sent temperatures plunging. 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°F below normal. Boston, for example, saw its most extreme cold wave in 100 years. ISO-NE said at the time, "The cold temperatures, together with winter storms and other complicating factors, led to some of the most challenging conditions our system operators have ever had to navigate." During the two-week stretch, oil accounted for 27%of the generation in New England, compared to 0.29% in the previous 25 days. Supplies of fuel oil dwindled to less than 20% of maximum storage capacity in the region by the end of the two-week stretch, with Winter Storm Grayson inhibiting additional fuel deliveries into the region.

LABOR DAY POWER SHORTAGES, 2018[21]

On September 3, 2018, hotter-than forecasted weather and a string of unplanned generator outages caused power system operating reserves to run short in New England. ISO-NE implemented several operating procedure steps to address the reserve shortage and recover the required level of operating reserves. On this holiday, consumer demand for power soared as people cranked up the A/C to deal with the swampy air around the region, driving the highest peak ever recorded on a Labor Day in New England. Ultimately demand was about 2,400 MW higher than expected when the day began (based on forecasted weather conditions for the day). Several power plants also went offline unexpectedly throughout the day, totaling about 1,600 MW of forced generation outages. Implementing Operating Procedure 4 enabled the ISO to purchase emergency energy from New York and New Brunswick and to ask market participants to reduce energy consumption at their own facilities, plus alerts to notify market participants of stressed system conditions.

WINTER STORM ELLIOT CHRISTMAS EVE CAPACITY DEFICIENCY, 2022[22]

During the Christmas Eve 2022 historic cold snap that affected much of the nation, the New England grid again came close to going dark. Thirty-six different power plants failed to deliver promised energy, and ISO-NE was forced to implement emergency operating procedures, stopping just a few steps short of asking the public for voluntary conservation measures. In this case, power plant outages and reductions coincided with net imports being approximately 100 MW less than had been expected. Prices in the Real-Time Energy Market averaged approximately $484/MWh over the course of the day, with averages reaching more than $2,200/MWh during the 5 p.m. hour. Union of Concerned Scientists published an analysis forecasting the benefits that offshore wind would have provided during this contingency event given recorded wind speeds, finding that if fully operational Vineyard Wind and Revolution Wind would have generated consistent power, avoiding capacity issues.[23]

New England's reliance on natural gas, fuel oil, and LNG, together with its constrained infrastructure, exposes ratepayers to volatile global commodity markets and increases electricity bills throughout the region. But the answer is not to seek greater access to natural gas supplies, which would be incompatible with the region's climate mandates; it is time for the region's focus to shift toward implementing clean energy solutions that reduce reliance on fossil fuels and build long-term energy security.

ISO-NE INTERVENTIONS TO-DATE TO IMPROVE RELIABILITY AND AFFORDABILITY FALL SHORT

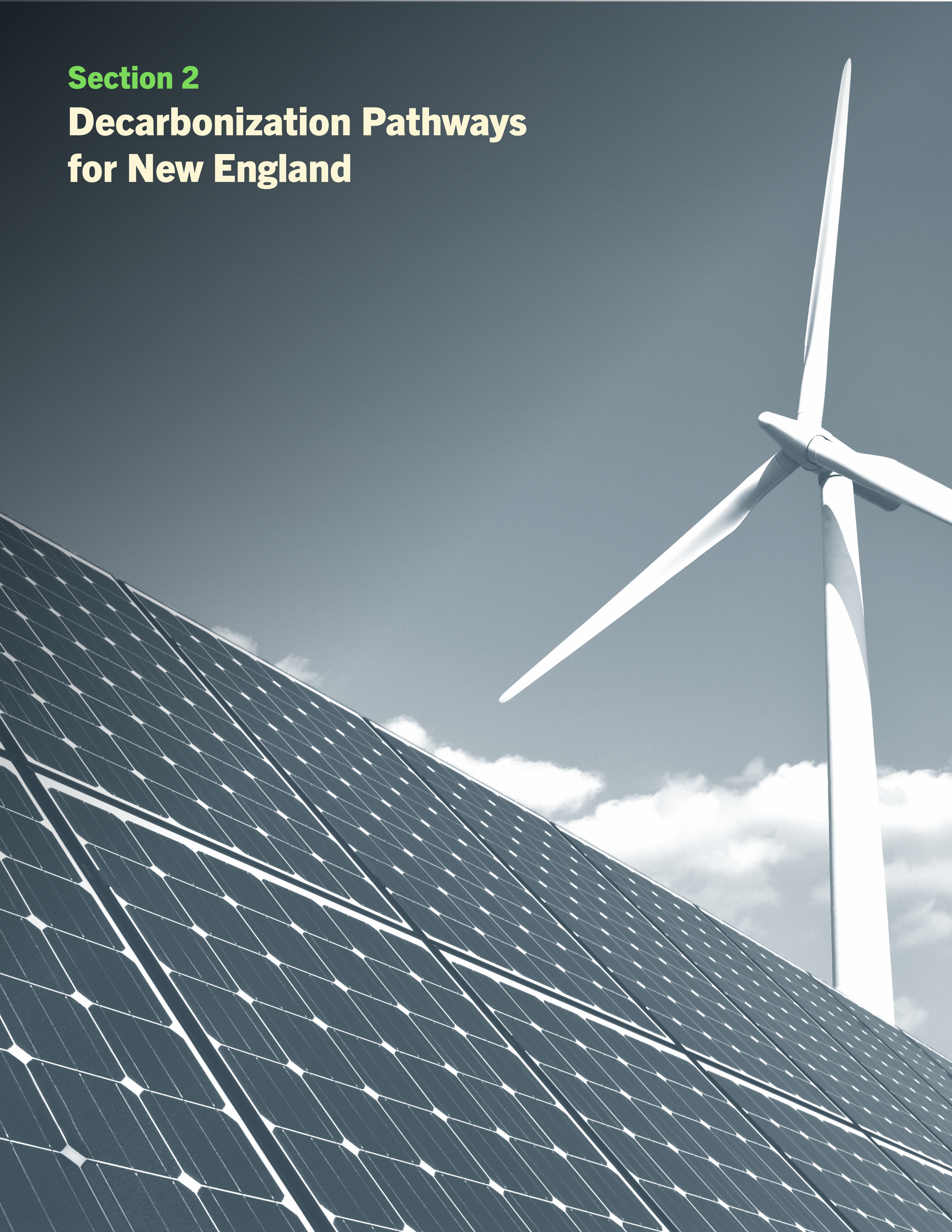
As the grid operator, administrator, and planner across New England, ISO-NE has been a central actor during periods of reliability and affordability challenges and responsible for long term planning exercises. In a 2021 presentation, ISO-NE laid out the interventions taken over the last twenty years to increase electric system reliability across the region, many of which have relied on fossil-fuel based solutions.[24] Arguably—given the energy security issues that persist today, and despite great costs incurred by ratepayers—none of them fully succeeded.

However, ISO-NE can build upon recent progress in enhancing reliability and security across the region, as demonstrated by the recent retirement of two fossil fuel facilities, and their replacement with clean energy infrastructure. Two facilities in Everett, Massachusetts, stand at the center of the region's energy security issues: the Mystic Generating Station (MGS) and the EMT. As mentioned, EMT has been importing LNG for the region since the 1970s, and in recent years, MGS—the largest natural gas power plant in the region—has purchased approximately 80% of imported LNG. In 2018, when the owners of MGS indicated plans to retire the facility by 2022, ISO-NE responded by flagging dire reliability concerns and initiated a reliability-must-run (RMR) contract—an out-of-market subsidy to keep the power plant online.[25] Several years and hundreds of millions of dollars later, a transmission solicitation run by ISO-NE identified a low-cost local transmission solution, Ready Path, to allow MGS to retire safely without reliability issues.[26] That transmission project was completed, and MGS officially retired in May 2024, marking the end of an era and the start of a new, important chapter in the region's grid reliability planning.[27]

The electricity generation status quo in New England is untenable given the emissions reductions targets that states have enshrined in law. The region's continued reliance on fossil fuel energy infrastructure risks increasing costs to ratepayers, threatens grid reliability, puts at jeopardy state climate goals, and exacerbates health and environmental justice impacts for local communities. Fortunately, recent modeling studies chart potential future pathways to decarbonize the region's electricity, buildings, and transportation systems—offering promising options to shift the region's energy away from the fossil status quo and toward a clean energy future.

Section 2

Decarbonization Pathways for New England



Section 2: Decarbonization Pathways for New England

OVERVIEW OF FIVE DEEP DECARBONIZATION PATHWAYS STUDIES

The Project Team reviewed five studies that modeled pathways to deep levels of economy-wide decarbonization by 2050—1) Princeton University's Net-Zero America: Potential Pathways, Infrastructure, and Impacts, 2) The Massachusetts Clean Energy and Climate Plan (CECP) for 2050, 3) Energy Futures Initiative and E3's Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future, 4) Brattle Group's Achieving 80% Greenhouse Gas Reduction in New England by 2050, and 5) E3's Massachusetts Department of Public Utilities 20-80 Technical Analysis of Decarbonization Pathways report (see Table X). Four studies are New England-specific, and the Net-Zero America study is nationally focused but presents many modeling results on a state-by-state basis. All pathways require siting significant amounts of energy infrastructure in communities across the region.

Decarbonization Pathway Studies are Not Forecasts: Each of the five deep decarbonization studies modeled multiple, distinct technological pathways to deep levels of decarbonization, but it's critical to note that these pathways studies are not forecasts and do not result in a single preferred decarbonization pathway. Generally speaking, this type of analysis is designed to enable policymakers to make comparisons across pathways to understand the tradeoffs, feasibility, relative costs, risks, and commonalities across multiple scenarios. While each study examines multiple scenarios, the Project Team focused this literature review on scenarios where electrification of building and transportation is the dominant end-use decarbonization strategy, with small but meaningful continued reliance on fossil and "alternative fuel" combustion in hard-to-abate sectors. Scenarios modeling decarbonization through heavy reliance on alternative fuels, such as hydrogen and biomethane, can incorporate significant cost and technical uncertainties associated with the limited supply of sustainable biomass feedstocks available to produce biofuels, the lack of consensus on the net GHG benefits of biofuels, and the inefficiencies associated with hydrogen electrolysis versus direct use of electricity in end-use appliances, among others.[28]

TAKEAWAYS AND LESSONS:

The following takeaways and lessons represent the averaged findings across the five studies and selected scenarios within those studies examined in this literature review.

ON FUTURE "SUPPLY" CONDITIONS:

- **Capacity:** Total installed capacity in the region increases to 145 GW – nearly 3.4 times higher than currently installed capacity. Solar (51 GW) and offshore wind (36 GW) dominate 2050 generation capacity, representing 39% and 28% of modeled 2050 generation capacity, respectively.

- **Generation:** While solar is anticipated to have the highest installed capacity (GW) of all resources, offshore wind drives the lion's share (49%) of annual generation (TWh) —due to its higher capacity factor.

- **Solar:** All studies envision an important role for distributed solar (generally defined as<5 MW),[29] but optimizing for cost-effectiveness results in 71% of all solar capacity installed by 2050 being utility-scale.

- **Combustion:** All studies found some lingering reliance on fuel combustion in 2050 to support grid reliability and resource adequacy while simultaneously minimizing system cost. The amount of combustion capacity remaining online and how often it was modeled to run were two of the key variables that significantly affected solar and wind build-out results (reflecting an increase or decrease by up to 60 GW). Fuel combustion capacity increases 20% by 2050, but capacity factors are extremely low (between 4 -8%).

- **Transmission:** Interregional electricity transmission capacity between New England and Canada was found to more than double (adding an average of 3.5 GW) to help achieve 2050 decarbonization goals.

ON FUTURE "DEMAND" CONDITIONS:

- **Annual Demand:** Year-round electricity consumption was found to increase 106% by 2050 to around 241 TWh on average across studies.

- **Peak Demand:** The annual peak was found to shift from summer to winter and increase 101% by midcentury to about 55 GW across studies. The three studies that quantified the benefits of load shifting found that it could reduce peak demand by over 7% (4.4 GW) on average by 2050.

- **Electric Vehicles & Heat Pumps:** The two primary drivers of annual load increases (TWh) are transportation electrification (48%) and building electrification (39%) across studies, but transportation is a much less significant driver of future winter peak demand compared to building heating, partially due to flexibility of vehicle charging load and the inflexibility of space heating during the coldest portions of the year. Space heating load from heat pumps largely drives increases in peak winter demand, just as space cooling from air conditioning drives today's summer peaks.

ON THE PACE AND SCALE OF TRANSFORMATION:

- **T-Minus Twenty Years:** The region has roughly two decades to realize the clean infrastructure additions needed for mid-century, factoring in the number of years it takes to construct large-scale projects.

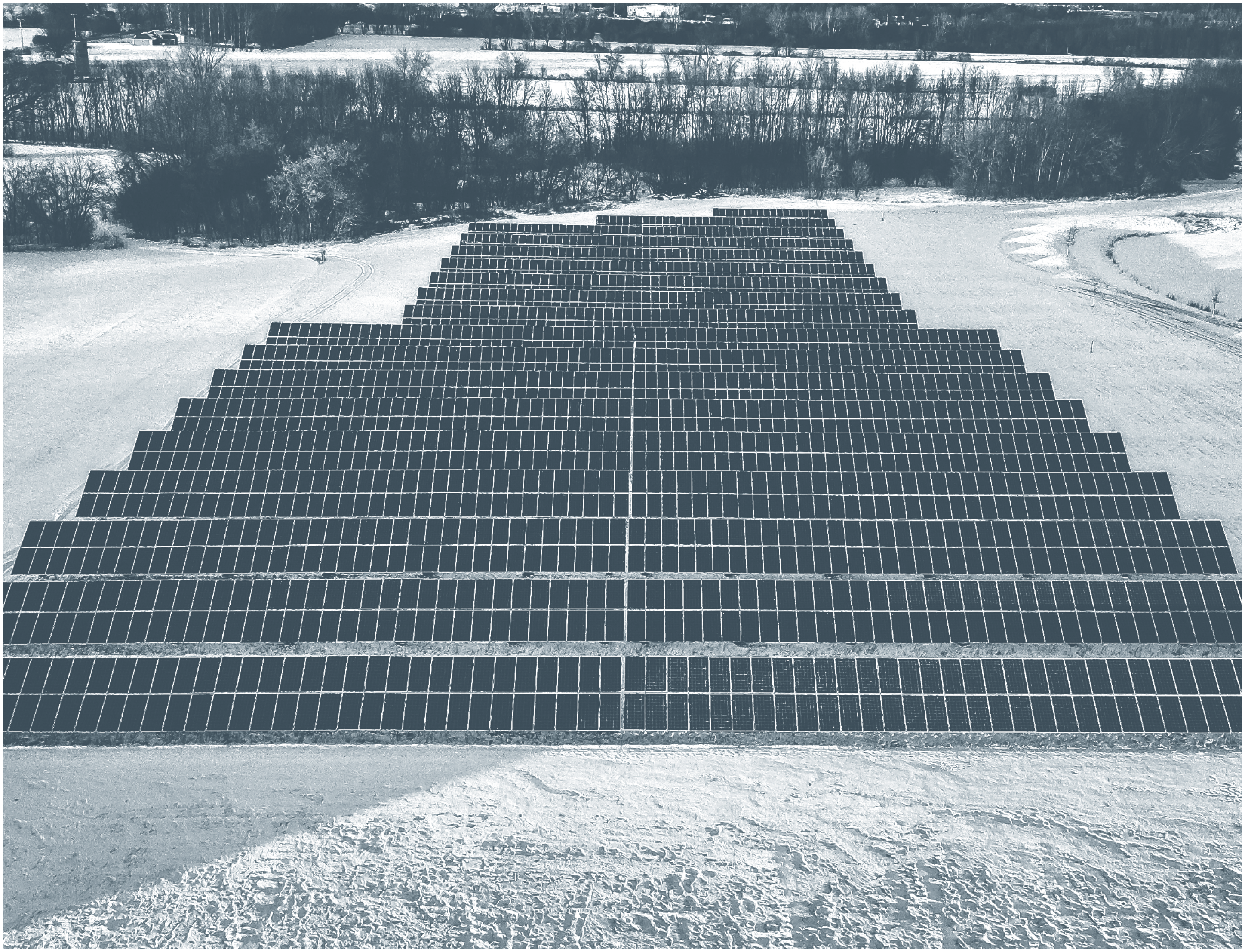
- **Annual Deployment Needs:** Keeping this pace will mean siting, permitting, interconnecting, and commissioning up to 5 GW of new clean energy capacity per year for the next twenty years.

ON STUDY GAPS AND AREAS FOR FUTURE RESEARCH:

- **Demand-Side Rigor:** Generally speaking, studies do not model the ability of building envelope efficiency improvements to curb electricity demand growth with sufficient rigor to match the sophistication of supply-side projections. Increased modeling focus on the cost-effective potential of building envelope improvements to reduce overall space heating demand could reveal lower levels of generation build-out than currently found by these studies.

- **Long-Duration Storage:** While all studies model contributions from energy storage (6-17 GW of added storage by 2050), none of the studies—partially due to high levels of uncertainty around technological viability and cost—robustly model the emerging class of long-duration energy storage with the capability to store and reinject energy over multi-day and seasonal periods. The commercial viability of long-duration storage has made significant strides in recent years as demonstrated by the $147 million in Department of Energy grant funding announced in 2024 supporting the deployment of an 85 MW long-duration storage project in Maine. Future studies will need to stay abreast of technology developments and advancements on LDES and other forms of clean firm technologies.

- **Maximizing Existing Transmission:** The studies did not examine opportunities to optimize grid build-out needs via deployments of Advanced Transmission Technologies (ATTs) and Grid Enhancing Technologies (GETs), such as high-performance conductors for transmission lines—another chance to limit build-out needs.



LITERATURE REVIEW: FIVE ECONOMY-WIDE DECARBONIZATION STUDIES

Table 4, below, lists the five studies of focus for this literature review and provides descriptions of the scenarios of focus within these studies.

Table 4. Overview of Five Economy-wide Decarbonization Studies and Selected Scenarios of Focus for Literature Review

STUDY	YEAR	SCENARIO	SCENARIO DESCRIPTION
Princeton University Net-Zero America [30] **("Princeton NZAP")**	2021	E+	"Assumes aggressive end use electrification, but energy supply options are relatively unconstrained for minimizing total energy system cost to meet the goal of net zero emissions in 2050."
Massachusetts Clean Energy and Climate Plan (CECP) for 2050 [31] **("2050 CECP")**	2022	High Electrification[32]	"Rapid adoption of whole-home heat pumps. Some use of clean fuels in 2050. Most similar to the 'All Options' pathway from the 2050 Roadmap Study." "The dominant strategy to decarbonize transportation and buildings is electrification."
EFI/E3: Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future[33] **("Net-Zero New England")**	2020	High Electrification	"This mitigation scenario electrifies most space and water heating within buildings, as well as most light-duty vehicles... The modeling also includes increased adoption of electric and hydrogen vehicles in medium-duty vehicles… and heavy-duty vehicles… as well as electric space heating and water heating appliances in buildings, and electrification of feasible industrial processes."
Brattle: Achieving 80% GHG Reduction in New England by 2050 [34] **("Achieving 80%")**	2022	Electrification Focused/ Large-Scale Resources[35]	The Electrification Focused scenario emphasizes electrification of building and transportation end uses with 'moderate' levels of building energy efficiency deployment. The Large-Scale Resources portfolio relies primarily on large-scale renewables procurements, maintains existing nuclear generation, and procures 42 GW of incremental hydro.
E3/Scott Madden: Massachusetts D.P.U. 20-80 Independent Consultant Report Technical Analysis of Decarbonization Pathways[36] **("D.P.U. 20-80")**	2022	High Electrification	Inspired by Massachusetts 2050 Decarbonization Roadmap "All Options" Scenario. "Building sector electrifies >90% of buildings, primarily through the adoption of air source heat pumps and "97% of light-duty vehicles electrified."

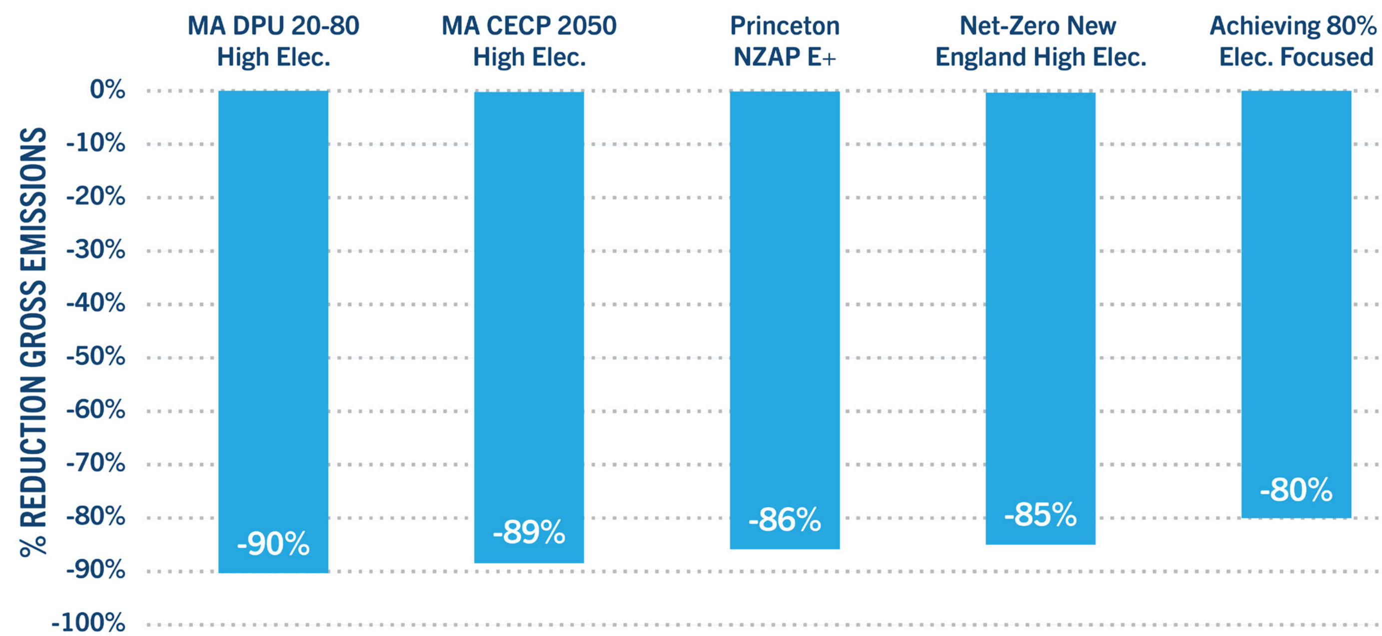
The Project Team recognizes that all of the above economy-wide decarbonizations studies modeled multiple scenarios within each study. For the purposes of brevity, all references to the "five studies" in the remainder of this section refer specifically to the five scenarios of focus (as described above The Project Team recognizes that all of the above economy-wide decarbonizations studies modeled multiple scenarios within each study. For the purposes of brevity, all references to the "five studies" in the remainder of this section refer specifically to the five scenarios of focus (as described above in **Table 4**) within the five studies.

ALL STUDIES MODEL SIGNIFICANT ECONOMY-WIDE EMISSION REDUCTIONS BY 2050 BUT EXACT LEVELS OF EMISSION REDUCTIONS VARY

Each of the five studies modeled scenarios to achieve a specific economy-wide GHG reduction target by 2050, relative to a baseline year of 1990. Although all five studies achieved significant reductions by midcentury, none of the studies were designed to model the same levels of gross or net GHG reduction (**Figure 1**). Across the studies, gross emissions reductions from the baseline ranged from a high of 90% (MA DPU 20-80 report) to a low of 80% (Achieving 80% report).

FIGURE 1

Reduction in New England Economy-Wide Gross GHG Emissions: 1990-2050 5-Study Comparison



	MA DPU 20-80 High Elec.	MA CECP 2050 High Elec.	Princeton NZAP E+	Net-Zero New England High Elec.	Achieving 80% Elec. Focused
Explicit Net-Zero Goal?	Yes	Yes	Yes	Yes	No
Was Net-Zero Modeled?	No	No	Yes	No	No

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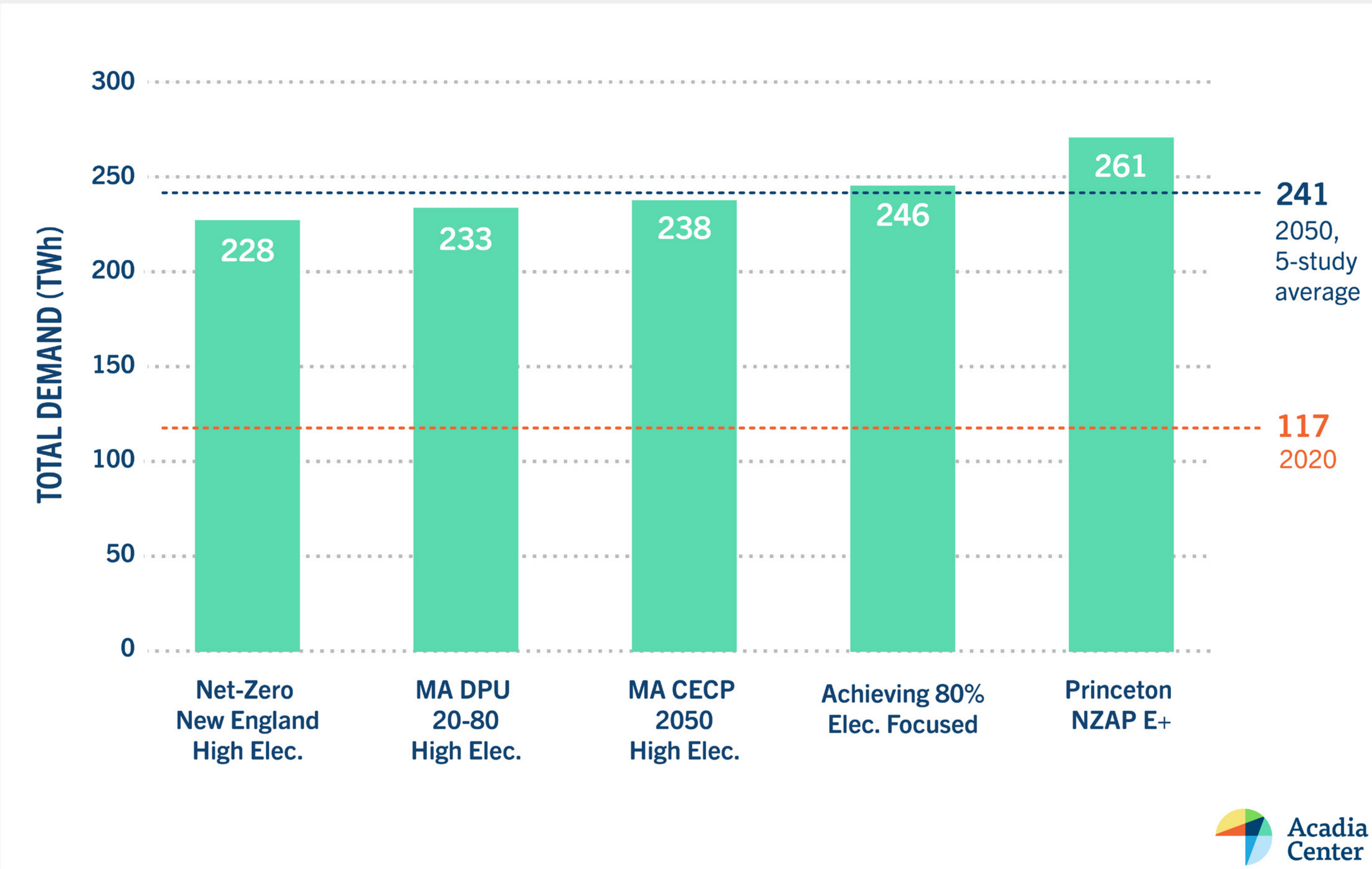
Three of the five studies acknowledged, but did not model, an explicit net zero goal. For example, the MA CECP 2050 report acknowledges that achieving net zero will "…likely require additional carbon dioxide removal and storage beyond the sequestration capacity of lands in the Commonwealth," but did not incorporate this additional carbon dioxide removal and storage into modeling.[37] The Princeton NZAP study was the only study to model achieving net zero economy-wide emissions and incorporated negative emission technologies, including direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS) into the analysis. Because of the criticality of electrification as a decarbonization strategy in each modeled scenario, differences in the emission reduction targets modeled in these five studies have ramifications for key modeling outputs from the studies, including regional peak electricity demand, annual electricity consumption, and the associated buildout of electricity generation capacity. For example, other variables held equal, one would expect higher peak 2050 electricity demand in studies assuming a 90% reduction in gross emissions by 2050 compared to a study assuming an 80% reduction in gross emissions.

