ISO new england

20 years

2017 Regional Electricity Outlook


Reliability
Resiliency
Responsiveness
Innovation
Quality
Efficiency
Involvement

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About this Report

ISO New England's unique role gives it an objective, bird's-eye view of trends that could impact the region's power system. The *Regional Electricity Outlook* is one of the many ways the ISO keeps stakeholders informed about the current state of the grid, issues affecting its future, and ISO actions to ensure a modern, reliable power system for New England. Also see our Annual Work Plan at **www.iso-ne.com/work-plan** for information on the ISO's major projects for the year to improve our services and performance. Contact ISO New England's Corporate Communications and External Affairs teams at (413) 535-4309 for copies of this report.

Please note: The facts and figures in this report were current at publication in January 2017. However, the ISO continually generates **data and analyses**.

For the most current information, please visit www.iso-ne.com/reo.

About Us

ISO New England is the not-for-profit corporation responsible for keeping electricity flowing across the six-state New England region: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. The company's power system engineers, economists, computer scientists, and other professionals ensure that the region has reliable, competitively priced wholesale electricity today and into the future. The ISO is independent – none of the ISO's board members, officers, or employees has a financial interest in any company doing business in the region's wholesale electricity marketplace. The Federal Energy Regulatory Commission regulates the ISO.

Our Mission

ISO New England's mission includes **three interconnected responsibilities**:

- **Overseeing** the day-to-day operation of New England's electric power generation and transmission system
- **Managing** comprehensive regional power system planning
- **Developing** and administering the region's competitive wholesale electricity markets

From the Board Chair

Philip Shapiro joined the ISO Board in 2010 and was named chair in 2014. He has extensive experience in finance and infrastructure. Read his full bio at www.iso-ne.com/about.

In our electrified world, a robust, state-of-the-art power system and thriving wholesale electricity marketplace are becoming more important for New England's consumers, its economy, and its environmental goals. As more renewable and distributed generation comes on line, the regional power system will remain an indispensable source of primary power for many, backup power for some, and a low-carbon power source for the transportation and heating sectors seeking to meet emissions requirements from the New England states.

This year marks our twentieth of successfully running the grid in New England, ensuring that the region's residents and businesses have electricity whenever and wherever they need it. During this time, we've also helped New England develop a highly efficient, reliable transmission system and competitive marketplace that, together, have facilitated an evolution in the region's generating fleet. This has helped decrease air emissions and wholesale electricity prices.

As we have done for the past two decades, the ISO will keep spotlighting the physical and economic factors that can impact reliability. A change in one area of the industry can send out ripples that require adjustments in other areas, an effect illustrated by the region's shift to natural-gas-fired generation and renewable resources. Most urgent is the need to address growing concerns over the ability of natural-gas-fired generators to dependably access

Philip Shapiro
Board Chair

> "As we have done for the past two decades, the ISO will keep spotlighting the physical and economic factors that can impact reliability."

adequate fuel during winter cold snaps. Without a timely solution, this fuel-security issue could put reliability at risk, as well as drive up costs and derail progress on meeting the states' clean-energy goals. Actions being taken or considered by the states to reach those goals, meanwhile, may inadvertently undercut the ability of the wholesale marketplace to continue delivering on its promise of securing reliable, competitively-priced electricity for New England today and into the future.

The ISO's independence, objective analyses, and long-term perspective are an asset to the region as we all try to navigate these uncharted waters. I am confident that the ISO and its dedicated professionals will take the necessary actions to protect the reliability of the power system and the integrity of the wholesale electricity marketplace designed to secure that reliability.

The strong collaborative spirit that exists among the ISO, public officials, and regional stakeholders—the market participants and consumer and environmental advocates in the area—will be key in the coming years as we attempt to leverage new technologies and stay ahead of the many challenges presented by our rapidly evolving industry. Working together, we can ensure that as New England strives to create the power system it wants, it also creates the power system it needs.

Sincerely,

From the CEO

Gordon van Welie
has been president and chief executive officer of ISO New England since 2001. Read his full bio at **www.iso-ne.com/about**.

Like many at ISO New England, I am concerned about keeping the lights on in coming winters. We prepare year-round and years ahead for challenging winter conditions because we know that New England depends on the constant flow of electricity that drives the economy and keeps families warm and safe. But the fact is that reliable winter operations are becoming increasingly difficult, particularly during cold snaps.

At the heart of the problem are factors that the ISO has been warning about for some time now but does not have the authority to directly address. On the coldest days of the year, natural-gas-fired power plants can't always access adequate gas because natural gas transportation and storage infrastructure hasn't kept pace with demand from the electricity sector. This is a real risk to reliability—nearly half the region's current electric generating capability and roughly half the proposed new capability

"We prepare year-round and years ahead for challenging winter conditions because we know that New England depends on the constant flow of

runs primarily on this fuel type. During the winter, generation that is not fueled by natural gas has been used to fill the gap, including resources that run on nuclear power, oil, and coal—the latter two of which have caused upticks in winter air emissions. However, these resources have begun to close down and leave the system because they are either less efficient, less profitable, or both. Replacing them will be even more natural-gas-fired generation, to a large extent.

Renewable power resources have also been coming on line quickly, and a number of New England states are moving to significantly increase the amount of renewable energy on the grid, as well as to further reduce emissions from fossil-fuel-fired generators. The ISO has been actively refining systems and market rules to integrate renewable resources, which currently make a valuable, and growing, contribution to offset some of the region's reliance on natural gas and will become integral to achieving a clean-energy future. Still, the region is decades away from installing enough renewable resources and grid-scale energy storage to allow for complete independence from fossil fuels. Connecting additional remote clean-energy resources is also going to require improvements on the transmission system.

electricity that drives the economy and keeps families warm and safe."

Gordon van Welie
President and CEO

"The region is decades away from installing enough renewable resources

For the foreseeable future, the region will require resources such as natural-gas-fired units that can do what wind and solar resources cannot: make large contributions to meeting regional electricity demand; run in any type of weather and at any time of day; quickly change output levels; and provide essential grid-stability services. On frigid winter days in particular, the region has no alternative but to depend on fossil fuels and the remaining nuclear power stations, while also working to improve fuel accessibility for natural-gas-fired generators. The latter will be particularly vital after the summer of 2019, when two more major non-gas-fired generators will have retired.

Improvements to fuel accessibility will require investments in natural gas infrastructure (including the possibility of forward procurement of liquefied natural gas to ensure its availability during the winter months) or greater flexibility to switch to oil as a backup fuel. Ideally, this will be achieved through market incentives, but as a last resort, the ISO may have to retain some non-gas-fired power plants.

For more than a decade, the ISO has been grappling with the fuel-security issue. But now we're also weighing options for managing an emerging complication—how to harmonize the region's competitive marketplace with state environmental goals.

The wholesale markets are designed to reveal the most cost-effective set of resources to meet the demand for electricity. They have served the region very well over the past two decades, attracting billions in private investment and creating a competitive environment that has helped drive down wholesale prices, spur innovation, and create one of the most efficient generation fleets in the country. Nevertheless, the efficacy of these markets is vulnerable to the unintended consequences of long-term state contracts for clean-energy projects.

The states view long-term contracts as the most expeditious way to promote the development of clean-energy resources and the transmission investments needed to deliver that energy. Because clean-energy resources typically have higher development costs and New England's wholesale markets do not price carbon, these resources are currently not competitive in the wholesale marketplace without some form of subsidy.

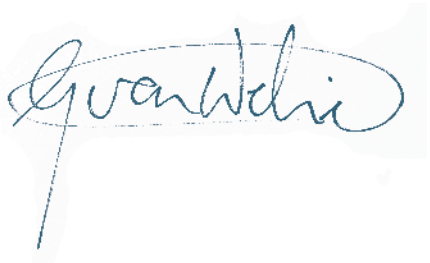
and grid-scale energy storage to allow for complete independence from fossil fuels."

Another perspective the region must also consider is the effects of these contracts on long-term reliability and the structure of the marketplace. As more renewable resources come on line, energy market prices will decrease significantly because of renewables' low fuel costs and state subsidies. As a result, other types of power resources will become even more dependent on revenues from the capacity market, which procures power resources to meet the region's future electricity needs. The participation of large quantities of state-subsidized renewables in the capacity market, however, will also undermine accurate capacity market prices—thereby accelerating the retirement of the very power plants that the region still needs to ensure a reliable electricity supply. Additionally, the capacity market will lose its ability to incentivize investment in, and retention of, efficient and innovative infrastructure and technologies, thereby forcing a return to long-term contracting for all resources.

This leads to a thorny market-design challenge: given that state policymakers are taking action to reduce emissions, how does the wholesale marketplace account for state-sponsored resources without compromising reliability and investment through the markets?

Many questions remain about how best to balance the region's two overarching policy objectives of securing reliability through competitive markets and meeting state carbon-reduction goals, as well as how to solve the pressing fuel-security issue. The ISO is applying its decades of expertise and firsthand experience to developing effective, efficient, and innovative solutions to these challenges in collaboration with our stakeholders. As the ISO commemorates its 20th year of service to New England and leadership in managing its highly reliable, cutting-edge grid, I look forward to working with our stakeholders with the confidence that, together, we will find answers to these questions.

Sincerely,



20 Years
of ISO New England

In just two decades, the ISO has helped New England revitalize its power system and lay the foundation for a cleaner energy future.

A New Era of Competition and Reliability

When you compare New England's electric power system of 20 years ago with today's power grid, the contrast is striking. For decades, the region's utilities operated as vertically integrated, regulated monopolies that generated, transmitted, and distributed electricity to retail customers at cost-of-service rates. Dissatisfied with these rates and a lack of investment in new infrastructure and more efficient, cost-effective technologies, the region began pursuing an alternative framework, one that would introduce competition into the industry.

After passage of the *Energy Policy Act of 1992*, the Federal Energy Regulatory Commission (FERC) created independent system operators and, in 1997, gave ISO New England responsibility for ensuring a reliable supply of electricity for the region and establishing and overseeing competitive wholesale markets for buying and selling electricity. Working closely with the New England states, electric power companies, and other regional stakeholders, the ISO helped lead the nation's most advanced effort at industry restructuring. A new competitive marketplace with open access to transmission lines created a level playing field for buyers and sellers of wholesale electricity. During this same period, five of the six New England states passed laws creating competitive retail electricity markets and ultimately divesting most of the utility-owned generation in the region. This transferred the risk in developing new power resources to investors and away from retail customers and created an incentive to build and run these plants as cost-effectively as possible.

ISO New England was designated a Regional Transmission Organization in 2005, with broader authority over development of the transmission system and greater independence to design fair and efficient wholesale markets. Today, the ISO continues to fulfill its historic mission of using competitive markets to secure a reliable supply of electricity for New England's households and businesses. Visit **www.iso-ne.com/history** to see the ISO timeline.

