# Contents

Acknowledgements .......................................................... 2
Foreword ........................................................................... 3
Introduction ....................................................................... 4
An Industry in Transition .................................................. 6
A Lower Carbon System ..................................................... 9
Managing a System in Transition ...................................... 10
Ambitious Goals Ahead .................................................... 12
Looking Forward: Electric Sector Trends and Opportunities .................................................. 13
  Renewable Energy: Expanding the Portfolio of Zero Carbon Generation ...................... 15
  Transmission: A Critical Resource for Expanding the Renewables Resource Base .......... 21
  Energy Storage: An Asset to Renewables Development & Reliability .............................. 22
  Nuclear Power: Economic Challenges for a Zero-Carbon Resource ................................. 24
  Energy Efficiency: More Savings, More Investment .......................................................... 25
  Distribution System Resource Planning and the Smarter Grid ........................................... 29
  Electric Vehicles: More Vehicles, More Electricity Demand .............................................. 30
Conclusion ........................................................................ 33
Acknowledgements

Lead Authors: Michael Bradley and Christopher Van Atten

This independent report, Power Switch, explores and documents electricity market trends and the disruptive power of innovation in the Northeast states, and the future challenges and opportunities for the electric power sector through 2030 in this region. This report is part of the RGGI Project Series, a series of independent research and analysis projects to inform and assist leaders and stakeholders in the Northeast.

M.J. Bradley & Associates would like to thank the Barr Foundation, the Merck Family Fund, the Devonshire Foundation and Daniel Hildreth for grants that helped make this work possible. We also thank Laurie Burt, of Laurie Burt, LLC and Project Coordinator for the RGGI Project Series, for her input and assistance throughout the project.

Grace Vermeer, Robert LaCount, Dana Lowell, Amlan Saha, Paul Allen, Lauren Slawsky, Kaley Bangston, Pye Russell, and Kim Voellmann of M.J. Bradley & Associates made important contributions to this report. M.J. Bradley & Associates would also like to thank Ann Berwick, David Littell (Regulatory Assistance Project), and Apurba Sakti (MIT Energy Initiative) for their helpful input on the report.

This project includes a companion video with interviews from leading energy experts, including Sue Tierney (Analysis Group), Gordon van Welie (President and Chief Executive Officer of ISO NE), Peter Kelly-Detwiler (Northbridge Energy Partners), and Kelly Speakes-Backman (Alliance to Save Energy).

This report reflects the analysis and judgment of the authors only and does not necessarily reflect the views of the foundations, Ms. Burt, or any of the reviewers.

This report and companion video are available at www.mjbradley.com.

About M.J. Bradley & Associates

M.J. Bradley & Associates LLC (MJB&A), founded in 1994, is a strategic consulting firm focused on energy and environmental issues. The firm includes a multi-disciplinary team of experts with backgrounds in economics, law, engineering, and policy. The company works with private companies, public agencies, and non-profit organizations to understand and evaluate environmental regulations and policy, facilitate multi-stakeholder initiatives, shape business strategies, and deploy clean energy technologies.

© M.J. Bradley & Associates 2016

For questions or comments, please contact:

Christopher Van Atten
Senior Vice President
M.J. Bradley & Associates, LLC
978-369-5533
vanatten@mjbradley.com
For word

Society has become more dependent than ever on electricity to drive our economy, power our devices and keep us connected. At the same time, expectations around the “quality” of the energy we consume have been evolving with growing interest in clean energy technologies and decarbonizing the electric grid. This is reflected in state policy decisions on energy efficiency, carbon regulation, and renewable energy, corporate commitments to purchasing renewable energy, and the millions of solar panels that households have installed on their roofs.

Technology innovation is giving producers and consumers new options to generate, use, manage, store, and save electricity. Combine this desire for clean energy with the right policy framework and the technological capability to deliver on these goals, in a cost-effective way, and you have the recipe to radically transform the electric system over the coming decades.

*Power Switch* discusses these trends, focusing on the Northeast region of the United States, which has long been a laboratory for innovative energy policies and technologies. For example, as discussed in the report, the first commercial offshore wind project in the U.S.—the Block Island Wind Farm—will begin commercial operation in 2016 off the coast of Rhode Island.

Competition is a big part of what drives innovation in the Northeast power markets. Competitive power markets and market-based environmental programs, like RGGI, create competition to supply low-cost power and lower-carbon megawatt hours. Competitive markets enabled the massive shift that has already occurred in the region to highly efficient, combined cycle power plants. This shift in the generation mix has led to dramatic reductions in electric sector carbon emissions, as well as other air pollutants. The big challenge for the region going forward will be how to reduce greenhouse gas emissions beyond the electric sector, including transportation and buildings. Many of the Northeast states have set ambitious medium-term and long-term greenhouse gas reduction goals, with most aiming to achieve an 80 percent reduction in emissions by 2050.

One way to achieve these targets would be to continue decarbonizing electricity production and supply, while at the same time transitioning building heating and transportation from fossil fuels to electric power. The basic building blocks to achieve such an outcome are (for the most part) known today, like electric vehicles, energy efficiency, wind and solar, fast ramping gas plants, transmission, advanced lighting and controls, cold climate heat pumps, and energy storage devices, but they have yet to be deployed at the scale required to meet the goals envisioned by the states. The rapid pace of innovation that we are witnessing with these technologies suggests that such a transition will become increasingly feasible, as companies continue to inhabit this new economic space.

We hope that this report, and the companion video, will encourage policymakers and other stakeholders to continue examining these issues and help to build an appropriate policy framework that will enable this process of “constructive innovation” to continue.

Michael J. Bradley
President of M.J. Bradley & Associates LLC
Introduction

The electric power system in the Northeast region has changed significantly over the past decade and continues to evolve, although to the casual observer it might not appear that much has changed.¹ This is partly by design. The electric system is able to accommodate changes in generating technologies and end uses, while still delivering the same reliable supply of energy to homes and businesses. However, look below the surface (or beyond the meter) and you will find that much has already changed and disruptive forces continue to reshape the system, creating challenges, but also exciting new opportunities for the region.

Driving these system changes are rapid advancements in technology, changes in fuel prices, aging infrastructure in need of replacement, and state and federal policy choices. Customers are also spurring this change as they embrace new innovative technologies, like electric vehicles, and pursue greater energy savings in their homes and offices. Technology is changing how consumers interact with the electric grid, how much electricity people draw from the grid and when they draw it. The future of the electric system will include more interconnected devices, more intermittent renewables, and a more distributed grid, but the full implications of these changes are far from clear. Just as Apple did not know the full suite of applications that would be available for the iPhone when it first hit the market, we do not know exactly what the electric system will look like in 20 years. What we do know for certain is that change is coming and the pace of innovation has only been accelerating.

¹ For the purpose of this paper, we define the Northeast region to include New England, New York, New Jersey, Maryland, Delaware, and Pennsylvania.
Technology innovation has been a disruptive force in other sectors of the economy with widespread social and economic implications. Computers, telecommunications, even the taxi business, has been upended in recent years by technology and business model innovation. The breadth and the pace of change can often be hard to predict because we have preconceived notions of how these systems should work and recent historic experience can often cloud our expectations of the future. The electric sector is different in many respects from these other sectors of the economy and change in the sector has tended to be gradual, but Peter Kelly-Detwiler, an expert on the energy industry, makes the case that the world of electric energy is undergoing a profound change and the change is accelerating: “[t]hanks to breakthroughs in high performance computing and materials science, a whole generation of vastly improved or entirely new technologies is likely to be unleashed on us in the very near future. And that surge of innovation will not stop. It will, in fact, accelerate.”