ELECTRIFICATION OF BUILDING AND TRANSPORTATION SECTORS DOUBLES END-USE ELECTRIC LOADS BY 2050

Across the scenarios of focus in all five studies, transitioning end uses, including building heating and transportation, from fossil fuel to electric drove significant increases in both overall annual end-use electric loads and electric system peak demand by 2050. As highlighted in **Figure 2** below,[38] the five-study average shows overall New England electric loads increasing approximately 106% from 2020-2050, from 117 to 241 TWh.

FIGURE 2

New England Total Annual End-Use Electric Loads: 2020 vs. 2050 5-Study Comparison

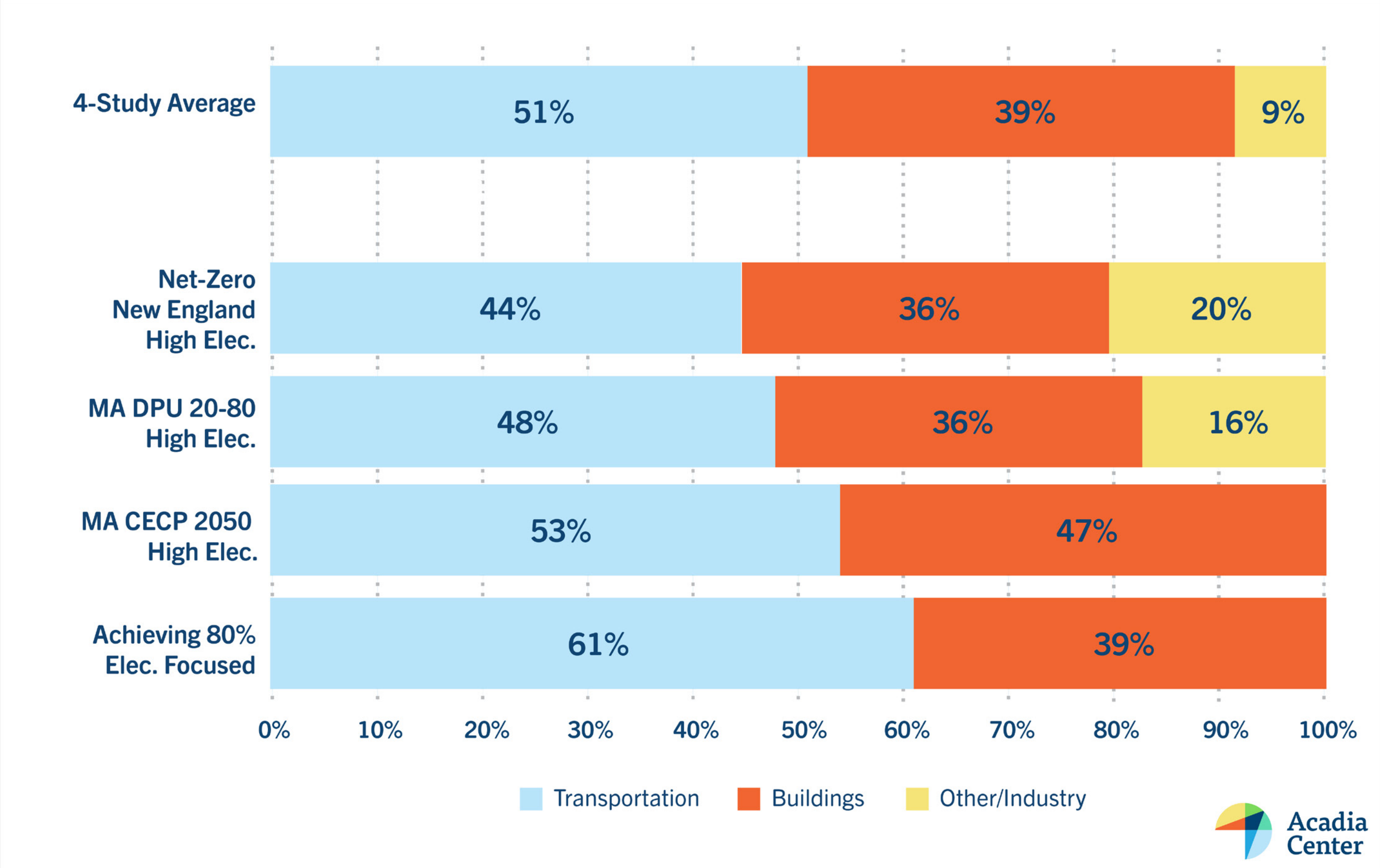


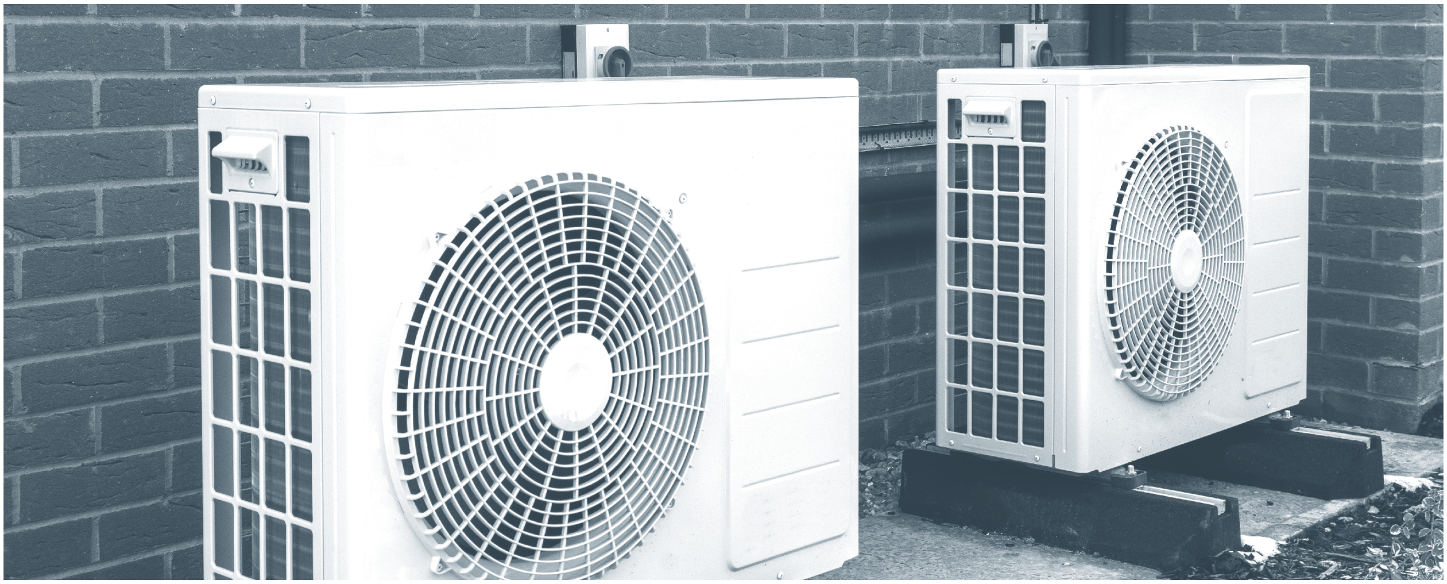
Although overall electric loads are expected to increase dramatically, total end use energy demand (including combustible fuels and electricity) is expected to decrease significantly, largely driven by the efficiency of heat pumps and battery electric vehicles compared to their combustion-based equivalent technologies. For example, the 2050 Massachusetts Decarbonization Roadmap All Options scenario (an electrification-focused scenario and precursor to the MA CECP 2050 High Electrification scenario) found a 44% decrease in overall building end use demand and a 55% decrease in transportation end use demand by 2050 compared to 2020 levels.[39]

Across the five studies, the percent increase in overall New England annual end-use electric load from 2020 to 2050 ranges from a low of 95% (Net-Zero New England) to a high of 124% (Princeton NZAP). As illustrated in **Figure 3** below, transportation is the primary driver of annual end-use electric load growth in New England, followed by the buildings sector, across the four studies that provide a breakdown of end-use electric load by sector.[40, 41]

FIGURE 3

% of New England 2020-2050 Total Annual End-Use Electric Load Growth Attributable to Each Sector: 4-Study Comparison



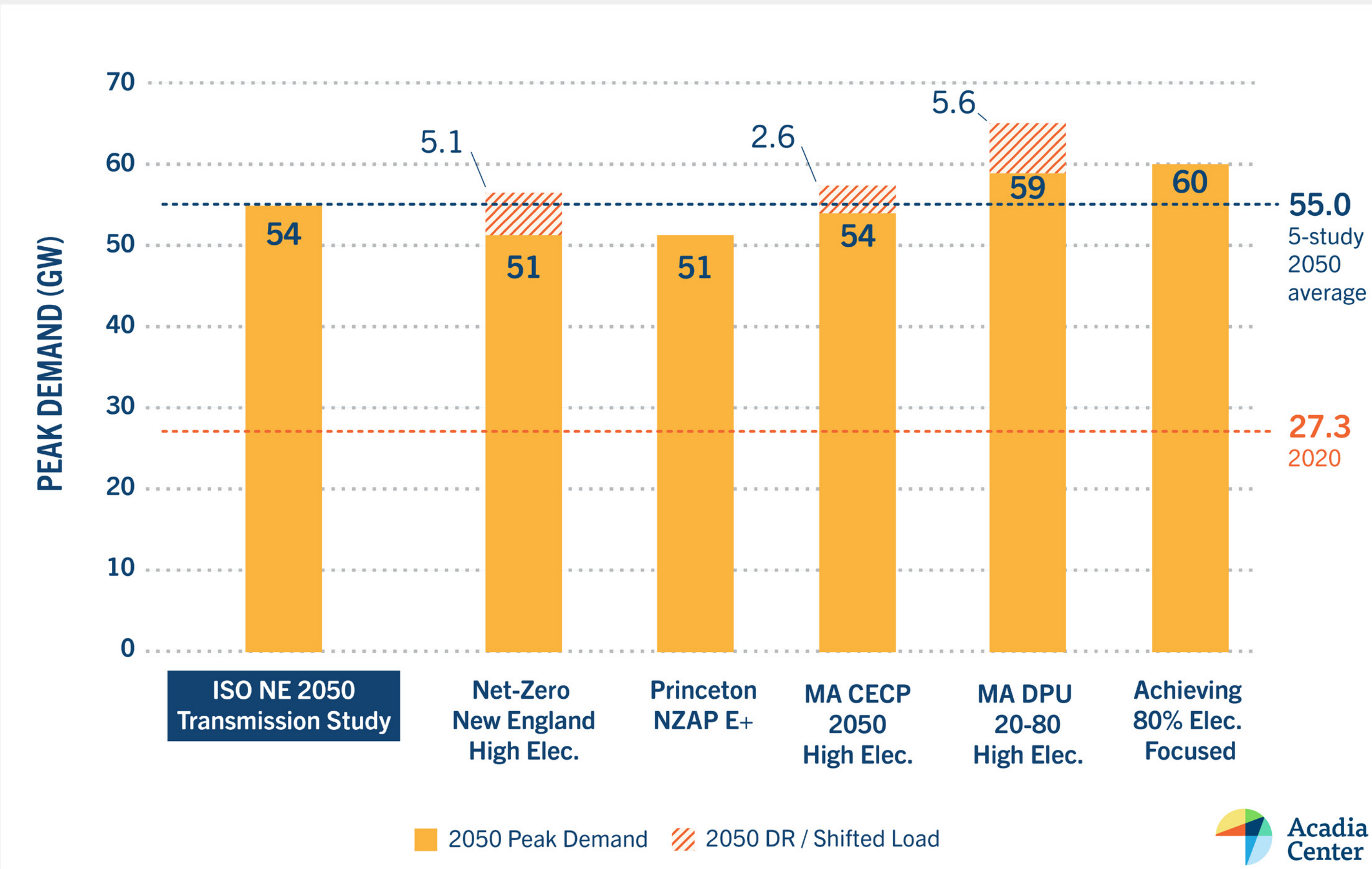


ELECTRIFICATION OF BUILDING SECTOR HEATING DRIVES INCREASES TO ELECTRIC PEAK DEMAND BY 2050

Across the five studies, increases in end-use electrification leads to large increases in electric peak demand in New England by 2050. These increases are primarily driven by the electrification of heating equipment and the high heat pump use during the coldest hours of the year, when heat pumps run less efficiently than in warmer periods. Given the pace of end-use electrification needed in the near- to mid-term to achieve climate targets, several of the studies show New England transitioning from a summer peaking to a winter peaking grid in the 2030s. As highlighted in **Figure 4** below, the five-study average shows overall New England 2050 peak demand doubling from 2020 to 2050, from 27.3 GW to 55.0 GW. These results are in line with the findings of the 2024 ISO New England 2050 Transmission Study (also included in Figure 4 below) which modeled future scenarios that included load projections and potential resource mixes out to 2050 based on the All Options Pathway in the Massachusetts 2050 Decarbonization Roadmap, a precursor to the MA CECP 2050 analysis. The ISO study modeled two scenarios, one with a 2050 winter peak of 57 GW and one with a reduced peak of 51 GW "...under a scenario in which New England retains some stored fuels like natural gas, oil, propane, hydrogen, etc. For heating and transportation."[42] The 54 GW winter peak shown in **Figure 4** below represents the average of these two ISO NE scenarios.

FIGURE 4

New England Peak Electric Demand: 2020 vs. 2050
5-Study Comparison

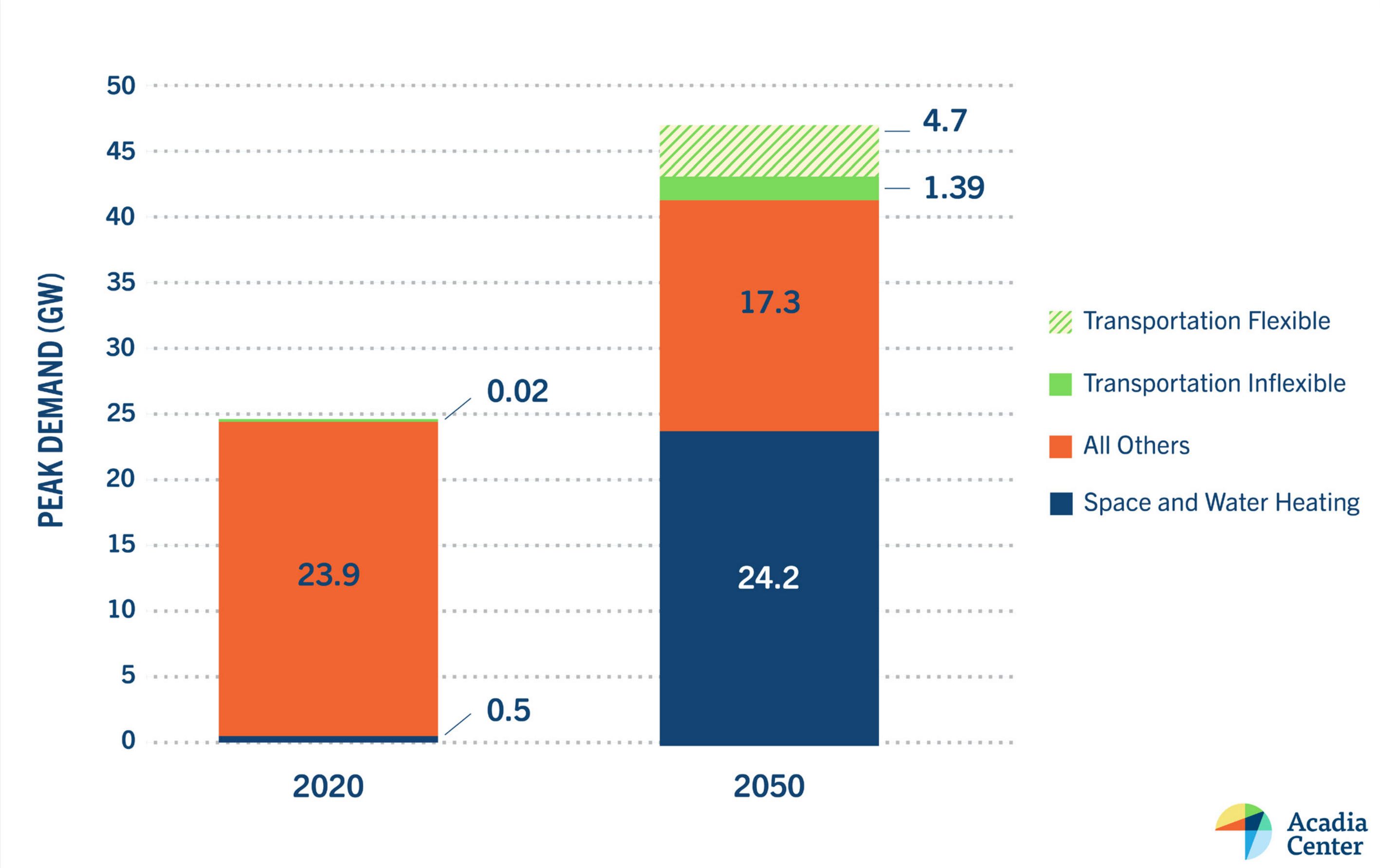


Across the five studies, the increase in overall New England peak demand from 2020 to 2050 ranges from a low of 87% (Net-Zero New England) to a high of 120% (Achieving Net Zero).

Although most of the studies do not provide a breakout of peak demand by end use in 2050, the MA CECP 2050 report did provide an hour-by-hour breakout of "coincident inflexible load" for three overarching end uses: transportation, space and water heating, and "all others". **Figure 5** below breaks out 2020 versus 2050 peak demand by end use in the "High Electrification" scenario for the 50 hours in each year with the highest coincident inflexible load.

FIGURE 5

MA CECP Full Electrification Scenario: Average New England Peak Demand in Top 50 Hours: 2020 vs. 2050

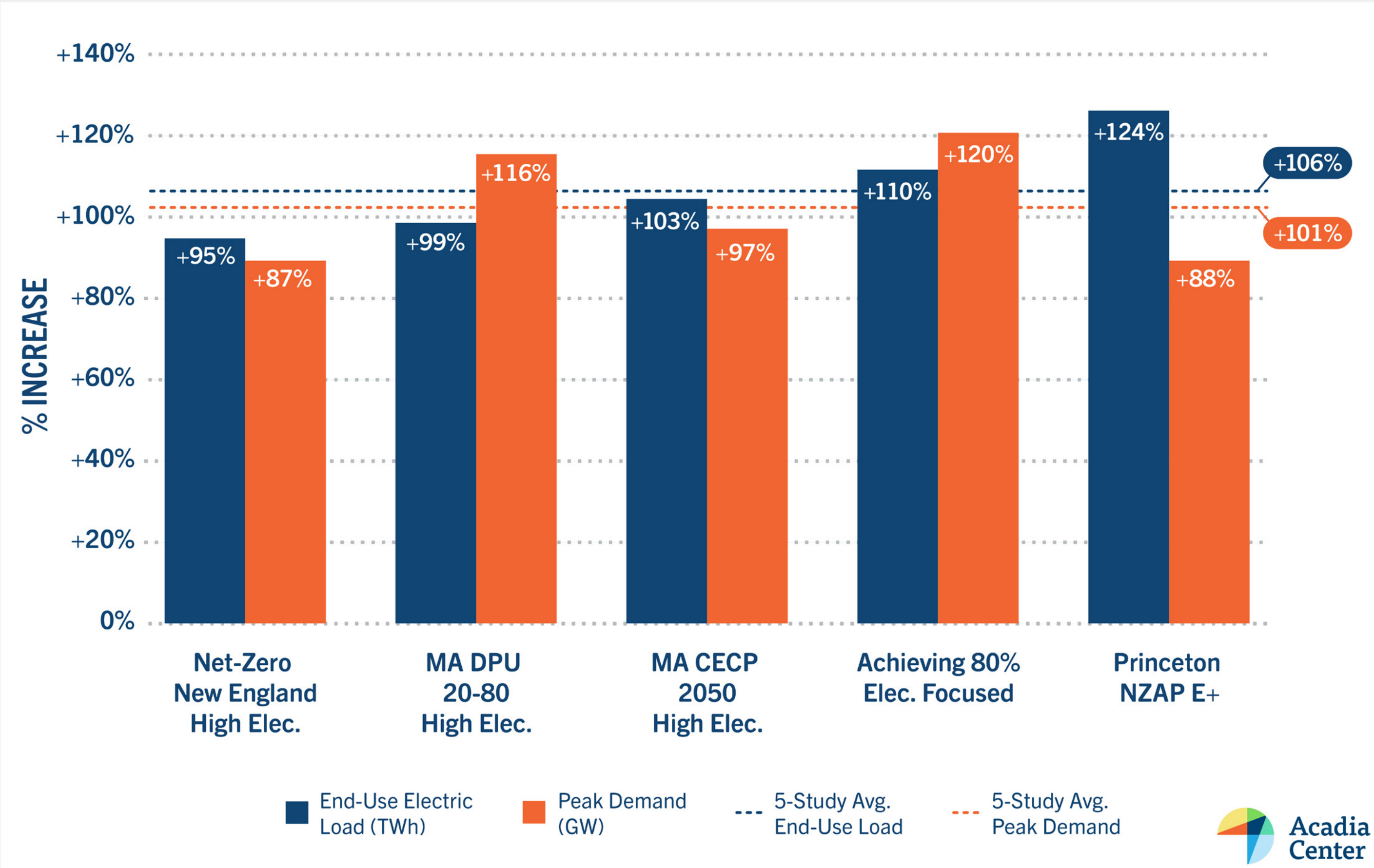


Space and water heating accounts for the majority (56%) of peak demand, with transportation accounting for just over 3%. This finding is somewhat surprising given the transportation sector is responsible for a higher percentage (53%) of total annual load growth from 2020 to 2050 than is the buildings sector (47%) in this scenario, as detailed in **Figure 3** above. The topic of load shifting and demand response, and how it is addressed in the five studies, is discussed in more detail later in this report.

Figure 6, below, summarizes the annual end-use electric load and peak demand modeling results from the five studies, highlighting that the five-study average found a doubling (106% increase) in annual load and a doubling (101% increase) in peak demand from 2020 to 2050. Interestingly, the study with the largest percent increase in annual end-use electricity load (Princeton NZAP, +124%), had the lowest percent increase in peak demand (+88%), demonstrating that the two are not necessarily correlated.

FIGURE 6

Percent Increase in New England Annual End-Use Electric Load vs. Peak Demand: 2020-2050 5-Study Comparison



BUILDING ENVELOPE IMPROVEMENTS AND LOAD SHIFTING/DEMAND RESPONSE SERVE KEY ROLES IN REDUCING 2050 PEAK ELECTRICITY DEMAND BUT MODELING APPROACHES VARY WIDELY

Because the five scenarios reviewed model significant levels of electrification in both the building and transportation sectors, the Project Team investigated how models incorporated two demand-side management strategies—building shell improvements (e.g., weatherization, insulation) and load shifting of end uses (e.g., EV charging, domestic hot water heating)—to help mitigate future peak winter demand.

BUILDING ENVELOPE IMPROVEMENTS

The five studies generally group envelope assumptions across three building categories:

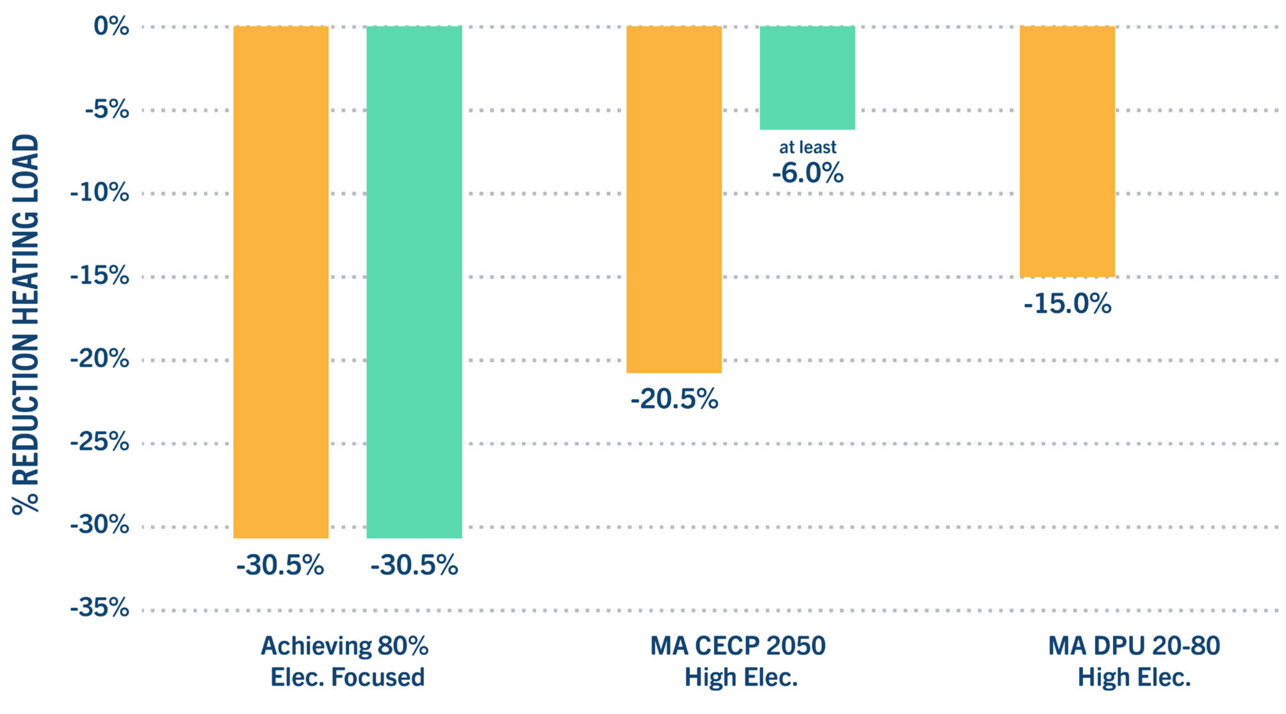
1) New buildings constructed after 2020;
2) Existing buildings retrofitted between 2020 and 2050; and
3) Existing buildings not retrofitted by 2050

Studies generally assumed the first two building categories have more efficient envelopes than the third category, but, as summarized below in **Figure 7**, envelope improvement assumptions that reduce space heating demand vary considerably across the five scenarios examined. The data points in the graph represent the weighted average reduction in heating load across all three categories of buildings relative to the average building envelope in 2020.

Notably, only two studies clearly documented envelope improvement modeling assumptions for the residential building stock (MA DPU 20-80 and Achieving 80%) and only one study (Achieving 80%) documented modeling assumptions regarding for commercial building envelope improvements. The Project Team obtained information on envelope improvement assumptions for a third study, MA CECP 2050, via email request. It is widely recognized, and acknowledged in many of the studies, that building envelope improvements will be essential for managing future winter peak demand and that minimizing future winter peak electric loads will be important for reducing capital costs associated with construction of electric generation capacity and associated grid infrastructure. For example, specifically regarding transmission costs, the ISO NE 2050 Transmission Study found that increases in peak load become significantly more expensive. The study estimated that increases in peak demand from 28 GW to 51 GW increase costs approximately $0.75 billion per GW of load added, while peak demand from 51 GW to 57 GW cost approximately $1.5 billion per GW. And, these transmission costs are only a portion of the total system-wide costs that building envelope improvements could address. Yet, several studies either did not model significant shell improvements or did not clearly communicate assumptions for modeling completed.[43]

FIGURE 7

New England Average Building Reduction in Heating Load by 2050 Resulting from Envelope Improvements Relative to Baseline Year: 3-Study Comparison



NOTE: For two of the five studies (Princeton NZAP and Net-Zero New England), assumptions regarding building shell improvements between the baseline year and 2050 were not available, and for one study (MA DPU 20-80) data was only available for residential buildings.

For the scenarios with available information on shell improvement modeling assumptions, those assumptions varied significantly. In the residential sector, the three scenarios with available assumptions ranged from a heating load reduction of 15% (MA DPU 20-80) to a high of 30.5% (Achieving 80%).