Markets Are Yielding Tangible Results

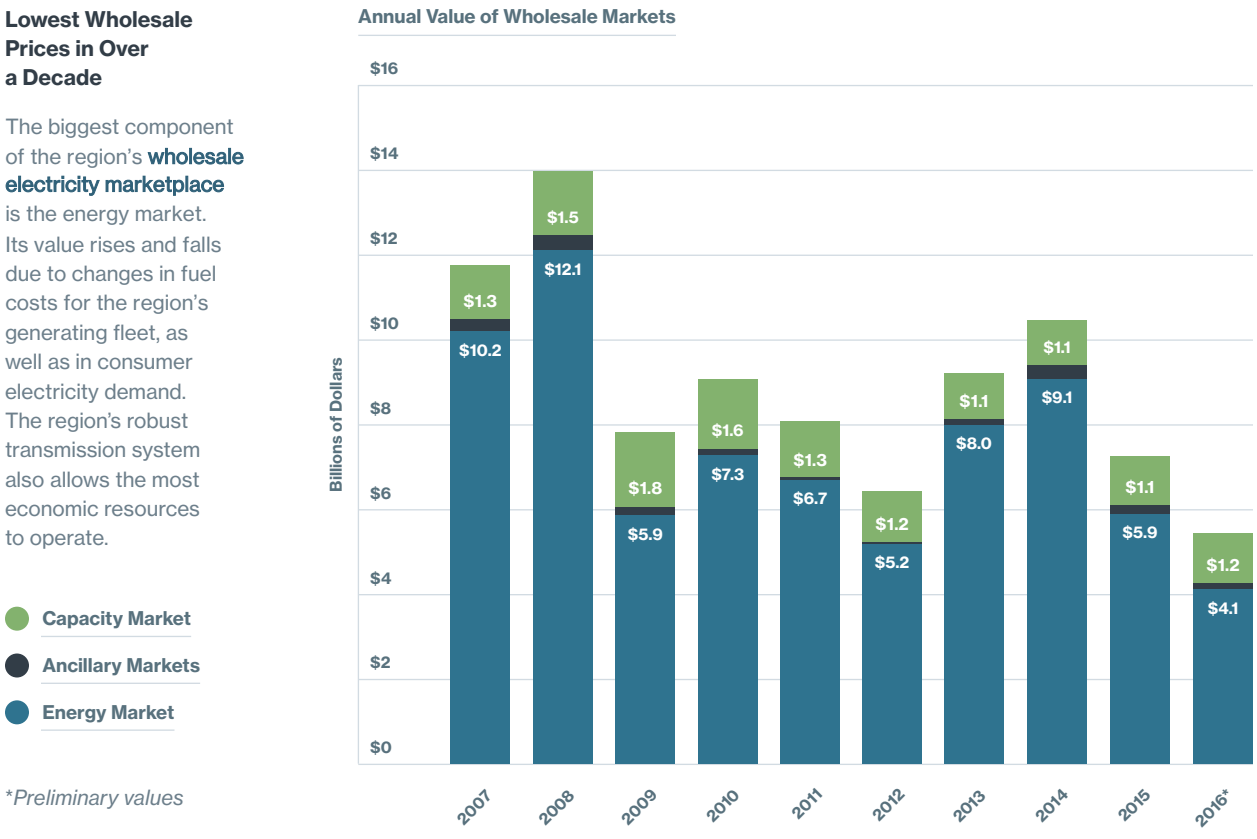
The open, transparent wholesale electricity marketplace designed and run by the ISO stimulates strong competition among over 400 buyers and sellers and has attracted billions of dollars in private investment in some of the most efficient, lowest-emitting power plants in the country. Markets select the lowest-priced power resources competing to produce electricity or provide other specialized services, compensating all suppliers equally, regardless of technology. Markets also provide the incentive for resources to offer prices for electricity as close as possible to their fuel and operating costs and to perform reliably. Competition drives private investment in energy production technologies that provide efficiencies and savings today, as well as in emerging technologies that may revolutionize energy production tomorrow. In addition, the ability of wholesale market prices to accurately reflect current conditions at specific locations serves as a signal to developers to invest in new power resources when and where they are most needed.

These characteristics of competitive markets have helped produce real benefits for New England:

- **Less air pollution**—The addition of over 13,000 megawatts (MW) of natural-gas-fired generation has been largely responsible for significant long-term reductions in **regional generator air emissions**, with nitrogen oxides (NO_x) falling by 68%, sulfur dioxide (SO_2) by 95%, and carbon dioxide (CO_2) by 24% between 2001 and 2015, as the region has largely shifted away from burning coal and oil.

Lowest Wholesale Prices in Over a Decade

The biggest component of the region's **wholesale electricity marketplace** is the energy market. Its value rises and falls due to changes in fuel costs for the region's generating fleet, as well as in consumer electricity demand. The region's robust transmission system also allows the most economic resources to operate.



*Preliminary values

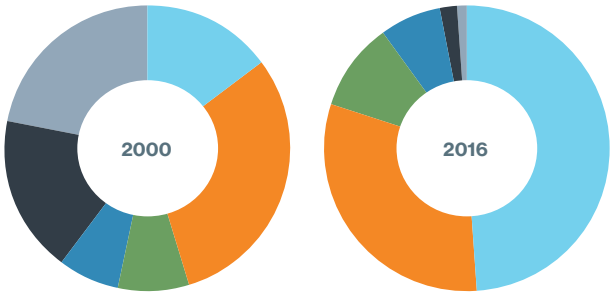
- **Lower wholesale energy costs**—The availability of low-cost natural gas from the nearby Marcellus Shale formation was the main driver of a 44% decrease in the average price of New England's wholesale electricity between 2004 (the first full year of the redesigned energy market) and 2016. In 2016, the combination of mild weather and extremely low natural gas prices resulted in the lowest average annual energy market prices since 2003.

- **Enough power resources to meet the region's needs**—The **Forward Capacity Market** (FCM) has procured about 30,000 MW of generating capacity, 800 MW of active demand response, and 2,000 MW of energy efficiency (EE) to meet New England's needs in 2017 and replace retiring generators. (The capacity market compensates resources that commit to being available in three years' time to meet the region's projected energy needs.) New projects that cleared in the FCM's 2016 auction will be located in the high electricity demand areas of Connecticut, Rhode Island, and Southeast Massachusetts. Generator availability, accounting for planned and unplanned outages, has also increased to 88% in 2016 from 75% in 1997.

A Shift to Cleaner, More Efficient Fuels

The markets, in combination with a boom in nearby lower-cost shale gas, have attracted highly efficient, flexible natural-gas-fired generators. These have almost entirely displaced higher-emitting oil and coal units in **producing electricity regionally**.

Annual Fuel Mix

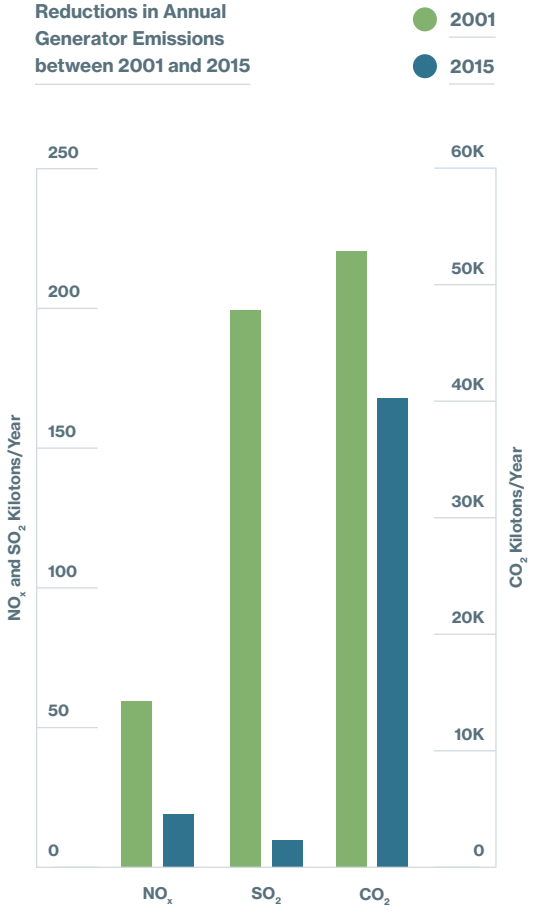


	2000	2016
Natural Gas	15%	49%
Nuclear	31%	31%
Renewables	8%	10%
Hydro	7%	7%
Coal	18%	2%
Oil	22%	1%

A Dramatic Drops in Emissions

The shifting fuel mix has led to significant decreases in **air emissions from the region's generators**.

Reductions in Annual Generator Emissions between 2001 and 2015



Improved Transmission Has Led to Better Reliability and Pricing

Before industry restructuring, New England saw little investment in transmission infrastructure, which resulted in congestion—system constraints that prevent the least-cost electricity from reaching certain locations and can threaten reliability. In 2006, the US Department of Energy labeled New England a Congestion Area of Concern.

Over the last 20 years, the ISO's continuous study and analysis of the transmission system has helped guide cooperative regional investment to fix weak spots and bottlenecks on the system. After years of strong investment, New England now has a more reliable and flexible power system, costly congestion has been virtually eliminated, and the region is no longer a Congestion Area of Concern. (See the *Regional System Plan* [RSP], ISO New England's 10-year planning report, at **www.iso-ne.com/rsp**, and learn about the region's new competitive process for eligible projects at **www.iso-ne.com/competitive-transmission**.) The **transmission system today** includes about 9,000 miles of high-voltage power lines and related facilities spanning the six states, as well as 13 interconnections with neighboring power systems that enable the import of competitive and emergency supplies from New York and eastern Canada. The region met 17% of its energy needs with imported electricity in 2016.

Strong Regional Transmission Investment Has Created a More Reliable, Efficient System

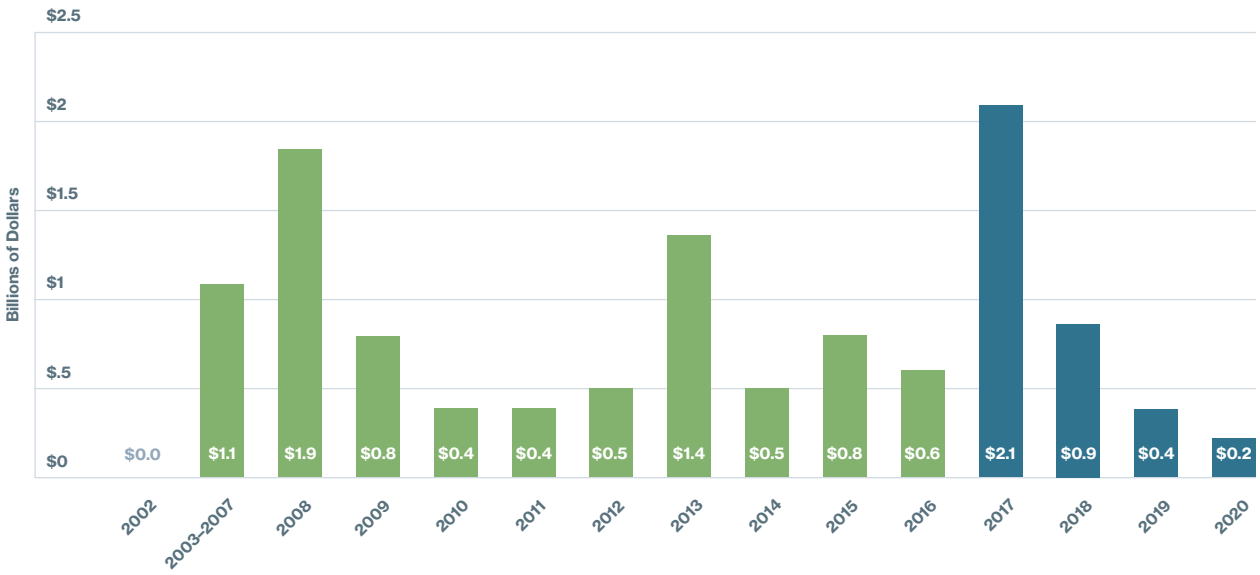
As of the October 2016 update to the Regional System Plan Project List, 690 project components had been placed in service and an additional 153 projects were anticipated over the next 10 years to ensure that electricity continues to move reliably and efficiently across the region. The estimated future investment shown here includes projects that are under construction, planned, and proposed.