The purpose of this report is to explore the major trends that are reshaping the electric power system in the Northeast and explore some of the implications of these changes. We focus on this region because the Northeast states have been at the vanguard of the changes that are transforming how electricity is produced and delivered in the U.S. The region has already experienced a major shift in the mix of resources used to produce electricity, with natural gas and renewables displacing older coal- and oil-fired power plants. The Northeast states are particularly well positioned to manage the ongoing changes with well-established energy and capacity markets, and flexible market-based regulatory programs that integrate well with the region’s power markets.

Utility restructuring and the establishment of competitive markets, provides the region with critical tools and a strong foundation to manage the on-going changes that are occurring within the sector. In the 1990s, virtually all of the Northeast states began the process of transitioning toward retail competition and industry restructuring, launching a new era of market and regulatory innovation. The region now has three well established electricity market operators—PJM, New York ISO (NYISO), and ISO New England (ISO NE)—with centralized reliability planning and coordination and market mechanisms that guide investment in the electric system.

RGGI is likely to play a central role in guiding the resource and investment decisions within the region. Many of the Northeast states have also embraced market-based environmental policies and carbon pricing. The Regional Greenhouse Gas Initiative (RGGI), which relies on a market-based trading system to reduce carbon dioxide (CO₂) emissions from the electric sector, is a prime example of the innovative policies championed within the region. Originally launched as an effort to demonstrate environmental policy leadership and encourage similar state or federal actions, RGGI has become a fully functioning marketplace for CO₂ emissions, putting the participating states well ahead of federal efforts to address carbon emissions. Since 2009, RGGI has set a gradually declining cap on CO₂ emissions from fossil-fired power plants with a final reduction goal to be met in 2020 and a further phase of reductions under active consideration. Emissions from the electric sector have dropped sharply since RGGI went into effect in 2009 due to a combination of factors including the recession, complementary energy and environmental programs, and fuel switching in response to lower natural gas prices. RGGI has been a catalyst for several of the market trends

---

discussed in this paper, including the expanded role of energy efficiency within the region. From 2009 to 2015, the RGGI states have reinvested nearly $2 billion in proceeds from the CO₂-allowance auctions back into the economy in various ways, including primarily on energy efficiency measures and community-based renewable power projects.

Electricity has the potential to play a dramatically expanded role in the region’s overall energy mix in the coming decades in order to achieve deep reductions in carbon emissions. Looking to the future, many of the Northeast states have set ambitious goals for themselves. All of the New England states, New York, Maryland, and New Jersey have established economy-wide goals or requirements for reducing greenhouse gas emissions with most aiming to cut emissions 80 percent from 1990 levels by 2050. This implies a major transformation in the region’s energy system, including changes well beyond the electric system. RGGI will continue to be a central element of the region’s climate and energy strategy; however, new and expanded strategies will be required to achieve these deeper reduction targets. To date, shifting from coal and oil to natural gas has been the primary source of CO₂ emissions reductions. However, this option has been largely exhausted in some states. Transportation is the leading source of CO₂ emissions within the region. There are certainly more opportunities to reduce emissions within the electric system, but as the system continues to decarbonize, electricity will provide opportunities for achieving emissions reductions more broadly across the economy by switching from gasoline powered vehicles to electric vehicles, and by switching from oil and natural gas use in boilers and furnaces to heat pumps powered by electricity.

The region has already experienced several waves of innovation and change, and there are more to come. The question now is: how will the electric system evolve over the coming decades, while continuing to maintain reliability and reducing greenhouse gas emissions across the economy?

An Industry in Transition

It used to be that the Northeast region relied almost exclusively on large, central station coal, oil, and nuclear power plants to supply the grid. Over the past several decades, however, the region has undergone a massive shift in the generation fuel mix with greater reliance on highly efficient, natural gas-fired combined cycle power plants. This shift from coal and oil to natural gas could be described as the first wave of change and innovation that swept across the region after the introduction of competitive power markets. The first large-scale combined cycle power plants arrived on the scene in the Northeast in the late 1980s and early 1990s. Today, there are more than 100 combined cycle power plants in the region with a total generating capacity of more than 40 gigawatts (GW). More recently, a second wave of change has been sweeping across the region with the deployment and integration of alternative energy sources, such as wind, solar, and demand response. Investments in energy storage and smart grid technologies have also been on the rise, bringing new innovations to the market that could dramatically reshape the energy system. In the future, electricity will

---

3 The Hay Road Energy Center in Wilmington, Delaware, a 1,130 megawatt combined cycle power plant, started commercial operation in January 1989.

4 Electricity markets have an extensive vocabulary. Power plants, generating facilities, and supply resources are all synonymous for the facilities that produce and deliver electricity to the grid, including coal-fired power plants, nuclear facilities, hydroelectric facilities, wind farms, and other technologies. Demand-side energy efficiency refers to energy saving measures and appliances in our homes and offices, like LED lighting and high efficiency dryers. Distributed
be used to an increasing degree as a transportation fuel and to heat the region’s homes and offices with heat pump technology—a further wave of technology innovation and change with important implications for the electric sector as well as the broader energy system.

These changes have been stimulated in part by the competitive forces of the market. In particular, the wholesale power markets and the competitive price of natural gas have been key factors driving the changes in the region’s fuel mix; fuel costs are the biggest component of a traditional power plant’s operating costs. Since 2010, natural gas prices have fallen 40 percent (Henry Hub Spot). The New York Independent System Operator (NYISO) reports that low natural gas prices have resulted in record low wholesale electric energy costs in 2015. The average wholesale electric energy price ($44.09 per megawatt-hour) was the lowest in the 15-year history of New York’s competitive markets for wholesale electricity. The PJM marketplace has also been experiencing record low prices. In March 2016, wholesale power prices plunged to a 15-year record low in the PJM Interconnection. Low gas prices have encouraged greater reliance on natural gas throughout the region; low gas prices have also created economic challenges for power plant operators and have led to a significant number of power plant retirements.

**Figure 2** Some of the Key Trends Shaping the Northeast Electric System

<table>
<thead>
<tr>
<th>U.S Henry Hub ($/MMBtu)</th>
<th>Northeast Generation (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7.18 (Jun '05)</td>
<td>6</td>
</tr>
<tr>
<td>$2.59 (Jun '16)</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2005</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>2005</td>
<td>2015</td>
</tr>
<tr>
<td>87</td>
<td>208</td>
</tr>
</tbody>
</table>

↓ 64% Decline in natural gas spot price

↑ 184% Increase in non-hydro renewable generation

↓ 58% Decline in coal-fired generation


generation refers to small-scale generating facilities, like solar panels, located at an individual home or business, close to the load that it is intended to serve.


7 Platts. PJM Average Power Prices Hit 15-Year Low in March. April 25, 2016.
At the same time, the industry has seen a significant upsurge in renewable generation driven by decreases in technology costs and constantly improving technology, combined with supportive state and federal policies. In 2015, renewables (including large hydroelectric facilities) accounted for more than 9 percent of total electricity production in the Northeast, but this share could increase significantly in the coming years. As discussed later in the report, the costs of producing electricity with wind and solar technologies have declined significantly, and further declines are expected as the technology continues to improve.

Figure 3 highlights the historic changes in the generation fuel mix across the region. New York and New England, in particular, have both experienced significant changes over the past decade. Between 2005 and 2015, coal-fired generation declined more than 80 percent in both New England and New York, and more coal plants are scheduled to close. There are currently only four coal-fired plants still operating in New England, although all may be closed over the next several years: Bridgeport Harbor Station in Connecticut (scheduled to close in 2021), Brayton Point in Somerset, Massachusetts (scheduled to close in 2017), and the Merrimack and Schiller facilities in New Hampshire (both scheduled to be sold and potentially converted to natural gas). A similar story is playing out in New York, where in the past several years a number of coal plants have retired or been converted to burn other fuels. The two coal plants in the state that continue to operate have low utilization rates and have struggled financially. The declines in oil use have been even

---

more dramatic (>90% since 1990). By contrast, the use of natural gas for electricity production, in New York and New England, has increased between two to six times since 1990.