DEMAND RESPONSE AND FLEXIBLE LOADS

Another widely recognized key strategy for mitigating future winter peak demand is demand response, particularly shifting of flexible loads outside of peak hours. The flexibility of various electric end uses varies considerably, but two end uses with high load shifting potential are electric vehicle charging and domestic water heating. As summarized in Table 2 below, the Project Team reviewed the five studies to better understand 1) the total modeled electric peak demand reduction in 2050 resulting from demand response, and 2) assumptions on the percent of total electric vehicle charging load and electric domestic hot water heating load in 2050 that can be shifted off peak.

Table 5. New England 2050 Peak Load Reduction from Demand Response and Assumed Flexibility of EV and Water Heating End Uses: 5-Study Comparison

STUDY & SCENARIO	2050 PEAK REDUCTION (GW)	2050 % PEAK REDUCTION	2050 % EV TOTAL LOAD FLEXIBLE	2050 % TOTAL WATER HEATING LOAD FLEXIBLE
MA DPU 20-80 High Electrification	5.6	-9.4%	50%	25%
MA CECP 2050 High Electrification	2.6	-4.6%	75%	0%
Princeton NZAP E+	Unknown[44]	Unknown	50%	20%
Net-Zero New England High Electrification	5.1	-10.1%	Unknown	0%
Achieving 80% Electrification Focused	Unknown	Unknown	Unknown	Unknown
Studies Average (Excluding Unknowns)	**4.4**	**-7.0%**	**58%**	**11%**

Like modeling assumptions regarding building shell efficiency improvements, assumptions on the scale of demand response and load shifting by 2050 vary considerably across studies. Demand response was modeled across four of the five studies examined, but one of the studies (Princeton NZAP) did not provide New England-specific data on the 2050 peak reduction potential. The three studies that included New England data averaged a 4.4 GW winter peak reduction in 2050, ranging from a low of 2.6 GW (MA CECP) to a high of 5.6 GW (MA DPU 20-80). This translates to a three-study average 2050 peak reduction of 7.0% relative to the 2050 peak absent demand response, ranging from a low of a 4.6% reduction (MA CECP 2050) to a high of a 10.1% reduction (Net-Zero New England). This high level of variation in assumptions and findings suggest that the topic of flexible demand is ripe for more rigorous focus in future studies and planning by states and grid operators.

INCREASE IN WINTER PEAK DEMAND DRIVES NEED TO INCREASE NEW ENGLAND ELECTRIC GENERATION CAPACITY BY 2050

As demonstrated by the modeling results of the five studies, New England electric generation capacity will need to increase substantially by 2050 to accommodate growing winter peak demand. As summarized below in **Figure 8**, the five-study average indicates that generation capacity will more than triple by 2050, from 43 GW to 145 GW.[45]

FIGURE 8

Installed New England Capacity by Resource Type: 2020 vs. 2050 5-Study Comparison

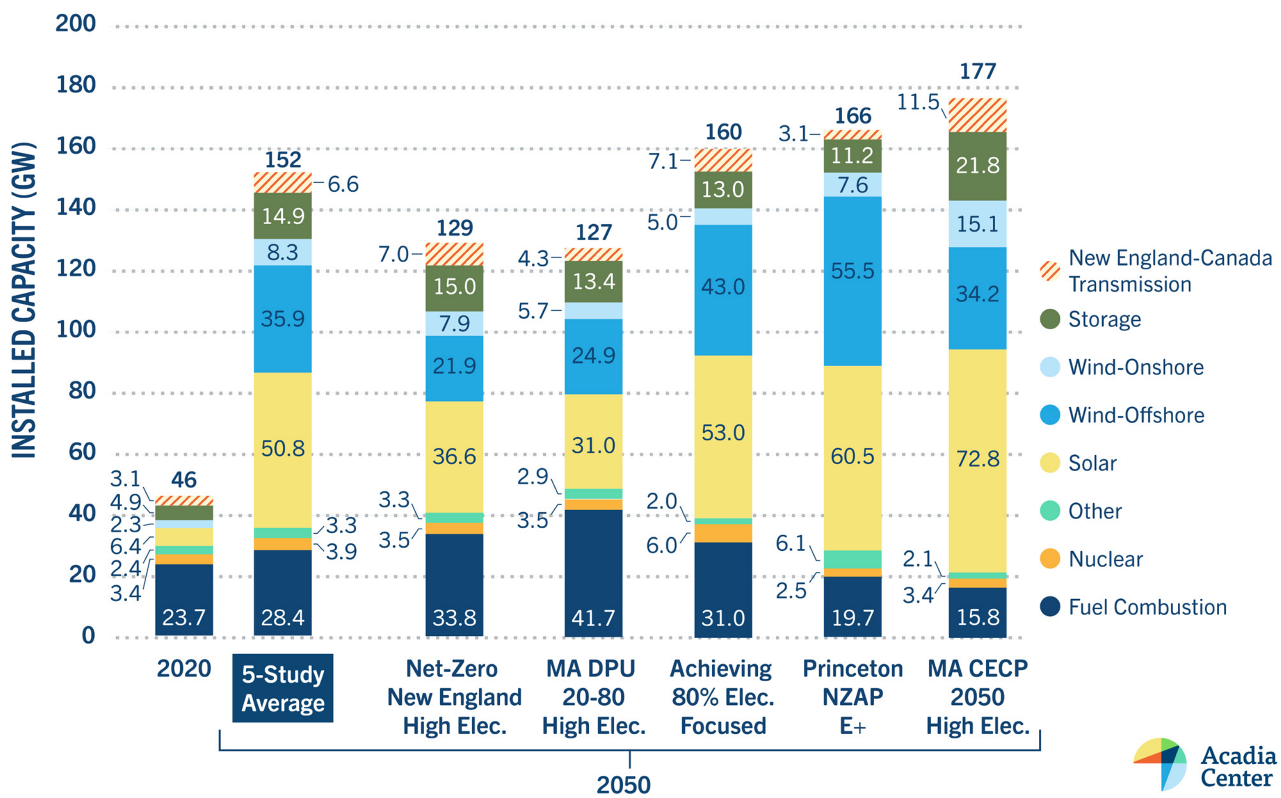
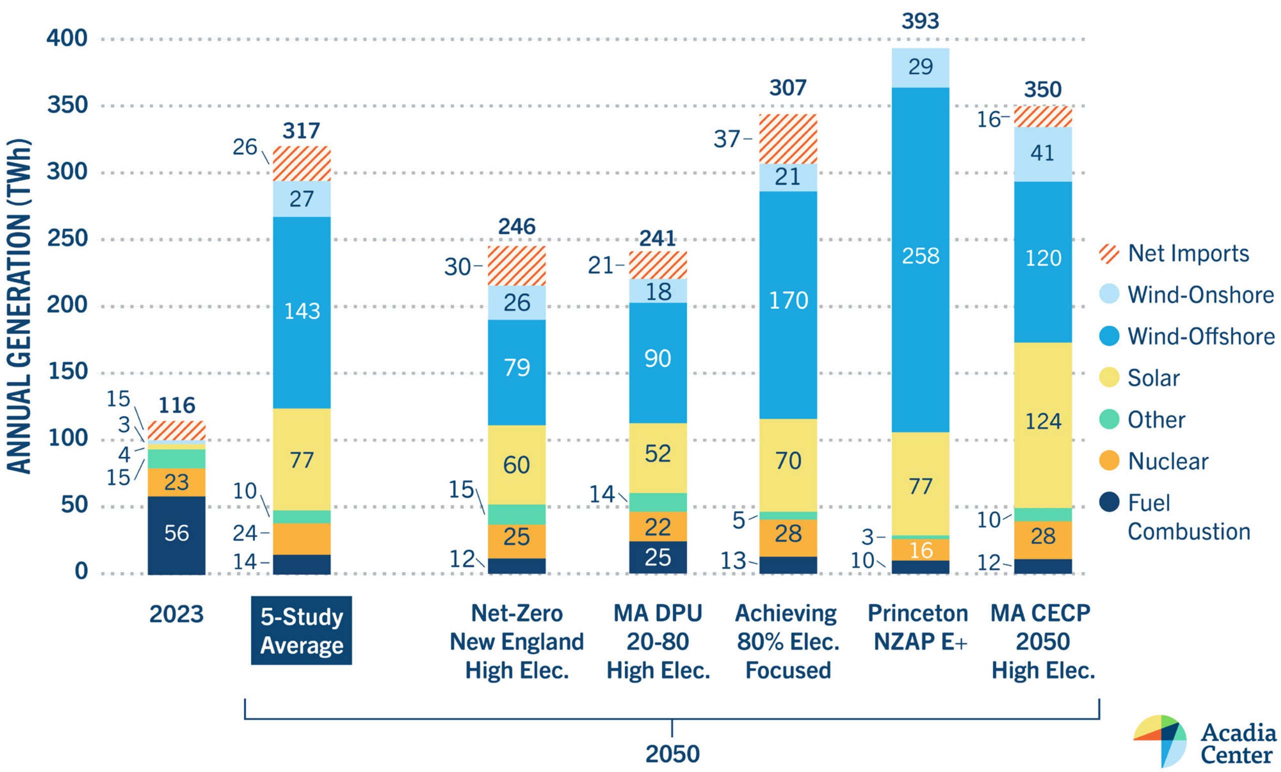


FIGURE 9

New England Annual Generation by Resource Type: 2023 vs. 2050 5-Study Comparison



As shown in **Figure 8**, across the five studies, the increase in overall New England generation capacity between 2020 and 2050 ranges from a factor of 2.8X (Net-Zero New England) to a factor of 3.8X (MA CECP 2050). There is a dramatic increase in solar and wind capacity, with the five-study average showing about 11 times wind and solar combined capacity in 2020 by 2050. Solar and wind account for 73% of total generation capacity in 2050 across the studies, while fuel combustion capacity accounts for 22% of total generation capacity. All studies maintain the region's existing nuclear units through 2050.

However, modeled levels of installed capacity in the region by 2050 don't tell the whole story. **Figure 9** on the prior page illustrates the annual generation (TWh) in New England by resource across the five studies, highlighting the workhorse role the studies envision for renewables.[46] In the five-study average, while renewables comprise 73% of installed generation capacity by 2050, they contribute 84% of annual generation (Figure 10). This disparity between installed capacity and annual generation is even more pronounced for offshore wind, which accounts for 28% of 2050 installed generation capacity but 49% of annual generation (**Figure 10**), owing to the resource's relatively high capacity factor.

While the five-study average indicates that fuel combustion capacity increases 20% from 2020 to 2050 (from 24 GW to 28 GW), generation derived form combustion resources decreases 75% from 2023 to 2050 (from 56 TWh to 14 TWh). Studies find low capacity factors for combustion plants (**Figure 11**),[47] reinforcing the roles for solar and wind as the backbone of electricity generation in 2050 and for fuel combustion capacity as "firm generation" during the coldest, least windy hours of the year to complement wind and solar variability. However, studies differ in terms of fuel combustion capacity anticipated to be online and how often that capacity is operating. The MA CECP 2050 study finds 50% less installed fuel combustion capacity in 2050 (15.8 GW) compared to the 2050 average of the other four studies (31.6 GW), but relatively high run-time and capacity factor—an important tradeoff affecting community impacts and siting requirements.Ongoing technological advancements fulfilling a "clean firm" role, such as long duration energy storage, may affect the ultimate size and operation of this "fuel combustion" category.

Figure 8 on page 25, showing generation capacity by resource in 2050, did not differentiate between distributed and utility-scale solar generation because two of the five studies (Achieving 80% and MA CECP) did not provide data on this topic. However, given the immense land use implications of utility-scale solar generation, **Figure 12** below highlights the breakdown of solar generation by type for studies where data is available.[48] The three-study average shows distributed solar accounting for 29% of total solar capacity by 2050, with utility-scale solar accounting for the remaining 71%.

FIGURE 10

% of New England Total Capacity, Total Generation & Capacity Factor by Resource in 2050: 5-Study Average

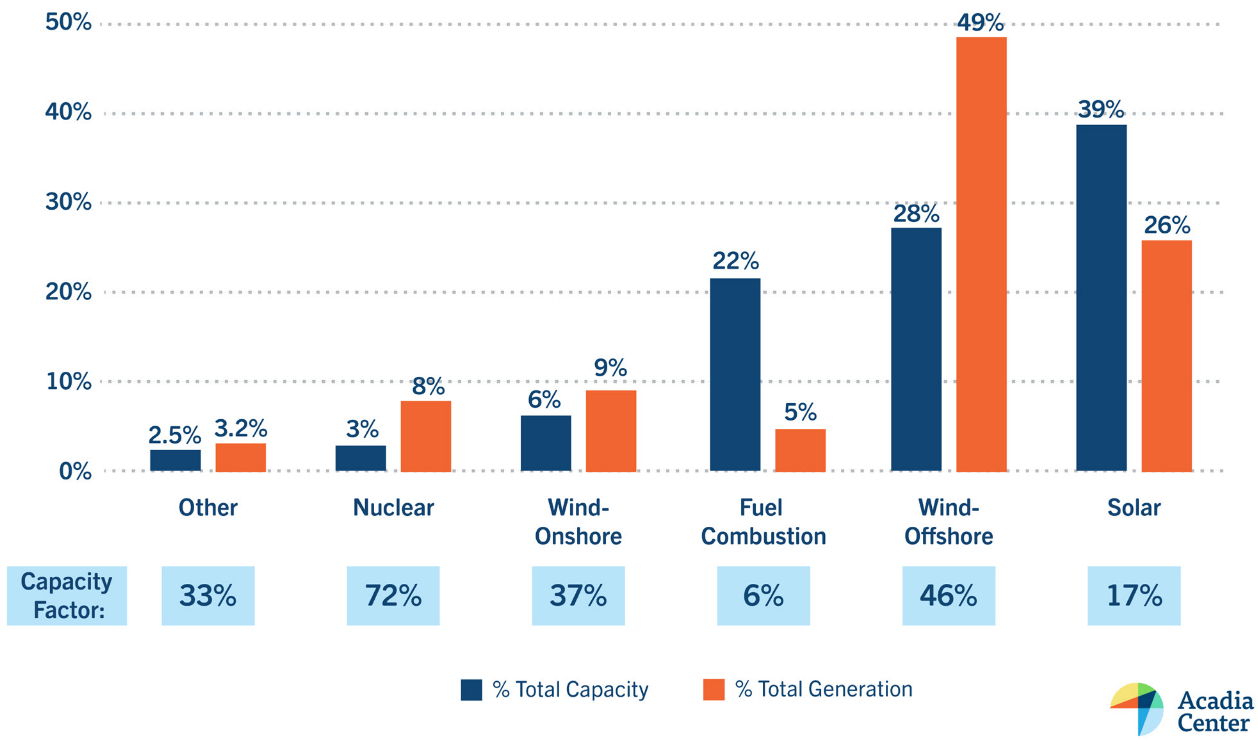


FIGURE 11

New England Firm Combustion Capacity and Capacity Factor in 2050: 4-Study Comparison

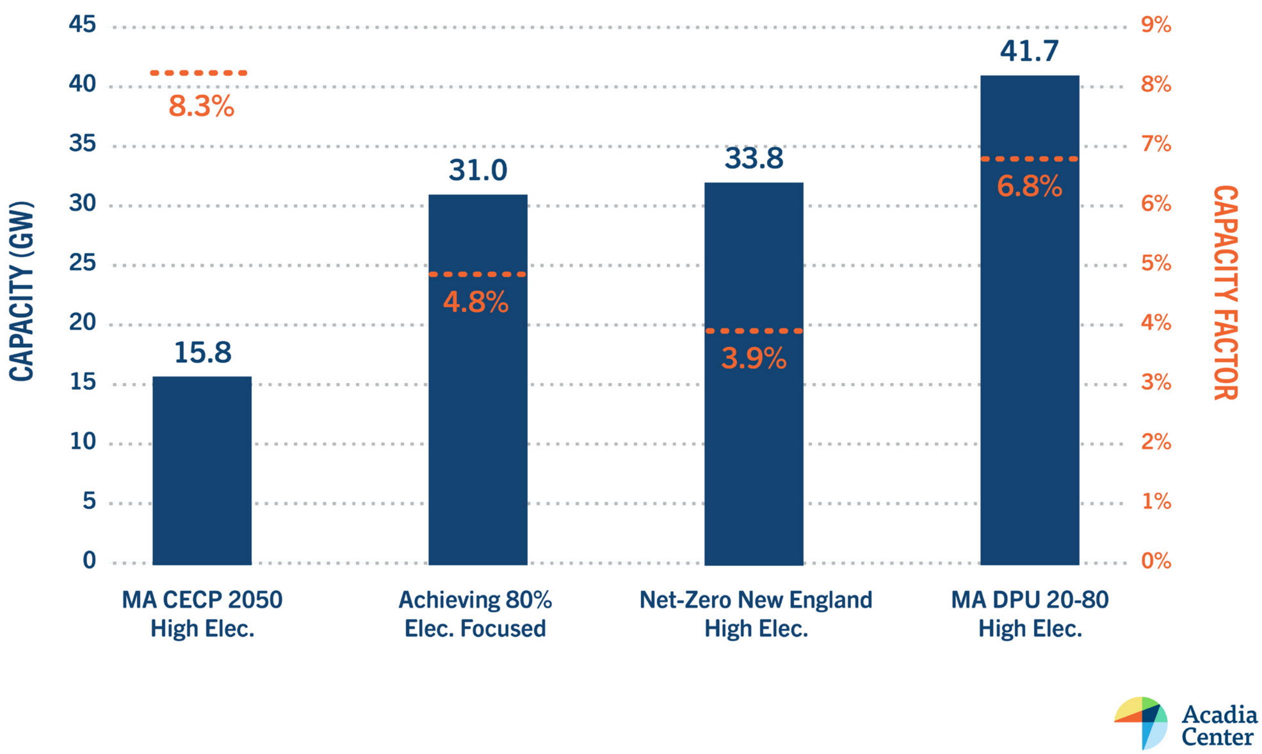
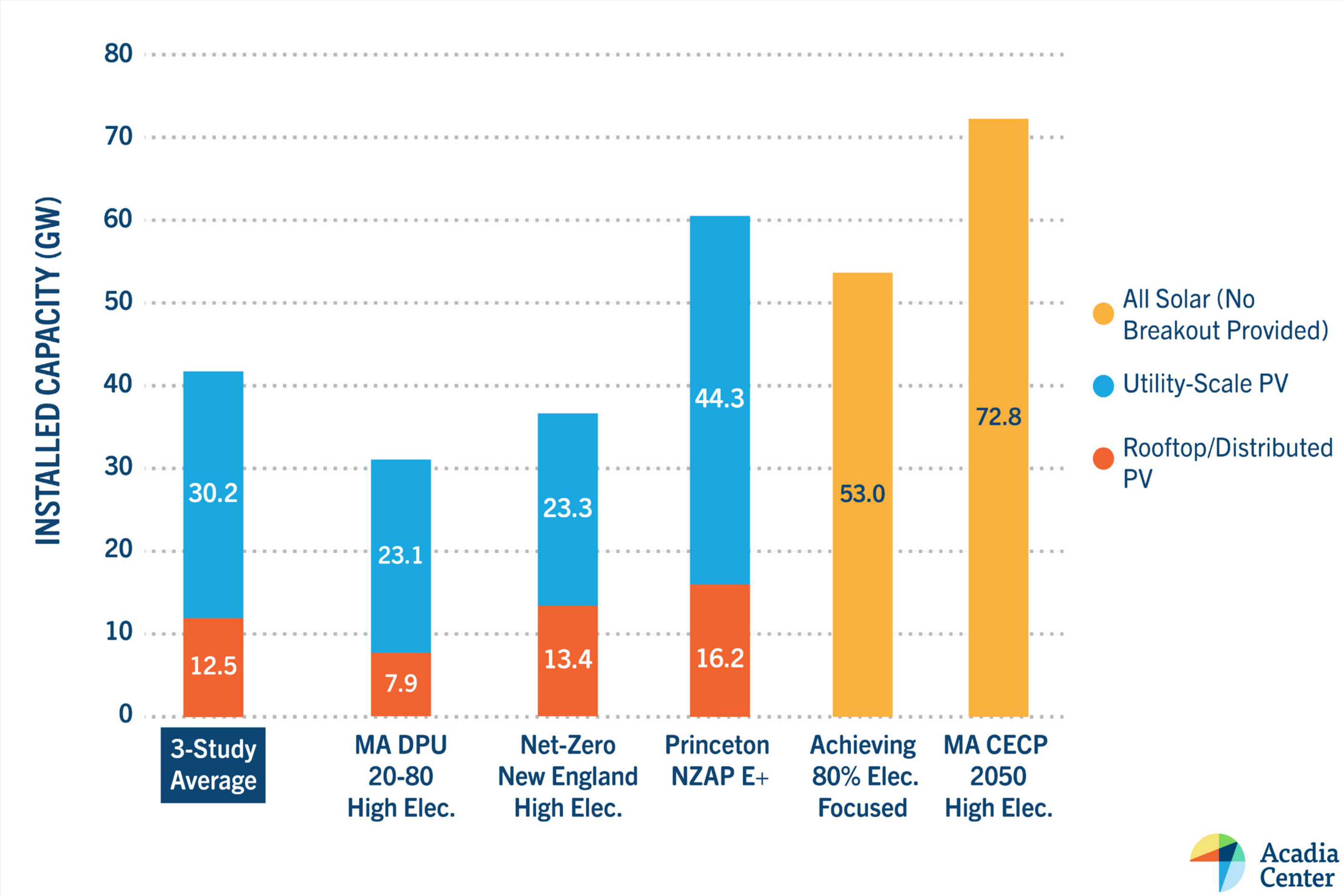


FIGURE 12

New England Distributed vs. Utility-Scale Solar Capacity in 2050: 5-Study Comparison

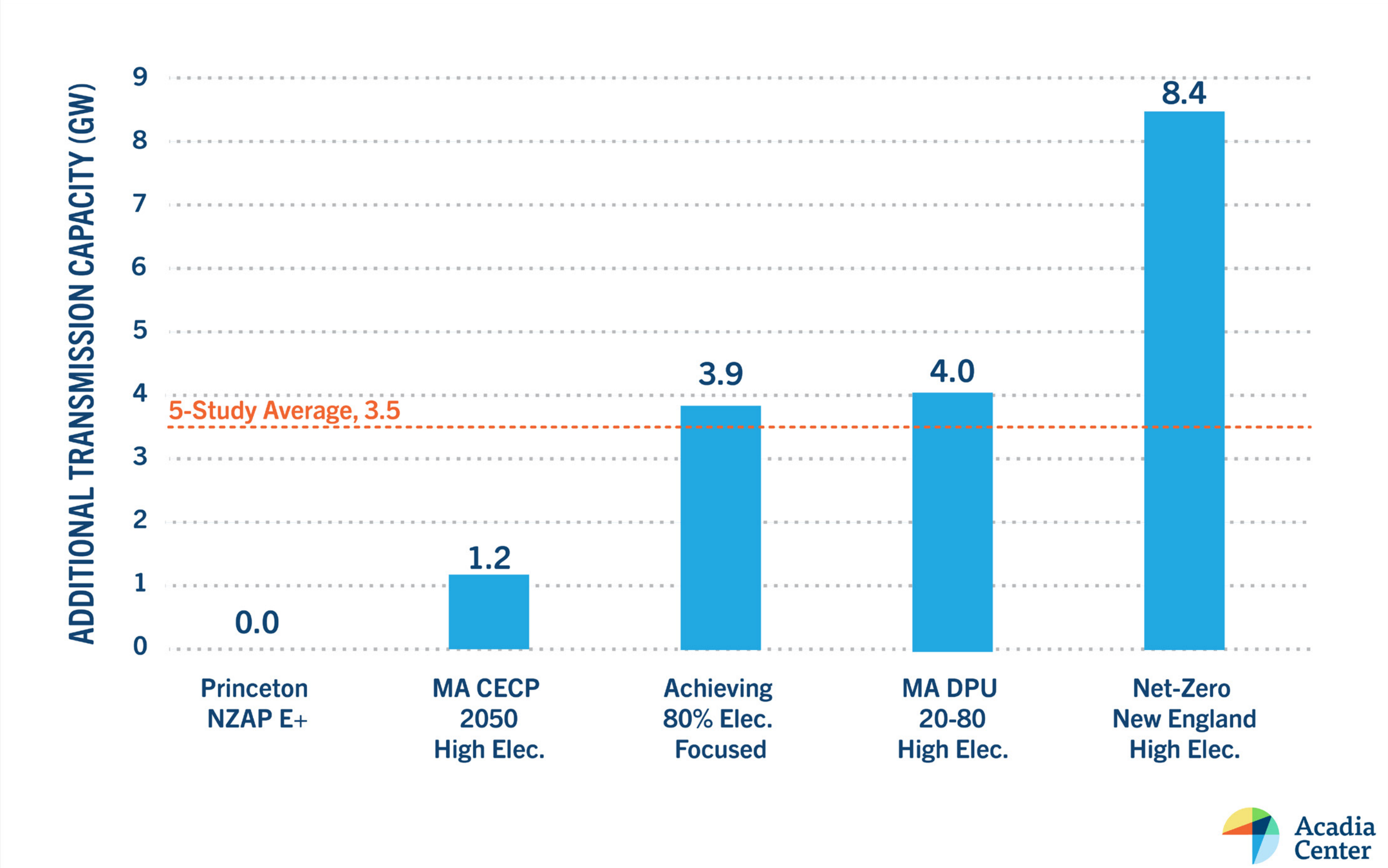


EXPANSION OF INTERREGIONAL TRANSMISSION REDUCES AMOUNT OF GENERATION CAPACITY NEEDED IN NEW ENGLAND, BUT MODELING ASSUMPTIONS VARY CONSIDERABLY ACROSS STUDIES

Expansion of interregional transmission will be crucial for reducing the amount of new electric generation needed in New England. Increasing transmission capacity between New England and other neighboring regions (i.e., Canadian provinces, New York) will make the region more resilient as it increases reliance on variable resources like wind and solar over time. The Massachusetts 2050 Decarbonization Roadmap—a precursor to the 2050 CECP that shares the same overarching modeling approach—specifically analyzed a Regional Coordination scenario to examine the benefits of lower assumed transmission costs, resulting in expanded buildout of both inter- and intra-regional transmission in the region.[49] By 2050, relative to the All Options scenario, this Regional Coordination scenario, modeled 2.4X more additions of inter-regional transmission (23.9 GW vs. 10.1 GW) and 2.5X more additions of intra-regional transmission (4.8 GW vs. 1.9 GW). This additional transmission reduced overall 2050 capacity needed in the region by over 10 GW relative to the All Options scenario—largely driven by decreases in solar, wind, and storage capacity.