Cumulative Investment through October 2016: $8.02 Billion

Estimated Future Investment through 2020: $4.07 Billion

Source: ***ISO New England Regional System Plan Transmission Project Listing*** (October 2016)

Transmission Investment in New England to Maintain Reliability



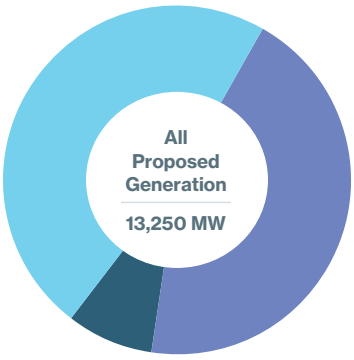
Yet to be determined is whether transmission projects needed to enable the interconnection of additional wind power in northern New England or hydro power from Canada will proceed. Elective transmission upgrades (ETUs)—transmission lines funded by private developers—may play a role in accomplishing this. As of January 2017, 17 ETUs had been proposed in the ISO Generator Interconnection Queue, totaling about 10,500 MW of potential transfer capability. Because of the volume of study requests, the ISO has streamlined the ETU grid-interconnection process.

The Region Is Attracting New Generation, but Transmission Improvements Are Needed to Interconnect More Wind Power

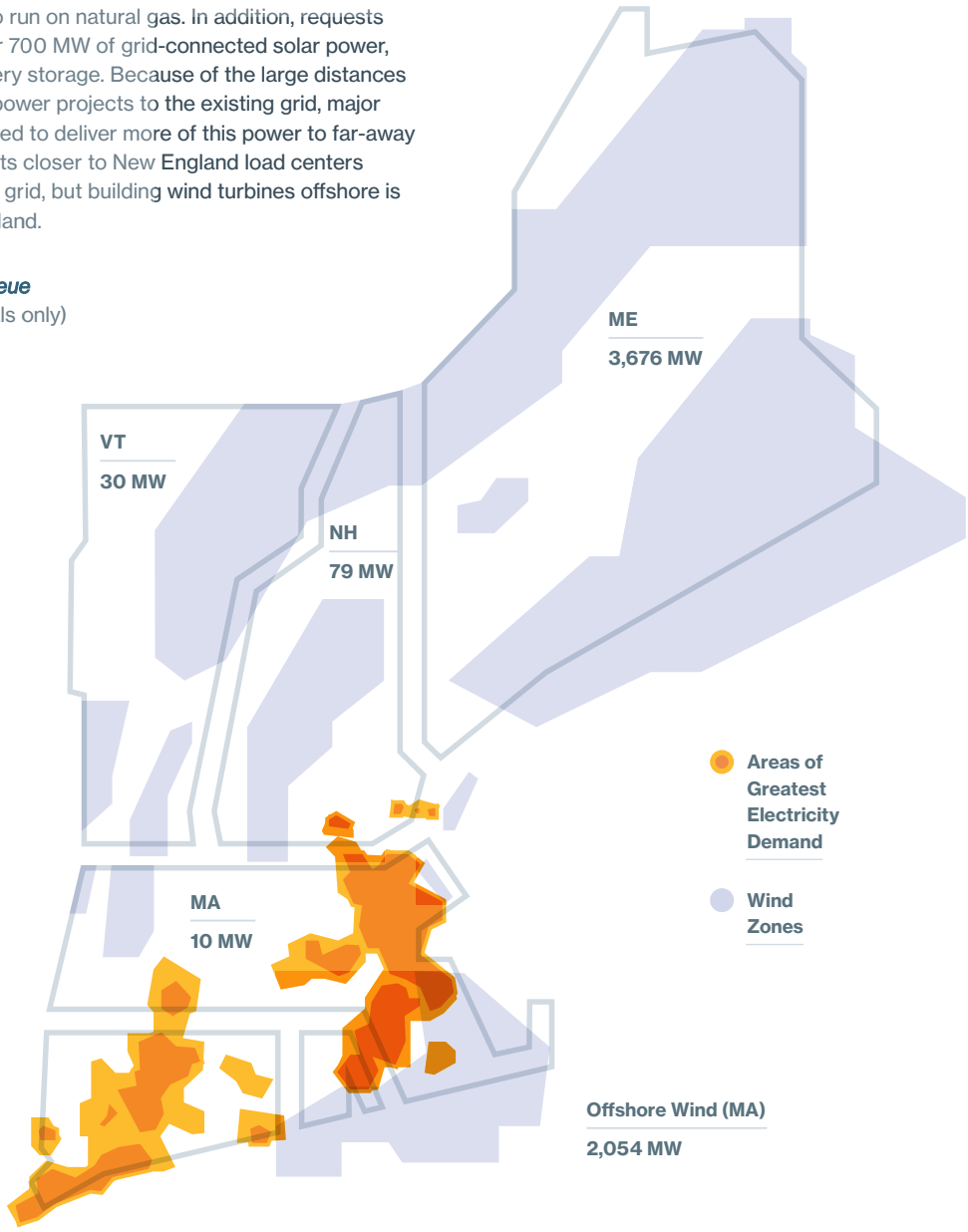
Higher market prices signal an investment opportunity for new, more efficient power resources to replace generators that are closing down and to displace those that are inefficient or expensive. The ISO is slated to study almost 90 grid-interconnection requests from proposed new generators, though many may not ultimately be built. About half this new capacity is proposed to run on natural gas. In addition, requests include over 5,800 MW of wind power, over 700 MW of grid-connected solar power, and almost 80 MW of grid-connected battery storage. Because of the large distances from some of the proposed onshore wind power projects to the existing grid, major transmission system upgrades will be needed to deliver more of this power to far-away consumers. Proposed offshore wind projects closer to New England load centers may require fewer upgrades to the existing grid, but building wind turbines offshore is typically more costly than placing them on land.

Source: *ISO Generator Interconnection Queue* (January 2017; FERC jurisdictional proposals only)

Wind Project Proposals in New England



- Natural Gas 48%
- Wind 44%
- Other 8%



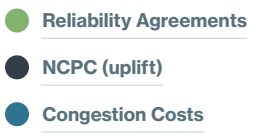
Transmission Project Costs Pay Off for the Region

Because the electric grid is so tightly networked, each state shares in the benefits—and costs—of reliability upgrades to this transmission system. New England's electricity consumers, who ultimately pay project costs, receive many benefits from this **investment in the regional transmission system**:

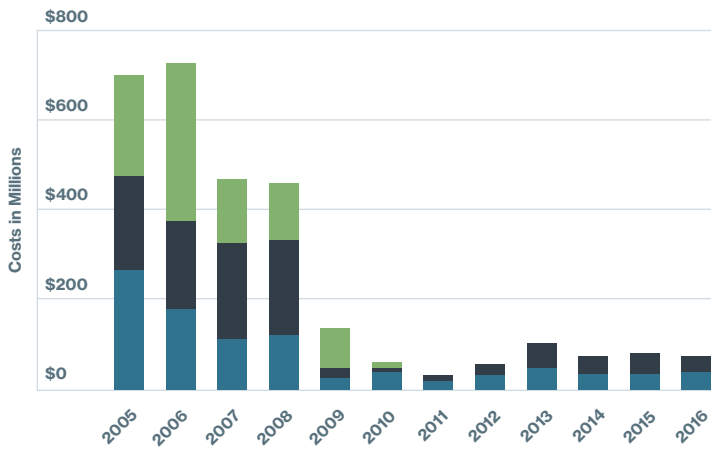
- **Less risk of expensive, dangerous blackouts**—The 2003 Northeast Blackout, for example, affected 50 million people in the Midwest and in the northeastern US and Canada, claiming three lives and an estimated $4.5 to $10 billion in losses. New England was largely spared during the blackout but subsequently took action to strengthen weak areas of the region's transmission system. Today, a robust transmission infrastructure, along with a strong fleet of power resources, rigorous system operator training, and strict adherence to industry reliability requirements, can help the ISO manage system disturbances.
- **Less air pollution**—Improving system weak spots and eliminating transmission bottlenecks has allowed new, efficient, low-emitting generators, such as those running on natural gas, to interconnect to the grid, run more often, and displace older, less efficient resources.
- **Lower wholesale energy costs**—Enabling the integration of these resources has also helped drive down wholesale electricity prices because of the relatively low cost of natural gas. Congestion costs are also extremely low today: in 2015, average energy-market prices at the wholesale Hub and across the six states differed by just 1–1.5%. Additionally, payments to resources providing operating-reserve support in transmission-constrained areas have markedly declined, and the region has been able to eliminate costly reliability contracts needed in the past to keep older, inefficient resources from retiring to ensure reliability.
- **Positioning for a greener, hybrid grid**—A strong, state-of-the-art transmission system is the "backbone" needed to support the connection of more renewable energy and the **transition to the smart grid**, which will open the door for more effective use of distributed energy resources.

Improvements Have Lowered Energy Costs

New England's revitalized transmission system and more efficient fleet have driven striking decreases in congestion costs and uplift costs, called Net Commitment-Period Compensation (NCPC), in the marketplace. Additionally, the ISO has not had to use special reliability contracts since 2010.



New England Costs for Congestion, Uplift, and Reliability Agreements



Ensuring Reliability in the Next 20 Years —and Beyond

The electricity industry continues to evolve, and so does the ISO. Through cutting-edge initiatives and strong regional collaboration, we're shaping the modern, high-performing power system New England relies on for safety, comfort, and prosperity.

The Shift toward a Hybrid Grid and Carbon-Free Society

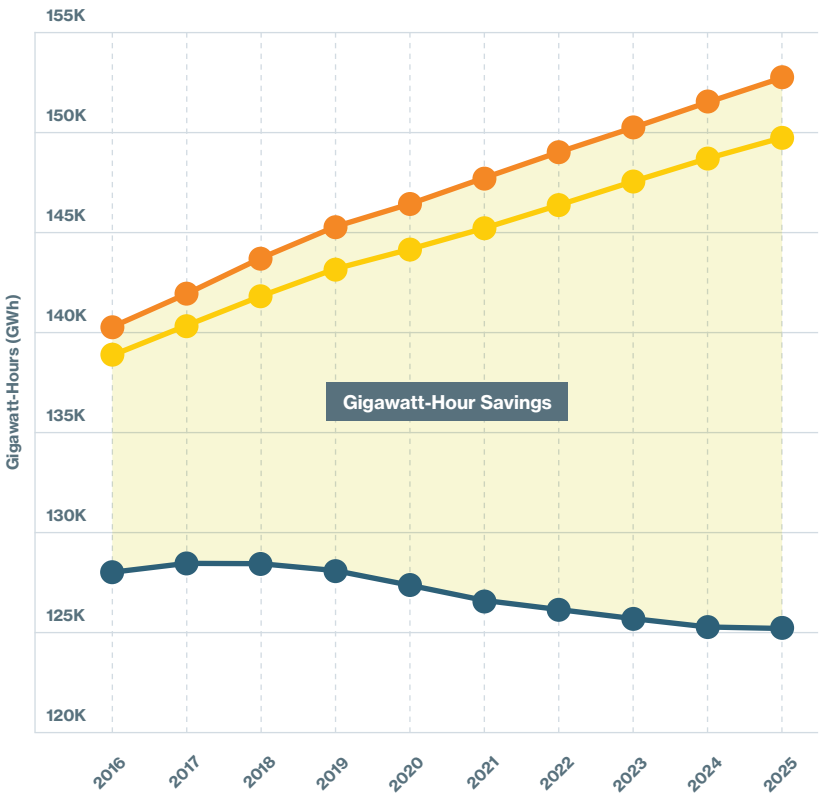
New England's traditional power system is rapidly transforming into a more complex, less predictable hybrid grid where electricity needs are met with large generators and other power resources connected to the regional transmission system, in combination with thousands of small resources connected "behind the meter" directly to retail customer sites or local distribution utilities. In addition to significant amounts of carbon-free renewable energy, the regional generation fleet will need to include fast, flexible power plants ready to jump in and balance the variable output from wind and solar resources; these will likely be natural-gas-fired generators in the near term because of their ability to turn on and off quickly. At the local level, rooftop solar systems and battery storage—along with energy-efficiency measures, electric vehicles, and smart meters—are changing how much electricity people draw from the regional power system, when they draw it, and what they add back to the grid.

