Informing the **Transmission Discussion**

A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States

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WIRES

Regional Discussion

ISO NEW ENGLAND

Contents

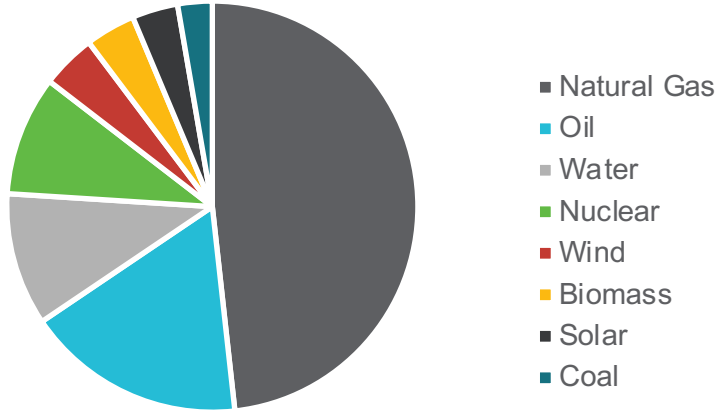
Overview

Introduction

- ISO New England Inc. (ISO-NE) is the regional transmission organization that serves Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont, created in 1997.
- The New England regional electric power system is comprised of 9,000 miles of transmission lines over 68,000 square miles and serves approximately 14.5 million people.
- ISO-NE reports that roughly 7,000 MWs of generation have retired since 2013 or will retire in the next few years, with another 5,000 MWs from coal- and oil-fired plants at risk of retirement in the coming years, although it does not expect reliability impacts from retirements.

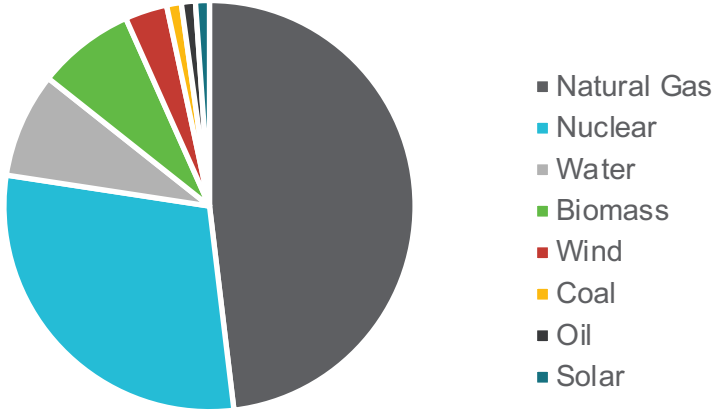
Key Regional Statistics	
States Covered	CT, MA, ME, NH, RI, VT
Square Mi. Covered	~68,000
No. of Utilities	13 investor-owned utilities; 47 munis; 4 generation and transmission co-ops
No. of Customers/Pop. Served	14.5MM population
Installed Capacity	30,916 MWs
Transmission Line Miles	~9,000 miles
Peak Hour Demand (2018)†	23,868 MWs summer (20,599 MWs winter)
Energy Production (2018)	103,702 GWhs
Forecast Growth (Annual)	-0.41% peak load growth† -0.40% energy growth

2019 Summer Capacity by Fuel Type



Source: ISO-NE

2018 Net Energy by Fuel Type



Source: ISO-NE

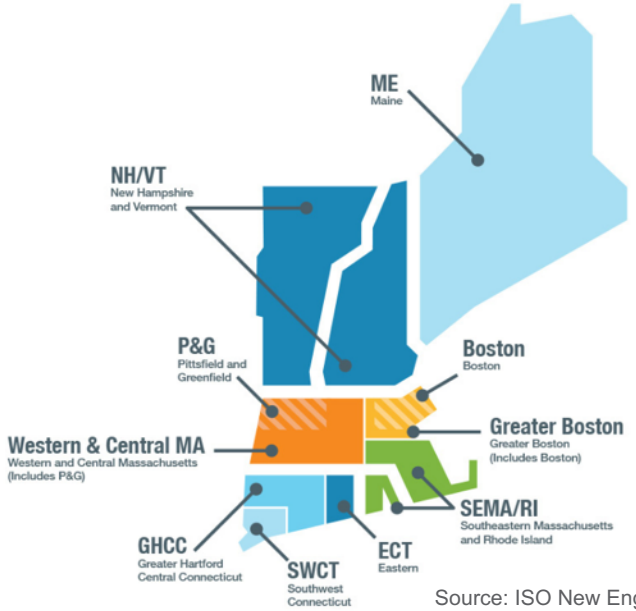
Sources: NERC 2018 LTRA; 2019 Regional Electricity Outlook; ISO-NE Stats
Notes: † Non-coincident.

Overview (Cont'd)

Key Study Areas for Planning and Issue Resolution

- For ISO studies of the New England transmission system, the region is subdivided into key study areas for practical work management reasons or for focus on a particular technical issue. The ISO regularly conducts needs assessments and other assessments in these key study areas pursuant to the Open Access Transmission Tariff (Section II of the ISO Tariff). The assessments and studies involve stakeholder review and input, primarily by the Planning Advisory Committee, and form the foundation for the Regional System Plan.

Key Study Areas



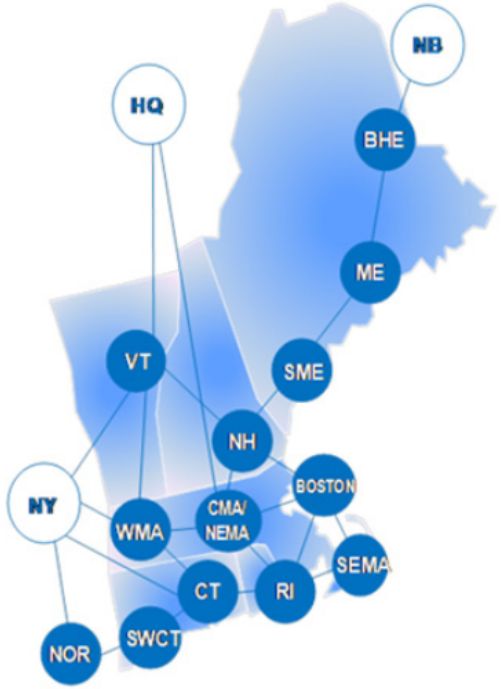
Source: ISO New England

System Planning Subareas

- The ISO has 13 planning subareas, which are depicted at right along with the three neighboring power systems.
- ISO-NE System Planning Areas:

Subarea	Region or State
BHE	Northeastern Maine
ME	Western and central Maine/Saco Valley, New Hampshire
SME	Southeastern Maine
NH	Northern, eastern, and central New Hampshire/eastern Vermont and SW Maine
VT	Vermont/southwestern New Hampshire
Boston	Greater Boston, including the North Shore
CMA/NEMA	Central Massachusetts/ northeastern Massachusetts
WMA	Western Massachusetts
SEMA	Southeastern Massachusetts/Newport, Rhode Island
RI	Rhode Island/bordering MA
CT	Northern and eastern Connecticut
SWCT	Southwestern Connecticut
NOR	Norwalk/Stamford, Connecticut
NB, NY, and HQ	New Brunswick (Maritimes), New York, and Hydro-Québec external Reliability Coordinator areas

System Planning Subareas



Source: ISO New England

Source: ISO-NE (https://www.iso-ne.com/about/key-stats/maps-and-diagrams/)

Overview (Cont'd)

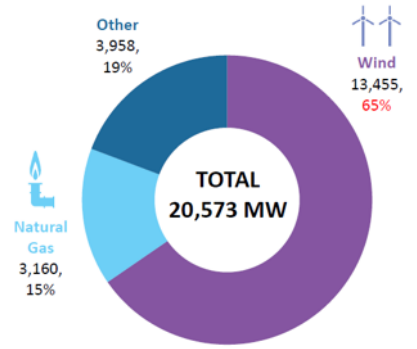
Evolving Resource Mix

- The generation fleet in ISO-NE is shifting from resources with on-site fuel (coal, oil, and nuclear) toward:
  - Resources with just-in-time fuel delivery (natural gas)
  - Weather dependent resources (wind, solar)
  - Distributed resources at homes and businesses (distributed solar PV)
- Retirements: More than 5,200 MWs of generation have retired or announced plans for retirement in coming years, and another 5,000 MWs of remaining coal and oil are at risk of retirement.
- Proposed additions: With 13,455 MWs in the interconnection queue, wind makes up the majority (65%) of total proposed additions. With 3,160 MWs, natural gas generation represents 15% of the queue, and the remaining 3,958 MWs is comprised of a mix of other fuels.