A key focus of discussion is high-voltage direct current (HVDC) transmission expansion between New England and Canadian provinces and the multiple benefits associated with this new transfer capacity. **Figure 13** below summarizes 2050 HVDC New England-Canada transmission expansion shown in the modeling from the five studies.[50]

FIGURE 13
Additional New England-Canada Interregional Transmission Capacity by 2050: 5-Study Comparison

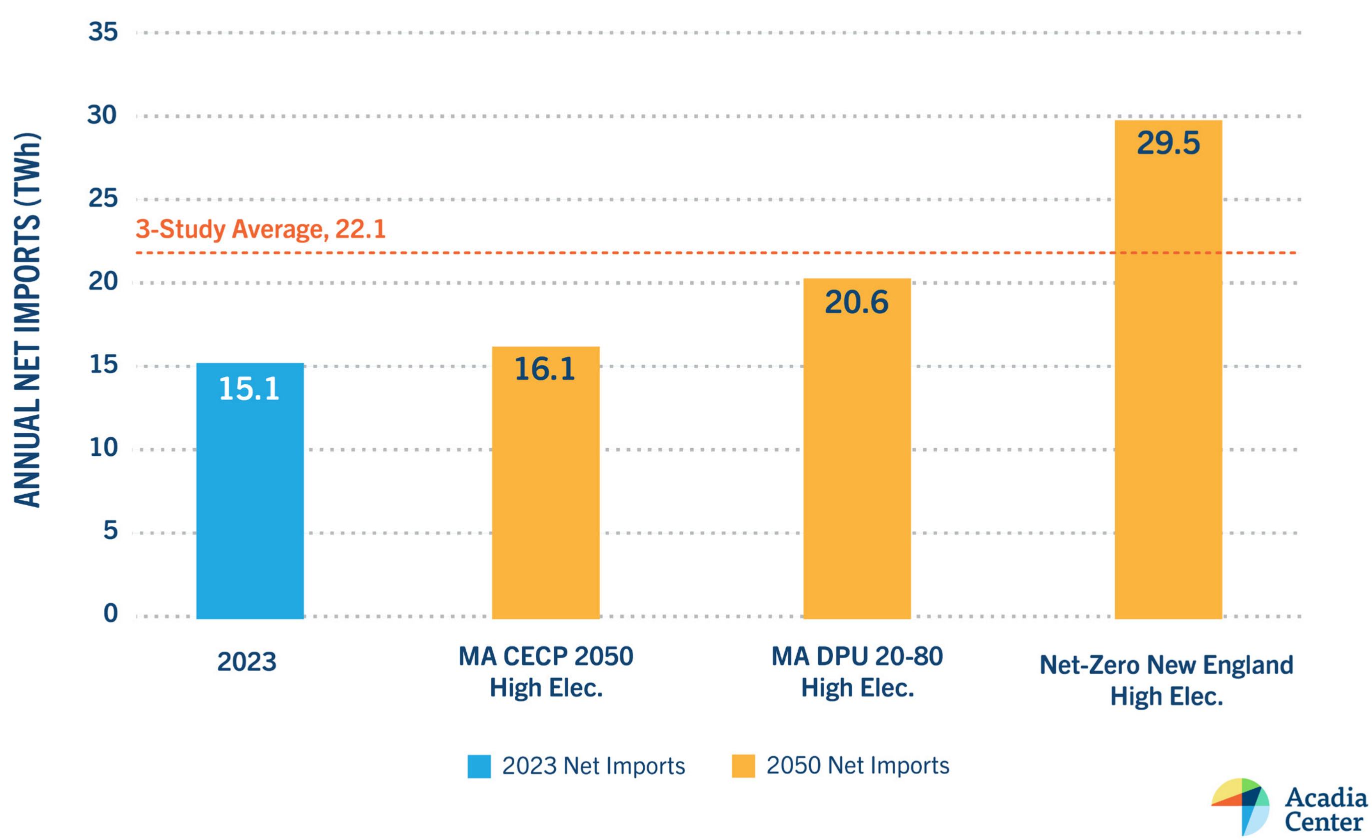


As **Figure 13** summarizes, the level of New England-Canada transmission capacity expansion varies considerably across the five studies. The five-study average is an expansion of 3.5 GW by 2050, representing a 113% increase in New England-Canada transmission capacity relative to 2020, but findings across studies range from a low of 0 GW (Princeton NZAP—additional transmission buildout between the United States and neighboring countries was not considered for that study) to a high of 8.4 GW (MA CECP 2050). Build-out of transmission capacity both between the New England states as well as between New England and New York will also be key to minimizing costs and maximizing resiliency within the region. However, only one of the five studies (MA CECP) explicitly modeled additional New England-New York transmission buildout. The MA CECP study modeled a 6x increase in New England-New York transmission capacity over the 30-year time period (2.0 GW to 12.2 GW) and a 2.9x increase in New England-New England (intra-regional) transmission capacity over the same time period (12.0 GW to 35.3 GW).

As shown in **Figure 14**, New England already imports a considerable amount of electricity from neighboring regions each year, to the tune of 15.1 TWh. Nonetheless, three of the studies examined present projections of future imports that would see the region's net imports grow to an average of 22.1 TWh by 2050 (1.4x), with a fairly wide band of projections around that average.

FIGURE 14

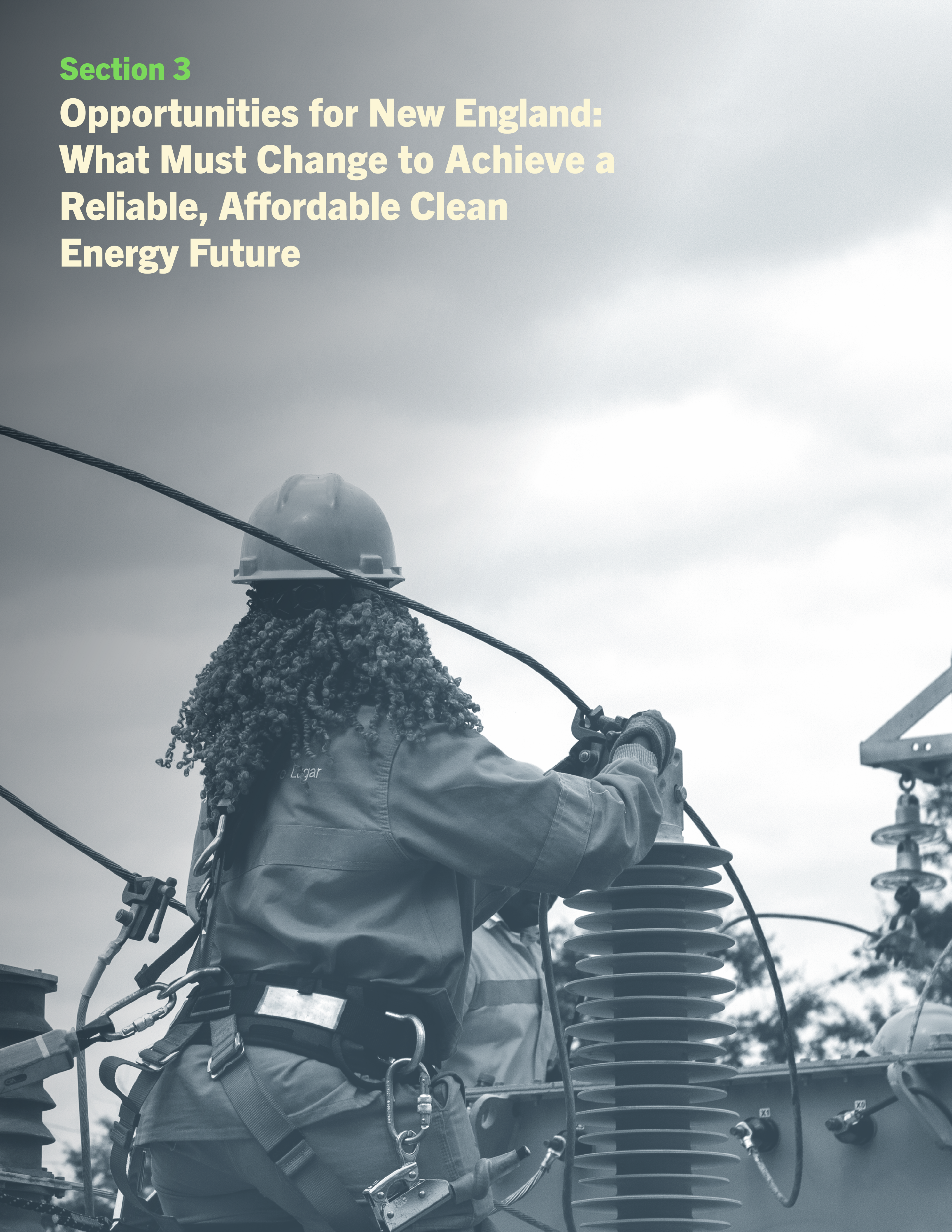
New England Annual Net Electricity Imports: 2023 vs. 2050 3-Study Average



In general, the studies provided inconsistent levels of specificity in terms of geographic origins of the projected increases in net imports: the Net Zero New England study found a significant increase in imports from Quebec, while New York and New Brunswick stay flat; the MA DPU 20-80 study did not provide a regional breakout; and the MA CECP study provided the most granular detail, finding roughly a doubling of net imports from Canadian provinces while New England would become a net exporter to New York by 2050. By 2050, generally speaking, the imports/exports between regions would likely consist of generation from clean energy resources, given neighboring jurisdictions' climate targets and resource mixes. As discussed further in the report, the variation in these findings—combined with further disparities likely to be found in the modeling for other jurisdictions' respective plans—indicates that improved interregional coordination and planning with New England's neighbors will be key to optimizing the broader region's grid for affordability, reliability, and decarbonization.

Section 3

Opportunities for New England: What Must Change to Achieve a Reliable, Affordable Clean Energy Future



Section 3: Opportunities for New England
What Must Change to Achieve a Reliable, Affordable Clean Energy Future

In order to meet increased demand, as projected across the studies analyzed in Section 2, while achieving decarbonization goals, New England will need to deploy significant amounts of clean infrastructure rapidly and in a responsible, inclusive manner - meaningfully reflecting community priorities and input. Additionally, ISO-NE and state PUCs must meet their paramount responsibility to maintain reliability and affordability for ratepayers. As examined in detail above in Section 2, New England is entering a new era of planning for grid reliability and affordability, driven by new load growth patterns, significant evolutions in the region's generation mix, shifting economics of generation resources, and increasingly unpredictable weather patterns caused by a changing climate. In this decarbonized, high-renewable future, preserving grid reliability largely encompasses four related elements:[51]

- Resource adequacy: supplying enough generation and storage to balance demand during all 8,760 hours of the year, especially during prolonged winter cold snaps;
- Flexibility: reacting and responding to changes in the variable output of wind and solar generation through a combination of planning, operational, and technological solutions;
- Stability: maintaining grid frequency in the event of major disruptions, such as the failure of a generator or transmission line;
- Resilience: solving for a changing climate and more extreme weather conditions that add uncertainty and risk, requiring a grid with the capacity to anticipate, absorb, adapt to, and recover swiftly from a wide range of shocks and stresses.

The following section describes a series of solutions and strategies to overcome technical barriers to achieve both state climate and reliability mandates while decarbonizing the electricity grid. The key mechanism to accomplishing this transition, while keeping the lights on and heat pumps running, is a wide portfolio of clean energy technologies to bring broad reliability and affordability benefits to the region, including:

- New and repowered renewable generation to save fuel and deliver when the grid needs power most, like solar during summers and offshore wind during winters;
- Short- and long-duration energy storage systems to balance diurnal and seasonal needs, stabilize wholesale market forces, and move surplus supply to match up with periods of peak consumption and/or under-production;
- New and expanded regional and interregional transmission lines to better move power from where available to where needed;
- Widespread upgrades to existing transmission and distribution infrastructure to get more out of the region's infrastructure – including via reconductoring and adoption of advanced transmission technologies (ATTs) and grid-enhancing technologies (GETs);
- The continued proliferation of distributed energy resources, flexible load, and virtual power plants (VPP)—turning homes, business, and vehicles into engines for the energy transition;
- Ample weatherization of the region's buildings and other "passive" demand-side measures to reduce peaks and overall consumption; and
- Uptake of emerging dispatchable, emissions-free resources (DEFR) to buttress solar/wind production with "clean firm" capacity and displace fossil capacity.

A portfolio approach for clean energy is already emerging and providing significant contributions today, looking ahead, New England will need a broader and more coordinated portfolio of clean resources,[52] including supply- and demand-side solutions, to match projected demand increases, particularly from EV and heating electrification, and meet resource adequacy needs. The region can deploy significant renewable resource additions and pursue other deep decarbonization strategies while existing natural gas plants reduce their runtime and ultimately phase offline.[53] Alongside these technical challenges are a host of sociopolitical barriers to siting, permitting, and deploying the infrastructure needed to achieve widespread decarbonization, discussed in more detail in Section 4.

DEMAND-SIDE RESOURCES INCREASE ENERGY EFFICIENCY AND MITIGATE PERIODS OF PEAK DEMAND

Today, ISO-NE projects that energy efficiency and behind-the-meter solar together will reduce grid demand in 2032 by 21,000 GWh, helping to counteract the upward pressure on demand from heating and vehicles (roughly the same magnitude of added demand during this timeframe).[54]

Even in this extensive framework for flexibility solutions, the role of resources like energy efficiency and weatherization are arguably underemphasized or even omitted, owing to their "passive" or "inflexible" nature. However, in New England, according to the MA 2050 CECP modeling analysis referenced in Section 2, about 56% of future ISO-NE peak winter demand will be driven by space heating in buildings under a high electrification scenario.[55] "Always-on" resources like passive efficiency, weatherization, and other shell measures can bring the demand curve down, mitigate the full extent of grid impacts during periods of stress, and make it easier for the more active flexible resources to meet resulting peak needs.

Furthermore, energy efficiency can and should be deployed as a competitive resource, able to be procured and acquired by the MWh or MW just as states and the region currently procure generation resources. Thinking about the most cost-effective ways to serve the marginal MWh or MW of demand, the region will likely find significant energy efficiency resources capable of avoiding demand for prices at or below, e.g., the volumetric costs of other public policy resources currently being procured, from offshore wind to community solar.

In general, there is a tendency to overlook demand driven by inefficiencies during periods of grid stress – as evidenced perhaps most notably in Texas during Winter Storm Elliot. While typically described as a supply crisis, the disaster was also inextricably linked to spiking demand owing to inefficient buildings and space heating systems not designed to operate efficiently in extreme cold conditions.

On the active demand management side, several of the major studies examined in Section 2, above, estimate that significant portions of electrified demand can be managed and effectively moved away from peak periods—including up to 75% of EV charging load and up to 25% assumed to be flexible.[56] Projecting load flexibility out to 2050 is a challenging exercise, and these estimates may prove to be conservative. However, there is mounting interest and promise in the Virtual Power Plants (VPP) model, which together should help unlock GWs of flexible capacity for the region by 2050 through a variety of resource types. All told, passive and active demand-side resources like energy efficiency and flexible demand will likely be just as important to preserving reliability as supply-side resources.

SOLAR SHINES BRIGHT AS FUEL-SAVER AND PEAK-SHAVER

Solar resources bring another critical set of reliability and affordability attributes to the region's current and future clean energy portfolio. On the summer-peaking system the region has today, more than 400,000 solar resources sprinkled across the region produce upwards of 7,500 MW of power during the hottest, sunniest days when air conditioning load causes demand to spike. This well-timed supply suppresses wholesale electricity prices, reduces the net peak on the system, and shifts the peak to later in the evening when the sun goes down, bringing temperatures (and air conditioning load) with it. Over the course of the year, solar resources fulfill a vital fuel-saving and emissions reduction role, reducing the need for conventional fossil fuel resources to run and avoiding the associated emissions and costs. Finally, solar is the easiest clean resource to co-locate with customer load, helping defer and avoid transmission and distribution system costs and line losses. As battery storage attachment and retrofit rates continue to climb, the region's fleet of solar resources will continue to grow and become more flexible in the future, helping smooth-out daily peaks and ramping needs, and further shaving the peak. While solar resources have costs associated with them—including from long-term contracts and net metering to state incentive programs—those costs are declining, and these fuel-saving, peak-shaving, and transmission and distribution benefits make solar a highly valuable contributor for the region's clean portfolio, now and in the future.

Across the studies reviewed in Section 2 of this report, solar was found to be the single largest source of installed capacity in the region by 2050 – ranging from roughly 30 to 70 GW of capacity, from about 6.5 GW installed in 2020. For the three studies that provided a detailed breakdown of solar resources between the larger "utility-scale" and smaller "rooftop/distributed" solar, capacity was heavily weighted toward utility-scale solar deployments, at an average ratio of roughly 3:1—likely owing to the relatively lower costs of the larger systems. Currently, average solar project-size across New England states ranges from 2.4 MW in New Hampshire to 6 MW in Maine, and the low-hanging opportunities for true utility-scale projects (greater than 5 MW) are already being quickly used up, leaving fewer feasible opportunities for these larger projects over time. As a result, future solar deployments in the region are likely to reflect more of a balance between utility-scale and distributed-scale systems, although smaller, ground-mounted, distribution-system connected projects (i.e., 1 to 5 MW) will continue to grow in number and contribute clean generation across the region.

On the flipside, there will be an increasingly important role for distributed solar, including residential and commercial rooftops as well as parking canopies and other auxiliary or dual-use systems. These systems will have the ability to directly serve customer load in many instances and pair with batteries to optimize costs and provide grid services. As solar costs continue to plummet (a recent Nature study predicts solar to have the lowest levelized cost of energy, LCOE, virtually worldwide as soon as 2030),[57] there will also be increasingly economic use-cases for microgrids, "DIY" installations like so-called balcony photovoltaics, and even in some cases grid-disconnected or "off grid" systems cheap enough to forego grid interconnection. However, the need for ground-mounted solar should not be ignored. While a study produced for the Massachusetts Department of Energy Resources (DOER) finds that New England states overwhelmingly possess the technical potential for siting needed solar resources on rooftops and previously developed lands,[58] cost optimization will remain a policy priority for regulators and elected officials. As such, there will be a continued role for ground-mounted solar deployment even as rooftop, parking canopy, and brownfield opportunities are maximized.

Siting, permitting, and land use challenges have been particularly prevalent for larger ground-mounted solar systems in the region, given some impacts on and concerns about farm and forested lands (as discussed further in Section 4). There are reasons for optimism on the immediate horizon, though, as strides are made to improve the cost and efficiency of dual-use "agrivoltaics" installations combining solar with agricultural uses. Furthermore, the first wave of ground-mounted solar projects across the region, installed circa 2007-2014, will likely have the opportunity to be "repowered" with new panels/modules within the 2050 timeframe, which will increase existing solar capacity through panel efficiency and may shrink projects' land footprint.

OFFSHORE WIND WEATHERS THE WINTERS, PLAYING A CRITICAL ROLE IN RELIABLE AND AFFORDABLE GENERATION

During costly winter peak periods, electricity generated from offshore wind will be crucial for keeping the lights on and prices low. Recent studies validate the role of offshore wind resources for providing generation during extreme cold events, while offsetting the high costs driven by increased fuel prices.

Offshore wind is already generating power for the region at scale—the Vineyard Wind project started deliveries from its first turbines in 2024. As the Vineyard Wind project is completed and other projects, such as Revolution Wind, come online next, the region will begin to see firsthand the important fuel-saving benefits of this resource class during peak winter periods. A Union of Concerned Scientists (UCS) analysis of wind speed data found that these two projects alone would have substantially mitigated (and avoided) the emergency operation procedures put into effect by ISO-NE during the 2022 Christmas Eve cold snap discussed in Section 1: "During the critical peak hour on Christmas Eve, Vineyard Wind would have delivered more than 700 megawatts to the grid—enough to eliminate the reserve shortage and create a 'capacity surplus.' Another project that will be located nearby and is scheduled to come online in 2025, Revolution Wind, also would have made a substantial contribution, delivering more than 600 megawatts during the peak hour."[59] More recent analysis from UCS found that a regional offshore wind fleet of 8,000 megawatts (which would be approached if all bids in the 2024 solicitation were accepted) could largely resolve the present winter reliability issues facing the New England grid.

Similarly, ISO-NE's modeling of potential offshore wind capacity during New England's historic 16-day cold spell between December 24, 2017 and January 8, 2018 discussed in Section 1 illustrates how offshore wind generating capacity would have affected electricity rates. Without any offshore wind power capacity present, hourly electricity prices peaked at over $340 per MWh. ISO-NE estimates that with 800 MW of offshore wind in place (roughly the capacity of Vineyard Wind), market prices would have decreased between $6-8 per MWh. The price reduction benefits are maintained even with sudden wind turbine cut-out events, which would have been triggered by the 2017-2018 cold spell.[60]

Another regional challenge researchers identified, which transcends offshore wind development, is that transmission congestion is likely to worsen as offshore wind is expanded.[61] According to the authors, adding 4,000 MW of offshore wind increases the frequency of transmission congestion by more than 20 percent between Southeast Massachusetts and Rhode Island, and more than 7 percent between Southeast and Northeast Massachusetts. New offshore wind—and renewable energy more broadly—will need to be accompanied by new interregional and intraregional transmission capacity to minimize congestion and maximize the system-wide benefits of zero-carbon resources.

INCREASING INTERREGIONAL TRANSMISSION UNLOCKS COMPLEMENTARY CLEAN RESOURCES AND REDUCES COSTS

Expanding interregional transmission capacity between New England and its neighbors will deliver renewable energy across the Northeast, reduce curtailment of renewable resources, and improve electricity affordability and reliability in the region. According to the DOE National Transmission Needs study, New England could need an estimated 5.2 GW of new

Vineyard Wind, Massachusetts

Vineyard Wind, the first commercial-scale offshore wind project in the US, is a 62-turbine, 800 MW facility off the coast of Massachusetts. Vineyard Wind secured the lease area in 2015 and submitted detailed project plans to federal and state authorities in December 2017, followed by extensive public engagement processes. Responding to concerns from fishing groups, Vineyard Wind adjusted its plans to minimize impacts on marine habitats. Despite delays caused by environmental assessments, the project received final approvals in 2020. The project has faced challenges including a dockworker's strike following disagreement on the Project Labor Agreement. In addition, the project has faced lawsuits from fishing groups and other stakeholders alleging environmental concerns. Vineyard Wind's project permits were upheld by a U.S. district judge in October 2023, although appeals are pending in the United States Court of Appeals for the First Circuit. Meanwhile, the site has achieved its first commercial energy deliveries and remains under construction; however, an unexpected blade break incident in 2024 has set project completion back and initiated a new wave of scrutiny on community and environmental impacts. See full case study in Appendix on page 60.

interregional transfer capacity with New York by 2035, more than two-and-a-half times the current transfer capacity.[62] DOE found an average cumulative value of three hypothetical 1,000 MW transmission links between New England and New York of $300 million per line.[63] Building new transmission transfer capacity would deliver significant value to both New York and New England, reducing congestion between the two regions and bringing down wholesale market prices.[64]

The addition of incremental hydropower from Quebec through the New England Clean Energy Connect (NECEC) transmission line, once operational, is anticipated to benefit grid reliability and reduce emissions year-round, delivering roughly 9,450 GWh annually. But developing two-way transmission between New England and eastern Canada could provide greater benefits. In terms of emissions reductions, analysis shows bidirectional transmission of between 2.7 GW and 4.8 GW with Quebec is required across pathways for New England to achieve net-zero. In terms of cost, a 2020 study finds shifting from the one-way import of hydropower-generated electricity from Quebec to the United States toward a bidirectional trading of electrons could reduce power system costs by 5-6% and allow New England to use Canadian hydropower reserves as a large battery that could absorb excess offshore wind and other renewable generation and discharge electricity to New England during demand peaks.[65] Assuming 4 GW of additional transmission capacity between the regions, power system costs could decrease by an estimated 13% in a near-zero carbon power system.[66] Adding bidirectional transmission ties with Canada also avoids the need for constructing additional balancing resources in New England, thereby reducing the total electricity system costs.[67]

All told, expanded transmission capacity and enhanced coordination between New England, New York, and eastern Canada will play an important role in reducing emissions and wholesale market prices by alleviating congestion and optimizing renewable energy delivery across the region.[68]

ENERGY STORAGE INTEGRATES RENEWABLES WHILE BALANCING SUPPLY AND DEMAND

Driven by remarkable price declines in recent years (90% less than a decade ago), alongside break throughs in battery chemistries and production improvements, batteries hold significant promise to revolutionize the makeup and operation of the New England grid. From a planning and modeling perspective, New England states and the region at large must prepare for the rising tide of battery deployments accordingly. As of April 2024, New England has 367 MW/767.5 MWh of battery storage capacity and an additional 1,865 MW of pumped storage capacity.[69] As of June 2024, there are 28,289 MW of active battery storage applications in the ISO-NE interconnection queue,[70] evidencing robust market interest in storage as a solution for the region. Short-duration storage (1-4 hour) is currently dominant, but new forms of medium, long, and multi-day storage (MDS) are emerging and will likely contribute to load balancing and peak needs of the future grid in the coming decades. A 2023 report from MDS provider Form Energy—which has recently been awarded a major federal grant to build an 85 MW, 8,500 MWh battery in Maine—found that an increased role for MDS could help avoid winter energy shortages at lower cost, complement offshore wind particularly well, and reduce the need to over-build generation.[71]

In a grid with high levels of renewable energy capacity, battery storage reduces variability and smooths intermittency, and can play an important role maintaining affordability through more pronounced energy arbitrage.[72] Since the New England grid is currently majority natural gas-powered, arbitrage opportunity in the wholesale market for energy storage is limited. But as the supply mix shifts towards intermittent renewables, wholesale markets will have increasingly high-priced hours later in the day and need for greater ancillary services, encouraging the beneficial dispatch of energy storage resources. Energy storage also enables wholesale electricity markets to integrate renewable energy and absorb and shift excess renewable generation, lowering wholesale energy costs, reducing the need for new grid infrastructure, and directly benefiting ratepayers.

In the short term, before renewable energy penetration creates more organic wholesale market opportunities for battery energy storage, and while advances in long-duration energy storage improve cost competitiveness against natural gas plants, states may need to support energy storage projects to offset high (but declining) upfront capital costs, including by better integrating them into renewable procurements and distributed-scale incentive programs. At a high level, states should help incentivize the pairing of long-duration energy storage with offshore wind, and the pairing of short-duration energy storage with solar, while setting targets and benchmarks for energy storage buildout alongside achievement of renewable deployment milestones.

LEVERAGING EXISTING RIGHTS-OF-WAY AND USING ADVANCED GRID TECHNOLOGIES CAN MAXIMIZE EXISTING CORRIDORS AND WIRES IN NEW ENGLAND

New England's grid, much of which was built in the mid-20th century, needs upgrades, and new transmission capacity is needed. New England states should harden the grid, speed grid infrastructure deployment, and minimize costs to ratepayers by prioritizing transmission construction in existing rights-of-way and deploying novel technologies on new and existing lines to maximize transmission capacity.

First, new transmission builds, rebuilds, and upgrades in existing rights-of-way can minimize costs by reducing the need for construction in new corridors, which are expensive to secure and develop especially in densely populated areas. ISO-NE's 2050 Transmission Study, referenced in Section 2, identifies high-value rebuilds and incremental upgrades in existing rights-of-way that would ensure reliability while limiting costs. Because the ISO estimates transmission costs of $23 to $26 billion (approximately $1 billion per year) to serve high-end peak winter load of 57 GW by 2050, any cost savings will help maintain affordability of the region's electricity system.[73]

Advanced transmission technologies (ATTs) and grid-enhancing technologies (GETs), or combinations of hardware and software tools including dynamic line ratings, power flow controllers, typology optimization, and high-performance conductors, can also be deployed on new, existing, and rebuilt transmission lines to increase capacity and reduce congestion. While these technologies do not eliminate the need for new transmission altogether, they can reduce and defer the need for new transmission.[74] This can deliver cost savings —by one estimate, if widely deployed on the national transmission grid in 2021, GETs would have reduced congestion by 40% and saved ratepayers $5 billion.[75] Another analysis found that deploying GETs in the PJM region could yield approximately $1 billion annually in production cost savings.[76] And, according to DOE, these advanced technologies could also reduce costs by avoiding short-term renewable generation curtailment—a case study on the potential for GETs in NYISO showed a reduction in curtailment of annual wind and solar generation of between 23% and 43%.[77]

Advanced technologies also provide resilience benefits and more data on transmission lines. A 2022 DOE report found dynamic line ratings provide significant reliability and resilience benefits, including during extreme winter weather events, where insight into real-time conditions can enable grid operators to take advantage of increased ampacity under cold temperatures and high wind speeds.[78]

SPEEDING UP INTERCONNECTION QUEUES WILL BRING MORE CLEAN ENERGY RESOURCES ONLINE

Interconnection—the process of connecting new generation resources, large and small, onto the grid—presents a formidable barrier to clean energy development rivaling if not exceeding siting and permitting roadblocks. New England's interconnection challenges, both on the bulk transmission system and on utility-operated local distribution networks, create bottlenecks that slow and reduce clean generation capacity coming online, thus inhibiting the region's ability to decarbonize the grid, maintain reliability, and ensure resource adequacy.

As documented in a recent LBNL study of interconnection queues, there are 405 active projects in ISO-NE's queue, totaling 51.2 GW of capacity.[79] Projects queued up exceed currently installed capacity and could, theoretically, provide peak load contributions greater than total current peak load observed on the ISO-NE grid.[80] Recognizing this substantial backlog and significant installed capacity projections for 2050 revealed earlier in this report, New England will need to process a greater number of interconnection requests more quickly over the coming years. A full examination of potential strategies to more quickly interconnect resources in New England is outside the scope of this report, but there are many emerging solutions—both regulatory and technological—that the region's grid operator and utilities should pursue.

MAKE ROOM FOR NEWLY EMERGING, QUICKLY DISPATCHABLE GENERATION TECHNOLOGIES

Jurisdictions planning for a fully or near zero-emissions grid will likely need dispatchable, emissions-free resources (DEFRs) for flexibility.[81,82] DEFRs could include a wide variety of generation depending on state policy preferences, cost-competitiveness, and technological advancements, ranging from enhanced geothermal (in some locations), long duration or multi-day energy storage, and advanced nuclear to fuel cells or combustion turbines running on green hydrogen, ideally produced by in-region renewables. States will need to deploy these resources in the 2040 to 2050 timeframe to fully displace the fossil fuel generation that would otherwise be needed (in small amounts) through 2050 according to the deep decarbonization studies analyzed in Section 2.