Energy-Efficiency Measures and Solar Power Are Flattening Annual Energy Use and Slowing Peak Demand Growth

With approximately $1 billion being invested annually, the New England states are national leaders in implementing EE measures, such as the use of more efficient lighting, appliances, cooling, and building operation. Over the next decade, EE and behind-the-meter solar reverse the growth in overall electricity demand to -0.2% and slow the growth in summer peak demand to 0.3%.

Source: ***Final ISO New England Energy-Efficiency Forecast 2020-2025*** and ***Final 2016 Solar PV Forecast*** (May 2016)

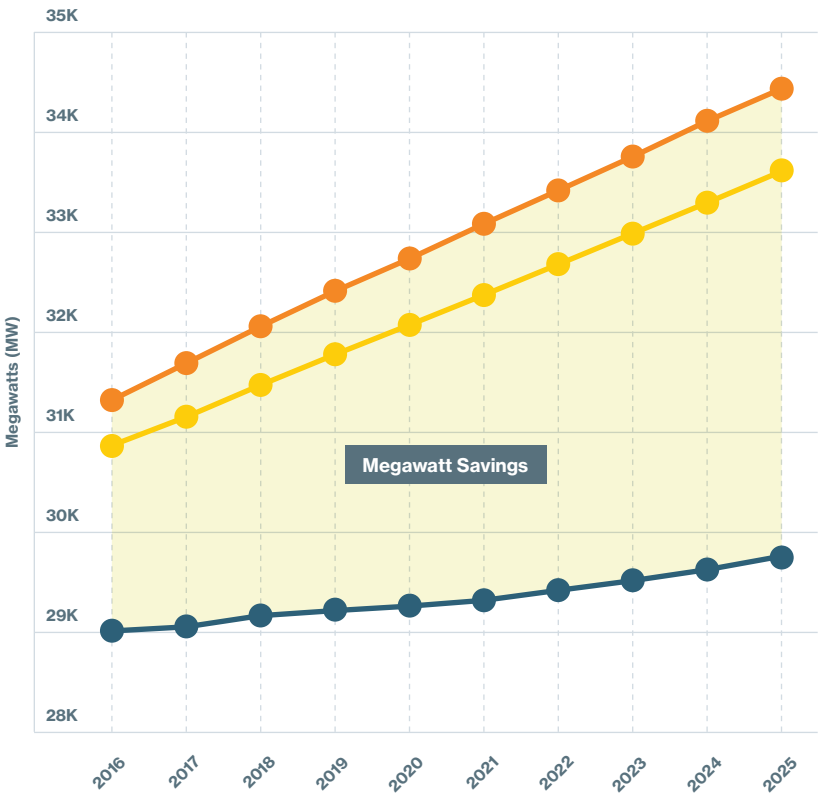
Annual Energy Use with and without EE and PV Savings



ISO Innovation Is Paving the Way

To fulfill our responsibilities to New England in light of this transformation, we've made major innovations to how we operate the grid and plan for the future, to our IT systems, and to the marketplace we design and administer. For example, we're leading the industry's use of high-speed cloud computing to analyze vast quantities of smart grid data. To help manage the fluctuating output of wind and solar power resources, we've developed a highly accurate hourly wind forecast for the region and each individual wind farm, participated in several national studies to develop accurate solar forecasts, and prototyped a better forecast for solar power. ISO staff also developed the first, multistate forecast in the nation on the growth of energy-efficiency measures, as well as the first, multistate forecast for behind-the-meter solar installations. Learn more at **www.iso-ne.com/smart-grid**.

Summer Peak Demand with and without EE and PV Savings



Gross Load

The gross load forecast (projected regional energy use)

Minus PV

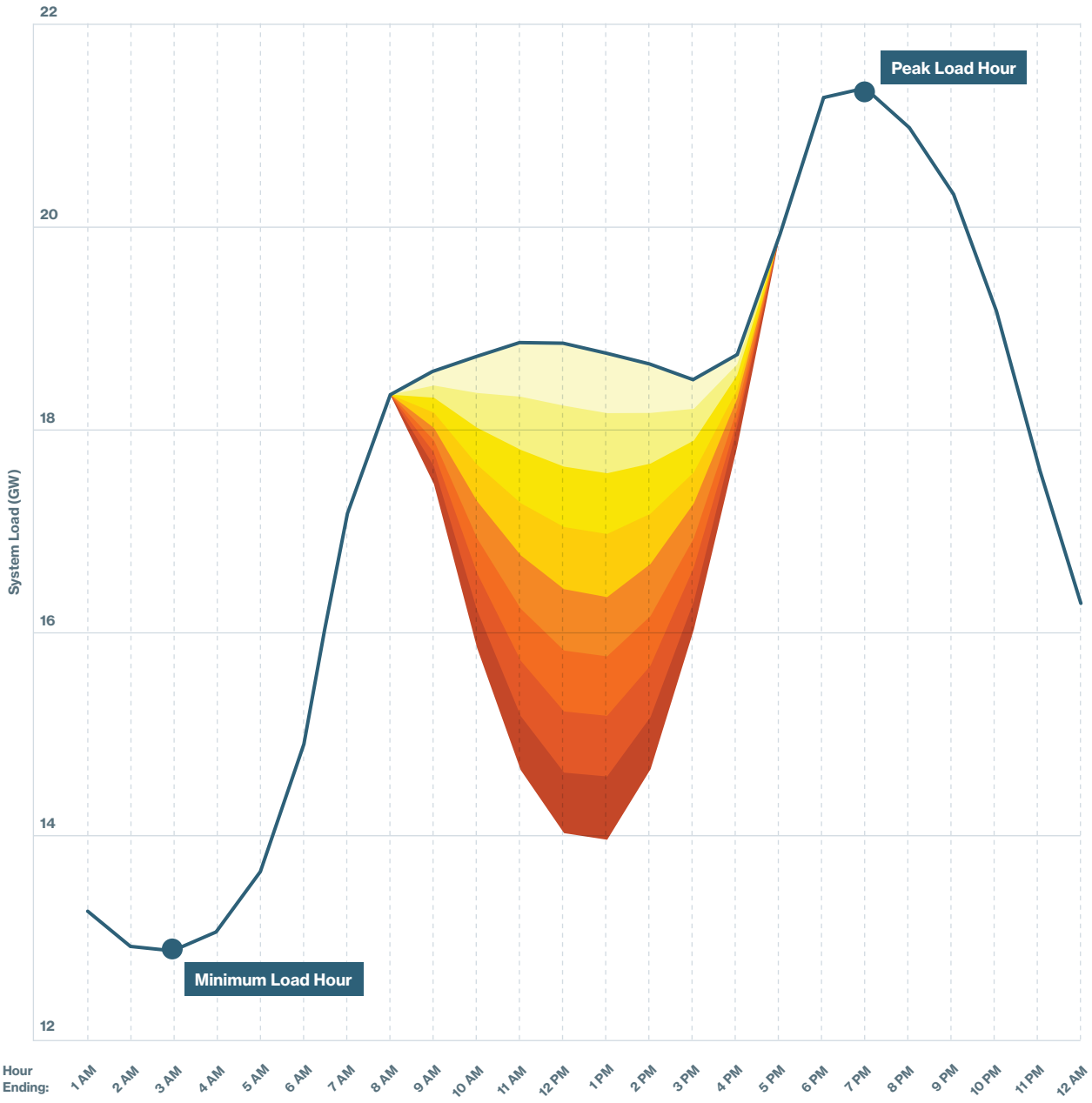
The gross load forecast minus forecasted behind the meter (BTM) solar photovoltaic (PV) resources

Minus PV, EE

The gross load forecast minus forecasted BTM PV, minus energy-efficiency (EE) resources in the Forward Capacity Market (FCM) 2016–2019 and forecasted EE 2020–2025

Note: Summer peak demand is based on the "90/10" forecast, which accounts for the possibility of extreme summer weather, such as an extended heat wave of about 94˚F.

Tuesday, January 7, 2014



Accurately Forecasting the Load-Reducing Effects of Solar Power Is Increasingly Important

Because most **solar power in New England** is connected behind the meter, it serves to reduce the amount of electricity drawn from the regional grid. This load profile simulates the impact that growing amounts of solar power will have during winter – and shows how it can't serve winter peak demand. The steepening ramp to peak load hour also illustrates how flexible, fast-responding power resources will become increasingly important for serving the region's needs.

Several **market-based changes** are also helping pave the way for future grid transformation:

- In 2016, we **incorporated wind resources and intermittent hydro resources into real-time dispatch for the first time**, enabling them to set real-time prices. This project used a pioneering methodology the ISO developed to efficiently account for the variable "fuels" powering these resources.
- We've opened the door for new energy-storage technologies, such as batteries and flywheels, to **compete in the Regulation Market** by introducing an "energy-neutral" dispatch signal to integrate these resources into grid operations.
- Changes in 2018 will make it easier for storage devices and similar technologies that both consume and inject energy to participate as dispatchable resources in the energy market.
- We've been a leader in **integrating demand-response resources** into the wholesale electricity marketplace and expect to complete full integration in 2018.

Facilitating Regional Collaboration to Solve Ongoing and Future Challenges

A fundamental part of ISO New England's mission is to be an advocate for reliability to ensure that the region has the electricity it needs when it needs it. A reliable regional power system is essential to New England today and will remain critical for decades to come, serving households and businesses that don't generate their own electricity and acting as backup power for those that do.

Many of the changes noted in this report are the result of strong **collaboration with our regional stakeholders**. Continued cooperation will be vital to solve for two of the most pressing **challenges to reliability**, as outlined in the next two chapters.