In Pennsylvania, New Jersey, Delaware, and Maryland, similar changes in the fuel mix have taken place, although several of these states still have significant coal generation. Across these four states, coal generation has declined over 40 percent since 1990 and now accounts for roughly 24 percent of the region’s electricity generation. By contrast, natural gas-fired generation has increased nearly 8-fold and now accounts for more than 30 percent of total electricity generation.

**Figure 4** Demolition of the Salem Harbor Coal-fired Power Plant

Demolition of the Salem Harbor coal-fired power plant in Salem, Massachusetts. Salem Harbor is being replaced with a $1 billion natural gas-fired power plant. More than nine gigawatts of coal capacity has been retired in the Northeast since 2010.

Photo credit: JDC Demolition Company

**A Lower Carbon System**

As a result of these changes in the generation fuel mix, the Northeast region has been successful in driving down emissions of CO₂ and other air pollutant emissions associated with the production of electricity. The electric sector has reduced its CO₂ emissions by roughly a quarter since 1990, across the Northeast (31 percent since 2005). Among the states that participate in RGGI, a market-based trading program that limits CO₂ emissions from the electric sector, the reductions have been even more dramatic. In the 9 state RGGI region, the electric sector has reduced its CO₂ emissions by 45 percent since 1990 (or roughly the same percentage since 2005). Electricity production, which once accounted for 30 percent of economy-wide CO₂ emissions across the RGGI states, now accounts for about 20 percent of emissions. Economy-wide CO₂
emissions have also declined, about 20 percent since 1990 in the RGGI region in large part because of the progress made within the electric industry (see Figure 5).

Figure 5  RGGI Region Historic CO₂ Emissions (million short ton) and Percent Share by Sector

Managing a System in Transition

The Northeast has been successful in managing and nurturing this market transformation, while driving economic growth and maintaining reliability, because of a mix of policy choices and well-functioning power markets, which have facilitated and enabled many of the changes that we discuss throughout this paper. The region has a history of leadership on energy and environmental policies, including market-based environmental programs like RGGI. Many of the states in the Northeast have also made commitments to clean energy goals and long-term greenhouse gas reductions.

Well-Functioning Power Markets. Beginning in the late 1990s, all of the Northeast states, with the exception of Vermont, began to transition toward retail competition and industry restructuring, launching a new era of market and regulatory innovation. The region now has three well established system operators—PJM, NY ISO, and ISO New England—with centralized reliability planning and coordination and market rules that have evolved over the years.

Utility restructuring and the establishment of the RTO markets provides the region with critical tools and a strong foundation to manage the on-going changes in the energy landscape. Locational marginal pricing\(^\text{12}\) ensures that the lowest cost resources are dispatched to meet energy demand even as the resource mix changes. Capacity markets ensure that adequate resources are available to meet future demand. Deactivation rules help to ensure an orderly retirement of existing generating facilities as the resource mix continues to evolve. A recent study by PJM found that markets have done well in attracting new generation investment

\(^{12}\text{The market-clearing price for electricity at the location the energy is delivered or received.}\)
based on transparent price signals that allow generators to make rationale economic decisions. On the distribution side, a variety of policies have been adopted in the Northeast ensure that utilities have an incentive to invest in energy efficiency, a key component of the region’s energy strategy.

**Market-Based Environmental Policies.** The Northeast states have a long-tradition of relying on market-based regulatory approaches. As far back as 1999, a subset of states in the Northeast established the nation’s first trading system for nitrogen oxide (NOx) emissions to reduce smog pollution. Between 2000 and 2008, many of the Northeast states adopted renewable portfolio standards (RPS), based on a system of tradeable renewable energy certificates. Massachusetts utilities, for example, can purchase renewable credits from any qualifying source that delivers power to the New England power grid, and other Northeast states allow this type of credit trading. Finally, in 2009, a large block of Northeast states launched the nation’s first carbon trading system, RGGI. These flexible, market-based approaches allow emissions goals to be met at lower cost, versus more prescriptive regulatory approaches. Market-based environmental programs (pricing mechanisms) also tend to integrate well with the region’s competitive power markets.

**A Commitment to Clean Energy and Greenhouse Gas Reduction Goals.** Many of the Northeast states have established aggressive GHG reduction goals and renewable energy targets, which will continue to influence the energy mix within the region. All of the New England states, New York, Maryland, and New Jersey have established economy-wide goals or requirements for reducing GHG emissions. Most aim to cut emissions 80 percent from 1990 levels by 2050. Many of the Northeast states have also adopted renewable portfolio standards (RPS). New Jersey, for example, has adopted a renewable standard, requiring utility companies to source 20 percent of their power from renewable sources by 2021. Legislation has also been considered by the New Jersey legislature that would establish an 80 percent renewables target by 2050.

---


14 A renewable portfolio standard is a regulatory mandate to increase the supply or production of electricity from renewable sources such as wind, solar, biomass and other qualifying technologies.

The RGGI program, which encompasses most of the Northeast, is arguably the centerpiece of the region’s commitment to decarbonizing the energy sector. Since 2009, RGGI has set a cap on CO₂ emissions from fossil-fired power plants with a final reduction goal to be met in 2020. The participating states are currently considering the potential tightening of the regional CO₂ emissions cap and adjustments for future compliance with EPA’s Clean Power Plan. The choice of a more stringent emissions cap, the second to be considered since RGGI started, will have an important influence on the region’s power mix in the coming decades by limiting the sector’s CO₂ emissions.

Technology Research and Development. The Northeast region has a high concentration of research and development programs, universities, and innovative start-up companies in the clean energy sector. In New York, NYSERDA, a publicly funded corporation focused on promoting energy efficiency and renewable energy, has well established technology R&D programs. In Massachusetts, the publicly-funded Clean Energy Center is dedicated to accelerating the development and deployment of clean energy technologies. One of the initiatives supported by the Clean Energy Center is the Greentown Labs. Greentown Labs provides office space and resources for energy and clean technology entrepreneurs to collaborate, test and develop ideas, market products and services, and share experiences with a community of like-minded individuals. Greentown Labs is now expanding its network in the Northeast by teaming with a similar incubator at New York University-the New York City Accelerator for a Clean and Renewable Economy.

Ambitious Goals Ahead

The degree of change that has already occurred within the electric sector in the Northeast has been dramatic. Supported by effective policy and market frameworks, the region has come a long way in modernizing its electric system. These changes have delivered many benefits including significant reductions in CO₂ emissions. However, the process of innovation never stops and the region has unmet goals with regard to the adoption of clean energy technologies.

There is widespread support for transitioning to a clean energy system that reduces the threat of climate change and other contaminants. Many of the Northeast states have established long-term goals to dramatically reduce greenhouse gas emissions from all sectors of the economy. As the electric system transitions to low- and zero-carbon technologies, electrification will offer an important opportunity for reducing carbon emissions throughout the economy. Greater reliance on electricity for transportation and heating offers the opportunity for dramatically reducing air pollution emissions.

The Northeast states have set ambitious goals for the future that extend well beyond the electric sector. As indicated above, all of the New England states, New York, Maryland, and New Jersey have established economy-wide goals for reducing GHG emissions with most aiming to cut emissions 80 percent from 1990 levels by 2050. Many of these states have also established interim goals. In evaluating the recent trends and future goals, several important points emerge. First, the road ahead will need to break new ground to achieve these deeper reduction targets. To date, it has been the electric sector that has delivered the bulk of the
emissions reductions, by shifting from coal and oil to natural gas. However, this option is virtually exhausted in some states and limited in others. Across the region, coal and oil only account for about 20 percent of total electricity generation; down from 40 percent of total generation in 2005.