Peak Demand vs. Annual Energy Use

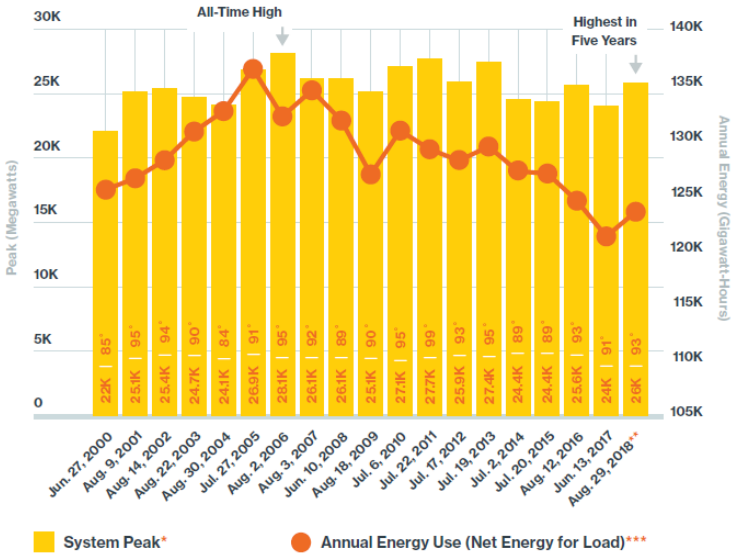
- Despite overall declines in grid energy use on an annual basis, spikes in electricity demand still occur, and ISO-NE's power system is planned and operated to meet those peaks even if they aren't historically high.
- Despite forecasts of declining load, ISO-NE must procure resources (i.e., generation, demand resources, and import capacity) to provide the capacity needed to meet the regional net installed capacity requirement (ICR), which is based on gross load and behind-the-meter PV load reductions. The representative net ICR is expected to grow from 34,300 MWs in 2022 to 35,700 MWs in 2026.

Proposed Generation in ISO-NE



Source: ISO Generator Interconnection Queue (January 2019)
FERC and Non-FERC Jurisdictional Proposals; Nameplate Capacity Ratings
Note: Some natural gas proposals include battery storage and dual-fuel units (oil). Some wind proposals include battery storage.

Peak Demand vs. Annual Energy Use on New England Power System



*The sum of metered generation and metered net interchange, minus demand from pumped storage units. Starting with full market integration of demand response on June 1, 2018, this total also includes the grossed up demand-response value.

**Annual peak, as of January 2019. Values are preliminary and subject to adjustment.

***Net energy for load (NEL) is the total amount of grid electricity produced by generators in New England and imported from other regions during the year to satisfy all residential, commercial, and industrial customer demand.

Source: ISO New England, *Seasonal Peaks since 1980 Report*, *Hourly Real-Time System Demand Report*, and *Annual Generation and Load Data for ISO NE and the Six New England States Report*.

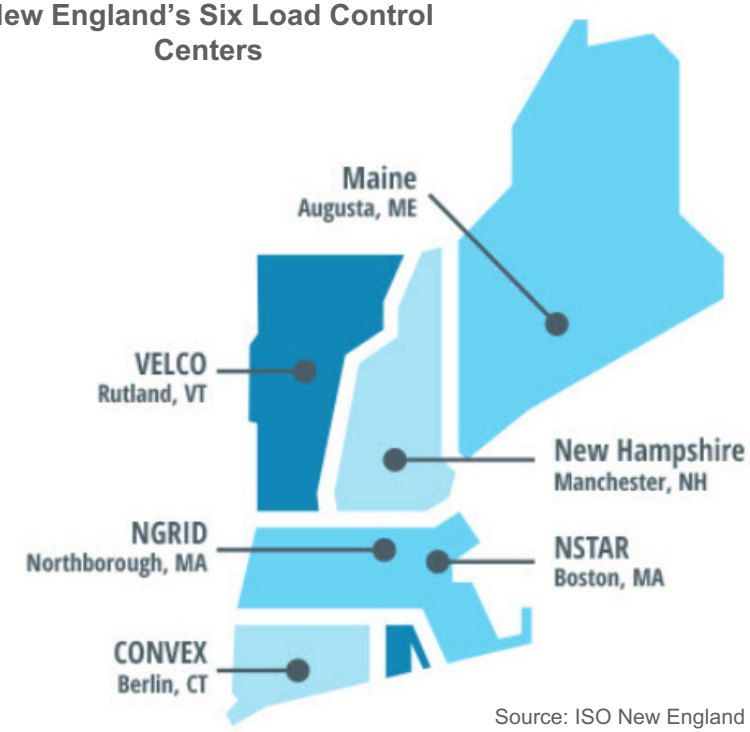
Source: ISO-NE

Transmission Topography and Investment

Local Control Centers (LCCs)

- From its master control center (MCC), ISO-NE is responsible for operating all transmission facilities rated 115 kV and above. New England also has six LCCs, which are run by transmission owners and are responsible for operating transmission facilities rated 69 kV and below, with certain exceptions.

New England's Six Load Control Centers

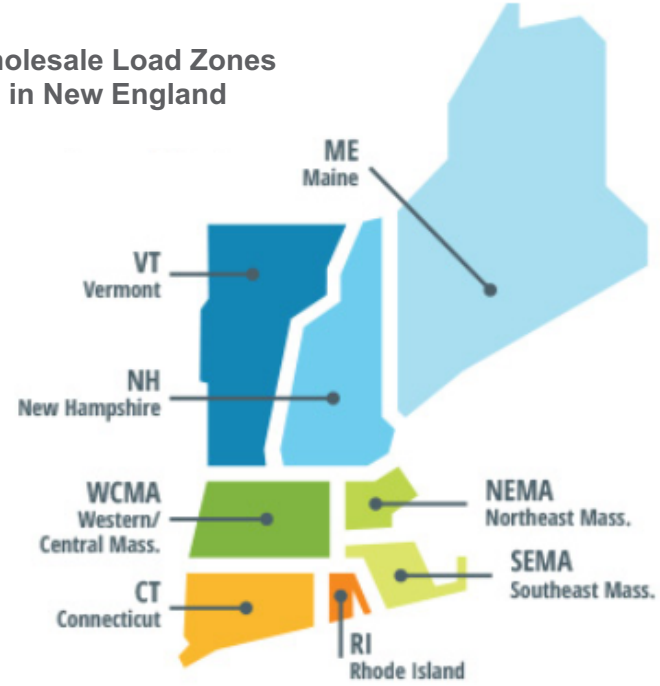


Source: ISO New England

Load Zones

- Pricing in the wholesale electricity marketplace is calculated at individual generating units, about 900 load nodes (specific points on the transmission system), eight load zones (aggregations of load nodes), and the Hub (a collection of locations in central New England where little congestion is evident). This map depicts the eight load zones.

Wholesale Load Zones in New England



Source: ISO New England

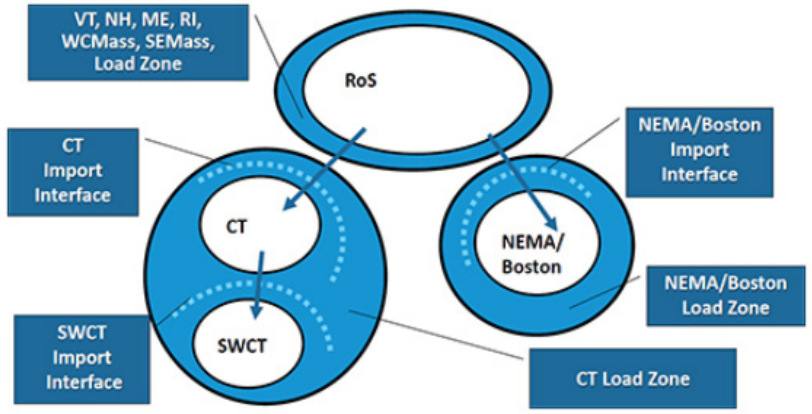
Source: ISO-NE (https://www.iso-ne.com/about/key-stats/maps-and-diagrams/)

Transmission Topography and Investment (Cont'd)

Reserve Zones

- The Forward Reserve Market procures reserve capacity for the region, which is divided into four reserve zones:
  - Greater Connecticut
  - Greater Southwest Connecticut (SWCT)
  - Northeast Massachusetts and Boston area (NEMA/Boston)
  - Rest of the system (Rest-of-System, ROS), which excludes the other, local reserve zones
- This diagram below illustrates the relationship between the reserve zones, load zones, and interfaces.