UPDATING HOW THE REGION PLANS FOR RELIABILITY, ASSESSES RISK OF ENERGY SHORTFALLS

The latest, current era of planning for grid reliability in New England has brought forth new planning and modeling tools aimed to better understand and manage for the evolving circumstances surrounding the region. In 2022 and 2023, ISO-NE worked with the Electric Power Research Institute (EPRI) to conduct a study for New England under extreme weather events; they developed what is now known as the Probabilistic Energy Adequacy Tool (PEAT) for ISO-NE to use, specifically to assess operational energy-security risks associated with extreme weather events over the next decade.[83] Using historic weather data and forward-looking projections for changing climate conditions, PEAT examined the impact of the top extreme weather conditions for the grid in two study years, 2027 and 2032. The top ten weather events indicated some system risk for both of those study years, primarily during winter periods. However, the modeling found direct reliability contributions from some of the new clean energy resources identified above; specifically: the presence of new hydropower transmission line capacity (or lack thereof) was a top determinant for the number and severity of shortfalls observed (if any)—"risks are mitigated by incremental imports from NECEC." This is a shining example of how important winter electrons and transmission capacity are for addressing overall system energy shortfall risks. Notably, "similar energy adequacy risk was found with and without Everett Marine Terminal in service," pointing back to the 2023 finding, discussed in detail in Section 1, that the retirement of EMT would not produce unmanageable grid reliability risk.

Climate Impacts and Extreme Weather Up the Ante for Grid Resilience

Worsening winter storms, rising sea-levels, summer heat waves and other risk factors are increasing the potential for disruptions to supply, transmission, distribution, and demand on our grid. Even though winters are getting milder on average (winter 2023-2024 saw average temperatures 4.9 degrees Farenheit above normal), increasing climate instability may mean that outlier events stray further from that average trend and make 'design-day' planning more challenging. ISO-NE's study of climate impacts for this region (ISO-NE PEAT Stage 1 findings) revealed:

The past: over the last thirty years, extreme heat has increased in frequency and extreme cold has decreased in frequency. Still, cold extremes are significantly more common than heat extremes. Overall, winter temperatures are warming at a faster pace than summer temperatures. And, New England summer and winter *minimum* temperatures are warming faster than *maximum* temperatures.

The future: Extreme heat is projected to continue to increase in coming decades while extreme cold is projected to continue to decrease. Climate scenarios begin to diverge sooner for extreme cold (2040) than extreme heat (2050), suggesting more cold weather uncertainty soon after the region's peak is expected to shift from summer to winter. Precipitation is expected to increase modestly, whereas overall wind speed increases will be small with some location-specific increases.

All told, the analyses conducted with PEAT found that the region's energy shortfall risk is dynamic and will be a function of the evolution of supply and demand profiles in the coming years. In the near-term, the winter energy shortfall risk "appears manageable" over the critical 21-day winter cold-snap period that was the main subject of the analysis. Examination of worst-case scenarios in 2032 indicated an increasing shortfall risk profile in the back half of this decade (2027-2032); however, ISO-NE's core findings hold true: "Timely additions of BTM and utility-scale solar, offshore wind, and incremental imports from NECEC are critical to mitigate energy shortfall risks that result from significant winter load growth and retirements." In other words, new clean energy is vital for reliability.

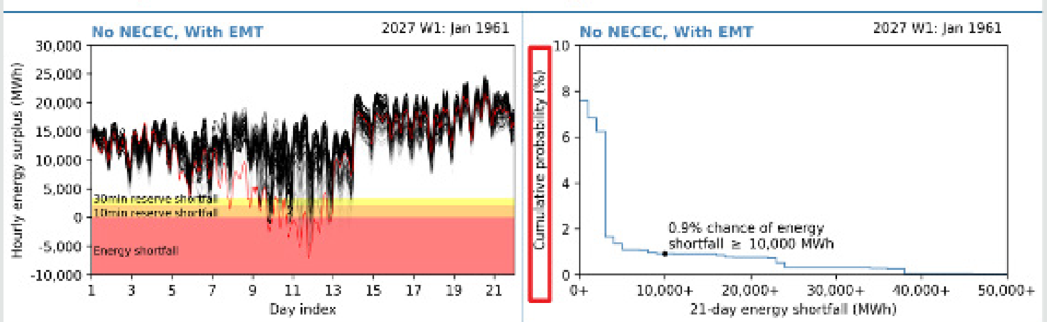
The second major new analytical tool is the Regional Energy Shortfall Threshold (REST).[84] Using results from the PEAT modeling summarized above, ISO-NE has more recently been working with stakeholders to establish a REST, meant to answer a very difficult question: what is the acceptable level of reliability risk for the region? The REST process is intended to identify where the appropriate balance lies in cost control, reliability assurance, risk tolerance, and reserve margins for both generation and transmission.

The primary focus of REST, like PEAT, is on the approaching decade and 2027 and 2032 study years. In these years, ISO-NE has continued to signal that "the risk of energy shortfalls during winter cold snaps appears manageable over a 21-day period, meaning that existing situational awareness measures, communication protocols, and operating procedures, such as calls for energy conservation, are likely to be

Figure 15

Identify Risk Metrics and Establish Thresholds, cont.

Example Metrics From ISO's 2027 Analysis



The red text boxes above and below highlight just a few of the metrics shared as part of the ISO's initial analysis of 2027 and 2032 events; these metrics highlighted the **worst-case (or max) 21-day total energy shortfall, probability of the case with the maximum 21-day energy shortfall, cumulative probability,** and **expected average 21-day total energy shortfall per case** – note that this metric is a probability-weighted average, akin to an expected unserved energy (EUE) metric.

# of cases having energy shortfall (of 720)	Max 21-day total energy shortfall in a case (MWh)	Min 21-day total energy shortfall in a case (MWh)	Expected avg. 21-day total energy shortfall per case with energy shortfall (MWh)	Probability of energy shortfall occurring	Probability of the case with max 21-day total energy shortfall
233	111,353	36	421	7.60%	0.0006%

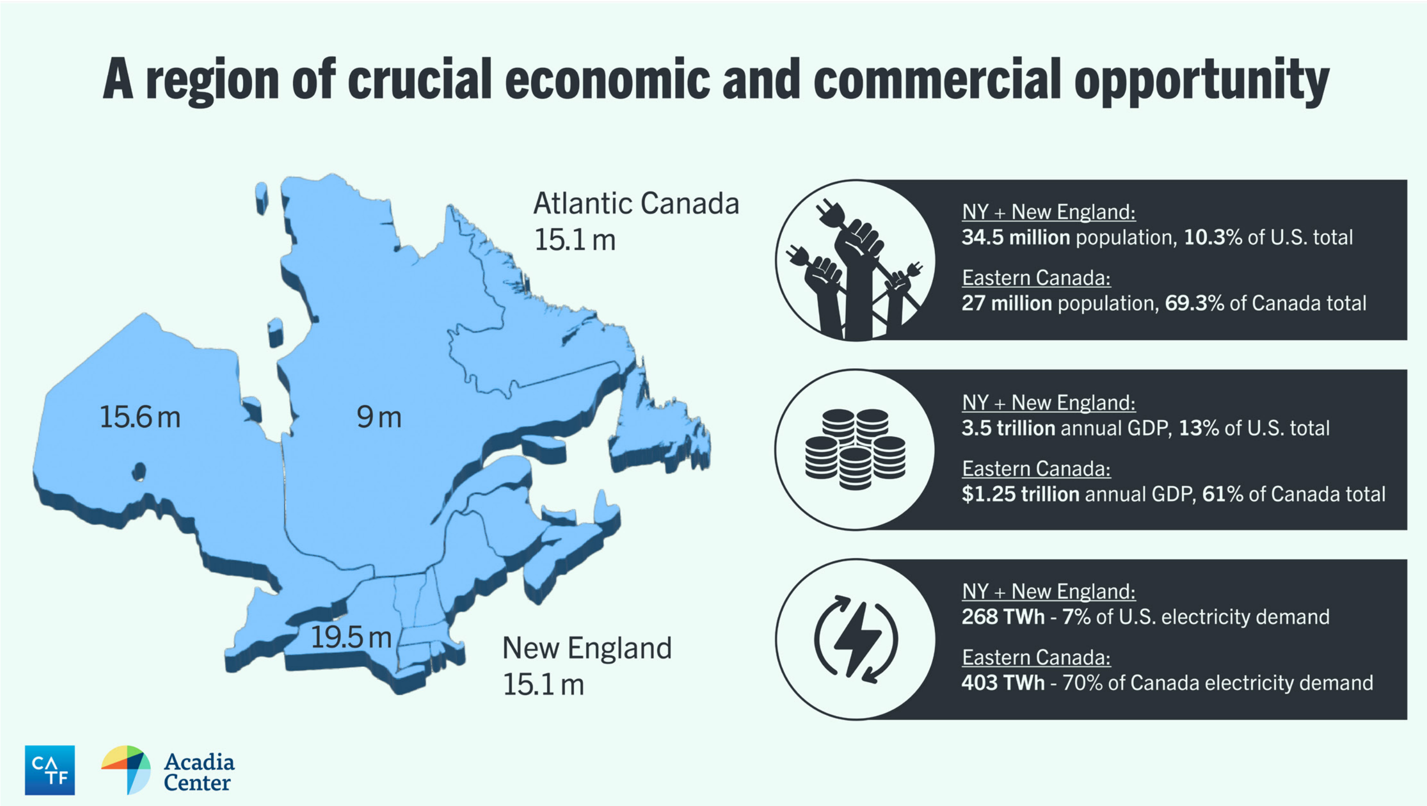
sufficient to mitigate the low probability risk of energy shortfalls."[85] The above is an example of how this probabilistic analysis plays out in one scenario for study year 2027.

The example in Figure 15, above, depicts energy system outcomes during a period of extreme winter weather, specifically one emulating the conditions of a major New England cold snap in January of 1961—and under specific assumptions for major study parameters (i.e., presence of NECEC line and/or EMT). The left graph shows hourly energy surpluses and shortfalls, and the graph on the right shows the cumulative probability for energy shortfalls of varying magnitudes to occur. In this specific example, the maximum 21-day total energy shortfall observed was 111,353 MWh, but the likelihood of this possibility occurring was extraordinarily low: a 0.0006% chance, compared to the 0.9% chance of an energy shortfall greater than 10,000 MWh, and a 7.60% chance of any energy shortfall occurring. This combination of shortfall quantities (MWh unserved) and probabilities (% chance of occurring) represents the basic intended value of the REST framework in helping examine and weigh future scenarios, including to potentially develop new regional solutions to correct for and/or avoid unacceptably large shortfall quantities or unacceptably high likelihood of occurrence.

Taken together, the PEAT and REST frameworks represent an important new set of tools and frameworks for the grid operator and interested stakeholders to use in planning for the future of the region's grid. They will undoubtedly need to be modified and improved along the way, including in several important respects, such as: better inclusion of medium and long-duration energy storage resources now beginning to come to market in the region; and a dramatically stronger embrace of interregional grid coordination and planning with neighboring balancing authorities on both the U.S. and Canadian sides of the border, rather than just project-by-project modeling assumptions for individual transmission lines.

On this latter point, the current lack of robust, coordinated interregional planning and limited interregional transmission connections between neighboring control areas (New York and Canada) inhibits optimized grid performance and poses reliability risks. This was made clear in DOE's National Interest Electric Transmission Corridors (NIETC) guidance and proposed corridors, which found for instance that "New England and New York could need up to 835% more transfer capacity in 2035 than the 2020 system permits." The more recent Internal Transfer Capacity Study (ITCS) produced by the North American Electric Reliability Corporation (NERC) found similarly that the Northeast possessed less transfer capacity between regions than most other parts of the country. To catalyze a more robust interregional planning framework, Acadia Center is co-convening the Northeast Grid Planning Forum (NGPF), focused on bringing New England States together with New York State and eastern Canadian provinces to plan for and manage transmission planning for this important 'macro-region.'

The reliability benefits of this approach to expanding the geographic footprint of the region's transmission planning are well summarized by NREL in the same aforementioned report,



finding that expanded transmission networks between balancing areas and interconnections are central to increasing reliability—ensuring the ability to move power from where it is available to where it is most needed.

Looking ahead later into the mid-2030s, the region's grid is expected to shift from a summer peaking system to a winter peaking system. ISO-NE specifically found in its latest CELT report: "By 2033, the 90/10 net winter demand forecast equals the 50/50 net summer demand forecast.… [B]y the mid-2030s, electrification is expected to cause winter peak demand to become the typical, prevailing peak season."

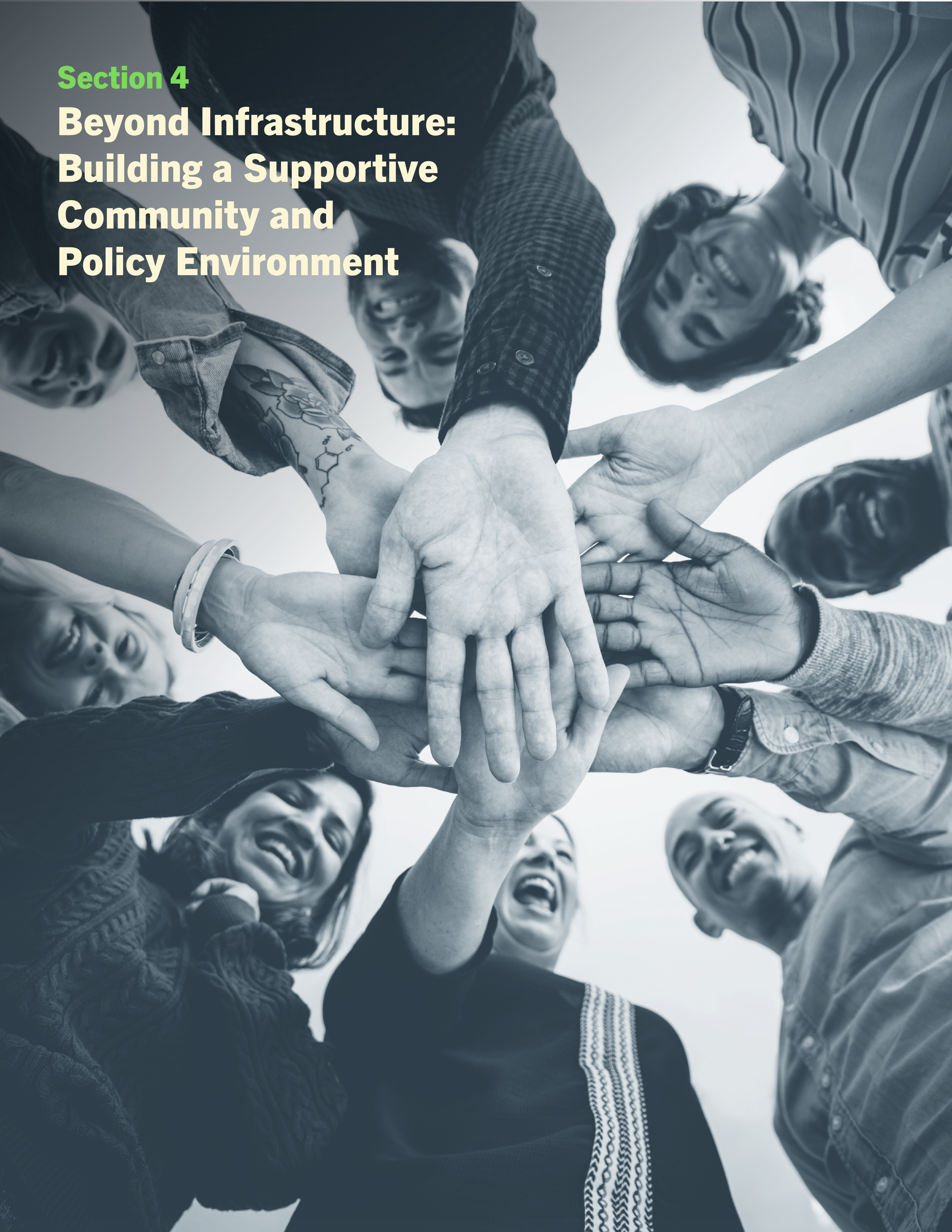
This evolution will necessarily mean new modeling results under PEAT and REST and potentially new solutions for the region as supply and demand conditions evolve dynamically in the years ahead. And undoubtedly, better interregional transmission planning will become even more important, even as it may grow increasingly complex as neighboring regions plan simultaneously for coincident or overlapping winter peak periods.

CONCLUSION

In summary, it will take a portfolio of clean energy resources—energy efficiency, offshore wind, solar, energy storage, transmission, and ATTs/GETs—coming together to help New England solve the four key pillars of grid reliability in a high-renewable, high-electrification future: resource adequacy, stability, flexibility, and resilience. Like any team, each of these individual resources will have a specific role to play and reliability attributes to help deliver. But the presence of a diversified portfolio approach will allow the whole to be greater than the sum of its parts. With increased peaks and shifting seasonal demand profiles, the modeling and planning tools relied on by the regional grid operator and utilities must evolve to stay abreast of emerging technology opportunities and keep the region's toolkit for clean reliability up to date. The new paradigm for the grid may seem daunting, but it is doable—the ingredients have all been identified, and putting them together in a holistic manner will allow the energy to truly shift.

Section 4

Beyond Infrastructure: Building a Supportive Community and Policy Environment



Section 4: Beyond Infrastructure Building a Supportive Community and Policy Environment

Studies describe how much energy infrastructure must be built in New England to reach climate goals, but constructing projects in the real world is rarely so simple. In practice, siting, permitting, and building projects requires more than technical potential and favorable economics—projects also need a supportive social and political ecosystem. There are a variety of sociopolitical barriers facing energy infrastructure deployment in New England, including policy, process, and capacity challenges; land availability and competing uses of the land; and community attitudes towards clean energy development. Some of these challenges are unique to New England, while others are shared with other regions across the country. By addressing these challenges, New England can make progress on the rapid but right-sized expansion of clean energy infrastructure needed to meet decarbonization goals and improve reliability—all while addressing and resolving, rather than skirting or bulldozing over, community preferences.

The insights presented in this section were informed by research, findings from national and regional studies, and indepth case studies on various clean energy projects around the New England region that exemplify project successes, challenges, and failures. To support the development of case studies, the project team conducted a series of interviews with various stakeholders in these projects, including community organizations, developers, advocacy organizations, and state agencies. A synopsis of each case study and relevant insights are scattered throughout this section, while the full case study analyses are compiled in the appendix.

POLICY, PROCESS, AND CAPACITY CHALLENGES

States across New England have set ambitious emissions reductions policies, yet current deployment rates are not keeping pace with statewide goals and community engagement efforts around siting and permitting are lacking—revealing a misalignment between policy ambition and the conditions for actual deployment of responsible projects. One aspect with significant bearing on project development is the level of jurisdiction for decision-making around project siting and permitting.[86] In some states, siting clean energy infrastructure is left entirely to local governments, creating a patchwork of local policies. In other states, siting decisions are made at the state level, like in Connecticut where the Connecticut Siting Council has jurisdiction over energy facility siting decisions for projects larger than 1 MW and can preempt local restrictions.[87] Across New England, there is generally a division of siting responsibilities, where smaller-scale generation resources are subject to local government approvals, while larger projects and other infrastructure (e.g., substations or transmission and distribution lines) are subject to state-level approvals (see Table 6).

LOCAL-LEVEL SITING AND PERMITTING

Where siting decisions are made at the local level, permitting and zoning regulations can slow clean energy development. Local officials, zoning boards, and town councils, when confronted with siting and permitting a new technology, may have inadequate funding, staff, and resources needed to fully consider how a project may fit into their community. For most communities, utility-scale clean energy generation may be a completely novel land use—some communities may not have any regulations or processes for clean energy siting, while others have not incorporated clean energy into planning or established permitting and review processes for individual projects. Ambiguous policies can create uncertainty for developers and confusion for communities and residents, and inconsistent zoning ordinances across municipalities create added challenges for projects that cross jurisdictional boundaries.

Given the newness of clean energy development, and because proposals are initiated by for-profit developers, communities may react to development proposals with caution. In some cases, this may lead to enactment of restrictive regulations that limit the development of clean energy. Structural elements have exacerbated this phenomenon, including communities being brought in late in the conversation, not being equipped to assess developer or utility data, or not having adequate tools or staffing to respond. Over 15% of counties in the U.S., including some in New England, have passed bans, moratoria, or other regulations that effectively limit the ability for communities to develop clean energy.[88] While some moratoria are temporary, allowing cities and towns to update their codes to accommodate the new land use, others are indefinite to effectively prohibit project development.

For this reason, when a renewable energy developer proposes a project in a community, they are often introducing the community to not just their business, but a new technology, and must play the crucial role of ambassador for the industry as a whole. With only one chance at a first impression, developers who do not perform sufficient outreach, engage only with local government officials to secure a quick approval, and do not take seriously local needs and concerns can engender local opposition and set back the entire industry.

Approval and permitting processes can be time intensive and add great complexity for responsibly developed and well-sited projects, even if those processes are intended to filter out inferi-

Johnston Winsor III Solar Project

In early 2022, Green Development proposed five solar farm projects, including Johnston Winsor III, in Johnston, Rhode Island, but all were rejected by the local zoning board after failing to obtain the supermajority of votes required for approval. Green Development appealed to the Rhode Island Supreme Court, which ruled that special-use permits require only a simple majority, allowing the project to be reconsidered by the Zoning Board. The project faced strong public opposition over deforestation and development on residential land. Stop Johnston Solar, a community opposition group, attempted to pass a ban on all large-scale solar development, but eventually failed. Green Development then proposed a scaled-down version of Johnston Winsor III, but it was unanimously denied by the Zoning Board in January 2024 after further public hearings. Green Development appealed the decision to the Superior Court, which found in July 2024 that the Zoning Board did not adequately detail its decision and remanded the cases. The future of the project remains uncertain. Rhode Island aims for 100% renewable electricity by 2033, but debates like Johnston Winsor III highlight challenges in locating larger-scale solar farms near residential communities, while demonstrating a dynamic where permitting delays can allow for mounting opposition. New legislation disincentivizes solar development in core forests while promoting preferred sites. See full case study in Appendix on page 56.

or projects that evoke legitimate local concern. Even if a project meets regulatory requirements and specifications, it may still not receive the necessary permits due to shifting regulatory goal posts or local leadership changes. For more on these factors, see the Johnston Winsor Solar III case study.

STATE-LEVEL SITING AND PERMITTING

Where the state has authority over siting decisions, concerns may arise over the lack meaningful community engagement, lengthy and cumbersome review processes, and under-resourced state agencies. State siting policies that provide clarity in decision-making processes, provide technical assistance, and expedite permit approvals could better effectuate deployment efforts, coordinate between state and local levels, and ensure broader ambitions and policy commitments are met. One regional example for shifting the share of jurisdictional authority of renewable energy siting between local governments and the state is the work of the Commission on Energy Infrastructure Siting and Permitting in Massachusetts. The recommendations from the Commission include clarity around local and state project review; permit consolidation at the municipal and state levels; a timely process to reach permit decisions; and streamlined appeals to a single justice at the Supreme Judicial Court with a strict timeline for decisions.[89] The Commission's recommendations also strengthen communities and local government's role in energy siting, including intervenor status for communities, mandatory community engagement and community benefits, and a robust pre-filing engagement process between developers, local governments, and state officials. Fortunately, the Massachusetts State Legislature acted to codify many of the recommendations put forward by the Commission after the end of the 2024 session, leaving stakeholders with a promising, regionally applicable framework for reforms, and very meaningful new processes to improve siting and community engagement in Massachusetts.

OPTIONS AND OPPORTUNITIES:

- **Pass comprehensive Permitting Reform:** Policymakers can act swiftly to develop and enact statewide permitting reforms for clean energy and grid infrastructure that balance urgency and clear, consistent non-discretionary standards with early and robust community input – focusing both on local siting standards as well as policies governing state-level energy facility siting boards and councils.

- **Improve siting and permitting processes:** State policymakers can update siting policies to improve clarity in decision-making processes, create avenues to expedite permit approvals, streamline appeals processes, require early and meaningful community engagement, and increase coordination and communication across state agencies, and between state agencies and local governments.

REGIONALLY MISALIGNED STATE POLICIES

The widespread adoption of state GHG emissions reduction policies across New England states indicates support among policymakers for decarbonizing the regional economy. All states except New Hampshire have legally binding emissions reductions requirements and targets – Rhode Island and Massachusetts are the most ambitious, requiring net-zero emissions by 2050.[90] All states set Renewable Portfolio Standards (RPS), requiring a percentage of retail electricity sales be met with renewable energy by a specific date. Yet, the re-

Figure 16: New England State Renewable Portfolio Standards[91]

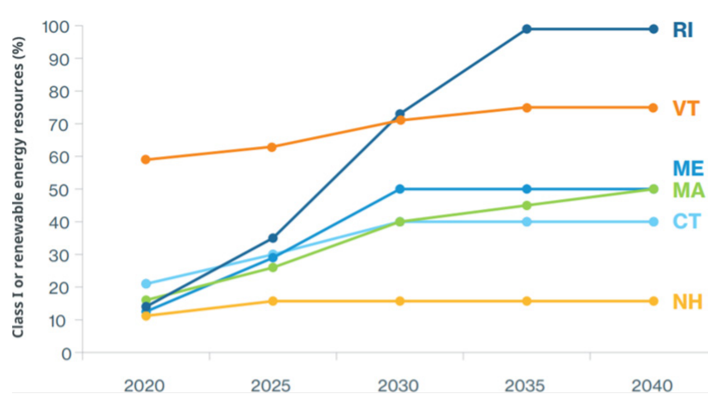


TABLE 6: STATE RENEWABLE ENERGY AND TRANSMISSION SITING AUTHORITIES					
STATE	**SITING AUTHORITY**	**STATE SITING ENTITY**	**SITING AUTHORITY DETAILS**	**RECENT LAWS**	**TRANSMISSION AUTHORITIES**
CT	State > 1 MW	Connecticut Siting Council	The Siting Council has permitting authority over projects larger than 1 MW. The council is directed to give consideration to municipal regulations, but is authorized to affirm or revoke municipal orders. Project size: 3.9 / 5	Significant reforms to the processes of the Connecticut Siting Council for permitting solar and transmission facilities, 2024[92] Solar facility decommissioning on farmland, 2023[93] Cumulative environmental impacts review and public engagement, 2023[94]	CT Siting Council has authority over transmission lines > 69 kV[95]
ME	Local and State	Department of Environmental Protection	Local governments have authority to adopt zoning requirements and to approve certain projects. Various state agencies have ultimate authority for approving impact- and environment-related permits, which are necessary for final project approval. Project size: 6 / 36	General environmental permitting authorities, 1997[96] Maine Solar Energy Act, 2013 and 2023[97] Maine Wind Energy Act, 2003 and 2023[98] Mitigation fees for farmland and wildlife conservation for solar, wind, and transmission projects, 2023[99]	ME Public Utilities Commission has authority over siting and permitting transmission lines >69kV through issuance of CPCN
MA	State ≥ 100 MW	Energy Facilities Siting Board	Siting authority for renewables in Massachusetts is based on facility size. For projects smaller than 100 MW, approval is local; for projects of at least 100 MW, approval is at the state level. The state has oversight of zoning restrictions and preemption authority for "unreasonably burdensome" zoning requirements. Project size: 2.6 / 3.5	Established initially as Energy Facilities Siting Council in 1973,[100] reorganized as Energy Facilities Siting Board in 1992 and merged into DPU[101]	MA EFSB has authority over transmission >69Kv and 1 mile in new corridor, >115kV and 10 miles in existing corridor, and lines interconnecting generation
NH	State ≥ 30 MW	Site Evaluation Committee	Siting authority for renewables is based on facility size. For projects smaller than 30 MW, authority is local. For projects of at least 30 MW, authority is at the state level. The state also has authority over certain projects between 5 MW and 30 MW. Project size: 3.92.4 / 42.8/ 5	Established Site Evaluation Committee, 2018[102]	NH Site Evaluation Committee has authority over transmission >100 kV associated with generating facility, or >100kV and 10 miles, or >200kV[103]

TABLE 6: STATE RENEWABLE ENERGY AND TRANSMISSION SITING AUTHORITIES, CONTINUED					
STATE	**SITING AUTHORITY**	**STATE SITING ENTITY**	**SITING AUTHORITY DETAILS**	**RECENT LAWS**	**TRANSMISSION AUTHORITIES**
RI	State ≥ 40 MW	Energy Facility Siting Board	Town and city governments have the authority to site clean energy facilities smaller than 40 MW through broad zoning authority. State law authorizes communities to adopt zoning ordinances that control the use of land and how it is developed. Project size: 5.4 / 2.2	RI EFSB established, 1986[104] General local government authority over zoning, 1991 and 2015[105] Limits state incentives for solar development in forests and encourages development on ”preferred” sites – rooftops, landfills, etc., 2023[106]	RI Energy Facility Siting Board has authority over transmission >69kV[107]
VT	Local and State	Public Utilities Commission	The state has minimum setback requirements for solar, prescribes the ways in which municipalities may establish their own siting standards, and remains the ultimate authority for issuing a permit. The Vermont Public Utility Commission (PUC) is also required to give “due consideration” to the recommendations of the municipal and regional planning commissions, as well as the municipal legislative bodies. Project size: 2.9 / 30.4	Act 174 incentivizes energy planning to gain deference from state PUC when siting renewables, 2016 Act 248 lays out the PUC siting authorities and process, 1969 and 2023	VT Public Utilities Commission has siting and permitting authority over electric transmission lines

quired targets and deadlines vary widely across the states. By 2040, New Hampshire requires 15.7% of retail electricity sales come from new renewable power, while Maine and Massachusetts require 50% and Vermont 75% by 2040.[108] Rhode Island has the most aggressive RPS, requiring 100% of electricity be generated by renewable energy by 2033.