Future opportunities for GHG reductions within the electric sector will need to rely on strategies that transform the overall efficiency of how electricity is generated, transmitted and used and greatly expands the use of zero-emissions sources of energy. For New York and New England, the only opportunities to significantly reduce GHG emissions from the power sector, in the not distant future, will be to reduce emissions associated with gas-fired power generation. At the same time, the power sector will provide opportunities for achieving emissions reductions more broadly across the economy by switching from gasoline powered vehicles to electric vehicles, and by heating homes and buildings with electric heat pumps, rather than relying on oil and other fossil fuels. Figure 7 shows the historic trends in CO₂ emissions within the Northeast region by sector, as well as an illustration of what an 80 percent reduction goal (from 1990 levels) would imply if applied across the region to CO₂ emissions.

Figure 7  Northeast Region Historic CO₂ Emissions (million short ton) and 80% Reduction Goal


Looking Forward: Electric Sector Trends and Opportunities

In many ways, the world was simpler prior to restructuring and prior to the rise of distributed generation and demand response, energy storage, and big data. Peter Kelly-Detwiler, an expert on the trends affecting the energy industry, said it best in his reflections on the “good old days” of the electric power system in the Northeast. “In the good old days before about 2010, you had the normal hurdles that typically accompanied the coordination of the bulk power system (loosely defined as generation and transmission—the big iron
stuff) and wholesale power markets...In general, supply was supply and demand was demand. While there were challenges inherent in ensuring that supply was always equal to demand, and that there would be enough generation to meet future needs, the world was fairly (but not entirely) predictable...In general, the kids stayed put in the sandbox, and everybody colored within the lines.” The system was built to serve the instantaneous demand of customers, with a large reserve margin to accommodate plant outages and other contingencies.

Today, the system is certainly more complex and new challenges lie ahead, as the trends discussed throughout this paper take hold. The electric system across the Northeast is entering a new phase in its evolution. The changes underway have been enabled by significant advances in energy technologies, but they have also been driven by necessity. To meet the state-by-state GHG goals in place across the region, the power sector will need to achieve significant GHG emissions reductions while delivering reliable and affordable service. These goals will require a transformation in how electricity is produced, delivered and used. Initiatives, like the Reforming the Energy Vision (or “REV”) process in New York, have been exploring these questions with a focus on creating a more distributed energy system and delivering greater value to consumers.

The good news is that Northeastern states have built a strong foundation to support this transformation. Renewable generation is rapidly increasing. Many states across the region continue to lead on energy efficiency. Despite these positive efforts and trends, more substantial change will be required in the future. These changes will require a rethinking by all stakeholders. Some of the questions facing the region include: How can electric utilities, projects developers, investors, and the wide range of companies working across the electric system value chain best support this transition? How well do current policies create effective and sustainable incentives for required investments? To what extent will the electric system be relied upon to power transportation and heating?

Transforming Energy Use in Vermont
Vermont, like several states in the Northeast, has been evaluating its options for reducing greenhouse gas emissions and transforming its energy system (see the Public Service Department’s “Total Energy Study”). In 2015, the state passed legislation (Act 56) putting its plan into action by establishing targets for reductions in fossil-fuel consumption. Electric utility companies are now encouraged to support “energy transformation” efforts, including home weatherization, increased reliance on electric vehicles, and the installation of cold-climate heat pumps. Technology advancements have made heat pumps (powered by electricity) a viable option for heating well insulated homes, even in the cold winter temperatures of Vermont. Utility companies, heating and cooling specialists, and energy system installers in Vermont are actively marketing high-efficiency heat pumps, ground-mounted and roof-mounted solar energy systems, and home battery storage devices from Tesla and Sonnen.
In the sections that follow, we discuss some of the key trends, opportunities, and challenges across the Northeast as the power sector transitions to a lower carbon system. Some of the key areas of change include: (1) renewable energy (steady growth); (2) energy efficiency (new opportunities); (3) electric vehicles (gradually expanding); (4) nuclear energy (economic challenges); (5) energy storage (early stages of development); and (6) transmission (critical enabler of renewable energy).

Renewable Energy: Expanding the Portfolio of Zero Carbon Generation

Renewable energy has been steadily increasing in the Northeast due to state policy mandates, declining project costs, federal tax incentives, and consumer preference.\textsuperscript{16} Today, wind and solar account for a small share of the overall electricity supply within the region. However, as the number of projects continues to increase, this number is expected to increase.\textsuperscript{17} Since 2010, the Northeast region has more than doubled its installed base of wind and solar capacity, and more growth is expected in the coming decades. This trend is critical to expanding zero-carbon energy and will largely set the pace for future GHG reductions given the current power generation mix across the region. States in the region are also looking at the option of importing additional hydroelectric power from Canada.

The Northeast states have relied on several different approaches to encourage renewable energy development. One of the mechanisms, as mentioned earlier in this report, has been to introduce carbon

\textsuperscript{16} On December 18, 2015, Congress passed extensions to the investment tax credit (ITC) for solar and the production tax credit (PTC) for wind energy projects. The Consolidated Appropriations Act extends the 30% ITC for solar to facilities that commence construction on or before December 31, 2019 (and are placed in service before 2024). The ITC then declines for projects that commence construction after 2019. The PTC for wind also gradually declines before expiring in 2020.

\textsuperscript{17} In 2015, wind and solar combined accounted for 2.0 percent of the region’s total electricity production.
pricing, through the RGGI program, and reinvesting some of the allowance auction proceeds in renewable energy projects. By pricing carbon into the market, renewable resources become more competitive in the marketplace. In addition to RGGI, many states in the Northeast established RPS standards in the late 1990s and 2000s to drive renewable development. The state laws generally require electricity suppliers (utility companies) to provide a minimum percentage of their sales from eligible renewable energy resources. The RPS standard in Massachusetts, for example, was set at 11 percent in 2016 (for Class I resources) and will continue to increase 1 percent per year. Figure 8 provides a forecast of the incremental renewable generation required to meet the RPS targets in New England, as they continue to increase through 2025. In 2015, Massachusetts, Connecticut, and Rhode Island issued a joint request for proposals (RFP) for renewable energy and transmission projects to help achieve these policy goals. By joining together in a coordinated procurement effort, the states were hoping to get a larger response from project developers to help meet the states’ clean energy standards.

New York has taken a somewhat different approach by adopting a “Clean Energy Standard,” requiring utilities and other energy suppliers to meet 50 percent of their sales from qualifying renewables by 2030, while also directing financial support to at-risk existing nuclear facilities. This reflects a recognition that existing nuclear facilities supply a large share of the current non-emitting generation in the state.

Another strategy has been to require utility companies to solicit proposals for renewable energy generation and enter into long-term contracts. Massachusetts, for example, passed an energy bill in August 2016 that requires the state’s utility companies to solicit long-term contracts for 1,600 megawatts of offshore wind power, and 1,200 megawatts of hydropower or other renewable resources. There is currently an active debate among stakeholders in the New England states exploring potential changes to the wholesale power markets that could be implemented to advance state public policy objectives, including clean energy and GHG reductions goals. Some of the options under discussion include strengthening the RGGI program, a new forward market for clean energy resources, or a carbon adder in the energy market (“carbon shadow pricing”).

Outside of the state policy programs and mandates, companies have also been driving demand for renewable energy by building wind and solar projects to power their facilities and signing contracts for renewable energy. Intel, Procter & Gamble, Apple, Google, Verizon, IKEA and others having been turning to renewables to help power their businesses.

Wind

Wind energy has been rapidly expanding in the U.S. There are more than 4 gigawatts (GW) of wind capacity installed in the Northeast. New York has the highest amount of wind capacity within the region (about 1.7 GW in 2015), followed by Pennsylvania. And more wind projects are currently underway. New York has

---

18 The NEPOOL “Policies and Markets Problem Statement” (May 17, 2016) captures the challenge for the New England market: “…The challenge is finding a means to execute states’ policy-related requirements at the lowest reasonable cost without unduly diminishing the benefits of competitive organized markets or amplifying the cost to consumers of implementing those state policies in order to maintain markets. In the same way that market mechanisms identify the lowest cost way to satisfy the region’s reliability needs, states seek to determine whether market mechanisms can accommodate public policies without unreasonably increasing the costs to consumers. …”


20 One gigawatt is equal to one billion watts or one thousand megawatts.
over 3.7 GW of wind power proposed for interconnection with the New York grid.\(^{21}\) Not all of these projects will get built, but it is an indication of the continuing development efforts. Maine has also been attracting significant wind development with more than 2 GW of proposed projects under review. Several wind projects in Maine, as well as New Hampshire, submitted proposals in response to the New England Clean Energy RFP discussed above; winning projects will need to be online by 2020.