Reserve Zones and Load Zones

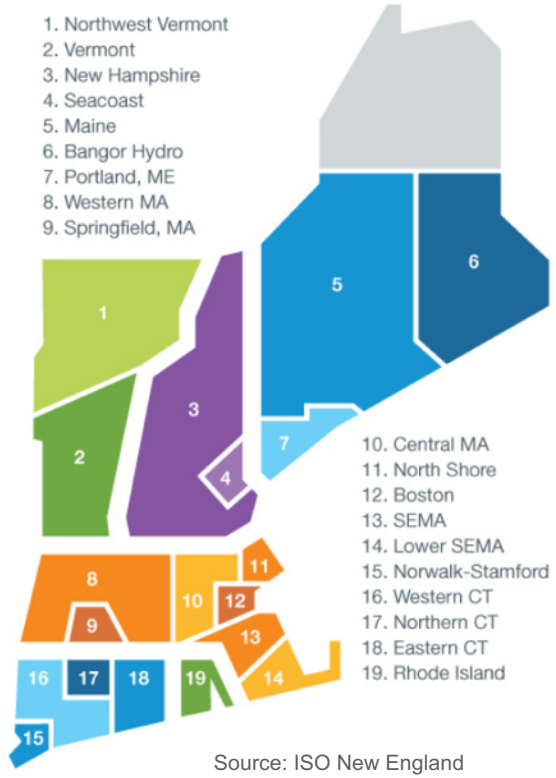


Source: ISO New England

Dispatch Zones

- The region is divided into 19 dispatch zones for the purpose of administering active demand resources. The zones, which are groups of pricing nodes, allow for a more granular aggregation of active demand resources at the locations and quantities needed to address potential system problems.

New England Dispatch Zones



Source: ISO New England

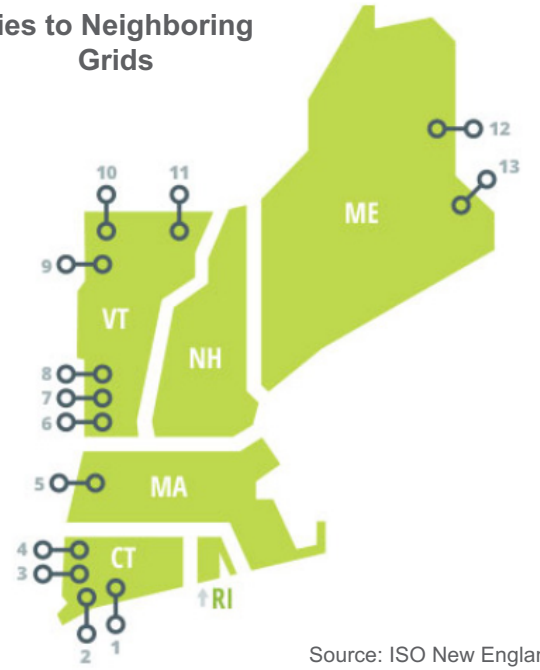
Source: ISO-NE (https://www.iso-ne.com/about/key-stats/maps-and-diagrams/)

Transmission Topography and Investment (Cont'd)

Ties to Neighboring Electric Power Grids

- ISO- NE has 13 total interconnections to three different neighboring systems:
  - New York (ties 1–9), which ties New England to the Eastern Interconnection
  - Hydro Québec (ties 10–11), which ties New England to the Québec Interconnection through direct-current (DC) transmission
  - New Brunswick (ties 12–13), which is tied to the Eastern Interconnection through New England

Ties to Neighboring Grids

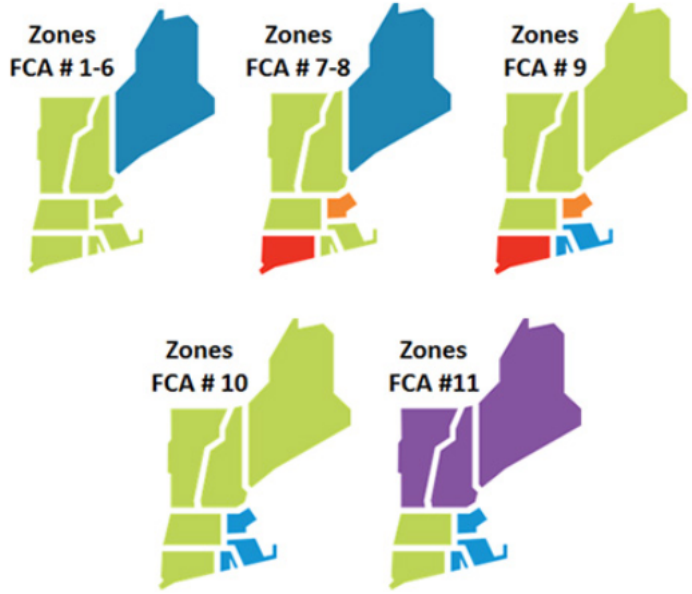


Source: ISO New England

Capacity Zones

- Capacity zones are a key input into the Forward Capacity Auction (FCA) and subsequent annual reconfiguration auctions because the amount of capacity purchased is based on these boundaries. They are specific geographic subregions (a combination of load zones) of the region's electric power system that are designated before each FCA. The ISO establishes capacity zones on an annual basis and evaluates all transmission interface transfer limits that could be relevant to capacity zone modeling.

Capacity Zones



Source: ISO New England

Source: ISO-NE (https://www.iso-ne.com/about/key-stats/maps-and-diagrams/)

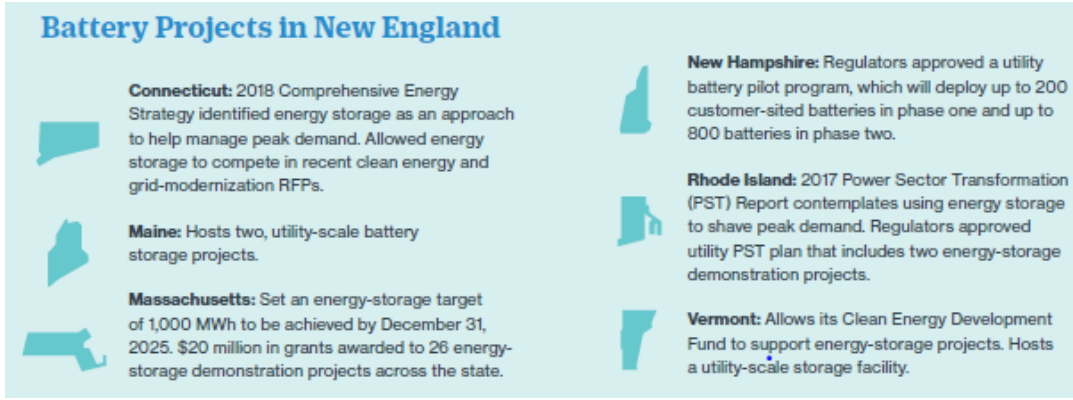
Transmission Topography and Investment (Cont'd)