The heterogeneity of policies across states adds an additional layer of siting complexity for regional-scale projects and may generate friction between states.[109] Projects may face greater scrutiny and more significant barriers in New Hampshire, given that state's lack of legally binding emission reduction requirements. Recently, New Hampshire has also limited the state's ability to enter PPAs for high-voltage lines, following the failure of Twin States Clean Energy Link (see above) thus making more difficult interregional HVDC construction in the future, and impacting energy distribution across the region.

Twin States Clean Energy Link, Vermont and New Hampshire

The Twin States Clean Energy Link was a proposed 211-mile transmission line connecting Québec to the New England grid through Vermont and New Hampshire. The bidirectional line would have increased electricity flow between the U.S. and Canada, enhanced interregional capacity, improved resilience, and facilitated the integration of clean energy projects, including Canadian hydropower. Despite committed support from the Department of Energy's Transmission Facilitation Program, a substantial $260 million community benefits plan, and a unique design that minimized the need for new overhead wires and new rights-of-way, the project developer, National Grid, canceled the project in March 2024, less than a year after its announcement. The cause of the cancellation is still unclear, although some have attributed it to difficulties in finding sufficient committed buyers for the power, and challenges in securing agreements with Hydro-Québec. Without adequate off-takers and uncertainties regarding energy capacity and market dynamics, the cancellation raises concerns about the viability of future major transmission projects in the region without enhanced coordinated planning between neighboring balancing authorities and utilities.

LOCAL GOVERNMENTS DESERVE ACCESS TO IMPARTIAL TECHNICAL SUPPORT

A significant challenge identified in our stakeholder interviews is the lack of expertise and capacity at local levels to effectively review project impacts, permit projects, and engage communities and developers throughout the siting process. Examples like Johnston Winsor Solar III (Appendix pg.56) highlight the need for state and federal agencies to provide technical assistance programs for local governments, model ordinances, and best management practices, which should be expanded to help local governments thoughtfully consider how energy infrastructure may fit into local comprehensive plans. Rhode Island agencies had previously taken action to develop statewide solar guidance and model ordinance materials for municipalities to use and consider.[110] While valuable and information-rich, these voluntary guidance materials can only go as far as interested municipalities are willing to embrace them, underscoring the need for robust outreach and engagement to communities to not only provide them with guidance materials but walk them through the process of adopting and tailoring updated zoning ordinance rules to meet both community needs and state policy goals. Finally, as referenced above, state agencies and contractors can also help be a conduit for information-flow between the community and the local utility or the regional grid operator, sharing information on existing grid infrastructure and points of interconnection (POI) as well as status updates on specific projects in the interconnection queue.

OPTIONS AND OPPORTUNITIES:

- **Increase government capacity:** State policymakers can make durable commitments to increase state and local government capacity, through added staff with technical expertise at permitting entities, financial resources for technical consultants, and state-local liaisons to ensure adequate bandwidth for timely review and permitting decisions of many gigawatts per year of new project capacity across the region.

- **Provide technical support to local governments:** State agencies can provide robust technical assistance, guidance materials, financial incentives, and education to local governments, updated frequently to stay abreast of changing market trends. This should include robust outreach and engagement to communities to not only provide them with guidance materials but walk them through the process of adopting and tailoring zoning ordinances to meet both community needs and state policy goals.

LAND USE AND SITING CHALLENGES

SITING CONSIDERATIONS

Where land may have the technical potential for clean energy deployment, other project-specific considerations may limit the potential site's practical feasibility, effectively reducing the amount of land suitable for development. Many factors go into siting a single energy facility. On top of the resource capacity to power energy generation projects (i.e., suitable solar or wind resources), a potential site must also have proximity to transmission or distribution lines, the appropriate landscape and subsurface characteristics (and absence of incompatible land and subsurface characteristics, like wetlands), and a large enough parcel size or the ability to aggregate multiple parcels. Even if a site is deemed suitable, it still may face challenges like high land prices, local zoning regulations, landowners uninterested in selling or leasing their land, or opposition from community groups. For transmission projects, developers must secure rights-of-way from landowners all along the proposed route, spanning multiple jurisdictional entities, including towns, counties, and even states, each with their own regulations. Without willing landowners, projects face serious headwinds. Siting a line across public land brings its own challenges, including mitigating impact on protected and sensitive lands and long and complex environmental permitting processes.

In the case of the proposed 160-mile transmission line serving the Aroostook Renewable Gateway in Maine, landowners unified strongly in opposition to the project over concerns about environmental, property value, farms, viewshed, and local economic impacts.[111] Many landowners suggested burying the line to address concerns over viewshed impacts, but that approach would incur substantial added costs and would likely compromise the project's financial viability. For the Aroostook Renewable Gateway transmission line, the developer LS Power estimated that burying the line would have increased the project costs by a factor of five, a huge increase for a project with a price tag already at $1.8 billion (see more on the project below).[112] Though these siting considerations play out on the scale of individual projects, in the aggregate, they effectively limit the land that is practically developable. Existing and planned developments for generation and transmission are the low-hanging fruit, sited in the locations with highest potential and lowest likelihood of conflict, meaning future development will face more challenges finding sites that are both technically and practically feasible. These learnings underscore the need for multi-level stakeholder dialogues across the region to coordinate land-use planning and ensure deployment is prioritized in the least-conflicted areas - while plans are also put into place for the higher-hanging fruit areas in years ahead.

King Pine Wind and Aroostook Renewable Gateway transmission line, Maine

King Pine Wind is a proposed 1,000 MW onshore wind energy facility in northern Maine, and LS Power Grid Maine is a proposed transmission line to interconnect the wind energy facility with southern Maine and the ISO-NE grid, called the Aroostook Renewable Gateway. In 2022, the Maine Public Utilities Commission (PUC) selected these projects through a request for proposals, and both King Pine Wind and LS Power arrived at power purchase agreements (PPAs) with Maine and Massachusetts, which was also interested in the Northern Maine procurement. Although the King Pine Wind project received positive responses due to careful siting at a remote location on previously disturbed land and its economic benefits, the transmission line faced significant public opposition and siting challenges, including moratoria from at least 11 towns. Ultimately, the Maine PUC terminated the transmission line procurement due to unresolved cost disagreements with LS Power, who requested a price adjustment amid project delays. Despite this setback, Longroad Energy remains committed to advancing the King Pine Wind project. See full case study in Appendix on page 52.

LAND USE CONFLICTS

Conflicting tensions around how land is used, and the conversion of land from one use type to another, creates additional friction around clean energy development. Land is a finite resource, and competing land use interests, such as agriculture, conservation, industry, and urban development further restrict the availability of sites for clean energy infrastructure. In New England, concerns around conversion of agricultural and forested land are particularly prevalent, due in part to the relatively small geographic size of New England compared to other states and regions.

The New England region is heavily forested—Maine is the most heavily forested state in the U.S. with forests accounting for nearly 90% of the land area.[113] Even in states like Rhode Island, which has less forested land and less available land overall, much of the potentially developable land for large-scale solar, for example, could require some clearcutting of forests, a concern identified by community members for many projects, including the Johnston Winsor III Solar project mentioned above.[114] Clearcutting for energy development has drawn criticism from many community and environmental groups. In 2023, Rhode Island passed legislation that disincentivizes solar development in core forests while promoting development on "preferred sites" of brownfields, landfills, along highways, and on rooftops and carports.[115] Notably, the restrictions for developing solar in forests are more stringent than for other types of commercial development. While brownfields, landfills, rooftops, and parking lots offer important avenues to limit land conversion and new greenfield development, these spaces cannot by themselves cost-effectively meet all of the region's clean energy needs.[116] Policies and land use planning processes should thoughtfully consider the balance between mitigating impacts on the most sensitive ecological landscapes, while identifying lower-conflict lands for the beneficial development of larger-scale projects.

The conversion of agricultural land has also drawn concern, particularly in rural communities, over loss of prime farmland and changing community identity. The amount of farmland has steadily declined in recent decades due to a variety of factors, including low-density residential development,[117] but a recent uptick in the conversion of farmland for clean energy generation has sparked debate over land loss, increased land prices, and land access. However, a survey of farmers in Connecticut, led by American Farmland Trust, found that farmers are generally supportive of solar development on farmland where care is taken to mitigate impacts on the most suitable farmland.[118] In many of those cases, solar can be a tool to help keep farms in operation, by providing important and reliable revenue streams for land less ideal for agricultural production. New approaches to the dual use of land for both solar and farming, where crops are grown or livestock grazes under solar panels, known as agrivoltaics, offers a promising path forward. However, while dual-use solar should be deployed where feasible, it should not be expected to be the norm for all solar development in the region. Nonetheless, even without full agrivoltaic configurations, other land management practices can be used to retain ecosystem functions, provide habitat, and help restore degraded soils under solar panels.[119] For traditional ground mounted solar, there are many site design and configurations, and considerations can be made to ensure low-impact development including minimizing disturbance during site preparation, construction, and careful vegetation management and maintenance.[120] Furthermore, clear decommissioning requirements can ensure productive farmland is returned to its original use or added back via agrivoltaic approaches when "first generation" solar panels and wind turbines reach end-of-life.

The proximity of a clean energy project to other land uses can also influence a project. Larger projects sited closer to residential areas tend to draw concern. A 2024 study by Lawrence Berkeley National Laboratory surveyed the perceptions of neighbors of large-scale solar projects and found that very large projects, those over 100 MW, generated substantially more negative attitudes than small or mid-sized projects.[121] Despite its size, the proposed 1,000 MW King Pine Wind facility in Maine has faced relatively little opposition as it is sited in a remote location that was previously used for logging (Appendix pg. 52). However, this project is a significant outlier for New England, as the population density of the region as a whole makes it more challenging to site energy infrastructure far from residential areas than in regions like the West, and land-based projects of that large size (>100 MW) are not feasible in most parts of New England to begin with. Even when sited near more populated areas, there are actions developers can take to mitigate project impacts. The Three Corners Solar project, the largest solar facility in Maine, has also faced reduced opposition due to careful siting decisions made by the developer, limiting visibility of the project and working closely with natural resource agencies to mitigate project impacts.[122]

OPTIONS AND OPPORTUNITIES:

- **Integrate clean energy into land use planning:** States and advocacy organizations can create programs to proactively engage communities in combined land use and clean energy planning to provide opportunities for self-determination, align development with the long-term goals of the community, and reflect the tradeoffs of siting energy resources. State energy planning processes can include cross-sectoral stakeholders from resource conservation, agriculture, and local governments to account for competing land use priorities and coordinate with adjacent state energy planning.

- **Prioritize low-impact development and account for cumulative impacts:** Policymakers can incentivize siting and development standards that promote low-impact development practices. Policymakers can modify permitting standards and processes to account for cumulative impacts that may be created by proposed projects in a community to limit further burden on communities that have historically housed energy or other industrial infrastructure.

- **Balance farmland and wildlife protections with energy deployment:** Address concerns regarding the conversion of agricultural and forested land by proactive state-and-local planning and decision-making to reflect the tradeoffs of siting energy resources, ultimately developing policies that balance protection of the most productive lands with the need for responsible energy deployment of a significant magnitude. State agencies can provide developers with best management practices to minimize impacts to wildlife and policymakers should consider adoption of mitigation hierarchies to limit impacts to high-quality agricultural land and wildlife habitat.

SOCIAL BARRIERS AND HISTORICAL IMPACTS

COMMUNITY OPPOSITION

Levels of community support or opposition are key factors in a project's success or failure. An industry survey led by Lawerence Berkeley National Laboratory found community opposition to be one of the top three leading causes of project cancellations and delays for wind and solar projects.[123] The survey results also indicated that opposition is becoming more prevalent and more expensive to address than it was five years ago. There are a range of drivers of opposition, including land use change, landscape aesthetics, environmental degradation, community identity, wildlife habitat, noise, health, safety, and others. Clean energy infrastructure is bound to have some impacts, both positive and negative, on a community; but failures to communicate these impacts and procedurally address community concerns can exacerbate tensions. Furthermore, community opposition to a project can galvanize longer-term community attitudes and even build local level organizing networks that may engage on future nearby siting matters, potentially in an unconstructive posture.

POOR COMMUNITY ENGAGEMENT

Lack of information, misinformation, and poor engagement practices on behalf of developers can further increase

Cranberry Point Energy Storage, Massachusetts

Cranberry Point Energy Storage LLC, developed by Plus Power, is a 150 MW, 300 MWh standalone battery energy storage system (BESS) in Carver, Massachusetts, that will replace some of the lost capacity from the retiring Mystic natural gas plant and the retired Pilgrim nuclear facility. Initially receiving local support, the project faced significant pushback from vocal community groups who campaigned against it and succeeded in passing an 11-month moratorium on BESS projects in the town. Cranberry Point filed a Zoning Petition with the EFSB in May 2022, seeking a comprehensive exemption from Carver's zoning bylaws, which the EFSB ultimately referred to the Massachusetts Department of Public Utilities (DPU). The DPU granted the exemption, recognizing the project's necessity for public convenience and welfare, thus allowing construction to begin in December 2023. The DPU's decision highlighted the importance of balancing state energy needs with local opposition, setting a precedent for future BESS projects in Massachusetts. Construction began in December 2023, with commercial operation expected by 2025. See full case study in Appendix on page 54.

opposition from communities. A 2022 study from the Massachusetts Institute of Technology found that 30% of opposition to renewable energy projects in the United States stemmed from a lack of procedural equity, meaning the process of community engagement, such as the community's ability to influence project outcomes, was inadequate.[124]

High profile project failures and stories of bad actors spread between communities and stoke opposition. In the case of the Aroostook Renewable Gateway transmission project, frustration and opposition towards the prior contentious New England Clean Energy Connect line figured prominently in groups' opposition to the proposed Aroostook line, especially when community members learned of the proposed route - despite the line being proposed by a different developer (see Appendix pg. 52). As a result, over a dozen towns enacted temporary moratoriums to halt the line.[125] As another example, the Cranberry Point Energy Storage project under development in Massachusetts is a six-acre, 150 MW battery storage facility located in a residential area (see Appendix pg. 54). Inadequate community engagement and information from the developer regarding safety and emergency response plans led in part to community opposition and misinformation regarding the project, including unsubstantiated claims of runoff poisoning a local water aquifer. Community members also felt the developer had done too little to address and mitigate concerns over fire risk, considering limited local resources in the event of an emergency. There is ample room for improvement and innovation in the methods used for community engagement. Access to information, engagement, and inclusion in decision-making processes play a key role for clean energy project successes both at the individual project scale and in the aggregate.

Community members may also feel they are taking on an unfair burden as a result of a proposed clean energy project in their area. In response, renewable energy developers have adopted community benefits programs with increasing frequency as a method to mitigate project harms, enhance project benefits, and provide other means to help communities achieve their long-term social and economic goals. Benefits can be delivered through a variety of means, including negotiated community benefit agreements or project labor agreements, funding for community organizations and public services, workforce agreements, or other financial or non-financial benefits.[126] However, if implemented poorly, community benefits may be treated by developers as a 'check the box' exercise to get community support. Or, if they feel their input was not considered and incorporated into the program, then communities may not be receptive towards the benefits offered by developers. While community benefit plans and agreements can play a valuable role delivering meaningful benefits and accelerating project deployment, it is important to recognize that the process of negotiating and implementing community benefits programs is as important as the benefits themselves.[127] Likewise, accountability measures should be adopted to ensure benefits are delivered to communities, as promises made but not fulfilled could further generate ill will toward future projects.

OPTIONS AND OPPORTUNITIES:

- **Facilitate proactive developer communication and engagement with communities:** Developers can proactively communicate positive and negative impacts (e.g., economic, environmental, health, and reliability) of proposed infrastructure development, as well as opportunities to mitigate impacts through community benefits or design modifications. Developers should increase access to information, promote engagement opportunities, and create procedural opportunities to identify community concerns and incorporate feedback into project siting, design, and decision-making processes.

- **Deliver meaningful benefits for communities:** Developers, communities, and governments can work together to consider additional means to deliver benefits to communities from individual projects. Development of a community benefit should occur through an early, inclusive, community-led process that not only informs the structure of community benefits program, but also incorporates community input into the design of the project itself. Accountability and monitoring metrics should be agreed on to ensure that promised benefits are delivered.

INTERFERENCE FROM VESTED INTERESTS

Those who have benefitted from the region's widespread reliance on fossil fuel infrastructure are reluctant to accept, and often in opposition to, shifting the resource mix towards clean energy generation. Lobbying efforts, misinformation campaigns, faux grassroots "astroturfing" organizations, and regulations led by vested interests may undermine efforts to prioritize clean energy investments and advance climate goals. Incumbent power generators have interfered in infrastructure development in numerous instances, particularly around transmission that would bring new clean energy supply into the market. In the case of the contentious New England Clean Energy Connect (NECEC) line, opposition arose from existing generators (both gas as well as nuclear) who were concerned about opening the market to Canadian clean energy.[128]

In some instances, fossil-fuel interest groups have funded direct opposition towards clean energy projects in the region. A study by Brown University's Climate and Development Lab found that many community organizations that oppose offshore wind development in Massachusetts and Rhode Island are funded and resourced by fossil-fuel interested donors.[129] In the case of Vineyard Wind, the first commercial-scale offshore wind project in the U.S., some opposition groups that appear to be grass-roots organizations are backed by organizations with close ties to fossil fuel industry groups, such as the American Energy Alliance and the American Fuel and Petrochemical Manufacturers.[130] The more that clean energy resources threaten the established market position of incumbent interests, the more these oppositional tactics will multiply and grow.

East Eagle Substation, Massachusetts

The East Eagle substation, part of Eversource's Mystic–East Eagle–Chelsea Reliability Project, was proposed in 2014 to address (at the time) growing electricity demand and relieve pressure on the Chelsea substation in Boston, Massachusetts. The project's location is in East Boston, a densely populated and largely working-class and immigrant community that has existing industrial activity, and environmental and noise pollution from Logan International Airport. The site itself is across the street from a playground, a newly constructed police station, a fish processing facility, jet fuel and heating oil storage tanks, and abuts a water resource, Chelsea Creek. The project faced significant pushback over the course of ten years. Community and activist concerns include safety for children and neighbors, flooding and fire risks, and further burdening an environmental justice community - along with significant procedural failures on the part of the utility. Legal challenges and protests have persisted throughout the project's development, but the project has continued forward and is under construction. See full case study in Appendix on page 58.

LEGACY AND DISTRUST OF INSTITUTIONS

A failure to diversify the region's energy mix has perpetuated its reliance on fossil fuels and contributed to chronic fuel shortages, high electricity rates, and risk of winter energy shortfalls. Decades of investment in fossil fuels resulted in heavily polluting infrastructure with real impacts on the health and well-being of communities, especially marginalized and disadvantaged communities.[131] This legacy has created baseline sentiments of public and community-group distrust in institutions like ISO-NE, IOUs and transmission owners, and some project proponents, as made clear in the case studies outlined in the Appendix. These sentiments of distrust can be difficult to repair and can make future developments additionally challenging.

Stakeholders from interviews also identified concerns around the cumulative impact of energy development in their communities. Cumulative impact considers public health and environmental impact of a proposed project in the context of existing and foreseeable conditions in the host community, not just within the context of a proposed project. Cumulative impacts are often discussed in relation to environmental justice as an additional burden on communities that have historically housed energy or other industrial infrastructure. However, stakeholders also suggested in interviews that cumulative impacts should be considered for rural communities as certain localities host a disproportionate share of the energy projects or other historic industrial activity.

The case study of the East Eagle substation provides a prime example of a community concerned about cumulative impacts and overburden and frustrated by past experiences with developments. A history of poor community engagement and exclusion from decision-making on behalf of the City of Boston and the utility also contributed to community concerns.[132] While these concerns in the case of the substation development ultimately stem from broader, deep-rooted issues around environmental justice (see Appendix pg. 58), it also demonstrates how a legacy of distrust and skepticism can affect the development of grid infrastructure. Substations were not examined in depth for the purposes of this report, but research by other organizations has identified 419 existing substations in Massachusetts and found through utility filings that 40 new substations may need to be sited and built to enable high electrification decarbonization pathways.[133] Of the existing substations, roughly 70 percent are within a mile of an EJ neighborhood. And while less is known of the 40 proposed substations, seven of the 11 mapped locations are within EJ neighborhoods.

OPTIONS AND OPPORTUNITIES:

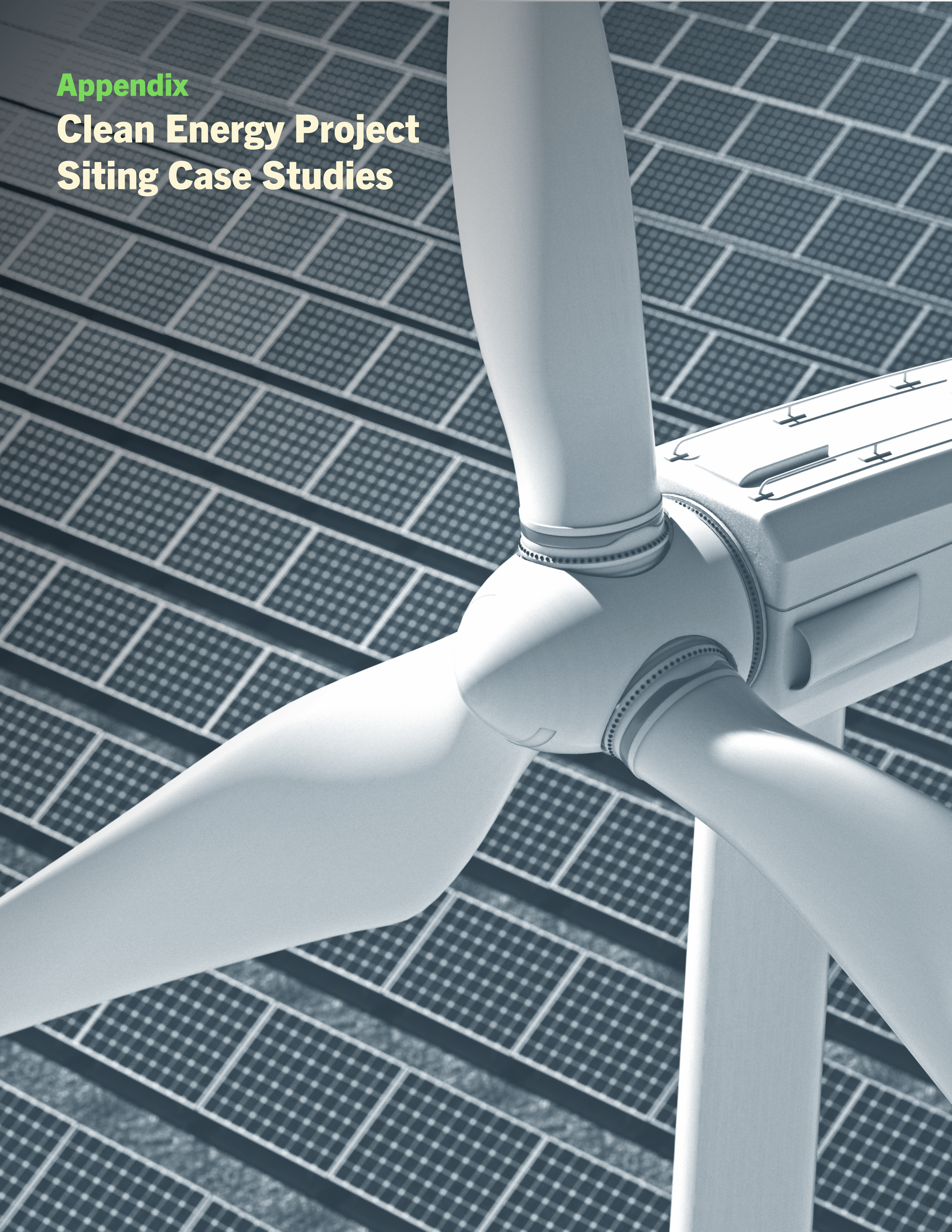
- **Minimize cumulative impacts:** Policymakers can modify permitting standards and processes to account for cumulative impacts that may be created by proposed projects in a community to limit further burden on communities that have historically housed energy or other industrial infrastructure.

CONCLUSION

In New England, "the energy is about to shift" has a dual meaning: the region's physical energy systems must rapidly shift from fossil fuel to clean, renewable energy, and the region's policies and processes for siting, permitting, and community engagement must also shift to be improved and strengthened commensurate with the task ahead. For all the infrastructure build-out that must occur to unlock New England's energy transition, none of it will be possible at scale and on time without genuine buy-in, acceptance, and trust from the people whose communities will host the many clean energy resources that must be sited and constructed. This report describes the history and status quo of New England's energy system (Section 1), analyzes potential pathways to decarbonization (Section 2), sketches out a blueprint for a reliable, affordable energy future using a clean portfolio approach (Section 3), and closes by exploring – and providing recommendations to address – the significant sociopolitical challenges of this energy shift (Section 4).