Looking to the future, offshore wind is expected to be a significant growth area for the Northeast. Today, offshore wind remains a nascent technology, with only one project (nationwide) nearing completion off the coast of Rhode Island.\(^{22}\) High costs and political opposition have so far stymied development efforts.\(^{23}\) This could change, however, as states along the Atlantic coast continue to pursue the technology. In addition to Rhode Island, several states are actively pursuing offshore wind development, including: Maryland\(^{24}\), New

---

**Figure 9**  
**Wind Generation by State and Region (gigawatt-hour)**

Wind generation has increased significantly in the Northeast; New York, Pennsylvania, and Maine have seen the largest increase, but this could change if offshore development picks up.

Source: EIA 923 2010; EIA 923 2015

---

\(^{21}\) NY-ISO, *Interconnection Queue.* Accessed August 5, 2016,  

\(^{22}\) Deepwater Wind is expected to complete its first offshore wind farm (30 MW) in 2016 off Block Island; this will be the first offshore wind farm in the U.S. connected to the mainland power grid.


\(^{24}\) Maryland Public Service Commission, “Offshore Wind Energy RFP.” Accessed August 5, 2016,  
http://marylandoffshorewind.com/.
Jersey, New York, and Massachusetts. As mentioned above, Massachusetts passed a new energy law that requires utilities to procure a combined 1,600 megawatts of offshore wind by 2027.

Europe has developed significant offshore wind capacity (>10 GWs), and companies are looking to leverage this development experience in the United States. As the industry grows in the U.S., more of the supply chain, and associated jobs, could move from Europe to the Northeast. Offshore wind is one of the few options available to add large blocks of zero-carbon energy to the Northeast power grid.

Solar

New Jersey had the highest amount of solar capacity within the region at the end of 2015 (more than 1,200 MW in 2015), followed by Massachusetts (see Figure 10). New Jersey was an early adopter of solar power with its solar RPS and SREC market, and industry analysts expect the state to double its solar capacity over the next five years. ISO New England is also projecting significant growth in solar capacity. The region’s electric market operator projects that solar capacity in New England will increase to about 3,300 MW by 2025 (with more than 4 TWh of electricity production). This is roughly equivalent to the annual output of a mid-sized fossil generating plant (600 MW @ 80% capacity factor).

---

29 New Jersey, Maryland, and Delaware have the best solar resource (the amount of solar radiation that reaches a specific location) among the Northeast states (4.5-5.0 kilowatt-hours per square meter per day).
30 Solar Renewable Energy Certificates (SRECs) are credits produced from qualifying solar energy projects.
More solar is being deployed because the technology has improved and installation costs have fallen significantly in recent years. The Northeast states have also established a robust solar industry with almost 43,000 workers\textsuperscript{33} employed by the solar industry in 2015, according to the Solar Foundation.\textsuperscript{34} Massachusetts and Vermont rank among the top five states for solar jobs per capita.\textsuperscript{35} Between 2009 and 2015, the levelized cost of generating electricity (LCOE: total cost of installing and running a project divided by expected electricity output over the project’s lifetime) from solar resources fell by 82 percent.\textsuperscript{36} The U.S. Department of Energy (NREL) projects that solar costs will continue to fall, with capital costs for utility-scale projects declining to roughly $1/watt by 2030.\textsuperscript{37} Others are more bullish, projecting that costs will dip below $1.0/watt by 2020.\textsuperscript{38}

![Solar Capacity through 2015 (megawatt)](image)

New Jersey and Massachusetts have added the most solar capacity among the Northeast states due to a combination of supportive policies, declining panel costs, and competition among solar installation firms.

Source: Estimated by U.S. EIA (Electric Power Monthly, year-to-date through December 2015). Distributed solar is less than 1 MW. EIA, ISO-New England, and the Solar Energy Industries Association all report state-by-state solar capacity, and the data vary to some degree because they each rely on different methodologies.

\textsuperscript{33} This includes jobs in solar installation, manufacturing, sales and distribution, and project development.
Integrating Renewables

As the amount of wind and solar power increases, one of the challenges will be to integrate variable energy resources that depend on the weather into the existing wholesale market structure and the operation of the grid. Wholesale electricity prices reflect the cost of producing electricity and delivering it over a high-voltage transmission system. As more renewable energy is added to the system, with zero fuel costs, the revenues earned by all generators through the energy markets is likely to decline. Faced with declining energy prices, it then becomes incumbent on capacity and ancillary service markets, and other mechanisms, to ensure that a flexible resource mix is available to maintain grid reliability. Market operators in the Northeast and other parts of the U.S. have been introducing reforms to address this challenge.

Distributed solar, located at homes and businesses, has been an attractive option in many states with various incentives available. Net metering is a billing system by which utility customers with on-site generation (primarily solar panels) can sell their excess electricity to their electric utility provider. Forty-one states and the District of Columbia have put in place some form of net metering rules. These rules also set the rates at which ratepayers are credited for the electricity they feed into the grid. These payments or credits have led to significant deployment of solar panels in the U.S., particularly in the residential and commercial sector.

NREL projects continued declines in the cost of wind and solar technology, making these alternative technologies increasingly competitive with natural gas combined cycle generation. The projected costs of wind and utility-scale solar technology in 2030 are lower than a new natural gas plant in some cases.

Source: National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) Summary Presentation – 2015 Final, Released July 8, 2015. Solar-PV utility-scale representative plant is single axis tracking with capacity of 100 MW. NREL projects low, medium, and high cost estimates for wind and solar to reflect to reflect the uncertainty associated with their cost and performance assumptions.

---

However, some within the industry, including many utilities, argue that the tariffs, which are often set at full retail electricity rates, are overly generous. They point out that retail rates include not just energy charges, but also distribution and generation capacity costs. The concern raised is that these payments or credits will shift a growing share of the maintenance and development costs of the electricity grid to an ever smaller group of ratepayers that do not use solar panels.

Net metering policies have given rise to contentious debates in several states. Over 60 percent of all states with net metering policies limit in some form the total amount of generating capacity that may connect to the grid to sell excess electricity to their utilities.\footnote{National Renewable Energy Laboratory. “Status of Net Metering: Assessing the Potential to Reach Program Caps,” September 2014. Accessed April 13, 2016, http://www.nrel.gov/docs/fy14osti/61858.pdf; and St. John, Jeff. “Breaking: California’s NEM 2.0 Decision Keeps Retail Rate for Rooftop Solar, Adds Time-of-Use.” Greentech Media, January 28, 2016. Accessed April 13, 2016, http://www.greentechmedia.com/articles/read/Californias-Net-Metering-2.0-Decision-Rooftop-Solar-to-Keep-Retail-Payme.} When the limits are exhausted only further regulatory or legislative action can enable new projects to take advantage of the terms available under net metering policies. But any such effort leads to a debate that has never quite been settled. A key question going forward will be how to balance the incentives for solar development while attracting investments into the sector to maintain critical infrastructure.