Transmission Planning

- ISO-NE develops a regional system plan (RSP) every two years, and the regional system planning process identifies the region's needs and the plans for meeting those needs over a 10-year time horizon. Each RSP updates the plan from two years earlier by discussing study proposals, scopes of work, assumptions, draft and final study results, and other materials.
- According to the latest version of the RSP, the overall need for major additional reliability-based transmission projects is expected to decline over the planning horizon. The low growth of net peak load means it no longer is a major driver of the need for new reliability-based transmission projects, and the development of Forward Capacity Market (FCM) resources in favorable system locations also defers the need for major new projects.
- The latest RSP shows the continuing need for certain transmission system upgrades. Per the 2019 RSP, $10.9 billion was invested in the ISO-NE transmission system from 2002 to June 2019, and an additional $1.9 billion is planned over the planning horizon, many of which are in siting or under construction. Looking ahead, integrating large-scale renewable energy resources, addressing the dynamic characteristics of load and the expansion of distributed resources, upgrading and refurbishing aging infrastructure, adding interchange capability with neighboring systems, and complying with new NERC standards are potential drivers for transmission. Per the 2019 RSP, "with these [planned] system upgrades in place, combined with the changes in assumptions to needs assessments, the need for additional reliability-based transmission upgrades may decline over the planning horizon, however additional needs may be driven by generation retirement and the impact of increased energy efficiency and photovoltaic programs."
- Through the Northeastern ISO/RTO Planning Protocol, ISO-NE coordinates interregional studies, including interconnection queue studies, and satisfies interregional planning requirements under Order No. 1000. New England, the New York ISO (NYISO), and PJM presented system needs to the Interregional Planning Stakeholder Advisory Committee, but the ISO/RTOs and stakeholders have not identified the need for new ties with New England (as of June 2019).

Planning for Energy Storage

- In addition to the two large-scale pumped-hydro energy-storage facilities in ISO-NE that can supply almost 2,000 MWs, several other state initiatives led to the development of new battery energy storage projects in the region.



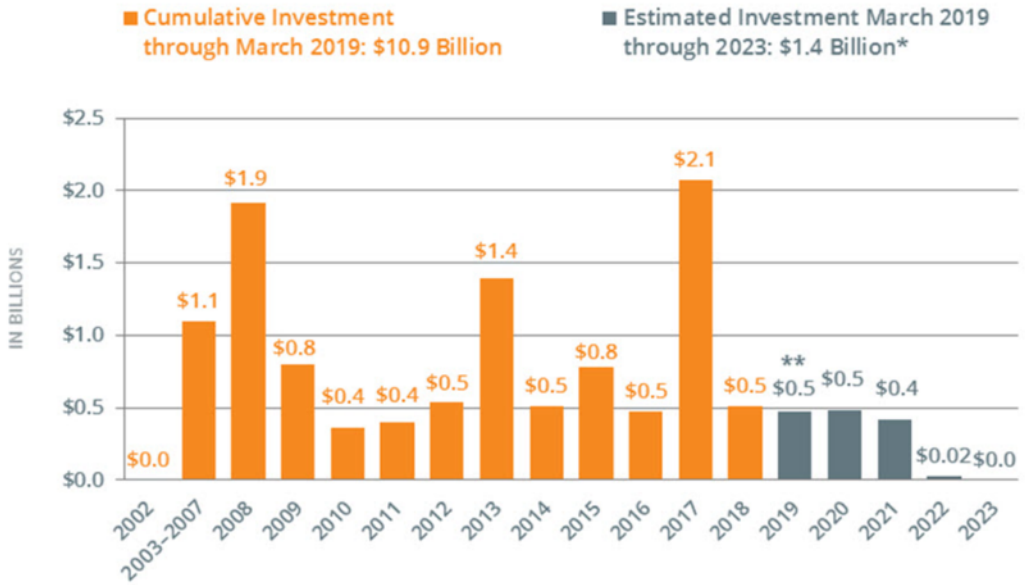
Source: ISO-NE; 2017 Regional System Plan

Transmission Topography and Investment (Cont'd)

Transmission Investments

- The ISO's continuous study and analysis of the transmission system has helped guide regional investment to fix weak spots and bottlenecks on the system that greatly improved its economic performance and maintained reliability of service.

Transmission Investment in New England to Maintain Reliability



* Estimated future investment includes projects under construction, planned, and proposed. Totals may not add up due to rounding.

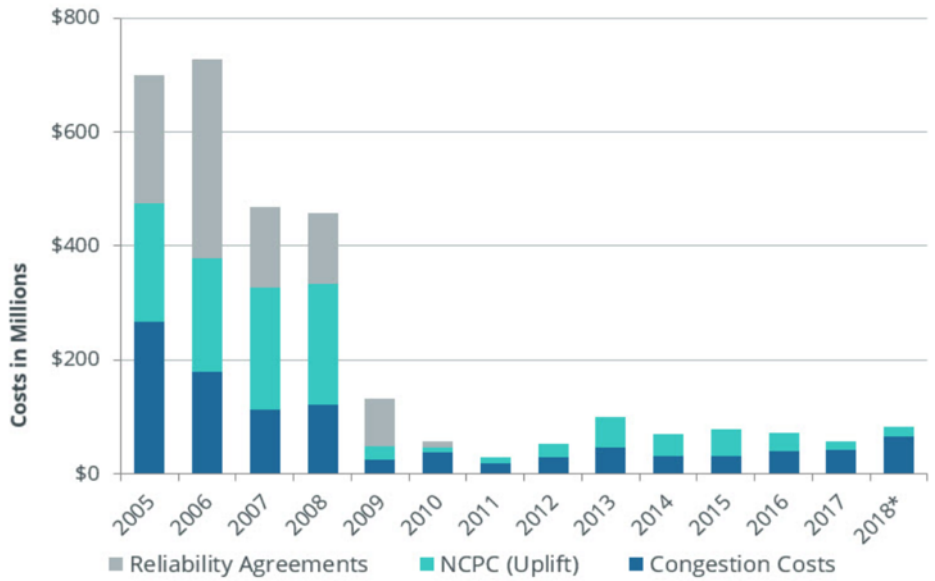
** $0.0 billion was in service through March 2019. $0.50 billion was estimated for the remainder of 2019.

Source: ISO New England, *RSP Transmission Project List* (March 2019)

Decreasing Congestion Costs

- Transmission system upgrades have contributed to decreases in congestion costs in the New England energy market and have, with the aid of low natural gas prices and other factors, helped drive down and mitigate "uplift" payments to run specific generators to meet local reliability needs.

New England Costs for Congestion, Uplift, and Reliability Agreements



Note: Reliability agreements have not been used in the region since 2010.

*Data are subject to adjustments.

Source: ISO New England

Source: ISO-NE (https://www.iso-ne.com/about/key-stats/transmission/)

Transmission Topography and Investment (Cont'd)

FERC-Jurisdictional Investment Base

- In New England, transmission owners recover transmission revenue requirements through a combination of local and regional open access transmission tariff (OATT) rates. The transmission owners provide regional network service (RNS) over their regional high-voltage lines pursuant to ISO-NE's OATT, and the rate for RNS is calculated annually using a formula rate for all pool transmission facilities (PTF) in New England. The RNS formula rate applies only to PTFs, those assets that have been turned over to the operational control of ISO-NE by transmission owners in New England.
- According to data from formula rate updates filed with FERC in 2018, year-on-year growth in aggregate transmission investment base among 11 companies in ISO-NE from rate year 2017–2018 to rate year 2018–2019 was moderate, rising from $8.467 billion to $9.077 billion, an increase of 7.20%. This compares to transmission rate base growth for those same 11 companies of 6.26% from rate year 2016–2017 to rate year 2017–2018, 7.16% from rate year 2015–2016 to rate year 2016–2017, and 4.64% from rate year 201–2015 to rate year 2015–2016.
- The tables at right provide a summary of the operating subsidiaries of each holding company in ISO-NE that utilizes formula-based rates with FERC, including authorized ROE incentives as applicable.