Appendix

Clean Energy Project Siting Case Studies



CASE STUDY: KING PINE WIND AND AROOSTOOK RENEWABLE GATEWAY

FAST FACTS

- **Developers:** Longroad Energy and LS Power
- **Wind Project Area:** Approximately 4,500 acres
- **Line Distance:** 160 miles
- **Capacity:** 1,000 MW (~170 turbines) and 1,200 MW 345kV line
- **Location:** Aroostook County to Cooper Mills, Maine
- **Wind Development Costs:** $2 billion
- **Line Development Costs:** $2.7 billion
- **Date Proposed:** March 2022 (transmission line), May 2022 (wind project)
- **Expected In-service Date:** 4th quarter 2029
- **Current Status:** Moving forward (wind project), Cancelled (transmission line)

PROJECT OVERVIEW

King Pine Wind is a proposed 1,000 MW onshore wind energy facility in northern Maine, and LS Power Grid Maine is a proposed transmission line to interconnect the wind energy facility with southern Maine and the ISO-NE grid.[134] The projects were selected by the Maine Public Utilities Commission (MPUC) on November 1, 2022 following a request for proposals (RFP) for the development of a transmission line to connect renewable energy projects in northern Maine to the ISO-NE grid.[135] The Legislature was generally supportive of the project and directed the PUC to issue the RFP through the passage of P.L. 2021, Chapter 380 (now 35-A M.R.S. Sec. 3210-I), which established the Northern Maine Renewable Energy Development Program.[136,137] Massachusetts also expressed interest in the Northern Maine procurement, an opportunity enabled by legislation passed in 2021 entitled “An Act Driving Clean Energy and Offshore Wind”.[138] Massachusetts signed an MOU with the PUC to facilitate information exchange, but bidders were still required to go through both the Maine and Massachusetts procurement processes.[139] By February, 2023, both the Massachusetts and Maine PUCs had approved the projects and the two states arrived at an agreement to purchase 60% and 40% of power respectively.[140] In December 2023, however, after several months of unresolved discussions, the Maine PUC terminated the transmission line procurement after LS Power requested an unspecified adjustment in price — which they attributed largely to rising costs from inflation.[141] King Pine Wind is tentatively advancing as the PUC rebids the transmission line RFP.[142] LS Power faced siting obstacles as local towns passed moratoria against high-voltage transmission lines.[143]

PUBLIC RECEPTION

The King Pine Wind project has generally received positive responses from regulators and the general public. Longroad Energy has developed several other wind projects in Northern Maine and is viewed as a good actor.[144] Additionally, the site of the wind project is remote and located on land previously used for logging, raising fewer concerns around environmental and viewshed impacts of the project. The King Pine Wind project also effectively communicated the economic, ratepayer, and local community benefits of the projects to local stakeholders.[145] And while LS Power’s proposed transmission line initially seemed to have public support, or at least public acceptance, public opposition began to grow in earnest once the developer released its proposed route.[146] A group of landowners along the proposed route created a citizen advocacy group, called “Preserve Rural Maine,” and hired an attorney who fought the New England Clean Energy Connect project.[147,148] Preserve Rural Maine organized communities along the proposed route, sharing information with town select boards, and advocating at the state legislature for policies to roll back eminent domain authority, revoke legislative approval of the project, and require alternative transmission line pathways.[149,150] The organization bases its opposition to the project on several factors, including impacts to the environment, property values, farms, other businesses, state tourism, and local economies.[151] Other landowners are concerned with the visual impact of the towers and the lack of meaningful community engagement in the siting decision-making process.[152] In addition to landowner concerns, at least 11 towns have enacted moratoria against the project in an attempt to force LS Power to shift the transmission line route.[153] Along with rerouting, many of the local landowners and towns are suggesting LS Power underground the line, citing projects like the Champlain Hudson Power Express in New York and the proposed Twin States Clean Energy Link in Vermont and New Hampshire as examples of such projects in the region.[154] While LS Power considered burying the lines underground, project representatives stated the costs would be substantial – more than five times the current project cost of $1.8 billion.[155]

PROJECT DECISION

Ultimately, the public opposition to the project and the local moratoria were immaterial, as the Maine PUC decided to terminate procurement of LS Power's transmission line based on disagreements over the project's costs. While negotiating a transmission service agreement (TSA) and Power Purchase Agreement (PPA) with the PUC, LS Power submitted a revised term sheet that would require a price adjustment. LS Power did not disclose the new price for the transmission project in the term sheet and insisted on pricing contingencies that would shift significant risk to the Maine PUC and ratepayers. In response, the PUC terminated the project's selection, declaring that "the Commission has no assurance that the LS Power project would remain 'the most cost-effective and efficient transmission access to renewable energy resources in Northern Maine,'" as required under state law.[156] In response, LS Power did not appeal the Commission's decision and clarified the reasoning behind amending their bid. According to LS Power, their bid contemplated entering into a contract by November 2022, which was consistent with the timeline under the Northern Maine Renewable Energy Development Program statute. However, the PUC offered only conditional approval by November, contingent on Massachusetts partially funding the project. The addition of Massachusetts to the procurement added another regulatory and negotiating party, introducing significant delay and risk to the project. In December 2023, without a signed contract from Maine or Massachusetts, LS Power could no longer hold to the terms of its bid. LS Power suggested the Maine PUC reform its transmission procurement process to be implemented by tariff rather than by contract. This approach would allow for Maine to benefit from competitive procurement, cost containment, and multistate participation while also assuring funding and clarifying risks for the developer.[157] Longroad Energy has stated its commitment to developing the King Pine wind project despite the LS Power procurement termination.[158]

CASE STUDY: CRANBERRY POINT ENERGY STORAGE PROJECT

FAST FACTS

- **Developer:** Plus Power
- **Capacity:** 150 MW / 300 MWh
- **Footprint:** Six acres
- **Location:** Carver, Massachusetts
- **Date Proposed:** 2018
- **Date of Final Approval:** June 2023
- **Expected In-service Date:** 1st Quarter of 2025
- **Current Status:** Under Construction
- **Interconnection time:** In queue since March 2018

PROJECT OVERVIEW

Battery storage developer Plus Power, acting as Cranberry Point Energy Storage LLC, is proposing a 150 MW, 300 MWh battery energy storage system (BESS) using Tesla Megapack lithium iron phosphate battery enclosures.[159] The facility is a standalone energy storage project and is not co-located with solar or other generation. The project is located on six acres of land adjacent to an existing Eversource substation in Carver, Massachusetts, and will replace some of the capacity lost by the retiring Mystic natural gas plant (1,400 MW) and the retired Pilgrim nuclear facility (677 MW).[160] The project is also near potential onshore transmission interconnection points for proposed offshore wind facilities.[161] The project was conceived in 2017 and received final approval from the Massachusetts Department of Public Utilities (DPU) in June 2023.[162] Construction began in December 2023 with commercial operation expected by 2025.[163] The project was permitted despite local community pushback from Save the Pine Barrens (now Community Land and Water Coalition), a local zoning moratorium for BESS, and several responsive zoning amendments in the Town of Carver.[164]

PUBLIC RECEPTION

Initially, public reaction to the proposed facility was generally agreeable. In 2018, Carver voted to change its zoning bylaws by adding battery storage as an allowable use by special permit in all zoning districts.[165] The motion passed by a vote of 92 "yes" and 14 "no" votes. By March 2019, the project had received the special permit and a Site Plan Review Approval from the Carver Planning Board and an Order of Conditions from the Town's Conservation Commission, allowing the project to proceed to construction. Over the next year, Cranberry Point applied for minor modifications to the project and amendments to the footprint, which were granted by the Town. In August 2021, Cranberry Point filed a petition for the construction of a generating facility with the state Energy Facility Siting Board (EFSB) under section 69J¼.[166] The filing triggered additional public notice requirements and public comment hearings, leading to a petition to intervene from Save the Pine Barrens.[167]

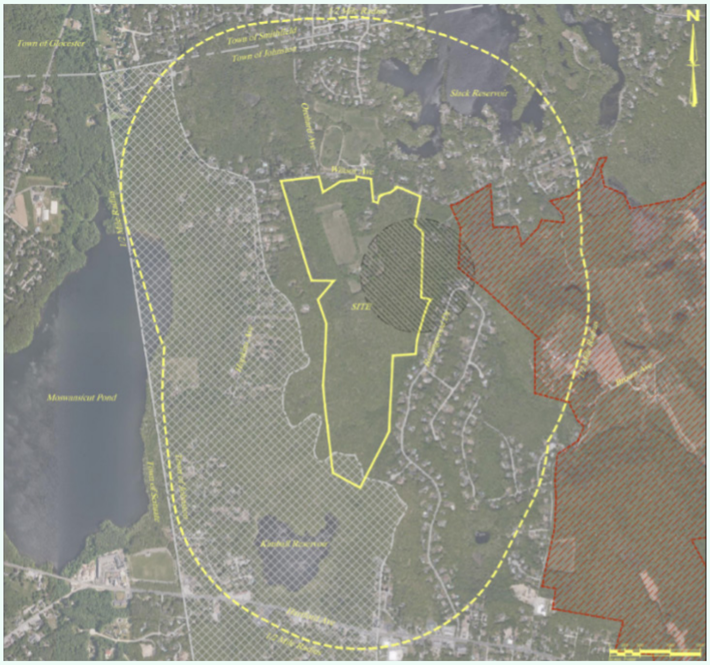
Save the Pine Barrens (now Community Land and Water Coalition) is a non-profit group that organizes and advocates against gravel mining and solar construction in Southeast Massachusetts. Shortly after intervening in the EFSB docket, the group began organizing against the Cranberry Point project alongside another entity - Carver Concerned Citizens.[168] In a series of posts on their blog, Facebook, and X (formerly Twitter) beginning March 2022, Save the Pine Barrens and Carver Concerned Citizens campaigned for a moratorium against ground-mounted solar and battery storage in the Town of Carver.[169] The two groups shared information about the battery project - calling into question the safety of the facility, claiming runoff will poison the local aquifer, and highlighting the increasing industrialization of the landscape due to BESS and solar projects.[170] The groups frame the project as an existential threat to the community, referring to Carver as "ground zero" and calling Cranberry Point a "battery bomb".[171] Fire safety is a real and legitimate concern facing battery projects. Fire risks can be prevented and mitigated, according to recent findings and recommendations from a New York state interagency working group, which outlines measures to address risks, including incident response plan requirements and industry-funded peer reviews for all projects.[172] Representatives from the citizen groups attended local planning board meetings, drafted op-eds, canvassed in the community, and collected the 10 signatures required for a warrant article petition to bring an 11 and-a-half month moratorium to a vote during the Carver town meeting on April 12, 2022. The moratorium passed, with 387 voting “yes” and 76 voting “no”, instituting a moratorium on solar and BESS projects in the town.[173]

PROJECT DECISION

Following the vote, Cranberry Point filed a Zoning Petition with the state EFSB on May 11, 2022, requesting a comprehensive exemption from Carver’s zoning bylaws. While the project was not directly affected by the moratorium – it had already secured permits to construct the project – Power Plus was concerned changes to the zoning bylaws could make it more challenging to obtain additional permits, putting the project at risk.[174] The Cranberry Point project is the first BESS proposed in Massachusetts to go before the EFSB, raising questions of departmental jurisdiction and environmental impacts.[175] The EFSB held a series of hearings between November 2021 and May 2023 on whether to grant a comprehensive zoning exemption.[176] Ultimately, EFSB concluded its authority under G.L. c. 40A, Sec. 3 did not include standalone BESS because they are not captured under the statutory definition of a generating facility.[177] The EFSB therefore referred the petition to MA DPU. Following a series of hearings, public comment, and submissions by both Save the Pine Barrens and Cranberry Point, MA DPU found Cranberry Point is a public service corporation, that the project is necessary for public convenience and welfare, and that a comprehensive zoning exemption is necessary to ensure the project proceeds. In its findings, MA DPU highlights the importance of the exemption from local zoning bylaws, stating “the purpose of this exemption provision is to ensure that local opposition does not prohibit needed services...without the ability of the Department to balance the state’s need for electricity with local interests, local opposition could implement veto power over facilities serving the state.”[178]

MA DPU’s approval of the comprehensive zoning exemption provided the project with the necessary assurances to begin construction, which started in December 2023. The project was selected by ISO-NE’s Forward Capacity Market Auction to provide reliability to the grid.[179] It is expected to complete construction and come online in early 2025. MA DPU’s decision to grant a comprehensive zoning exemption to Cranberry Point sets a precedent for future BESS projects in Massachusetts.

CASE STUDY: JOHNSTON WINSOR III SOLAR PROJECT



FAST FACTS

- **Developer:** Green Development
- **Site Location:** 118 Winsor Ave, Northwest Johnston, RI
- **Developer Investment:** $2.5 million

ORIGINAL PROPOSED PLAN (2022)

- **Size:** 90,000 solar panels, 325-acres (2022)
- **Capacity:** 24 MW
- **Date Proposed:** March 2022
- **Date Denied:** April 28th, 2022

REVISED PLAN (2023)

- **Size:** 46,000 solar panels, 158-acres (2023)
- **Capacity:** 19 MW[180]
- **Date Proposed:** November 2023
- **Expected In-service Date:** 2028
- **Date Denied:** January 25th, 2023
- **Current Status:** Zoning Board decision to be rewritten following court appeal

PROJECT OVERVIEW

Green Development, a renewable developer based in Cranston, Rhode Island, proposed five separate solar farm projects to the Johnston Zoning Board early in 2022, including Johnston Winsor III. The original proposed project included a 90,000 panel, 24 MW solar farm on a large plot of land near residential communities in North Johnston. In April 2022, the board rejected all five proposed solar farms after a long public hearing with many testimonials opposing the projects.[181] A community coalition, Stop Johnston Solar, led much of the opposition, which focused on concerns about the proximity of "large industrial solar projects" to residential houses.[182] Green Development subsequently revised and proposed Johnston Winsor again in the fall of 2023 but again faced sustained opposition.

Rhode Island has ambitious clean energy goals; the state hopes to have a 100% renewable electricity sector by 2033. Solar—along with offshore wind and other renewables—will contribute to this goal, but projects like Johnston Winsor III highlight the state-wide issue of where best to locate larger, ground-mounted solar farms, given concerns about land conversion and proximity to residential communities. Opponents often suggest renewable energy projects should be built on degraded land, but it can be significantly more expensive for renewable companies to develop projects on brownfields or landfills due to higher permitting, engineering, and legal fees, as well as the assumption of greater risk, which limits investment options.[183] In 2023, Rhode Island's General Assembly passed comprehensive solar siting reform legislation (H5853 and S0684) dis-incentivizing development of solar projects in core forests (contiguous forested land of 250 acres or more), while continuing incentives for projects on "preferred sites," including brownfields, landfills, along highways, and on rooftops or carports.[184] These changes will affect solar development in Rhode Island, and their exact impact on larger, ground-mounted projects is still coming into clearer view.

PUBLIC RECEPTION

Community organization Stop Johnston Solar mobilized residents to oppose both the initial project and the 2023 revised project proposal, filling hearing rooms over several Zoning Board meetings in 2022 and 2023. According to a post from an administrator of the Stop Johnston Solar Facebook Group, over 150 residents attended each hearing.[185]

Many shared concerns over the presence of industrial development near neighborhoods and over the local tree-clearing required for the project. (Note: because the lot was zoned residential, it could have been cleared for other development).[186] Green Development proposed donating 82 acres of the site—about 52% of the parcel—to the town after project construction. The other 76 acres would be cleared of trees and leveled to install the solar arrays.[187] Deforestation is a significant impact from solar development in Rhode Island. According to the Rhode Island Department of Environmental Management, from 2018 to July 2021, 69% of all forest loss, or 1,041 acres, was due to solar development.[188] Other arguments from community groups include flooding concerns, worry for local aquifers, and environmental and historical significance of the land. One resident testified in December, “The proposed location is a historic farmstead, which has both cultural and natural and historic significance.” Stop Johnston Solar contended in a public letter that over 150 acres of land would be cleared for the project with 46,000 solar panels, and the project would threaten lowering home values, fire risks, and toxic waste. Above all, the group explicitly opposes solar development on residential land: “solar panels belong on rooftops and land zoned for industrial and commercial purposes ONLY and NOT on land intended for residential use.”[189]

PROJECT DECISION

In March 2022, the Johnston Town Planning Board approved Green Development’s five solar farm plans, before the project went before the Zoning Board. Because the land of the proposed Johnston Winsor III was zoned residential, it required special-use permits from the Zoning Board and a supermajority vote for approval. With public testimony uniformly opposing the project, two of five board members voted against approval at an April meeting, and Johnston Winsor III failed to meet the supermajority threshold.[190]

Green Development appealed the Zoning Board’s decision to the Rhode Island Supreme Court, with their complaint centering on the requirement for a supermajority vote to obtain a special-use permit. Ultimately, the Supreme Court agreed with the plaintiffs, and decided that obtaining special-use permits in Rhode Island shall only require a simple majority. As such, Green Development was again granted the opportunity to bring their project before the Zoning Board.[191] During this time, Johnston residents, led by Stop Johnston Solar members, attempted to pass a ban on all large-scale solar development on residential zoning land in the Rhode Island town. Facing the risk of lawsuits from introducing the ban, the Johnston City Council rejected the proposal, leaving open the legal possibility for projects like Johnston Winsor III.[192]

Considering community concerns, Green Development proposed a scaled-down version of Johnston Solar when it went before the Zoning Board for a second time on September 28, 2023, followed by contentious public hearings November 2nd, December 14th, and January 25th. The board unanimously denied the project on January 25th, 2024, citing several reasons the proposal did not meet the threshold for granting a special-use permit.[193] Green Development again appealed the decision to the Providence County Superior Court. In July 2024 the court decided that the Zoning Board did not do an adequate job of writing a detailed decision and remanded the cases back to the Zoning Board to issue a detailed and appropriate written decision. The cases were dismissed without prejudice, allowing Green Development to appeal again in the future.[194] The future of the proposed project remains uncertain.

CASE STUDY: EAST EAGLE SUBSTATION IN EAST BOSTON

FAST FACTS

- **Utility:** Eversource
- **Capacity:** 115/13.8 kV
- **Footprint:** 27,000 sq ft
- **Location**: East Boston, Boston, MA
- **Estimated Cost:** $106 Million
- **Date Proposed:** December 2014
- **Date of Final Approval:** November 2022
- **Expected In-service Date:** Q4 2025
- **Current Status:** Under Construction

PROJECT OVERVIEW

The East Eagle substation is a part of Eversource's larger Mystic–East Eagle–Chelsea Reliability Project, which includes the construction of a new substation, two new underground transmission lines to connect to existing substations, and improvements to existing substations in the area. Eversource found that these additions were needed to account for growing electricity demand and to relieve pressure on the Chelsea substation which is near capacity.[195] The project was proposed in December 2014 and reach final approval eight years later in December 2022. The new transmission lines were completed in September 2020, but construction on the substation is not expected to be complete until 2025. The project's location is in East Boston, a densely populated Environmental Justice neighborhood located adjacent to Boston's Logan International Airport. The site itself is across the street from a playground, a newly constructed police station, a fish processing facility, jet fuel and heating oil storage tanks, and abuts a water resource, Chelsea Creek. The project faced significant community pushback over the course of ten years. Community concerns include safety for children and neighbors, flooding and fire risks, and further burdening an environmental justice community—along with significant procedural/process failures on the part of the utility.

PUBLIC RECEPTION

Since the project was first proposed in 2014, it has faced significant community pushback. Initially, the substation was proposed to be developed on the corner of the lot directly adjacent, by 18 feet, to Channel Fish, a longstanding fish processing plant. The Channel Fish owner, concerned that electromagnetic activity from the substation would interfere with their equipment, placed signs and posters around the neighborhood and petitioned for intervenor status with the Energy Facilities Siting Board (EFSB), which led to a hearing process. Eventually, in 2018, the City agreed to a land swap with Eversource so they could build the substation on the other side of the property.[196] This new site was further from the fish processing facility, but closer to the waterway and across the street from a playground. Following this decision, community opposition increased greatly, with community members and activists citing concerns over flooding, fire risk, safety, and added burden to a community that already experiences significant industrial and environmental pollution.[197] Community members were specifically concerned about potential flooding induced by heavy storms and sea level rise, which could cause potential fires. Given the site is adjacent to jet and heating fuel storage tanks, this furthered community concerns over fire risk. Environmental justice concerns were also a main contributor to community opposition. The site is in a largely working-class and immigrant community that has existing industrial activity, and environmental and noise pollution from Logan International Airport. Concerns over environmental justice were elevated by acting Mayor, Kim Janey, as well as several state representatives and members of U.S. Congress, and national environmental organizations who urged Eversource to rethink the plan.[198] Community activists have made clear in their argumentation the understanding that many new and expanded substations will be needed to facilitate the energy transition, and that their opposition in this case was not about the substation itself per se but rather about the procedural and engagement failures of the utility in conducting adequate proactive outreach to the community and providing meaningful opportunity for input upfront.

Community members also vocalized frustration with the lack of opportunity for upfront outreach, meaningful engagement, and the inaccessibility of meetings and hearings held online due to the ongoing COVID-19 pandemic. A local advocacy organization, GreenRoots, partnered with the Conservation Law

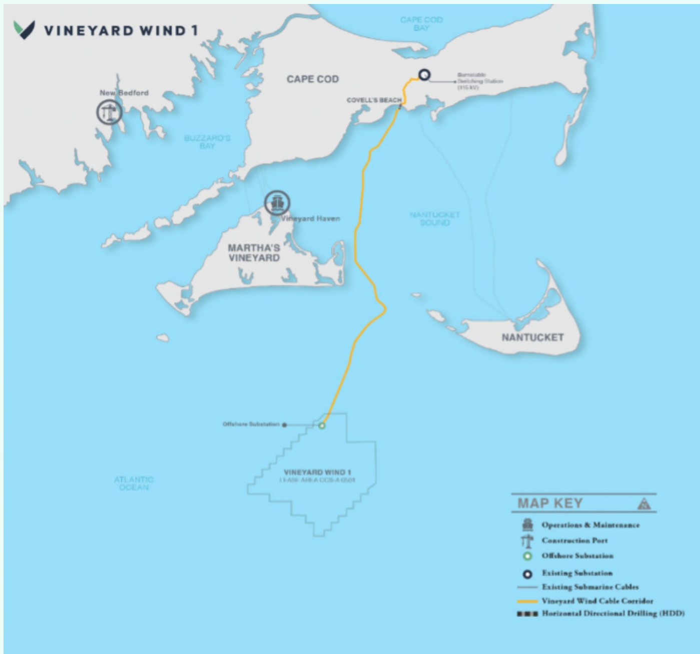
Foundation and Lawyers for Civil Rights to file a federal lawsuit against the Environmental Protection Agency (EPA) for failing to accommodate language access and translation services in violation of the 1964 Civil Rights Act.[199] The EPA declined to consider the case because it fell outside its jurisdiction.

Following final approval of the project in February 2021, Eversource signed a $1.4 million dollar community benefits agreement (CBA) with the Eagle Hill Civic Association and the Salesian Boys and Girls Club. The package included funding to improve the neighboring parks and green spaces, tree plantings, and energy efficiency and HVAC upgrades to the Boys and Girls Club. Additional community concern arose over who, ultimately, would pay for the community benefits package. Although the CBA states that Eversource would pay for the benefits package, the utility later stated that the cost would be passed on to ratepayers, leaving uncertainty over who would be responsible for paying for the benefits.[200] Because the utility is eligible for a guaranteed rate of return on capital expenditures, community members are also concerned Eversource could profit off the community benefits package, even if costs are passed to ratepayers.[201] Throughout the construction of the project, community members and advocacy organizations have actively been protesting and demonstrating outside the site.[202]

PROJECT DECISION

Eversource initially submitted plans to the EFSB in December 2014. Following community concerns from the local seafood processing business Channel Fish, EFSB held hearings throughout 2016. The project was approved in November 2017 on the condition that Eversource investigated moving the substation to the other side of the property in a land swap with the City of Boston. Eversource and the City agreed to the land swap in November of 2018, which led the EFSB to have to reevaluate the project in its new location. Community members expressed concern in evidentiary hearings. The ongoing COVID-19 pandemic further delayed the process, and the EFSB issued final approval over the project in February 2021, conditioned on Eversource developing a CBA with local organizations. In August 2021, Eversource signed a $1.4 million agreement with the Eagle Hill Civic Association and the Salesian Boys and Girls Club. GreenRoots and the Conservation Law Foundation filed an appeal of the Siting Board's decision with the Massachusetts Supreme Judicial Court, but the decision was upheld in November 2022. In the same month, the EFSB granted Eversource final approval via a certificate to bypass 14 state and local environmental permits. GreenRoots and the Conservation Law Foundation filed another appeal over this certificate with the state's Supreme Judicial Court. The project began construction in January 2023.

CASE STUDY: VINEYARD WIND 1



FAST FACTS

- **Developer:** Avangrid Inc. and Copenhagen Infrastructure Partners P/S
- **Footprint:** 306 km2 (75,614 acres)[203]
- **Capacity:** 800 megawatts (62 turbines)
- **Site Location:** 15 miles south of Martha's Vineyard, MA (federal wind energy area OCS-A-0501)
- **Final Cost:** $4 billion
- **Date Proposed:** 2017
- **Initial In-service Date:** January 2024[204]

PROJECT OVERVIEW

The first commercial-scale offshore wind project in the US, Vineyard Wind is a 62-wind turbine farm 15 miles from the shore of Massachusetts, which has achieved first commercial energy deliveries and remains under construction.[205] The project, led by Avangrid Inc. and Vineyard Offshore (an affiliate development company of Copenhagen Infrastructure Partners), has a nameplate capacity of 800 MW and plans to deliver electricity to over 400,000 homes and businesses. The federal siting process began in 2015 with the Department of Interior's public auction for offshore wind development areas, followed shortly thereafter by the Massachusetts offshore wind solicitation in 2016. In 2021, Vineyard Wind received the Final Environmental Impact Statement (FEIS). The project missed its initial goal of delivering electricity starting in 2023, and first began delivering electricity January 2nd, 2024.[206] As of June 2024 20 of the 62 planned wind turbines are installed with ten delivering electricity to the grid.[207] In July 2024 a turbine blade broke and debris washed on shores, prompting increased scrutiny over an already contentious project, and halting construction and power production.[208] Once complete, the project anticipates reducing carbon emissions in Massachusetts' electricity sector by over 1.6 million tons per year. In addition to helping Massachusetts meet its clean energy-production goals, the project also assists the state in its goal of contracting 5,600 megawatts of offshore wind by 2027.[209]

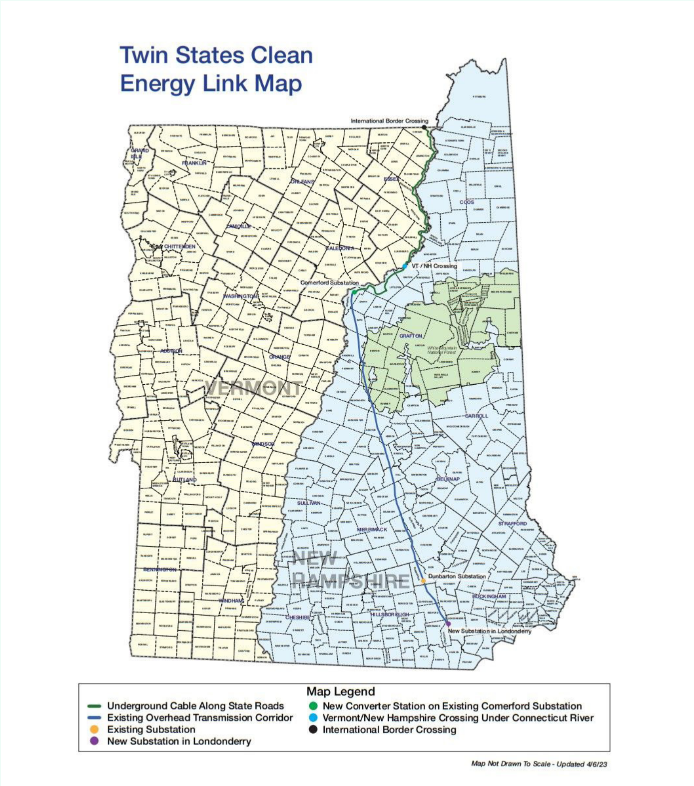
PUBLIC RECEPTION

Throughout its construction phase, the project has faced a handful of challenges. A dockworker's strike in May 2023, stemming from complaints that Vineyard Wind's existing Project Labor Agreement (PLA) with the Massachusetts Building Trades Council did not account for the loss or alteration of dockworker jobs, which held up turbine components on the dock for six days.[210] While the project developers subsequently agreed to a historic PLA in July 2023 and issued a press release in December 2023, announcing it had more than doubled its union-hiring commitments, the New Bedford mayor, the town's union ILA Local 1413, and some underrepresented groups remain skeptical.[211] Vineyard Wind also continues to face public pushback from fishers and other interest groups. Commercial fishing groups have filed several lawsuits to overturn the project's environmental permits and construction approvals, contending turbines encroach upon their fishing grounds. In October 2023, a U.S. district judge rejected challenges to the project's federal environmental permits, dismissing two cases.[212] The plaintiffs appealed, and the case will go to the United States Court of Appeals for the First Circuit. A conservative think tank, the Texas Public Policy Foundation, historically supportive of the fossil fuel industry, is representing fishing groups in one of the cases. Massachusetts residents (Nantucket (ACK) for Whales, previously Nantucket Residents Against Turbines), and a pseudo-solar developer (Allco Renewable Energy Ltd.), have also brought lawsuits. The main grounds for complaint against Vineyard Wind in all three lawsuits are environmental concerns. All cases alleged the Department of Interior violated the Endangered Species Act, the Marine Mammal Protection Act, and the National Environmental Policy Act when BOEM granted permits for the project. Allco has previously sued other New England large-scale wind projects and claims that turbines damaged by hurricanes will impact marine life.[213]

PROJECT DECISION

Vineyard Wind received the necessary approvals from federal, state, and regional agencies, completing their siting process in 2020, but ran into unforeseen permitting issues subjecting the project to an additional Supplemental Environmental Review that extended the approval process. Vineyard Wind competitively obtained the OCS-A-0501 lease area in 2015. in response to federal and state solicitations, the developers submitted project plans, including a construction and operations plan, to the federal Bureau of Ocean Energy Management and transmission plans to the Massachusetts Energy Facilities Siting Board in December 2017. In March 2018, BOEM opened a public comment period and held five open meetings in Massachusetts and Rhode Island ahead of writing the initial Environmental Impact Statement (EIS) and held another public comment period following BOEM's release of the draft (DEIS) in December 2018. After BOEM's robust public stakeholder engagement processes, Vineyard Wind responded to concerns from fishing groups and announced it would scale down to limit impacts to fisheries and sensitive marine habitats.[214] The Department of Interior held a contested lease auction in 2018, in which Vineyard Wind secured a second lease area, OCS-A-0522.[215] In May 2019, after receiving final approvals from state agencies (MEPA and EFSB), BOEM announced it would delay its decision on Vineyard Wind and conduct a cumulative impact assessment on East Coast offshore wind projects. This announcement was responsive to concerns from fishing groups and posed a serious threat to Vineyard Wind. However, after gaining positive public comments and surviving the environmental analysis, BOEM issued a Supplement to the Draft Environmental Impact Statement (SEIS) for the project in June 2020.