**Transmission: A Critical Resource for Expanding the Renewables Resource Base**

As the Northeast states seek to achieve aggressive renewable energy goals, developers are proposing new transmission projects to move power from remote energy projects to the region’s load centers. New York, for example, is evaluating potential transmission projects to move electricity from new upstate wind farms down to New York City. As of September 1, 2016, fourteen transmission projects had been proposed in the ISO New England Interconnection Queue, totaling more than 9,000 MW of potential transfer capability to bring power from large-scale hydroelectric facilities in eastern Canada and wind projects in northern New England, as well as other resources.\footnote{ISO New England. The Transformation of the New England Power System: Infrastructure Needs and Market Implications. September 28, 2016. https://www.iso-ne.com/static-assets/documents/2016/09/gvw__nec_9_28_2016.pdf.}

On a local level, as energy sources are increasingly distributed throughout the system and interspersed with consumers, the grid is becoming more integrated. This is changing the way that the grid is managed and operated by shifting the direction the power flows on lines, emphasizing the need for local generation, additional connections, and coordination among generators, grid managers, and consumers. Entities across the Northeast are investing in new programs to facilitate the move to a more flexible, integrated transmission and distribution system.

The evolving nature of the grid, combined with the need to upgrade and maintain aging infrastructure, has triggered significant investment in the past decade. According to the Edison Electric Institute, investor-owned utilities alone invested about $73 billion in transmission infrastructure from 2010 through 2014 and are estimated to spend another $85 billion from 2015 through 2018. In the Northeast, DOE notes that investment reached nearly $2 billion in 2012. Looking forward, DOE also reports that, as of 2014, over 130 circuit-miles were in construction in New York and New England and neighboring parts of Canada; another 1,300 circuit miles were planned to be completed by 2019, and an additional 75 circuit miles by 2024. In addition to under construction and planned lines noted in this report, which either have completed permitting,
are required for regulatory reasons, or have a complete design, DOE also tracks “conceptual” lines that are either projected in transmission plans or may be required to meet NERC standards. This same northeastern region has over 600 conceptual circuit miles in the pipeline.

There have been challenges siting and permitting some large transmission projects. Developers typically need approval from several state and federal agencies, which is a multi-year process. Markets that cross state lines, such as ISO NE, can help by coordinating Regional System Planning processes to conduct joint planning, though each affected state retains jurisdiction over the specific siting in its territory. The ISO has also occasionally used cost distribution across all users in its market, based on an understanding that the benefits of new transmission lines can spread far beyond their exact pathways. However, this remains a challenge for transmission improvement and development across the region.

Energy Storage: An Asset to Renewables Development & Reliability

As the Northeast plans for a system that is more dependent on variable renewable resources, energy storage will play an important role in providing cost-effective and reliable electricity. Storage systems draw energy from the system when there might be more than necessary (for example, when wind generation increases in the evening), and discharge stored energy when it is needed to serve customer demand. At the end of 2015, U.S. storage capacity reached 221 MW, up 243 percent from 2014, and is expected to surpass 4 GW by 2020.\(^{43}\) In the Northeast, states are working to advance the technology through procurement mandates, pilot programs, and market design changes aimed at recognizing the services that can be provided by a range of energy storage applications.

Energy storage goes far beyond battery technologies. In fact, the largest form of energy storage in the United States and Northeast is pumped hydro storage, where water is pumped uphill during times of off-peak

---

demand, then released in controlled amounts to power turbines during times of peak demand. New York is one of the national leaders today for energy storage with 1,400 MW of pump storage capacity on-line.\textsuperscript{44}

Other energy storage applications include flywheels, which use a motor to store energy as kinetic energy in a mass that spins at very high speed. When power is needed, the grid can pull energy from the flywheel, using the motor as a generator to return the energy to the power grid. Flywheels offer strong and rapid frequency regulation services by providing fast response and high ramp speed, an increasingly important task with more renewable generation on the system. In recent years, battery technologies have been the most common storage medium used by project developers, accounting for 96 percent of total storage deployment in 2015.\textsuperscript{45} Maine has recently added a 500 kW battery system.\textsuperscript{46} Three more battery projects totaling 94 MW are currently in the New England ISO queue. PJM has 1,831 MW of storage under study in the interconnection queue.

Storage technologies could enhance the value of wind and solar by allowing electricity to be stored for later use. Storage technologies can also provide important services to the grid, including reducing peak demand, voltage support and frequency regulation, and grid resiliency. There is still work to do, however, in terms clarifying regulatory treatment of storage technologies and crafting effective business models for energy storage systems.

Energy storage can be applied in a variety of ways to strengthen and improve the cost-effectiveness of the electricity system. For example, a battery storage system in Boothbay, Maine was deployed to help avoid the need for transmission upgrades. This was part of a pilot project testing non-transmission alternatives to meet peak demand, including ice cooling systems, distributed solar, energy efficiency, and a large diesel generator. Storage systems can also provide voltage support and frequency regulation services, which are increasingly important to incorporate higher levels of variable energy sources. Energy storage can also be used to store and later disperse renewable energy—this can occur through state initiatives, through pairing renewable installations with batteries or other storage devices (as some home rooftop solar companies now offer), or through markets, as they begin to reflect larger price differentials between hours of high renewable production (leading to often very low energy prices) and hours with little or no renewable production.

The Northeast states have begun pursuing market and regulatory changes to integrate more storage. For example, in 2009, the NYISO became the first grid operator in the nation to implement regulations that enable storage systems to participate in the markets as frequency regulation providers, providing reserve capacity for grid operators. To provide these systems access to the market, a new type of regulation service provider was defined: Limited Energy Storage Resource (LESR).

The New England ISO had a brief setback in 2014 when the FERC denied changes to its market for voltage regulation services, arguing that these new changes were discriminatory to storage technologies.\textsuperscript{47} Since then, however, the ISO has made further modifications to its tariffs to allow for increased energy storage participation. A recent report by the New England ISO identified opportunities for different technologies and responding to stakeholder feedback, and this June submitted a filing to FERC to request market changes to increase market participation of energy storage resources. It also had a pilot program in place (from 2008 to 2015) that encouraged alternative technologies to participate in wholesale electricity markets, in which a flywheel system participated by providing quick response regulation and other services.\textsuperscript{48}

States and utilities throughout the region have instituted procurement and subsidy programs aimed at increasing storage penetration and further supporting energy storage R&D. For example, the New York State Energy Research and Development Authority (NYSERDA) will fund seven companies based inside the state to either scale up projects or demonstrate how energy storage can help transform the state’s electricity grid.\textsuperscript{49} Green Mountain Power, the largest utility in Vermont, has partnered with NRG and Tesla to provide customers with personal home energy storage systems paired with solar installations.\textsuperscript{50} And, Massachusetts announced in May 2015 a $10 million energy storage initiative that will analyze opportunities to support storage options, including a pilot program and further policy options to encourage storage deployment.\textsuperscript{51}

**Nuclear Power: Economic Challenges for a Zero-Carbon Resource**

As renewable energy expands across the Northeast, states are confronted with critical questions regarding the largest current source of carbon-free generation—nuclear power. Nuclear energy accounted for 35 percent of the Northeast region’s total electricity production in 2014 and 79 percent of the region’s zero-carbon energy generation.\textsuperscript{52} Among the RGGI states, there are seventeen nuclear units currently in operation, although several are scheduled to close. Pennsylvania is home to a significant nuclear fleet, including nine units at five locations. There are three nuclear power stations in New Jersey.

For many years, these facilities were highly profitable sources of zero-carbon energy generation, while also providing round-the-clock power. However, low wholesale electricity prices are posing a major economic challenge for many of the region’s nuclear plants. Nuclear units are finding it harder to cover their operating costs and sustain profitability in competitive markets where low natural gas prices are driving down the wholesale price of electricity. Nuclear plants now may also encounter further economic pressures with wind and solar energy also driving down wholesale electric prices.