ISO-NE Transmission Formula Rate Summary

Ticker	Parent company	Filing entity	Trans. investment base 2017-2018 ($000)	Trans. investment base 2018-2019 ($000)	Investment base growth 2017-2018 to 2018-2019 (%)	Base ROE (%)*	Investment subject to incentive ROE ($000)	Incent. ROE (%)*
AGR	AVANGRID	Central Maine Power	1,143,917	1,104,754	(3.42)	11.07	968,238	11.74
AGR	AVANGRID	United Illuminating	535,456	539,112	0.68	11.07	370,397	11.74
EMA	Emera Inc.	Emera Maine	247,793	228,831	(7.65)	11.07	None	NA
ES	Eversource Energy	Connecticut Light & Power	2,274,460	2,456,226	7.99	11.07	1,273,540	11.74
ES	Eversource Energy	NSTAR Electric	1,228,858	1,293,099	5.23	11.07	202,708	11.74
ES	Eversource Energy	Public Service Co. of New Hampshire	651,299	715,270	9.82	11.07	77,711	11.74
ES	Eversource Energy	Western Massachusetts Electric	615,517	687,987	11.77	11.07	370,442	11.74
NEE	NextEra Energy	New Hampshire Transmission	35,716	43,487	21.76	11.07	None	NA
UTL	Unitil	Fitchburg Gas & Electric	3,011	2,795	(7.17)	11.07	None	NA
NA	National Grid USA	New England Power	1,030,976	1,186,573	15.09	11.07	253,206	11.74
NA	NA	Vermont Transco	699,917	818,484	16.94	11.07	179,121	11.74

* Inclusive of 50 basis point incentive adder for membership in ISO-NE. Total ROE capped at 11.74% inclusive of all incentive adders pursuant to FERC Opinions 531, 531-A and 531-B.
Source: Regulatory Research Associates, an offering of S&P Global Market Intelligence

ISO-NE Transmission Investment Base Values ($M)

Ticker	Parent Company	Filing Entity	2011-'12	2012-'13	2013-'14	2014-'15	2015-'16	2016-'17	2017-'18	2018-'19	CAGR (2011-'12 to 2018-'19) (%)
AGR	AVANGRID	Central Maine Power	177.5	533.7	418	651.4	855.4	1,136.3	1,143.9	1,104.8	29.85
AGR	AVANGRID	United Illuminating	386.7	377.5	409.3	449.6	458.7	480.5	535.5	539.1	4.86
EMA	Emera Inc.	Emera Maine	161.8	178.5	229.2	241.4	236.7	248.1	247.8	228.8	5.07
ES	Eversource Energy	Connecticut Light & Power	1,849.2	1,756.0	1,778.5	1,915.7	2,004.0	2,172.4	2,274.5	2,456.2	4.14
ES	Eversource Energy	NSTAR Electric	605.9	601.5	731.3	952.8	981.9	1,055.8	1,228.9	1,293.1	11.44
ES	Eversource Energy	Public Service Co. of New Hampshire	313.7	360.7	385.3	448	493.1	554.2	651.3	715.3	12.5
ES	Eversource Energy	Western Massachusetts Electric	139.5	185.6	443.5	564.1	553.7	583.8	615.5	688	25.61
NEE	NextEra Energy	New Hampshire Transmission	39.3	36.8	37.5	37.9	37.1	40	35.7	43.5	1.46
UTL	Until	Fitchburg Gas & Electric	0.5	0.7	0.9	2.6	2.7	2.7	3	2.8	28.97
NA	National Grid USA	New England Power	643.1	696.4	729.9	857.3	963.1	1,013.2	1,031.0	1,186.6	9.14
NA	NA	Vermont Transco	541	543.6	598.4	644.1	654.9	681.1	699.9	818.5	6.09

Source: Regulatory Research Associates, an offering of S&P Global Market Intelligence

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Sources: S&P Global Market Intelligence; Annual Markets Report; NEPOOL Participants Comm. Report

Transmission Topography and Investment (Cont'd)

Transmission Projects

- Several major transmission projects in ISO-NE have been developed in response to state solicitations for carbon-free energy, designed to move hydro power and renewables from Canada, New York, and remote areas in northern New England to load centers further south.
  - New England Clean Power Link: The $1.2 billion 300 kV to 320 kV line would run approximately 98 miles underwater from the Canadian border through Lake Champlain to Benson, Vermont, before running another 56 miles to a new converter station slated in Ludlow, Vermont.
  - New England Clean Energy Connect: The 145 mile 300 kV to 320 kV line would connect Quebec to Maine, enabling the transfer of hydropower from Hydro-Quebec to New England load centers, with an estimated cost of $950 million.
  - Maine Power Express HVDC: Despite losing out on a solicitation from Massachusetts, the project may still see its power lines run more than 300 miles underground and undersea from southern Aroostook County, Maine, to a converter station in Boston.
  - Northeast Renewable Link: With an in-service date of late 2021 or early 2022, the 345 kV project is designed to transmit a mix of new wind, solar, and small hydropower generated in New York and would run 23 miles from Nassau, New York, to an Eversource substation in Hinsdale, Massachusetts.
- Others, such as the Vineyard Wind Connector project, have been designed to move offshore wind into New England. The project, comprised of submarine and onshore underground electrical transmission along with a new substation, will connect the Vineyard Wind offshore wind project, located 15 miles south of Martha's Vineyard and Nantucket and 34 miles from the coast of Cape Cod, to an existing substation in Barnstable owned by Eversource Energy subsidiary NSTAR Electric.

Project Name	Project Owner(s)	Length (miles)	Voltage (kV)	From State or Province	To State or Province	From ISO	To ISO	Year in Service	Current Status	Project Type	Estimated Max Const. Costs ($000)
Atlantic Link 320 kV	Clean Power Northeast Development	375	320	New Brunswick	Massachusetts	New Brunswick	New England	2022	Early Development	New	NA
Evergreen Express	NextEra, New Hampshire Transmission	114	345	New Brunswick	Maine	New Brunswick	New England	NA	Early Development	New	NA
Line A201/B202 Rebuild (Granite State Power Link Segment B)	Citizens Energy Corp., GridAmerica Holdings Inc.	109	345	New Hampshire	New Hampshire	New England	New England	2022	Early Development	Rebuild	NA
Maine Power Express HVDC	Loring Holdings, LLC, National Resources Energy, LLC, Transmission Developers Inc.	315	345	Maine	Massachusetts	New England	New England	2022	Early Development	New	NA
New England Clean Energy Connect	Central Maine Power	145	320	Quebec	Maine	NA	New England	2022	Advanced Development	New	950,000
New England Clean Power Link	Transmission Developers Inc.	152	320	Vermont	Vermont	New England	New England	2022	Advanced Development	New	1,200,000
Vineyard Wind Connector	Avangrid Renewables LLC, Offshore MW LLC, Vineyard Power Cooperative	27	220	Massachusetts	Massachusetts	New England	New England	2021	Advanced Development	New	NA

Note: Includes all projects greater than 115 kV and line length greater than 10 miles
Sources: S&P Global Market Intelligence; ScottMadden analysis

Resilience Issues

Overview

- ISO-NE has experienced several major resilience events over the past decade. Those events are summarized in the table on the next page. Most events affecting the power system in recent years are driven by severe weather events, but other events such as vandalism, suspicious activity, and system operation have played a role (see table at right).
- As a frame of reference for the potential economic impact of a resilience event, the combined 2018 annual GDP for all six states in New England was $4.3 trillion, representing more than 5% of the total for the United States.