CASE STUDY: TWIN STATES CLEAN ENERGY LINK



FAST FACTS

- **Developer:** National Grid and Citizens Energy Corp.
- **Length:** 211 miles (101 new, buried and 110 upgrades, existing overhead)
- **Capacity:** 1,200 megawatts HVDC, bi-directional
- **Line Path:** Québec, CA to Londonderry, NH
- **Projected Cost:** less than $2 billion
- **Date Proposed:** April 2023
- **Construction Start Proposed:** 4th Quarter of 2026
- **Date Cancelled:** March 4, 2024

PROJECT OVERVIEW

Twin States Clean Energy Link was a proposed 211-mile-long transmission line interconnecting Québec, Canada, via Vermont, to the New England grid in New Hampshire. The project developer was National Grid, a multinational electricity and gas utility company, in partnership with the nonprofit Citizens Energy Corp., an organization focused on delivering benefits to communities impacted by transmission projects. The bidirectional line would have increased the ability for electricity transfer between the two countries, while enhancing the capacity of the New England grid, and providing improved resilience, reliability, and efficiency. Furthermore, the line would have enabled more clean energy projects to connect to the grid, including Canadian hydropower, reducing regional greenhouse gas emissions and balancing the intermittency of renewables deployed in the region. The project proposal received substantial local, state, regional, and federal support, including one of three Transmission Facilitation Program (TFP) grants awarded by the U.S. Department of Energy's Grid Deployment Office in 2023.[216] The breadth of support for the project was likely a result of the considerable community benefits it entailed, as well as the unique project design, which limited the need for new overhead wires and new rights-of-way. The project was cancelled by National Grid less than a year after its public announcement. National Grid did not directly provide a public explanation for the cancellation, claiming only that the project was not viable at this time.

PUBLIC RECEPTION

At the time of its cancellation, Twin States Clean Energy Link was a widely popular project with support from state and federal leaders; New Hampshire Governor Chris Sununu and U.S. Energy Secretary Jennifer Granholm both lauded the project after its selection by the Transmission Facilitation Program.[217,218] The project also received early local support in both Vermont and New Hampshire.[219] Several aspects of the project may have engendered a positive reception from stakeholders, including the identification of robust community benefits, novel construction approaches to minimize visual impacts, and reports that found significant ratepayer savings. National Grid partnered with Citizens Energy Corporation to develop a community benefits plan for the project, totaling $260 million in direct benefits from the project.[220] This amount is in addition to the estimated property tax revenues, land lease payments, energy market savings, and the 1,200 union construction jobs associated with the project.[221] Citizens Energy planned to reinvest $100 million from the project into local, community-identified projects along the project route through community benefit agreements, in addition to contributions to the Northeastern Vermont Development

Association of $20 million and $60 million in community benefits distributed among the non-host states of Massachusetts, Connecticut, Rhode Island, and Maine.[222,223] The Twin States project also took significant steps to mitigate visual impacts from the project, which likely increased support from locals and elected officials. The project includes 101 miles of buried lines along highways and for a crossing under the Connecticut River, plus 110 miles of upgrades to existing overhead wires, thereby minimizing visual impacts by reusing the vast majority of existing infrastructure, or simply putting it out of sight underground.[224] This approach would have made the community-level routing conversations much easier as visual impacts and securing new rights-of-way are both major drivers of opposition. Finally, though it could not be independently verified, National Grid claims an independent market assessment identified over $8.6 billion in wholesale energy market cost savings over the lifetime of the project.[225] For a region facing high energy prices, this could have been a significant boon.[226]

While National Grid and Citizens Energy took steps to ensure the project would be received positively by the public, it's possible, even likely, that opposition would have arisen over the course of the project. One source of public opposition to this project would likely be current and historic impacts to First Nations peoples in Québec. A coalition of First Nations previously filed a lawsuit against Hydro-Québec in an attempt to stop New England Clean Energy Connect in 2021 over use of energy from hydro dams on tribal land, and continued frustration of lack of consultation.[227]

PROJECT DECISION

Twin States Clean Energy Link was cancelled before it truly began the siting and permitting process. Based on requirements for similar projects of this scope and scale, including New England Clean Power Link and the Northern Pass Transmission Project, Twin States would have likely required the following permits and approvals:[228]

- NEPA environmental impact statement (EIS);
- Presidential Permit for crossing the US-Canada border;
- Various state environmental permits from New Hampshire and Vermont;
- Certificate of Public Good from the Vermont Public Service Board
- License to cross public waters and state-owned land from the New Hampshire Public Utility Commission;
- Siting Permit from the Vermont Public Service Board; and
- Site Certificate from the New Hampshire Site Evaluation Council

For a similar project, the Northern Pass Transmission Project, which crossed through only one state—New Hampshire—the siting and permitting process took roughly eight years and ended when the Site Evaluation Council denying the permit.[229] Twin States Clean Energy Link had not started the federal or state siting processes before it was cancelled. However, the project did secure a major capacity contract with the federal government. The project was selected in April 2023 to participate in the application process for the Department of Energy, Grid Deployment Office's Transmission Facilitation Program (TFP).[230] The project was eventually selected for capacity contract negotiations through the TFP, which committed up to $1.3 billion to three transmission projects across six states.[231] Through the TFP, DOE served as the anchor off-taker for the project by purchasing up to 50% of the line's capacity, thereby reducing the project's development risk.[232] In selecting Twin States, DOE GDO cited the bidirectional design of the project – providing access to clean firm power from Québec, Canada while allowing the New England grid to export power to Canada when renewable production exceeded demand – as a key factor. DOE GDO also noted that the National Transmission Needs Study predicts the Northeast region will need 1.5 gigawatts of new transfer capacity with its neighbors by 2050; Twin States would have fulfilled 79% of that interregional need.[233]

National Grid's decision to cancel the project, after securing the capacity contract with DOE, and before beginning the siting and permitting process in earnest, is mystifying. An anonymous source claimed the line was canceled because National Grid and Citizens Energy were unable to find buyers for the transmission line's power, despite the commitment from DOE.[234] The project was cancelled less than a year after it was publicly announced and just five months after DOE's TFP commitment—a very short timeline for bringing in additional buyers. One potential explanation is that National Grid was unable to secure an agreement with Hydro-Québec to purchase the bidirectional flow of energy. The lack of a wholesale market in Québec, coupled with the lack of parties with transmission rights to Hydro-Québec's system, means that without an offtake agreement, Twin States transmission rights holders would be unable to source energy from the hydro project, or deliver energy to the northern terminus.[235] Additionally, Hydro-Québec has recently indicated that its ability to export electricity is anything but infinite, indicating the need to add 100 TW/h of additional electricity, or about half its annual generating output.[236] This means it's possible Hydro-Québec didn't have the capacity to export the 1,200 MW south to the US, while also meeting the clean energy goals of the Canadian province, and fulfilling its previous export obligations. Finally, without more offshore wind coming online, or a massive/accelerated buildout of solar in the region, there's a distinct lack of adequate clean energy capacity to transmit north regularly to satisfy a bidirectional agreement, at least as of today. Regardless, if National Grid truly could not find off-takers for a line with such significant state and federal backing, then it raises real concerns for development of future major transmission lines in the region. The cancellation leaves only two transmission lines between the Northeast and Québec under development, the Champlain Hudson Power Express and the New England Clean Energy Connect project, which is proceeding despite major opposition and permitting hurdles.

Endnotes

1 This framework draws from the insightful work conducted by Dr. Louise Comeau on *Factors Affecting Social Acceptance of Renewable Energy and Transmission Projects* in Canada.

2 Shankman, S. (2024, October 17). Months late, Mass. Lawmakers poised to pass major climate bill. *Boston Globe*. https://www.bostonglobe.com/2024/10/17/science/massachusetts-climate-bill-revived-after-failure/

3 The Massachusetts Clean Energy and Climate Plan (CECP) for 2050 is the only one of the five studies examined that modeled an extensive buildout of interregional transmission between both New England and Canadian provinces and New England and New York. By 2050, the CECP "High Electrification" scenario modeled 11.5 GW of New England-Canda transmission capacity and 12.2 GW of New England-New York transmission capacity.

4 Independent System Operator – New England. (2024, January 19). *Key Grid and Market Stats: Resource Mix.* https://www.iso-ne.com/about/key-stats/resource-mix/#:~:text=Nearly%20half%20of%20the%20region's,about%2055%2C600%20GWh%20in%202023

5 Federal Energy Regulatory Commission. (2020, August 5). *Order No. 888. Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities.* https://www.ferc.gov/industries-data/electric/industry-activities/open-access-transmission-tariff-oatt-reform/history-oatt-reform/order-no-888

6 United States Environmental Protection Agency. (2024, August 8). *Clean Air Power Sector Programs: Power Sector Evolution*. https://www.epa.gov/power-sector/power-sector-evolution

7 International Energy Agency. (2008). *Natural Gas Market Review.* Organisation for Economic Cooperation and Development. https://iea.blob.core.windows.net/assets/ba75239e-06a9-4ab8-beba-bbdaed2d6a03/NaturalGasMarketReview2008.pdf

8 Cembalest, M. (2023, March 28). *Growing Pains: The Renewable Energy Transition in Adolescence.* J.P. Morgan. https://am.jpmorgan.com/content/dam/jpm-am-aem/global/campaign/energy-paper-13/growing-pains-renewable-transition-in-adolescence.pdf

9 Northeast Gas Association. (2024). *About LNG: Use of LNG in the Northeast.* https://northeastgas.org/about-lng In 2023, the Everett LNG regasification terminal near Boston, Massachusetts, received about 87% of total U.S. LNG imports, all by LNG carriers from Trinidad and Tobago and Jamaica. The remaining 13% of LNG imports were delivered by truck from Canada into Alaska, Maine, Montana, New York, Vermont, and Washington.

10 Cowan, T. (2024, March 19). *U.S. residential gas consumers bear brunt of LNG exports.* Institute for Energy Economics and Financial Analysis. https://ieefa.org/resources/us-residential-gas-consumers-bear-brunt-lng-exports

11 ISO – New England. (2018, January 17). *Operational Fuel-Security Analysis*. https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf. "The natural gas system was sized and built to meet the peak demand needs of the local natural gas utilities (also called local distribution companies, or LDCs) serving heating customers. The natural gas utilities contracted for the pipeline capacity, so they have first priority for gas delivery."

12 The New England region's residential sector has the highest annual average price of electricity in the lower 48 states. The annual average price for the region in 2022 was almost ten cents higher than the national average. The New England region's residential sector also had the largest increase in prices between 2021 and 2022 at 3.22 cents per kWh – an increase of almost 15%.

13 Van Welie, G. (2023, February 10). *Letter to US Senators Concerning Winter Storm Elliott*. ISO-New England. https://www.iso-ne.com/static-assets/documents/2023/02/combined_storm_elliott_op4_letters.pdf

14 Mclaughlin, T., & Disavino, S. (2022, February 11). *New England carbon emissions spike as power plants turn to dirtier fuel.* Reuters. https://www.reuters.com/world/us/new-england-carbon-emissions-spike-power-plants-turn-dirtier-fuel-2022-02-11/

15 ERCE (2021, August). *IPCC Sixth Assessment Report Global Warming Potentials*. https://erce.energy/erceipccsixthassessment/

16 Reyes, S. (2024, June 3). *New report finds gap between leaders and laggards on methane emissions widens, underscores importance of new regulations.* Clean Air Task Force. https://www.catf.us/2024/06/new-report-finds-gap-between-leaders-laggards-methane-emissions-widens-underscores-importance-new-regulations/

17 Brandt, A. (2024, March 13). *Methane emissions from U.S. oil and gas operations cost the nation $10 billion per year*. Stanford Report, Stanford University. https://news.stanford.edu/stories/2024/03/methane-emissions-major-u-s-oil-gas-operations-higher-government-predictions#:~:text=Measurement%20matters&text=Total%20estimated%20leaked%20emissions%20range,roughly%201%25%20of%20gas%20production.

18 Hellgren, L. (2024, June). Benchmarking Methane and Other Greenhouse Gas Emissions. Clean Air Task Force & Ceres. https://cdn.catf.us/wp-content/uploads/2024/05/31103518/oil-gas-benchmarking-2024.pdf

19 Walton, R. (2015, September 10). *Jump in winter oil burn from generators pushes up New England carbon emissions.* Utility Dive. https://www.utilitydive.com/news/jump-in-winter-oil-burn-from-generators-pushes-up-new-england-carbon-emissi/405378/

20 ISO Newswire. (2018, April 25). *Winter 2017/2018 recap: Historic cold snap reinforces findings in Operational Fuel-Security Analysis.* ISO-New England. https://isonewswire.com/2018/04/25/winter-2017-2018-recap-historic-cold-snap-reinforces-findings-in-operational-fuel-security-analysis/

21 ISO Newswire. (2018, September 7). Labor Day was no holiday for New England's power grid: Weather and resource outages led to capacity shortage conditions. ISO-New England. https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-1647.pdf

22 ISO Newswire. (2023, January 4). *ISO-NE maintains system reliability through generator outages, loss of imports on Christmas Eve.* ISO-New England. https://isonewswire.com/2023/01/04/iso-ne-maintains-system-reliability-through-generator-outages-loss-of-imports-on-christmas-eve/

23 Muller, S. (2024, January 3). The Equation. *Offshore Wind Will Add Power When New England Needs It Most.* Union of Concerned Scientists. https://blog.ucsusa.org/susan-muller/offshore-wind-will-add-power-when-new-england-needs-it-most/

24 ISO New England. (2021, December 22). *ISO New England Energy Security Timeline: 2004 – 2005: Multiple Approaches Undertaken to Address Region's Energy Security Risks*. https://www.iso-ne.com/static-assets/documents/2021/12/new-england-fuel-risk-2021-2022-necpuc-12-22-2021-final.pdf

25 ISO New England. (2018, May). *Petition of ISO New England Inc. For Waiver of Tariff Provisions.* Federal Energy Regulatory Commission. https://www.iso-ne.com/static-assets/documents/2018/05/iso_petition_for_waiver_of_tariff_provisions.pdf

26 National Grid. (2023, June 15). *Eversource and National Grid Complete Ready Path Solution to Strengthen Greater Boston's Electric Reliability and Support Retirement of Mystic Generating Station in 2024.* https://www.nationalgridus.com/News/2023/06/Eversource-and-National-Grid-Complete-Ready-Path-Solution-to-Strengthen-Greater-Boston-8217-s-Electric-Reliability-and-Support-Retirement-of-Mystic-Generating-Station-in-2024/

27 The future of EMT as pertains to the reliability of the region's gas system is a separate but related issue, as evidenced by the Department of Public Utilities (DPU) petition and subsequent approval of EMT gas contracts.

28 The role of alternative fuels in decarbonizing building and transportation end uses is not a core focus of this paper, but Massachusetts DPU Order 20-80-B provides an example of a PUC rejecting recommendations to change current gas supply procurement policy to support the addition of renewable natural gas due to "concerns regarding the cost and availability of RNG as well as its uncertain status as a zero-emissions fuel…": https://acadiacenter.wpenginepowered.com/wp-content/uploads/2023/12/12-06-23-Acadia-Center-MA-DPU-Gas-Utility-Order-20-80-Press-Release-V2.pdf

29 The exact definitions of "distributed" and "rooftop" solar were not clearly defined across studies.

30 Larson, E., Greig, J., Jenkins, J., et al. (2021, October 29). *Net-Zero America: Potential Pathways, Infrastructure, and Impacts.* Final Report. Princeton University. https://netzeroamerica.princeton.edu/the-report

31 Executive Office of Energy and Environmental Affairs. (December 2022). Clean Energy and Climate Plan for 2050. Commonwealth of Massachusetts. https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2050

32 The 2050 CECP focuses primarily on the "Phased" scenario, which places more emphasis on near-term adoption of hybrid heating systems that utilize a "partial building" heat pump that works in tandem with a fossil fuel heating system, but the "Massachusetts Workbook for Energy Modeling Results" appendix to the 2050 CECP provides detailed quantitative outputs on the "High Electrification" scenario. The 2025/2030 CECP companion study goes into more detail on the "High Electrification" scenario narrative.

33 Mettetal, E. & Breckel, A. et. al. (2020, November). *Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future.* Energy and Environmental Economics & Energy Futures Initiative. https://efifoundation.org/wp-content/uploads/sites/3/2022/03/Net-Zero-New-England_Report_Nov-2020.pdf

34 Hagerty, M., Weiss, J., & Higham, John. (2019, September 2). *Achieving 80% GHG Reduction in New England by 2050: Why the Region Needs to Keep its Foot on the Clean Energy Accelerator.* The Brattle Group. https://www.brattle.com/insights-events/publications/achieving-80-ghg-reduction-in-new-england-by-2050-why-the-region-needs-to-keep-its-foot-on-the-clean-energy-accelerator-2/

35 The Achieving 80% report was unique in that it modeled both demand side "scenarios" (e.g., "High Electrification") and corresponding supply side "clean energy portfolios" (e.g., "Large-Scale Resources") separately. This literature review chose to focus on the "Large-Scale Resources" clean energy portfolio.

36 Energy and Environmental Economics (E3) & Scott Madden. (2022, March 18). *The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals: Technical Analysis of Decarbonization Pathways.* Independent Consultant Report. Massachusetts Department of Public Utilities 20-80. https://thefutureofgas.com/content/downloads/2022-03-21/3.18.22%20-%20Independent%20Consultant%20Report%20-%20Decarbonization%20Pathways.pdf

37 See Massachusetts Clean Energy and Climate Plan for 2050, page xix.

38 Throughout this literature review, the included figures leverage available data from the five reports and scenarios analyzed. However, the exact format the data is presented in varies considerably across reports. For example, some reports only present some pieces of data in a graphical, opposed to tabular, format. Thus, in some cases, direct measurement of graphs in the five reports was necessary to estimate the underlying data in order to generate the graphs seen in this literature review.

39 Evolved Energy Research. (2020, December). *Energy Pathways to Deep Decarbonization: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap.* Pg. 35. Commonwealth of Massachusetts. https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

40 The Princeton NZAP study did not provide a breakdown of 2050 end-use electric loads by sector in 2050 in New England and was not included in Figure 3 below.

41 Only two of the four studies modeled a change in overall electric load for sectors outside of buildings and transportation. While the industrial sector was included in both the MA CECP 2050 and Achieving 80% studies' analyses, neither study showed a measurable change in industrial sector electricity demand through 2050. The increase in "Other/Industry" load in both MA DPU 20-80 and Net-Zero New England appears to be primarily driven by electrification of industrial end uses. Net-Zero New England refers to the "Industry" sector and mentions that "53% of industrial energy consumption is electric" by 2050 under the High Electrification scenario. The MA DPU 20-80 refers to an assumption of "medium" levels of industrial electrification in their High Electrification scenario.

42 ISO New England. (2024, February 12). *2050 Transmission Study.* Pg. 15. ISO New England. https://www.iso-ne.com/static-assets/documents/100008/2024_02_14_pac_2050_transmission_study_final.pdf

43 Obtaining MA CECP 2050 study data on building heating load reductions resulting from envelope improvements required email communication with the report authors. Based on available data, the Project Team was only able to determine that commercial building shell improvements resulted in at least a 6% reduction commercial heating load, but this reduction could be larger than 6%. This is reflected in Figure 7 below.

44 While the Princeton NZAP study did model the impacts of DR/load shifting, the total demand reduction from DR/load shifting in New England in GW terms was not included in the report or supporting materials. Although not captured in Table 2, Princeton NZAP was the only study that explicitly included the peak load reduction impact of "large intermediate loads", including electrolysis, electric boilers for industrial process heat, and direct air capture in their modeling. The study assumed 100% of these loads are flexible but did not quantify the flexible load in GW terms for New England.

45 In Figure 8 below, only inter-regional transmission capacity between New England and Canada is shown. Two of the studies also included data regarding New England-New York inter-regional transmission capacity, but this data was not included for the cross-study comparative purposes of the graph.

46 Regarding Figure 9, while the Princeton NZAP study did provide New England annual generation data (TWh) for renewable resources, the study did not include this data for combustion generation or nuclear generation. The Project Team used the 2050 New England installed capacity data for fuel combustion and nuclear generation provided for the NZAP E+ scenario and applied the average 2050 capacity factors for fuel combustion generation and nuclear generation across the other four studies examined in this literature review to estimate 2050 fuel combustion and nuclear generation in the NZAP E+ scenario.

47 Data on the 2050 capacity factor for fuel combustion generation in the Princeton NZAP E+ scenario was not obtainable and, thus, was not included in Figure 10 below.

48 While three studies provided data on distributed (or "rooftop" in some cases) solar capacity, these terms were not clearly defined in any of the studies, leaving some ambiguity when interpreting the results.

49 See Energy Pathways to Deep Decarbonization, Table 8, Page 64 for details on the Regional Coordination scenario regional transmission buildout. https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

50 Only inter-regional transmission capacity between New England and Canada is shown in Figure 13 below. Two of the studies also included data regarding New England-New York interregional transmission capacity, but this data was not included for the comparative purposes of the graph.

51 Adapted from Denholm, P., Chernyakhovskiy, I., & Streitmatter, L. (2024, April). *Maintaining Grid Reliability – Lessons from Renewable Integration Studies.* National Renewable Energy Laboratory. U.S. Department of Energy. https://www.nrel.gov/docs/fy24osti/89166.pdf

52 According to National Renewable Energy Laboratory's report *Maintaining Grid Reliability – Lessons from Renewable Integration Studies,* "demand for electricity during all hours of the year can be met through a portfolio approach."

53 As discussed in Section 2, while relatively high levels of combustion capacity may remain on the New England grid into 2050, they will produce very low generation output.

54 ISO Newswire. (2023, May 1). *Next decade will see steady increase in New England's electricity use, 2023 CELT Report predicts.* ISO New England. https://isonewswire.com/2023/05/01/next-decade-will-see-steady-increase-in-new-englands-electricity-use-2023-celt-report-predicts/

55 Data from Massachusetts Clean Energy and Climate Plan for 2050 "Massachusetts Workbook for Energy Modeling Results". Based on top 50 hours of peak demand in New England in 2050. https://www.mass.gov/media/2553881/download

56 Section 2 discusses the topic of load shifting in more detail. 75 percent EV charging flexible load (MA 2050 CECP) and 25% water heating flexible load (MA DPU 20-80) represent the high-end estimates across the five studies in the respective categories.

57 Nijsse, F., Mercure, J., Ameli, N. et al. (2023, October 17). The momentum of the solar energy transition. *Nature Communications*, 14, 6542. https://doi.org/10.1038/s41467-023-41971-7

58 Knight, P., Griot, O., Carlson, E. et al. (2023, July 6). *Massachusetts Technical Potential of Solar: An Analysis of solar potential and siting suitability in the Commonwealth.* Synapse Energy Economics. https://www.mass.gov/doc/technical-potential-of-solar-in-massachusetts-report/download

59 Muller, S. (2024, January 3). The Equation. *Offshore Wind Will Add Power When New England Needs It Most.* Union of Concerned Scientists. https://blog.ucsusa.org/susan-muller/offshore-wind-will-add-power-when-new-england-needs-it-most/

60 ISO New England System Planning Department. (2018, December 17). *High-Level Assessment of Potential Impacts of Offshore Wind Additions to the New England Power System During the 2017-2018 Cold Spell.* ISO New England. https://www.iso-ne.com/static-assets/documents/2018/12/2018_iso-ne_offshore_wind_assessment_mass_cec_production_estimates_12_17_2018_public.pdf

61 Akdemir, K., Kern, J., Lamontagne, J. (2022, July 15). Assessing risks for New England's wholesale electricity market from wind power losses during extreme winter storms. *Energy*, Vol. 251. https://doi.org/10.1016/j.energy.2022.123886

62 See modeling results for high clean energy growth and moderate load future. Grid Deployment Office. (2023, October). *2023 National Transmission Needs Study: New England.* U.S. Department of Energy. https://www.energy.gov/sites/default/files/2023-12/43451_DOE_GDO_Needs_Study_Fact_Sheets_New_England_v6_RELEASE_508_Compliant.pdf

63 Millstein, D., Wiser, R., Jeong, S., Kemp, J., (2023, February). *The Latest Market Data Show that the Potential Savings of New Electric Transmission was Higher Last Year than Any Point in the Last Decade.* Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/lbnl-transmissionvalue-fact_sheet-2022update-20230203.pdf

64 The cost of congestion, and the potential value of new transmission, is the difference in wholesale electricity prices between two locations. The highest congestion value for interregional transmission in the Eastern Interconnection is between New England and New York, with an average potential price arbitrage value of $38 per MWh. See also LBNL Market Data Factsheet.

65 Dimanchev, E., Hodge, J., Parsons, J. (2020). *Two-Way Trade in Green Electrons: Deep Decarbonization of the Northeastern U.S. and the Role of Canadian Hydropower.* Massachusetts Institute of Technology Center for Energy and Environmental Policy Research. https://ceepr.mit.edu/wp-content/uploads/2021/09/2020-003-Brief.pdf

66 Dimanchev, 2020

67 Evolved Energy Research. (2020, December). *Energy Pathways to Deep Decarbonization: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap.* Pg. 35. Commonwealth of Massachusetts. https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

68 For more information about Acadia Center's work on these interregional opportunities, see the Northeast Grid Planning Forum here: https://acadiacenter.org/resource/the-northeast-grid-planning-forum-framing-paper/.

69 New England battery storage capacity and pumped hydro capacity data from U.S. Energy Information Administration Form EIA-860M *Monthly Update to Annual Electric Generator Report* for the month of April 2024. https://www.eia.gov/electricity/data/eia860m/

70 Data selected by sorting for battery and filtering out withdrawals. ISO New England. (2024, October 11) *Public Queue Data. Interconnection Requests Tracking Tool.* https://irtt.iso-ne.com/reports/external

71 Wilson, R., Raman, K., Burger, R. (2023, September). *Clean, Reliable, Affordable: The Value of Multi-Day Storage in New England.* Form Energy. https://formenergy.com/wp-content/uploads/2023/09/Form-ISO-New-England-whitepaper-09.27.23.pdf

72 Energy arbitrage is, essentially, the economic benefit derived from buying low price electricity to charge a battery system (in the middle of the day) and later selling the stored energy at a higher price (in the evening) when discharging. See: Department of Energy Resources. (2023, December 31). *Charging Forward: Energy Storage in a Net Zero Commonwealth.* Commonwealth of Massachusetts. https://www.mass.gov/doc/charging-forward-energy-storage-in-a-net-zero-commonwealth-report/download

73 By way of comparison, current and historical spending on transmission projects in New England, is approximately $0.73 billion per year. ISO New England. (2024, February 12). *2050 Transmission Study*. Pg. 15. ISO New England. https://www.iso-ne.com/static-assets/documents/100008/2024_02_14_pac_2050_transmission_study_final.pdf

74 Department of Energy. (2022, February). *Grid-Enhancing Technologies: A Case Study on Ratepayer Impact.* United States Department of Energy. https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

75 The Brattle Group. (2023, April 20). *Building a Better Grid: How Grid Enhancing Technologies Complement Transmission Buildouts.* WATT Coalition. https://watt-transmission.org/watt-coalition-releases-report-on-synergy-between-grid-enhancing-technologies-and-new-transmission-lines/

76 Rocky Mountain Institute. (2024). *GETting Interconnected in PJM: Grid-Enhancing Technologies Can Increase the Speed and Scale of New Entry from PJM's Queue.* https://rmi.org/insight/analyzing-gets-as-a-tool-for-increasing-interconnection-through-put-from-pjms-queue/

77 Department of Energy. (2022, February). *Grid-Enhancing Technologies: A Case Study on Ratepayer Impact.* United States Department of Energy. https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

78 U.S. Department of Energy (DOE). *Grid-Enhancing Technologies: A Case Study on Ratepayer Impact.* Pages 5-6. February 2022. Available online at: https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

79 Rand, J., Manderlink, N., et al. (2024, April). *Queued Up: 2024 Edition.* Lawrence Berkeley National Laboratory. U.S. Department of Energy. https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%202024%20Edition_R2.pdf

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