\textsuperscript{52} MJB&A analysis based on EIA-923.
As a result of these changing economics, which in some instances has been exacerbated by operational challenges at specific units, several nuclear plants have announced plans to retire before their license periods expire, or have already begun the process of decommissioning, as is the case with Vermont Yankee. Oyster Creek in New Jersey and the Pilgrim plant in Massachusetts are both slated to retire in 2019. State regulators have intervened in an attempt to save the James Fitzpatrick and R.E. Ginna facilities in upstate New York. These units currently serve to significantly lower the overall GHG intensity in the Northeast region, and the nature of what type of energy will replace the output of these plants is not a trivial question. If gas is the dominant resource used to replace existing nuclear plants, the challenging GHG goals in specific states may become insurmountable under current timelines.

Energy Efficiency: More Savings, More Investment

Energy efficiency has become an integral part of the energy landscape in the Northeast and continues to be an area ripe for innovation. State, community, and utility-managed efficiency programs reduce energy bills and help to alleviate reliability concerns during periods of peak electricity demand. New businesses have been established to serve the demand for efficiency and energy management services, creating an important source of employment and business activity within the region. For example, GE recently launched a Boston-based startup focused on high efficiency lighting and other alternative energy technologies, including load controls, sensors, motion detectors, and wireless monitoring systems. According to the Northeast Energy Efficiency Partnerships (NEEP), there are more than 300,000 people in the Northeast and Mid-Atlantic employed in the energy efficiency space, including electricians, construction workers, HVAC installers, and program managers.

Many of the Northeast states rank among the top in the nation for their energy efficiency programs and policies: Massachusetts (#1), Vermont (#3), Rhode Island (#4), Connecticut (#6), Maryland (#7), and New York (#9). All of these states have made a concerted effort to prioritize energy efficiency using a portfolio of programs and policies. Key among these are: (1) decoupling or lost revenue mechanisms, (2) performance incentives that allow utility companies to earn a return on their investment in energy efficiency programs that is on par with investments in supply-side resources, (3) savings targets for utility companies, and (4) markets that recognize energy efficiency as a resource, similar to traditional supply-side generating facilities. The goal in many of these states has been to align utility shareholder interests, customer interests, and public policy objectives. Utility ratemaking can allow utilities to earn a return on their investments in energy efficiency programs; customers benefit and businesses are more competitive with lower energy bills; and progress can be made toward other policy objectives (e.g., reducing carbon emissions).

---

Many of the Northeast states have also established aggressive savings targets for utility companies with funding provided from RGGI auction revenues and system benefit charges. Rhode Island and Connecticut, for example, both require utility companies to acquire all cost-effective energy efficiency before securing additional supply-side resources. Maryland requires its utility companies to achieve a 2 percent reduction in electricity sales from 2013 levels by 2020.

Energy efficiency offers a significant opportunity to enhance customer value and affordability. Many of the Northeast states have recognized the value of efficiency and have sought to increase investment in energy-saving technologies. Technology innovation is opening new opportunities for even deeper energy savings.

The New York Public Service Commission (NY PSC) has gone even further by making major structural reforms to its electric utility regulations in an effort to further promote efficiency and carbon reductions. New York utilities will continue to operate as natural monopolies, but their revenues will be tied to the delivery of “consumer value,” rather than simply earning a regulated rate of return for investing in transmission or central station power plants. The new regulatory structure will diversify the ways that utilities can earn revenues, incentivizing investments in cost-effective demand-side energy efficiency and distributed generation. As an example of what this could look like, the NY PSC cites Consolidated Edison’s Brooklyn/Queens Demand Management (BQDM) Program, approved in December 2014. The program

Figure 12 Per Capita Investment in Energy Efficiency (Utility Programs)

Per capacity investment in energy efficiency (electric) has generally been increasing among the Northeast states.

Source: NEEP REED Database: Expenditures as Percent of Total Cost, and ACEEE Electricity Efficiency Program Spending and Savings tables.

enabled Consolidated Edison to defer the construction of a $1 billion electrical substation in Brooklyn by using a combination of energy efficiency, solar, and batteries. The Commission authorized a return on total program expenditures, as well as performance incentives tied to goals on customer savings, thereby aligning utility financial incentives and customer interests.

The electric power markets in the Northeast—ISO NE, NY ISO, and PJM—have all established market rules allowing energy efficiency and demand response to participate to varying degrees in the energy, capacity, and ancillary service markets, competing along-side conventional generating facilities. For example, in New England, demand-side resources accounted for 8 percent of the resources procured to meet future projected demand in the 2016 forward capacity auction.\(^57\)

In the coming years, the six New England states will invest more than $1 billion annually in energy efficiency programs, and much more will be spent directly by households and businesses looking to reduce their energy costs.\(^58\) As a result, energy efficiency (and distributed solar) is projected to produce a net reduction in the New England region’s grid-based electricity use, offsetting more than 100 percent of anticipated growth (see Figure 11).\(^59\) ISO NE projects the region’s overall electricity demand will decline - 0.2 percent annually (although peak summer demand continues to increase).\(^60\) In contrast, electricity demand in New England increased by 0.5 percent annually between 2000 and 2010. NYISO also projects a decrease

---


\(^{59}\) Ibid.

in load growth in the coming years due to energy efficiency investments (see figure 13). A large source of funding for energy efficiency programs in the northeast is the RGGI program, under which states utilize the majority of revenues from allowance sales to fund energy efficiency programs that further reduce regional GHG emissions.

The challenge for utilities and energy service providers going forward will be to secure savings from a more diverse set of technology measures and program participants. Gone are the days when compact fluorescent lightbulbs (CFL) could be relied on to deliver large energy savings; federal law has effectively banned standard incandescent light bulbs. The future of energy efficiency is now focusing on high efficiency LED lighting, integrated controls, zero energy buildings, intelligent building technology, high-performance heat pumps, big data, and smart grid technologies.

---


Commercial lighting systems, in particular, have been rapidly improving and now come equipped with automatic controls that adjust lighting based on daylight availability and switch off lights at specified intervals. Intelligent lighting control systems can integrate lighting and building controls for a single room, a whole building or even multiple campuses. These networked systems are able to learn building use trends and optimize comfort and energy savings by automatically adjusting lighting and other systems as usage patterns change over time. Integrated controls can also provide complete facility energy usage information as well as remote operation and control capabilities.

Energy management systems are also available for residential use. Home energy management systems allow households to monitor their energy use and control devices within the home from their phone or computer to reduce energy use and shift usage to off-peak periods. The technology is still in the early stages of adoption, but offers the potential for deeper energy savings and better integration of advanced energy devices.

**Distribution System Resource Planning and the Smarter Grid**

The development of the smart grid is improving control of the grid and the ability of system operators, and even consumers, to monitor their energy use. Increased control allows operators to send nearly instantaneous signals to “smart” grid equipment, generators, and sources of demand to adjust operations, leading to better reliability outcomes and lower operating costs. Visibility helps system operators plan better for and rapidly respond to grid conditions by allowing entities to see how facilities are operating in real time and how consumers are drawing electricity. With smart grid capabilities, utilities can instantly know the exact location of outages; utilities and customers can both track usage on a minute-by-minute basis. Other aspects of the smart grid allow for greater control of the grid and connected resources, ranging from near-instantaneous changes to small generators’ output to increased ability for customers to adjust their demand to take advantage of lower prices or to lower grid stressors, either individually or through emerging companies that help large groups of customers participate in new demand management programs. These capabilities—and many more—have led to reduced system losses and electricity costs.

A key benefit of the smart grid is helping to improve the integration of renewable generators, especially those that are distributed among consumers. For example, the smart grid can improve distributed resource “visibility” by transmitting signals from distributed resources back to central locations, allowing grid planners and managers to track the output from small resources throughout the grid that previously were invisible to the system. Grid managers can then better account for these resources in ensuring that demand meets supply, and individual distribution lines are capable of handling the flows of electricity likely to be on them. The smart grid can also provide increased data that can be used for forecasting future renewable output by using collected generation data to build models that predict distributed resource generation under certain conditions. Finally, smart inverters, which are used to connect many distributed resources to the system (especially solar resources) are allowing these resources to respond in real time to grid conditions, adjusting output to provide frequency or voltage adjustments to retain reliability, to continue to provide power through grid disruptions, and help smooth out natural variation in renewable power. Taken together, these and other smart capabilities of the grid are allowing the system to incorporate higher levels of distributed resources while maintaining a reliable system.