Fuel Security in the Northeast United States

- Although the region is projected to have sufficient resources to meet capacity requirements and enough transmission facilities to meet reliability criteria, fuel security remains a primary issue the region must resolve to meet its energy supply needs. The limited availability of the natural gas transportation infrastructure to supply gas to generating units can present fuel security risks to the region, especially during winter-operating periods, even as New England's current reliance on natural gas as a primary fuel for generating units is projected to grow.
- The challenge is "assurance that power plants will have or be able to obtain the fuel they need to run, particularly in winter – especially against the backdrop of coal, oil, and nuclear unit retirements, constrained fuel infrastructure, and the difficulty in permitting and operating dual-fuel generating capability."
- Range of solutions being considered and discussed with stakeholders include:
  - Changes to "pay for performance" parameters
  - Market designs that increase incentives for forward fuel supply and resupply
  - Inclusion of opportunity costs associated with scarce fuels and emission allowances

Reported Electric Disturbance Events Affecting New England (2017–Apr. 2019)

Cause	2017	2018	2019 YTD
Fuel Supply Deficiency	0	0	0
Severe Weather	4	8	1
Vandalism	0	1	0
Suspected Physical Attack	0	0	0
Actual Physical Attack	0	0	0
Suspicious Activity	1	0	0
Transmission Interruption	0	0	0
System Operations	0	2	0

Note: For multiple causes, classified under one only.
Source: DOE OE-417; ScottMadden analysis

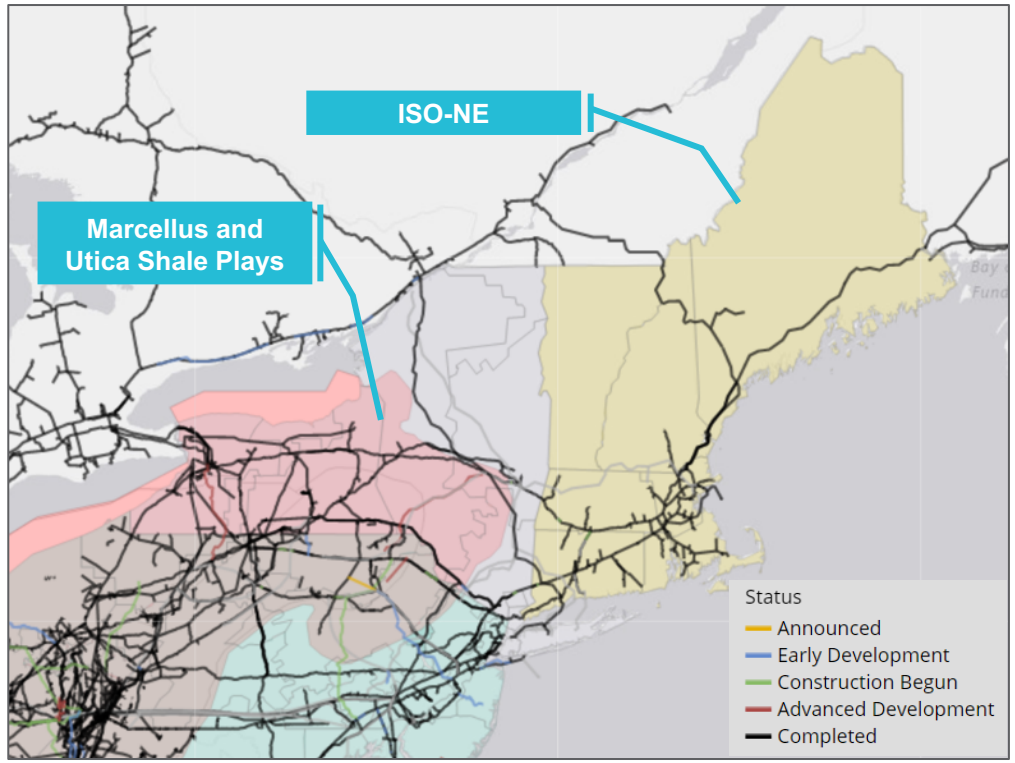
Sources: Bureau of Economic Analysis; ISO-NE Resilience Filing; U.S. Dept. of Energy

Resilience Issues (Cont'd)

Fuel Security in the Northeast United States (Cont'd)

- Despite ISO-NE's close proximity to plentiful natural gas from shale production in the Marcellus (and Utica), pipeline capacity constraints into ISO-NE have limited the volume that can be delivered into the region.
- A handful of new pipeline projects and expansions completed in recent years have provided limited additional capacity:
  - Algonquin Incremental Market (AIM) – 342,000 Dth, 37.6 miles (NY to MA)
  - Portland Natural Gas Project – 168,000 MMcf/d, 295 miles (NH to ME)
  - Maritimes and Northeast – 418,100 Dth, 1.7 miles (NB to ME)
- However, siting and permitting in the densely populated New England region is particularly challenging, and regulatory and stakeholder pushback has delayed and/or forestalled other pipeline projects, and there are no projects currently permitted or under construction in the region.
- Oil-fired plants, which typically do not run often, become critical on cold winter days when the fuel for natural gas-fired generators is limited and expensive. But during cold weather, oil and dual-fuel (natural gas/oil) plants can rapidly deplete their on-site oil supply or reach environmental limits on their run times.
  - Extreme cold weather also creates a number of obstacles to restocking oil supplies, as was illustrated during the 2017–2018 winter cold spell: severe weather and sea and river ice hampered resupply by oil barges and delayed oil truck deliveries.
  - With extended days of burning oil, several resources either had concerns about hitting federal and state emissions limitations or were impacted by emissions limitations. Over two weeks during the 2017–2018 winter, power providers in ISO-NE used two million barrels of oil—twice the average yearly amount.
- In one controversial case, after receiving a request to delist Mystic River Units 8 and 9, FERC granted an ISO-NE request that the units remain online as a reliability must-run price taking unit until reliability and fuel security concerns can be resolved.

Select Current and Planned Pipelines Projects in the Northeastern United States



Sources: S&P Global Market Intelligence; 2019 Regional Electricity Outlook; ScottMadden analysis

Resilience Issues (Cont'd)

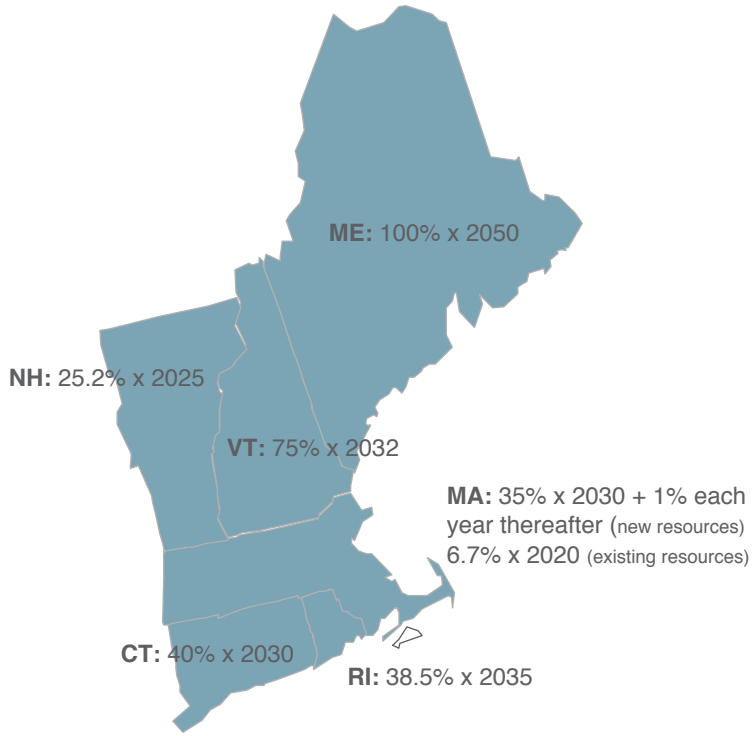
Selected Major Bulk Power Events Affecting New England

Event	Description
Northeast Snowstorm (Oct. 29–30, 2011)	• An unprecedented fall snowstorm hit the Northeastern United States, breaking all previous October records. Parts of New York, New Jersey, and Pennsylvania also received more than a foot of snow. The quantity of snow held by the unusually top-heavy trees, coupled with the soft, wet ground, resulted in a great number of healthy trees, most outside of utility rights-of-way, being uprooted and falling onto distribution and transmission lines. • On the morning of October 30, near the end of the storm, more than 3.2 million homes and businesses were without power. Thousands were without power for more than a week, some for as long as 11 days. Estimates put storm costs between approximately $1 billion and $3 billion.
Polar Vortex (Jan. 2014)	• In early January 2014, the Midwest, South Central, and East Coast regions of North America experienced a weather condition known as a polar vortex, where extreme cold weather conditions occurred in lower latitudes than normal, resulting in temperatures 20°F to 30°F below average. NYISO recorded its all-time peak winter load on January 7. • For NPCC (including New England [and Canada]), nearly 2 GWs of cold weather generation outages were reported, with about 770 MWs related to fuel-gelling issues. Some dual-fuel units experienced challenges ranging from a lack of natural gas required for starting the alternate fuel to fuel freezing in the injectors. Outages related to curtailments and interruptions of natural gas delivery were the significant contributor of the NPCC generator outages. These outages totaled a maximum of 3,296 MWs of generators, and they significantly impacted NPCC's generation resources starting at approximately 10:00 a.m. on January 7, 2014.
Winter Storms Riley and Quinn (Mar. 1–20, 2018)	• In March 2018, Winter Storm Riley, a powerful nor'easter caused major impacts in the Northeastern, Mid-Atlantic, and Southeastern United States, bringing hurricane force winds to coastal New England and producing more than two feet of snow in some areas. Although the most severe damage was caused by flooding, as well as snow, unusually high tides and storm surges along the coast, wind, and downed trees caused very large inland power outages. Recovery efforts were also hampered as a second nor'easter, Winter Storm Quinn began to impact the area just a few days later • At least two million customers lost power at some point during the storm throughout the week in 13 states. The storm was called a "bomb cyclone" because of how quickly pressure dropped—24 millibars in 24 hours.