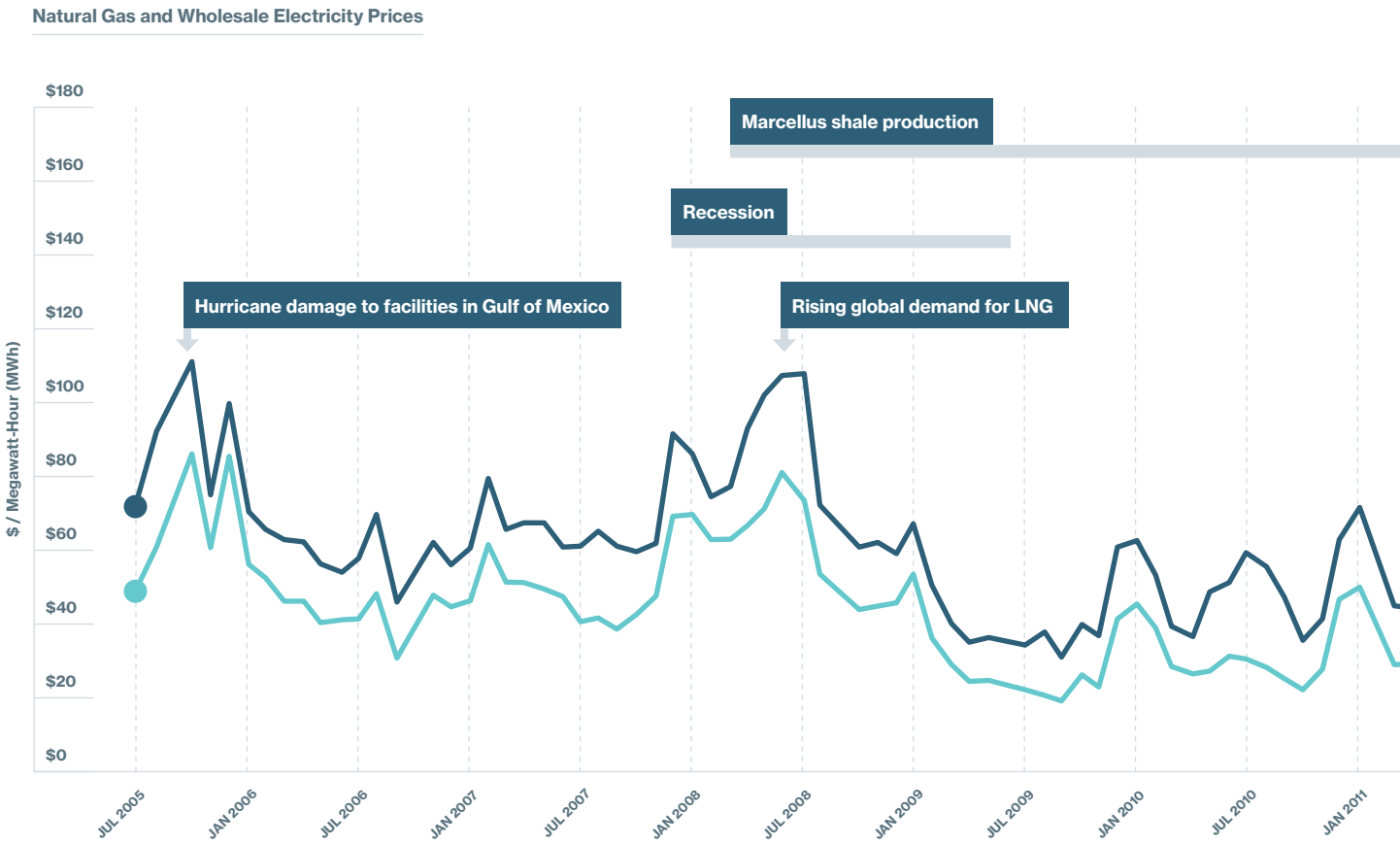
Challenge: How to Secure Adequate Fuel for Natural-Gas-Fired Generation

Timely solutions are imperative for this major challenge to the regional power system. Reliability, rising winter air emissions, and electricity price volatility are all at stake.

Reliable Electricity in New England Is Tightly Linked to Natural Gas

A fundamental part of the ISO's job is to keep the amount of electricity that power resources are supplying to the grid in near-perfect balance with the amount of electricity consumers are using. The region's highly efficient **natural-gas-fired generation resources** are currently the biggest contributor for achieving that balance. Natural gas:

- Fuels nearly half the region's electricity annually—49% in 2016
- Is the primary fuel source for over 40% of regional capacity and an alternate fuel source for over 10% more
- Represents almost half the currently proposed new generation projects in the region
- Will be needed to balance wind and solar resources until other flexible resources (such as grid-scale energy storage) are economical and widespread



Natural Gas Pipeline Constraints Limit Fuel for Generators during Cold Snaps

Traditionally, the natural gas pipelines that deliver low-cost shale gas into the region have been built and sized to serve customers of gas utilities—not specifically to serve electricity generators. Gas utilities commit to the long-term contracts required for incentivizing pipeline development. Generators, on the other hand, typically forego these premium contracts, instead arranging for fuel only as needed and relying on unused pipeline capacity for delivery. Because generators have no guarantee of when or how long they'll be called

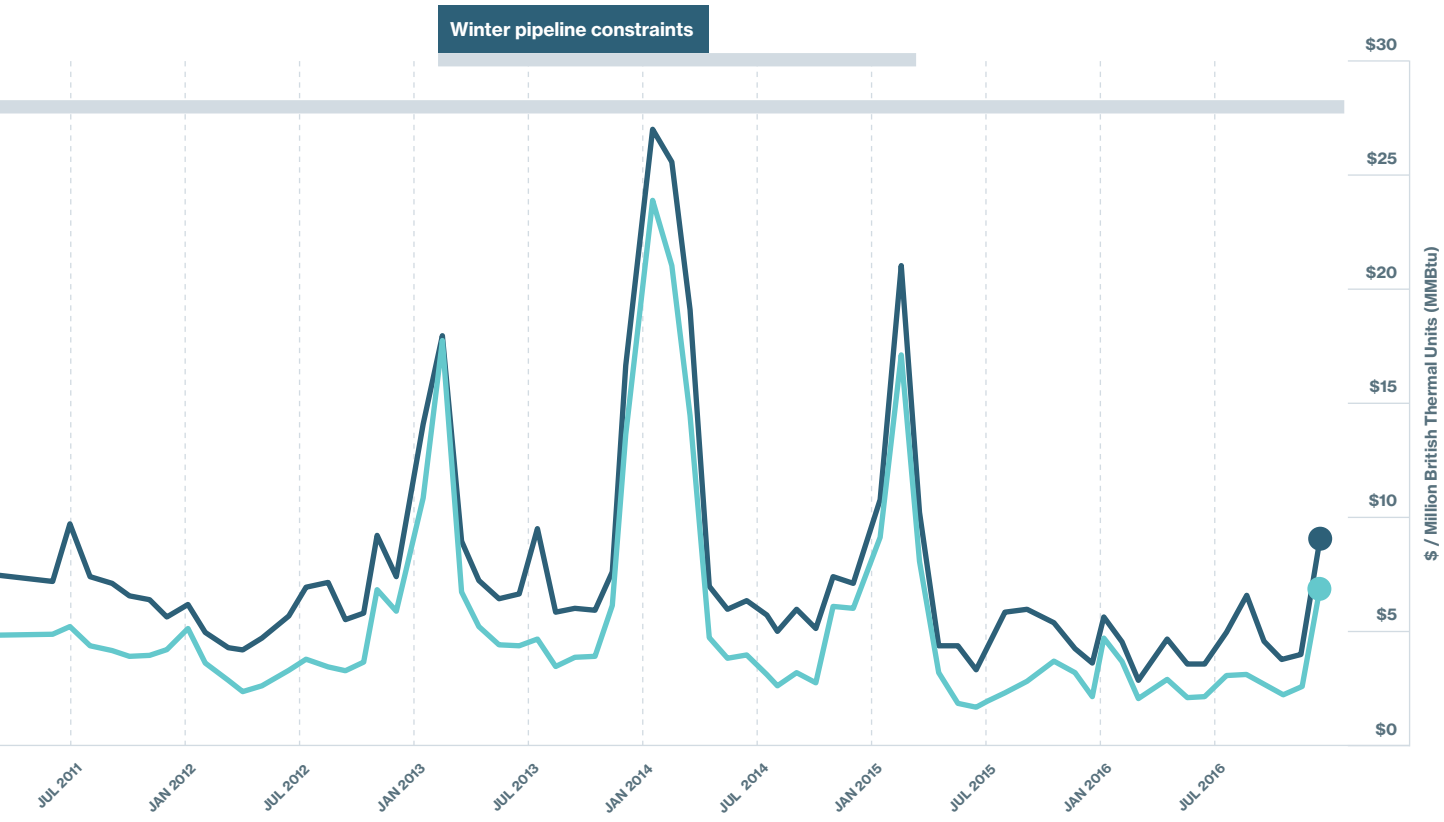
Natural Gas Pipeline Constraints Can Lead to Price Volatility

Natural-gas-fired generators set the **price for wholesale electricity** most of the time. When natural gas prices spike due to pipeline constraints, wholesale electricity prices spike, too. In contrast, when the region's gas-fired generators have unconstrained access to natural gas, wholesale electricity prices tend to be low and competitive nationally.

Underlying natural gas data furnished by ICE Global markets in clear view

Natural Gas Prices
at Algonquin City Gate

Wholesale Electricity Prices
in Real-Time Energy Market



to run—and there's no practical way to store excess natural gas or electricity—this "just-in-time" strategy helps natural-gas-fired generators keep their costs as low as possible to maintain competitiveness in the wholesale electricity markets. While that works for most of the year, on cold days, the pipelines are running at or near maximum capacity solely to meet heating demand. During several past winters, this situation has severely limited the delivery of fuel for much of the region's generating capacity, which, in turn, threatened the reliable supply of electricity and drove up wholesale electricity prices and air emissions.

Some pipeline capacity was added in 2016 and more is expected in 2017 to serve increased demand from retail gas customers. Over the next few winters, some of this capacity will likely be available for generators on the coldest days, helping to lessen fuel supply concerns and associated volatility in wholesale electricity prices. However, eventually this extra capacity will likely be used for heating as gas utilities sign up more customers. To compound matters, most of the benefit from additional fuel available to generators on the coldest days will be canceled out as new natural-gas-fired generators fill the void of retiring non-gas-fired power plants. In other words, though the pipeline "pie" may be getting bigger, there will be more mouths to feed. When it comes to the power system's ability to meet electricity demand on the coldest days, the results may be a wash.

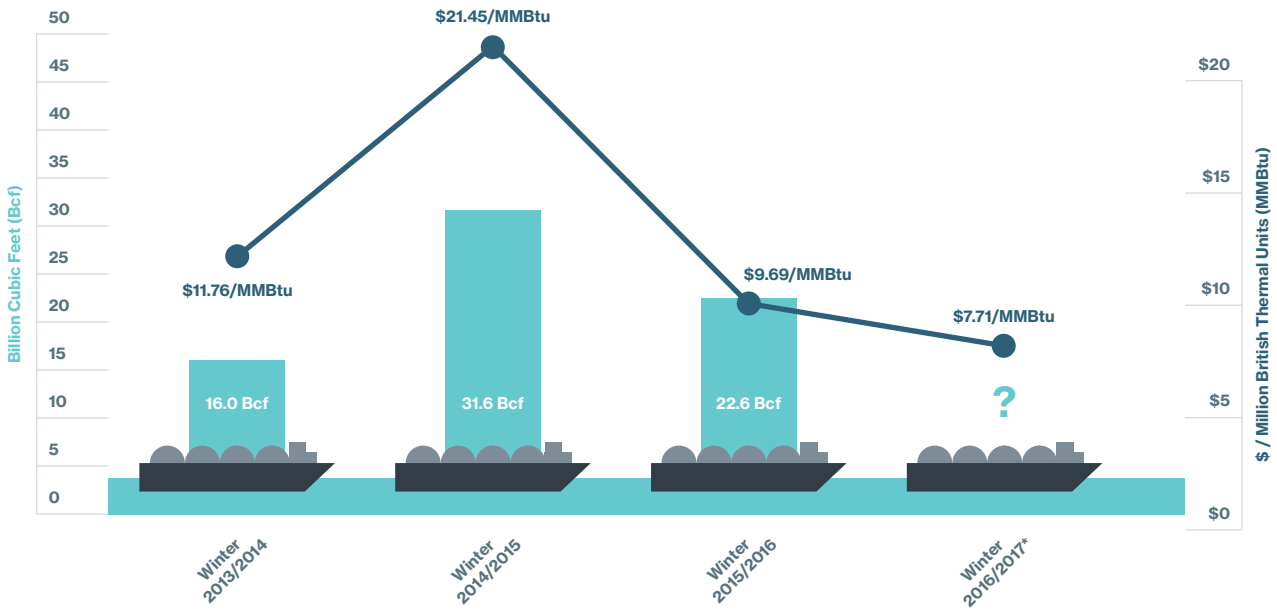
Will Imported Liquefied Natural Gas (LNG) Fill the Gap?

The least expensive option that the region's natural-gas-fired generators might take to improve performance is to invest in dual-fuel technology that allows them to switch to oil when pipeline gas becomes too expensive or unavailable. But state restrictions on air emissions may limit this option, thus requiring more natural gas plants to turn to LNG in winter when pipeline gas is unavailable or its price spikes.