Many states across the Northeast have put in place programs to advance smart grid deployment. For example, building upon an initial roll out of smart electric meters in 2004, utilities in Vermont are
participating in eEnergy Vermont, which received over $200 million in federal grant to improve system communication, upgrade and automate distribution equipment, and increase smart meter use. In Pennsylvania, state legislation in 2008 authorized utilities to upgrade customers to smart meters and move them to “time of use” pricing, which differs retail rates based on the time electricity is consumed, which can be a critical tool for managing peak demand, mitigating distribution and transmission costs, and improving system reliability. A 2012, $19 million pilot in Harrisburg installed hundreds of electronic devices, a new distribution management system, and dedicated communications systems that worked together to improve service, reliability and system operations. The implementing utility, PPL plans to install distribution automation technology in close to half of its service area (central and eastern Pennsylvania) by the end of the decade.

**Electric Vehicles: More Vehicles, More Electricity Demand**

Electric vehicles (full battery-electric and plug-in hybrids) account for a small share of new passenger car sales in the U.S. (1.5% in 2015, excluding light trucks); however, new models are coming on the market each year and several states have set a goal of having at least 3.3 million zero emission vehicles on the road by 2025 (see inset box). In 2015, it is estimated that roughly 116,000 EVs were sold in the U.S. In the long

![Figure 15: Cost of Lithium-Ion Battery Packs ($/kilowatt hour)](image)

Source: Source: Bloomberg New Energy Finance 2016

---


term a significant shift to electric vehicles could drive large reductions in transportation sector CO₂ emissions, while creating additional demand for electricity. Given the currently anticipated growth, however, EVs are not expected to have a significant effect on electricity demand in the next 5 to 10 years. In the long term, a shift to electric vehicles could have profound implications for several major economic sectors by displacing oil demand and providing a large potential base of demand-response capacity.

The key challenges in scaling up the use of electricity as a transportation fuel include: (1) increasing electric vehicles sales; (2) building public fueling infrastructure, providing confidence in the availability of charging stations; and (3) potential electric system impacts (distribution-level) from high concentrations of plug-in vehicles.

**States Seek Expanded Role for Electric Vehicles**

In 2013, California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont signed a memorandum of understanding (MOU) to support the deployment of zero emission vehicles (ZEV), including battery electric vehicles and fuel cell vehicles. One of the major goals of the MOU is to deploy at least 3.3 million ZEVs and adequate fueling infrastructure within the eight states by 2025. To reach this goal, annual electric vehicle sales over the next ten years would have to increase by 400% or more compared to 2014. In May 2014, the task force created by these states published a ZEV Action Plan, which identifies 11 priority actions to accomplish the goals of the MOU, including development of uniform standards related to vehicles and infrastructure; development of state-wide building codes to support installation of charging infrastructure; establishing ZEV purchase targets for government fleets and commitments for the use of ZEVs in state contracting; evaluation of additional monetary and non-monetary incentives for ZEV purchase; and development of a coordinated education and outreach campaign to promote the benefits of ZEVs.

The auto industry has made significant progress in developing viable electric vehicles in the last 10 years. In 2010, there were only two EV models commercially available from major auto manufacturers—today there are more than 25, with additional models projected to be available every year. The vast majority of EVs are two- and four-door compact sedans such as the Nissan Leaf, Volkswagen e-Golf, and Ford Focus EV, with price tags ranging from $23,000 to $43,000, and advertised range per charge from 53 to 107 miles. There are several luxury models available including the BMW i3 and Mercedes B-Class, with a price of approximately $43,000 but comparable size and range as the other compacts. The only true mid-size EV on the market is the Tesla Model S, which gets 240 miles per charge but has a price tag of more than $70,000. The all-wheel drive version of the Model S includes a larger battery pack that allows it to travel 270 miles on a charge but costs over $100,000.

While the current generation of EVs have proven to be reliable and appealing to a number of early adopters, more widespread adoption continues to be hampered by their high cost relative to gasoline vehicles, and by their limited range. Battery costs are the most significant driver of both EV purchase cost and the effective
range of commercial models. Battery costs have fallen by more than 60 percent in the last 5 years, and are projected to continue to fall, which will allow for future EVs with greater range and lower purchase cost.

General motors will begin selling the Chevy Bolt in Fall 2016 (model year 2017). This EV will be priced as low as $37,500 (MSRP) and will have 200+ mile range. Tesla has also begun taking pre-orders for their 2018 Model 3 sedan, which will begin production some time in 2017. This EV has an MSRP as low as $35,000 and will have a range of “at least 215 miles” according to Tesla. If these vehicles prove successful, they could significantly expand the market for EVs beyond the limited pool of early adopters.

In order to encourage EV adoption, both the federal government and some states provide financial incentives. The federal government provides a tax credit of $2,500 to $7,500 for the purchase of battery electric vehicles (BEV) that run exclusively on electricity or plug-in hybrid electric vehicles (PHEV), depending on the size of the battery pack. However, these credits will start to phase out for specific EV models once the manufacturer has sold 200,000 vehicles. In the Northeast, Massachusetts and New Jersey provide state financial incentives for light-duty EV purchases. Massachusetts offers a $2,500 rebate for purchase of an EV or Chevy Volt (a PHEV) and a $1,500 rebate for the purchase of most other PHEVs. New Jersey exempts BEVs from the state sales tax. New York does not offer incentives for light-duty EV purchases but does have a rebate program for medium-duty battery electric trucks.

Electric vehicles have the potential to be a game changer by creating substantial new demand for electricity, while trimming demand for oil. The Northeast states currently spend upwards of $20 billion per year on imported oil. EV deployment would not only reduce the region’s dependence on imported oil, but could also significantly reduce air pollution emissions from the transportation sector. EVs could also be used to help manage the grid by discharging energy back to the grid during periods of peak demand.

Compared to the same model gasoline vehicle, EVs cost $12,000 to $19,000 more before federal and state rebates. For example, after the state and federal tax credit, a Massachusetts resident would pay only $2,000 to $9,000 more for a EV compared to the same gasoline vehicle. If a consumer drives 10,000 miles per year, the vehicle owner would save about $310/year in fuel costs with an EV, at current fuel prices ($2.27/gallon for gasoline and $0.125/kWh for electricity). Thus, the current, average pay-back period on the purchase of an EV is six to 29 years even with federal and typical state incentives. However, pay-back periods would be significantly shorter with fuel prices at 2014 levels (average of $3.36/gallon). At these average prices, the annual fuel cost savings for an EV could have been as high as $700, which would make the pay-back period, after federal and typical state incentives, as short as three years.

As discussed earlier in this report, many of the Northeast states have committed to economy-wide greenhouse gas reduction targets, and the transportation sector is the leading source of CO$_2$ emissions (38% in 2013). Achieving these reduction goals would be impossible without significant progress in reducing transportation sector emissions, and EVs offer one of the best options for addressing transportation sector
emissions. Electric vehicles would also reduce the region’s dependence on imported oil. The figure below estimates the reductions in CO\textsubscript{2} and the increase in electricity demand with different EV penetration levels.

**Conclusion**

This report covered a fair amount of ground in discussing the electric market trends in the Northeast. However, it has really only scratched the surface in terms of addressing the full policy landscape, the innovative technologies that are continuing to emerge, and the challenges that lie ahead. However, we hope that this report will be a helpful introduction to these topics and motivate further exploration and dialogue. If the region transitions to rely more on electricity to power the region, the need for a reliable and cost-effective electric system will only further increase. The industry is at a crossroads, there will be significant changes between now and 2030, and it will be fascinating to engage and observe the changes to come.