Sources: NERC; Utility Dive; National Oceanic and Atmospheric Administration

Renewables Integration

State Renewable Portfolio Goals within the ISO-NE Footprint (as of June 2019)



Source: DSIRE

Demand-Side Considerations: Renewable Portfolio Standards

- New England states have established ambitious clean and renewable energy goals, many of which have recently been increased, and those policies are expected to significantly impact energy and demand resources in ISO-NE:
  - Connecticut (raised in 2018): 40% by 2030
    - Class I: Traditional renewables; Class II: Trash-to-energy; Class III: CHP and waste heat
  - Maine (raised in 2019): 80% renewables by 2030, 100% total by 2050
    - Class I: New resources; Class II: Existing renewables
  - Massachusetts (raised 2018): 35% by 2030 + 1% every year thereafter
    - Class I: New resources; Class II: Existing resources
  - New Hampshire: 25.2% by 2025
    - Class I: New renewables –15% by 2025; Class II: New solar – 0.7%; Class III: Existing biomass – 8%; Class IV: Existing hydro – 1.5%
  - Rhode Island: 14.5% by 2019; 38.5% by 2035 (No classes)
  - Vermont: 55% by 2017, increasing 4% every 3 years, to 75% by 2032
    - Tier I: Traditional renewables; Tier II: New distributed renewables (< 5 MWs); Tier III: New distributed renewables or fossil-fuel savings equivalent
- Two utilities in the ISO-NE footprint have introduced clean energy commitments (see below).

Utility Name (States of Operation)	Goal Type	Target Dates	Description (Date Implemented)
Green Mountain Power (VT)	Emission Reduction	2025	100% carbon-free energy by 2025
National Grid (MA)	Emission Reduction	2020 2050	45% reduction in GHG emissions by 2020 80% reduction by 2050

Source: SEPA

Sources: 2019 Regional Electricity Outlook; NEPOOL Participants Comm. Report

Renewables Integration (Cont'd)

States Accelerate Procurement of Renewable Energy

State(s)	State Procurement Initiatives for Large-Scale Clean Energy Resources	Resources Eligible/ Procured	Target MW (nameplate)
MA, CT, RI	2015 Multi-State Clean Energy RFP	Solar, Wind	390 MW
MA	2017 Section 83D Clean Energy RFP	Hydro Import	Approx. 1,200 MW (9,554,000 MWh)
MA, RI	2017 Section 83C Offshore Wind RFP	Offshore Wind	1,600 MW (MA) 400 MW
CT	2018 Renewable Energy RFP	Offshore Wind, Fuel Cells, Anaerobic Digestion	254 MW
CT	2018 Zero-Carbon Resources RFP	Nuclear, Hydro, Class I Renewables Energy Storage	Approx. 1,400 MW (12,000,000 MWh)
RI	2018 Renewable Energy RFP	Solar, Wind, Biomass, Small Hydro, Fuel Cells and other Renewables	400 MW

Demand-Side Considerations: Additional State Procurement of Renewables

- With laws mandating steep reductions in greenhouse gas emissions, some New England states began offering additional incentives to bring more solar, hydro, and wind power online over the past few years.
- More recently, several New England states have established public policies that direct electric power companies to enter into long-term contracts for carbon-free energy that would cover most, if not all, of the resource's costs. Massachusetts, for example, directed its utilities to sign 20-year contracts committing the state's electricity customers to pay for the development of large-scale offshore wind and hydroelectricity import projects. In all, three of the six states are seeking to develop or retain approximately 5,600 MWs of clean energy and storage resources, and the Massachusetts Department of Energy Resources (DOER) recently analyzed costs and benefits of additional procurement and recommended proceeding with solicitation of 1,600 MWs of additional offshore wind.
- The federal Bureau of Ocean Energy Management (BOEM) recently auctioned leases in offshore Massachusetts for additional wind development (see graphic on the following slides). This public policy trend is expected to grow as legislators in all New England states seek to accelerate the transition to a clean energy economy.
- All New England states also participate in the Regional Greenhouse Gas Initiative (RGGI), a cooperative effort of New England and Mid-Atlantic states to cap and reduce CO_2 emissions from the power sector. It is a mandatory, market-based CO_2 emissions limits. Through a program review in 2017, the RGGI states agreed to a number of program changes, including a 30% cap reduction between 2020 and 2030, essentially ratcheting down the availability of allowances to generators that produce greenhouse gases.

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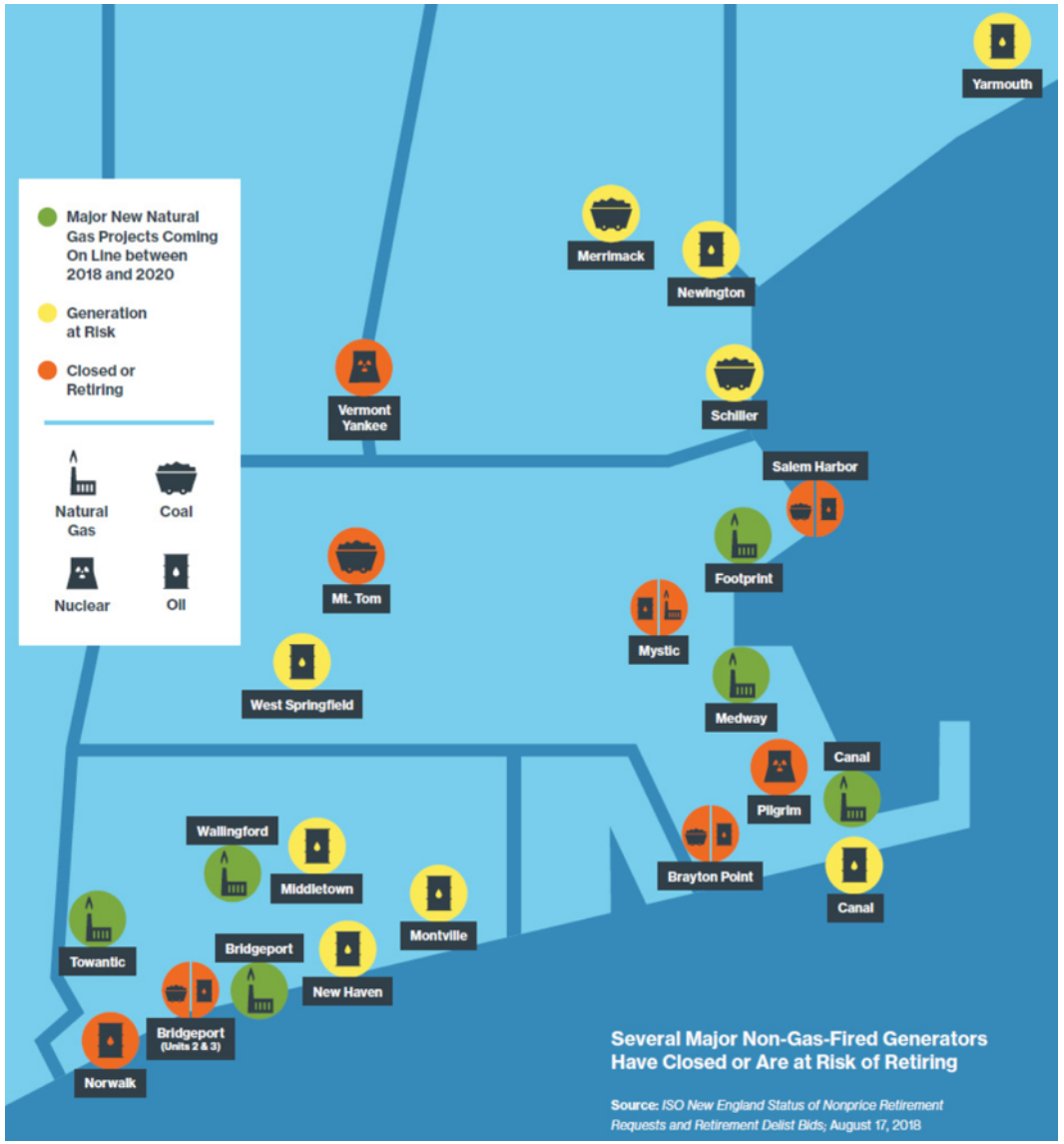
Sources: 2019 Regional Electricity Outlook; NEPOOL Participants Comm. Report