However, several factors can impede generators' access to LNG when it's most needed. First, LNG is a global commodity that's imported to New England by ocean tanker, so it must be contracted for months in advance—an option most generators elect not to pursue. Second, the arrivals of any spot LNG cargoes depend on global prices and vary from year to year; they also supply the entire Northeast and beyond—not just New England generators. Third, severe weather could prevent the timely arrival of ships.

Over recent years, the ISO's **Winter Reliability Program** has helped incentivize a small number of generators to secure contracts for winter deliveries of LNG. These types of contracts, as well as the building of on-site LNG storage, are among the options generators could invest in to satisfy upcoming performance requirements in the capacity market.

LNG Tanker Deliveries to New England During Winter and Natural Gas Futures-Market Prices



LNG Deliveries Hinge on a Global Market and Winter Weather Predictions

The amount of LNG coming into the region varies from year to year. When prices are high for natural gas delivery into New England, more LNG tankers are attracted to the region. Expectations of a severe winter can cause prices to increase – and futures-market prices typically illustrate this effect. But if a winter turns out to be more frigid than the futures market anticipated, the region may end up with an inadequate supply of LNG.

Algonquin Natural Gas Futures Prices as of Previous October 1

Winter LNG-Sourced Deliveries to New England Interstate Pipelines

The preliminary total through mid-January 2017 was 6.4 Bcf; more deliveries are expected before winter's end. See* ***www.iso-ne.com for updated data**.*

Sources: *Winter 2016-17 Energy Market Assessment,* FERC; NatGas Analyst Tool by Genscape, a part of DMG Information (DMGI), **www.genscape.com**

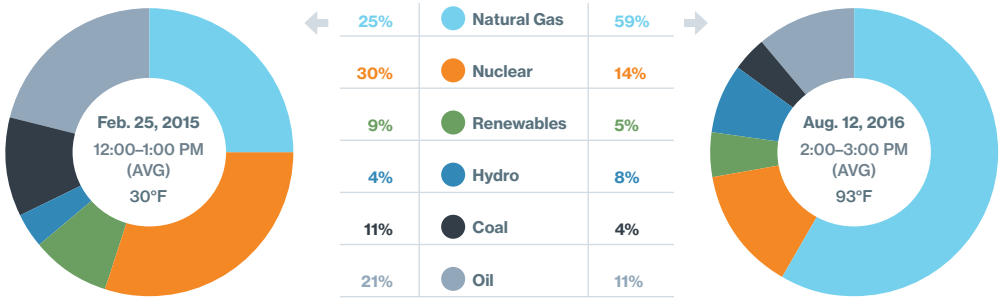
Non-Gas-Fired Generation Options Are Dwindling

Resources powered by oil, coal, and nuclear energy have been critical for keeping the lights on during recent winters, but **these units have begun to close**, citing profitability and other factors. About 4,200 MW—an amount equal to almost 15% of the region's current generating capacity—will have shut down between 2012 and 2020 and is being replaced primarily by new natural-gas-fired plants. The upcoming closures of just two of those resources—Brayton Point Station in May 2017 and Pilgrim Nuclear Power Station by May 2019—will remove 2,200 MW of non-gas-fired capacity. Over 5,500 MW of additional oil and coal capacity are at risk for retirement in coming years, and uncertainty surrounds the future of 3,300 MW from the region's remaining nuclear plants.

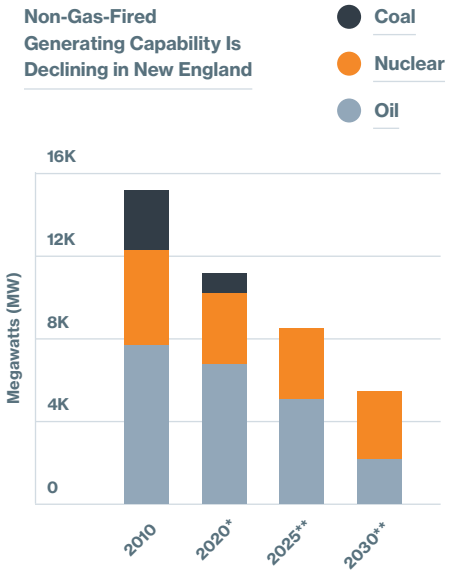
Major Generator Retirements Limit the ISO's Options for Meeting Winter and Peak Demand

Nuclear power typically provides around 30% of the region's energy. Coal- and oil-fired resources, despite providing only about 3% of the region's electricity last year, can also make valuable contributions on the coldest days of winter, as well as on the hottest days of summer when demand is very high or major resources are unavailable. For example, on the 2016 summer peak day shown below, a nuclear generator was unexpectedly off line and coal and oil filled the gap. Within a decade, though, the region may have little to no generating capacity left fueled by coal and oil, and is also at risk of losing more nuclear generators.

Non-Gas-Fired Resources Are Critical During Winter and Peak Summer Days



Non-Gas-Fired Generating Capability Is Declining in New England

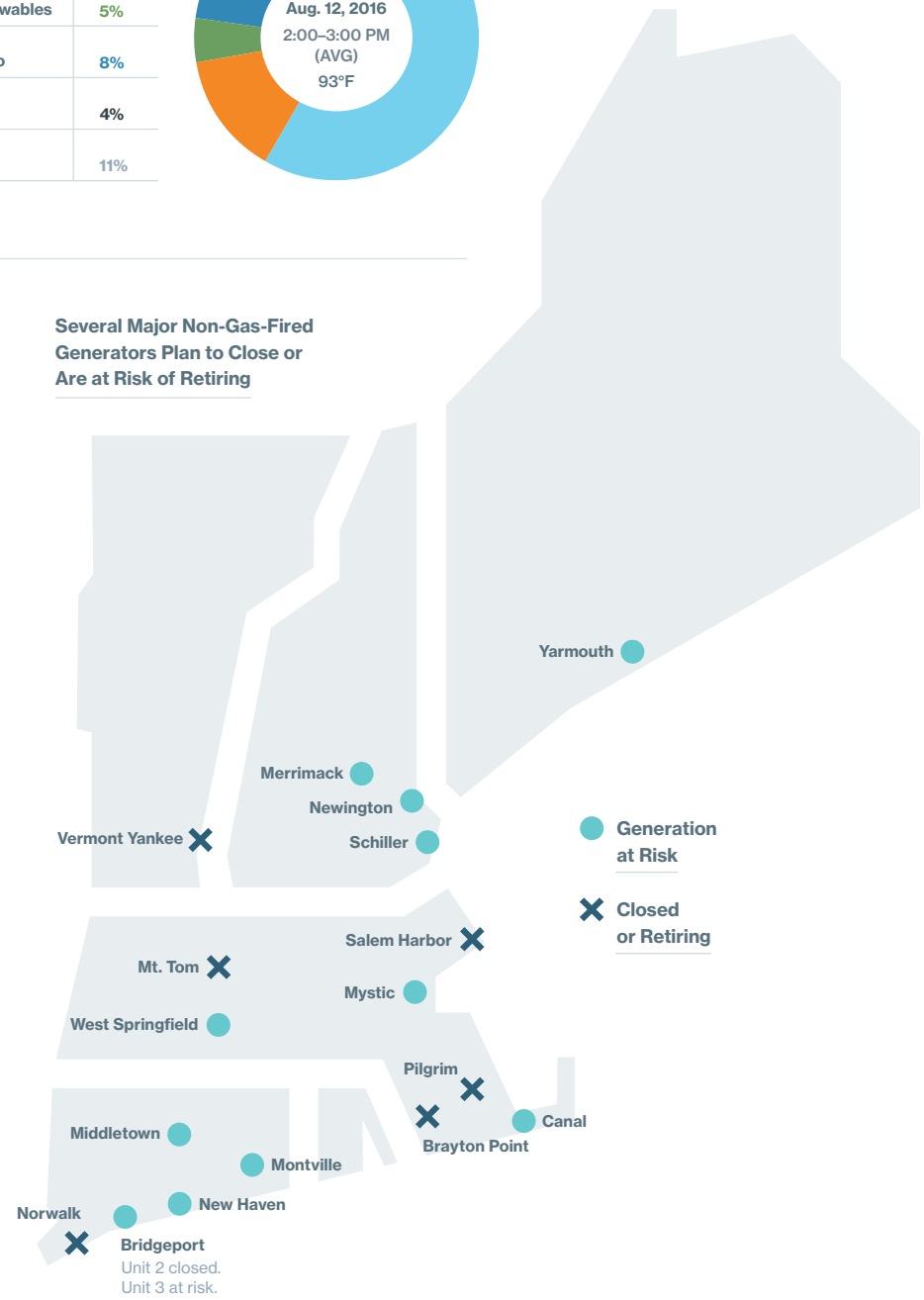


** Includes major planned retirements*

*** Hypothetical values assuming the loss of over 5,500 MW from generators identified as being at-risk of retirement due to plant age and infrequent operation*

Sources: ***Forecast Report of Capacity, Energy, Loads, and Transmission*** (2010, 2016); ***Status of Non-Price Retirement Requests and Retirement De-List Bids*** (August 2016); ***2016 Economic Studies Phase I Assumptions***, ISO-NE (2016)

Several Major Non-Gas-Fired Generators Plan to Close or Are at Risk of Retiring



Skating By on the Coldest Days

With over 35,000 MW of regional generating capability, demand resources, and imports, meeting New England's winter peak demand of roughly 21,000 MW, plus a reserve margin of about 2,600 MW, should be a routine "day at the office" for ISO system operations. Despite sufficient capacity and some relatively mild winters, though, ISO system operators have actually managed very tight operating conditions over recent years. To keep the power flowing, the ISO has relied heavily on non-gas-fired generators and had to **follow procedures** several times when energy from available resources was insufficient (i.e., *ISO Operating Procedure No. 4: Action During a Capacity Deficiency*). If a "perfect storm" of problems were to occur, ISO system operators could be forced to use stronger measures, such as asking the public to conserve electricity or, in extreme cases, ordering controlled power outages. This risk increases after the upcoming generator retirements. Among the possible events the ISO has to be ready for during extreme temperatures: fuel constraints that can sideline thousands of megawatts of natural-gas-fired generation; mechanical problems for some of the region's aging non-gas-fired generators; reduced imports from neighboring grids dealing with the same weather; and delays of oil and LNG deliveries.

If a "perfect storm" of problems were to occur, ISO system operators could be forced to use stronger measures … in extreme cases, ordering controlled power outages.

Will Adding More Renewables Help During Winter?

Wind and solar resources can offset some natural gas use, but their help is limited by still-low levels of regional installation. Additionally, wind speeds are variable and can drop during extreme cold snaps, paradoxically creating a need for natural-gas-fired generators that can ramp up and down quickly to balance fluctuations in supply or demand and maintain continuity of electricity supply. Solar energy, meanwhile, isn't dispatchable by the ISO and doesn't help meet peak winter demand, which happens after the sun has set. Moreover, winter conditions, with snowfall and fewer daylight hours, also dampen solar output. Extreme cold could also reduce imported Canadian hydropower through proposed new long-distance transmission lines because Canada is a winter-peaking system and may need the power itself.

The ISO's Efforts Have Mitigated the Fuel-Security Risk but May Not Solve the Problem

While the ISO doesn't have the authority to require generators to make long-term investments in fuel supplies, we have been developing tactics for the past six years to mitigate the fuel-security risk, such as:

- Developing new situational awareness and forecasting tools for our system operators to confirm fuel availability for natural-gas-fired units
- Improving communication and coordination with interstate pipeline operators
- Implementing **Winter Reliability Programs** that pay demand-response resources to be available and generators to boost winter fuel inventories of oil and LNG or to invest in dual-fuel technology (the ability to switch between different fuels, typically natural gas and oil)
- Fine-tuning the energy markets to strengthen resource performance
- Instituting **"pay for performance" (PFP) enhancements** that, starting in 2018, will reward resources that make investments to successfully boost performance during periods of system stress, such as by ensuring adequate fuel, while resources that don't perform will forfeit capacity payments

While these efforts help, they are unlikely to result in a timely "fix": PFP incentives (i.e., the rate for PFP payment or forfeiture) will ramp up only gradually through 2024. Additionally, many states' increasingly stringent air emission limitations may prevent natural-gas-fired generators from installing cost-effective oil-fired backup fuel systems. As a result, the region's winter reliability concerns will continue until generators decide to sign contracts for LNG—or, ultimately, greater natural gas pipeline capacity.

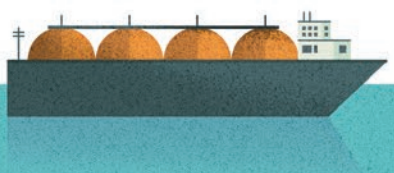
Without timely investment to expand natural gas or LNG infrastructure, the region should expect significant energy market price volatility when the gas pipelines are constrained.

The Region May Face Expensive, Higher-Polluting Options in the Coming Years

Without timely investment to expand natural gas or LNG infrastructure, the region should expect significant energy market price volatility when the gas pipelines are constrained. Plus, the region may soon be forced to take stronger—and likely costly—steps. The first step will be to further strengthen market incentives for generators to contract for fuel. As a last resort, the ISO may be forced into retaining some non-gas-fired generators that may be older, expensive, and higher-emitting—a strategy that runs counter to the states' ambitious carbon-reduction goals.

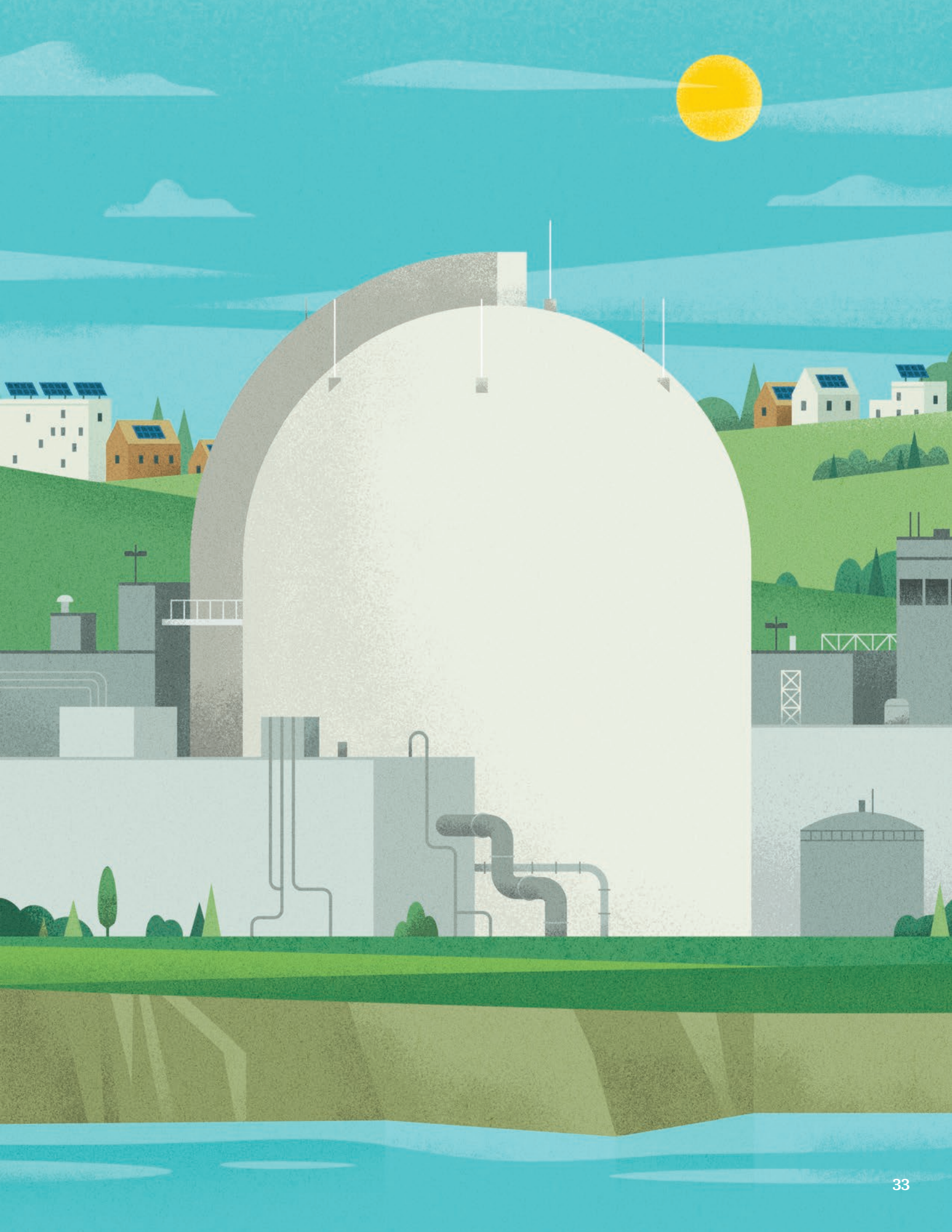
Other emerging factors are also likely to push the ISO to rely more on higher-emitting, less efficient resources to meet regional electricity demand and will add to operational complexity during winter:

- Siting challenges are causing delays in building some of the region's new power resources, particularly those running on natural gas. New transmission lines needed to maintain reliability, as well as elective transmission projects that can connect to clean-energy resources, are also often met with opposition.
- Some states are considering tightening emission limits for all generators—even state-of-the-art units running on relatively low-emitting natural gas. This could force the ISO to run higher-emitting generators in other parts of the region.
- Any additional closures of regional nuclear facilities will remove major sources of zero-emission energy for New England.



Challenge: How to Balance Competitive Markets and State Environmental Policies

State efforts to promote clean-energy resources and cut carbon emissions have long-term implications for the wholesale electricity marketplace's ability to secure reliable sources of electricity for New England. New market mechanisms are being sought to create a bridge between reliability needs and state environmental goals.



State Policies Are Driving the Growth of Clean-Energy Resources

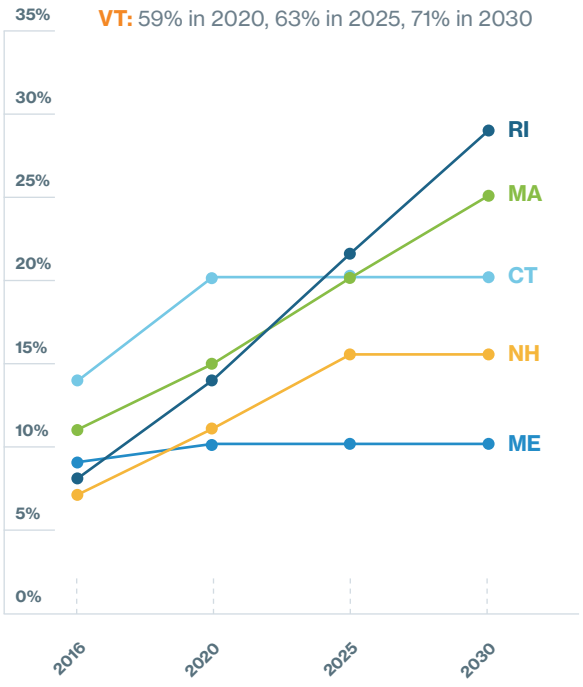
Even with low to no fuel costs, most **renewable resources** are still relatively expensive to build and connect to the grid, so they aren't competitive in the wholesale marketplace. Federal and New England state efforts to cut carbon emissions—by using emission limits, the mandated use of green power, and tax credits and incentives—are spurring growth in these resources. The New England states are also pursuing long-term contracts for clean-energy and energy-storage projects. While these out-of-market revenues are succeeding in attracting such projects, they're also having an impact on the traditional resource types needed to meet the region's electricity needs, balance intermittent renewable generation, and provide the grid-stability services that renewables don't.

The States Have Set Aggressive Goals for Increasing Renewable Energy

State Renewable Portfolio Standards require electricity suppliers to provide customers with increasing percentages of renewable energy. Vermont's standard recognizes new and existing renewable energy and is unique in classifying large-scale hydropower as renewable. The New England states are also promoting greenhouse gas (GHG) reductions on a state-by-state basis and at the regional level, through a combination of legislative mandates (e.g., CT, MA, and RI) and aspirational goals (e.g., ME, NH, VT, and NEG-ECP).

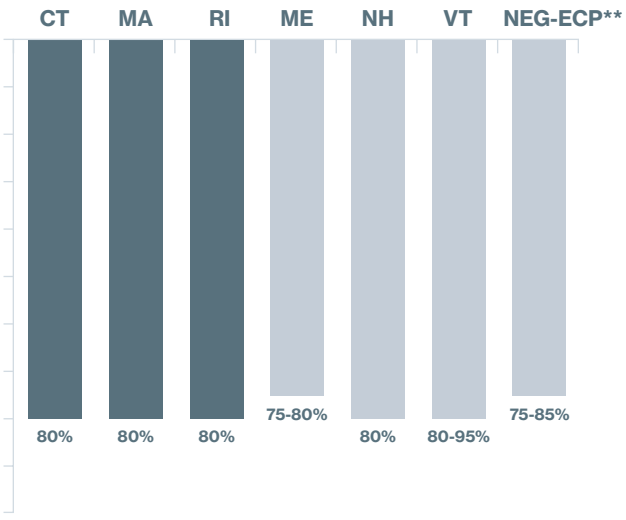
State Renewable Portfolio Standards Are Rising

Class I or new renewable energy resources (%)



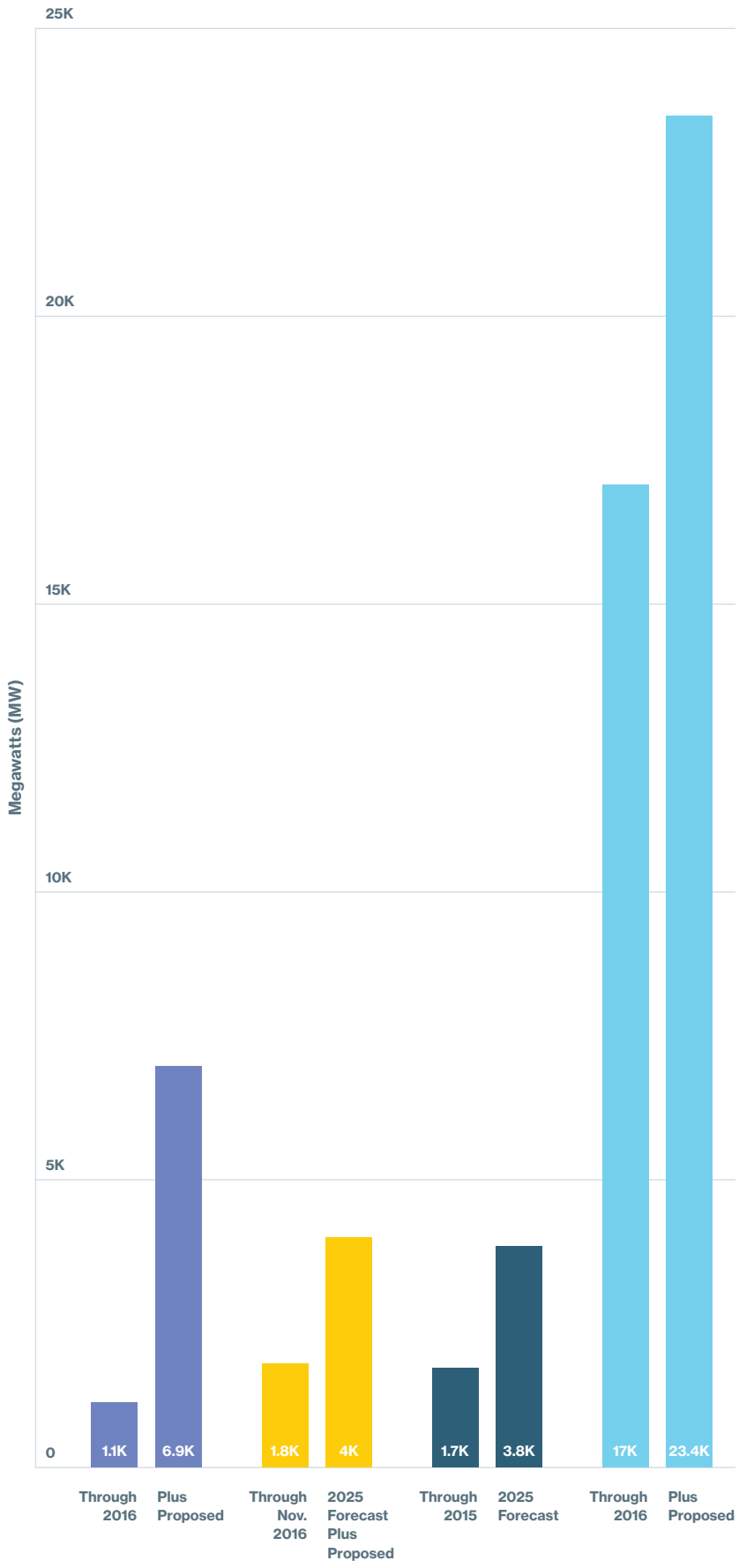
State Goals Seek Deep Reductions in CO_2 Emissions

Percentage reduction in greenhouse gas emissions below 1990 levels by 2050*



Some states have different baseline and target years

***New England Governors and Eastern Canadian Premiers (NEG-ECP)*



Clean-Energy Resources Are Playing a Small but Growing Role

The amount of renewable energy and energy efficiency in New England has been growing rapidly, though it will be many years before it may match the amount of natural gas capacity currently on the system and proposed for development.

Notes: All values are nameplate capacity, except for existing natural gas, which reflects summer seasonal claimed capability for generators reporting natural gas as a primary or alternate fuel. Solar power values reflect existing and proposed grid-connected resources, as well as existing and forecasted behind-the-meter resources. The energy-efficiency values reflect resources participating in the capacity market, as well as forecasted future capacity.

Sources: ***ISO-NE Generator Interconnection Queue*** (January 2017), ***2016 CELT Report***, ***Final 2016 ISO-NE Solar PV Forecast***, ***DGFWG August 2016 Survey Results***, and ***Final Energy-Efficiency Forecast Report for 2020 to 2025***

Out-of-Market State Subsidies Can Undermine the Competitive Marketplace

Markets work well when their prices reflect the costs of building and operating power-supply resources. Accurate prices are a cornerstone of competitive markets that motivate and compensate resources to make cost-effective investments. State policies that subsidize renewable resources can interfere with accurate pricing in the energy markets because these subsidies offset operating costs. This enables subsidized resources to sell energy for artificially low prices, putting traditional generators that New England needs for reliability at a price disadvantage.

To make up lost energy-market revenue and remain financially viable, power resources needed for reliability will have to raise their offers in the long-term capacity market. It's critical, therefore, that state-subsidized renewables don't also suppress prices in the capacity market by bidding at artificially low prices. To ensure accurate capacity pricing, the ISO has developed capacity market rules that prevent resources from bidding below their actual costs. As a reasonable balance between these rules and state actions, the capacity market allows a limited amount of state-subsidized renewable resources to enter the market and be counted toward meeting the region's capacity needs.

However, as more state-subsidized renewables come on line, that limit will begin to exclude more and more such resources from the capacity market. This means they won't be counted toward the region's capacity needs; other types of resources will be developed and counted instead. This is an inefficient and potentially costly outcome for electricity consumers who ultimately will fund both the resources that clear the wholesale market and count as capacity resources, as well as the excluded renewables that are subsidized through state-mandated charges on retail electricity bills.

Ensuring the capacity market can both sustain the traditional generation resources needed for reliability and accommodate more state-subsidized renewables is a conundrum with no simple solution. (Learn more in the ISO discussion paper, ***The Importance of a Performance-Based Capacity Market to Ensure Reliability as the Grid Adapts to a Renewable Energy Future***.)

The Region Is Exploring Ways to Better Accommodate State Goals within the Competitive Marketplace

The New England Power Pool (NEPOOL), the association of regional market participants, launched the Integrating Markets and Public Policy (IMAPP) Initiative in 2016 to explore ways to leverage the competitive marketplace to meet the New England states' respective environmental goals. The ISO has participated in the discussions and will continue to work with NEPOOL and the New England states on issues and proposed changes. The implementation of these emerging ideas is likely several years away. To follow the effort, visit **www.iso-ne.com/IMAPP**.

As the **power system's resource mix** evolves, the ISO is also pursuing other innovative market refinements to ensure appropriate compensation for resources making critical contributions to reliability, such as by providing fast response, flexible operation, and voltage and frequency support. Follow projects to improve price formation using the Wholesale Markets Project Plan webpage at **www.iso-ne.com/wmpp**.

Ensuring the capacity market can both sustain the traditional generation resources needed for reliability and accommodate more state-subsidized renewables is a conundrum with no simple solution.

Measuring ISO New England's Performance and Contribution to the Region

Accountability and Transparency

Open, fair, and independent decision-making are the defining characteristics of ISO New England. To ensure the highest levels of transparency, industry stakeholders are an integral part of the ISO's budget processes, regional system planning, and market development. They also interact regularly with ISO staff and directors, take part in the nomination of the ISO Board, and participate in dozens of committees and working groups.

For example, in 2016:

- The ISO coordinated or participated in about 60 meetings of the **Markets, Reliability, Transmission, and Participants Committees**, as well as 17 **Planning Advisory Committee** meetings, which stakeholder representatives from over 100 entities attended.
- The **Consumer Liaison Group** met quarterly to share information about the economic impacts of New England's power system and wholesale electricity markets on consumers.
- **ISO Customer Support** handled almost 14,000 calls and helped customers resolve 7,700 issues.
- Over 1,000 stakeholders attended ISO **classroom or web-conference trainings**.
- About 50 **e-learning modules** and 170 **presentations** were maintained on the ISO website for stakeholder use.

A Robust Stakeholder Process

Interested parties, with their diversity of perspectives, expectations, interests, and ideas, can help inform discussion and generate solutions to regional challenges and effective outcomes for New England's consumers and market participants. The ISO's stakeholders are a wide-ranging group, including:

- The **New England Power Pool** (NEPOOL)
- **State regulators**, including the New England Conference of Public Utilities Commissioners (NECPUC)
- **State and federal legislators, attorneys general, and environmental regulators**
- The **six governors**, primarily through the New England States Committee on Electricity (NESCOE)
- The **Consumer Liaison Group**, a forum of electricity consumers and state consumer advocates

Results on a Budget

We maintain a culture of cost accountability and transparency in our service to the region. The ISO is a not-for-profit entity without equity—as such, we rely on collections under the ***ISO New England Transmission, Markets, and Services Tariff*** to fund operational expenses. Our **rigorous annual budgeting process** includes meaningful stakeholder input, oversight from the ISO Board, and review by the Federal Energy Regulatory Commission.

The ISO's 2017 **operating budget** is **$192.7 million**—an increase of 4.1% over the 2016 budget—before incorporating the prior years' true-up (actual expenses versus budgeted collections).

- More than half the increase is necessary to maintain the ISO's current operations by funding competitive compensation, software licenses and maintenance, and retirement and medical benefits. The budget includes no new hires for 2017.

- Most of the remaining increased costs are attributable to cybersecurity enhancements, participation in the IMAPP initiative, and compliance with FERC orders.

$1.12 per Month

The services and benefits the ISO provides to keep the power flowing will cost the average New England residential electricity consumer $1.12 per month in 2017, based on 750 kilowatt-hours per month usage. This is a slight increase from $1.08 per month in 2016.

(Note: The 2016 cost was previously reported as $0.99 per month; however, a new calculation method now accounts for reduced projected annual energy use due to behind-the-meter solar power and energy-efficiency measures.)

The ISO's financial statements and other metric reports are available at **www.iso-ne.com/about**.

Customer Satisfaction

Stakeholder feedback is a helpful indicator of the quality of the products and services the ISO offers, as well as areas needing improvement. The latest survey of market participants (2016) revealed high overall satisfaction levels. Positive satisfaction among respondents with an opinion was **96%**.

Enhancements to the ISO Website

Enhancements to the ISO website and data portal, ISO Express, continue. Of note in 2016:

- The **new webpages** Annual Work Plan, Wholesale Markets Project Plan, and Customer Readiness 12-Month Outlook help stakeholders track projects and prepare for changes.
- A **new ISO Express graph** shows the real-time fuel mix by megawatt. This complements the enhanced real-time fuel-mix chart launched in 2016, which better reflects the percentage of each fuel that dual-fuel units are using. ISO Express' default dashboard has also been redesigned to include more data, and the pricing data reports are now easier to use.
- The **FCM Participation Guide enhancements** provide more helpful guidance for operating in the Forward Capacity Market.
- **Expanded webpages** such as Current Power System Status now include all 11 possible actions from ISO Operating Procedure No. 4: *Action during a Capacity Deficiency*; notifications are also now timestamped and specify the affected areas of the system.

A Focus on Performance and Standards Compliance

The ISO is dedicated to the safe, reliable operation of the grid through extensive training for staff and continuous process improvement to ensure compliance with directives from FERC, the North American Electric Reliability Corporation (NERC), and the Northeast Power Coordinating Council (NPCC).

In its last audit, the NPCC recognized the ISO for areas of excellence. The 2015 Operations and Planning Compliance Audit assessed ISO compliance with 38 standards and 124 requirements addressing power system reliability. The NPCC Audit Team lauded the ISO's operating performance over the previous three years and concluded that it had no improvement recommendations or areas of concern for the ISO.

Cybersecurity

The US Department of Homeland Security reports that the energy sector has become a major target of cyberintrusion attempts. If a widespread cyberattack on generators succeeded in knocking out just 7% of units (about 50) across New England, New York, and other parts of the Northeast, it could leave over 90 million people without power and have an over $200 billion impact on the economy, according to a 2015 report by Lloyd's and the University of Cambridge Centre for Risk Studies. This is an unlikely, yet possible, scenario. In light of these and other serious risks, the ISO is committed to making sure our systems remain secure:

- To be able to detect, withstand, and recover from any cyberattacks, we've implemented an **extensive system of process controls, advanced detection and response systems, and redundancy** in systems and control centers.
- Our **24/7 Security Operations Center** provides round-the-clock monitoring of the ISO network, and a 2017 project will apply best practices for isolating access to networked services and systems internally.
- We've **tightened security controls** for cyberassets and visitors to ISO facilities, in compliance with NERC's revised critical infrastructure protection cybersecurity standards. We'll also be tightening security controls for hardware, software, and services associated with system operations, in response to anticipated NERC standards for supply-chain management.
- The ISO participated in NERC's GridEx III exercise on cybersecurity and physical security in November 2015 and will be participating in GridEx IV in 2017. Additionally, all ISO employees participate in **annual cybersecurity training**.

If a widespread cyberattack on generators succeeded in knocking out just 7% of units … across New England, New York, and other parts of the Northeast, it could leave over 90 million people without power.

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