Renewables Integration (Cont'd)

Supply-Side Considerations: Retirement of Coal, Oil, and Nuclear Capacity

- More than 5,200 MWs of oil, coal, and nuclear power plants will have retired from 2013 to 2022, and another 5,000 MWs of coal- and oil-fired generation could be retiring in coming years (see "at risk" to the right).
- The region's remaining two nuclear facilities (Millstone and Seabrook, which comprise a combined 3,300 MWs) will continue to be important components of the grid because they are carbon free and have a dependable, on-site fuel supply.
- Nuclear power currently supplies a quarter of the grid electricity consumed in the region per year.
- Notable recent exits:
  - Brayton Point Station (1,535 MWs from oil and coal)
  - Salem Harbor Station (749 MWs from oil and coal)
  - Vermont Yankee (604 MWs from nuclear power)
  - Pilgrim Nuclear Station (677 MWs from nuclear power)
  - Norwalk Harbor Station (342 MWs from oil)
  - Mount Tom Station (143 MWs from coal)
  - Bridgeport Harbor Station (564 MWs from coal)

New, Closed or Retiring, and At Risk Generation Resources in ISO-NE



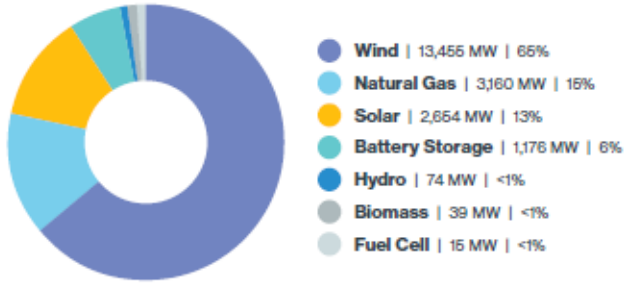
Source: ISO-NE (https://www.iso-ne.com/about/key-stats/resource-mix/)

Renewables Integration (Cont'd)

Supply-Side Considerations: New Renewables and Natural Gas-Fired Generation

- In 2018, the amount of new wind power seeking interconnection in ISO-NE was for the first time more than double the amount of natural gas-fired generation proposed—and today, there are four times more wind power proposals than natural gas. Of the roughly 13,500 MWs (nameplate) of wind power being proposed regionally (as of January 2019), about 9,500 MWs would be offshore of Massachusetts, Rhode Island, and Connecticut, with most of the remaining 4,000 MWs located onshore in Maine.
- Massachusetts utilities have executed contracts (subject to regulatory approval) for 800 MWs of offshore wind to be online by 2023, and the winning bid has been selected for an additional 800 MWs of offshore wind by 2027. Connecticut and Rhode Island utilities have also negotiated contracts for offshore wind to be online by 2023.

Proposed Generation Projects in ISO-NE by Fuel and Technology (MW)



Total: 20,573 MW

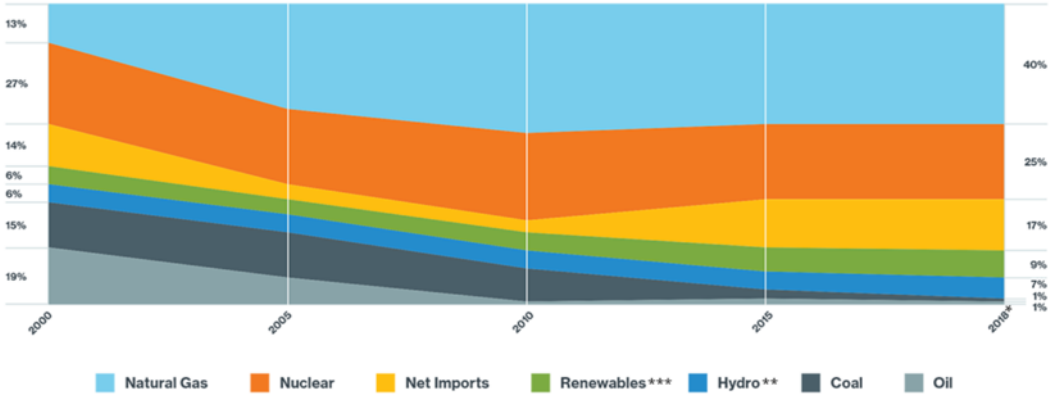
Proposals by State

Massachusetts	10,426 MW	Rhode Island	1,366 MW
Maine	4,578 MW	New Hampshire	302 MW
Connecticut	3,682 MW	Vermont	218 MW

Source: ISO Generator Interconnection Queue (January 2019)

Note: Not all proposed new projects are built; historically, 70% of megawatts have ultimately withdrawn.

ISO-NE Percent of Electric Energy by Fuel Type (2000–2019)



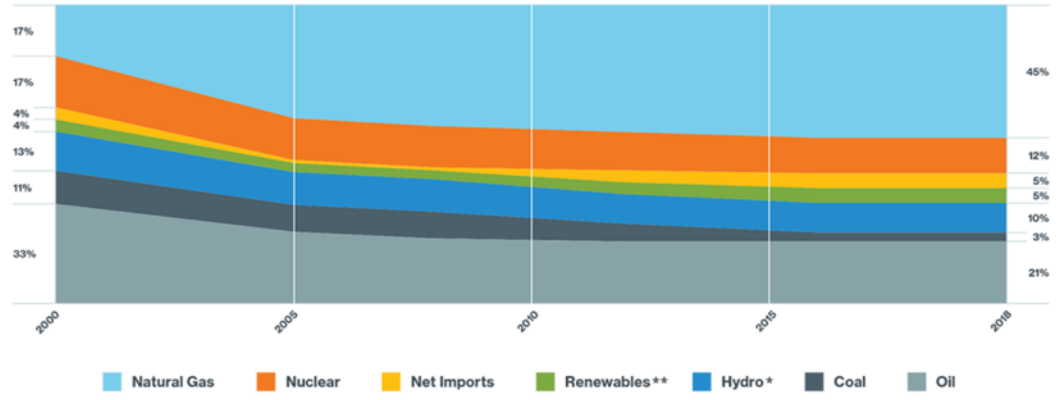
*Data are subject to adjustments. This chart approximates the amount of generation by individual fuels used by dual-fuel units, such as natural-gas-fired generators that can switch to run on oil and vice versa. Before 2016, generation from such units was attributed only to the primary fuel type registered for the unit.

**Includes pondage, run-of-river, and pumped storage.

***Renewables include landfill gas, biomass, other biomass gas, wind, grid-scale solar, municipal solid waste, and miscellaneous fuels. Hydro is not included in this category primarily because the various sources that make up hydroelectric generation (i.e., conventional hydroelectric, run-of-river, pumped storage) are not universally defined as renewable in the six New England states.

Source: ISO New England

ISO-NE Percent of Capacity by Fuel Type (2000–2019)



*Includes pondage, run-of-river, and pumped storage.

**Renewables include landfill gas, biomass, other biomass gas, wind, grid-scale solar, municipal solid waste, and miscellaneous fuels. Hydro is not included in this category primarily because the various sources that make up hydroelectric generation (i.e., conventional hydroelectric, run-of-river, pumped storage) are not universally defined as renewable in the six New England states.

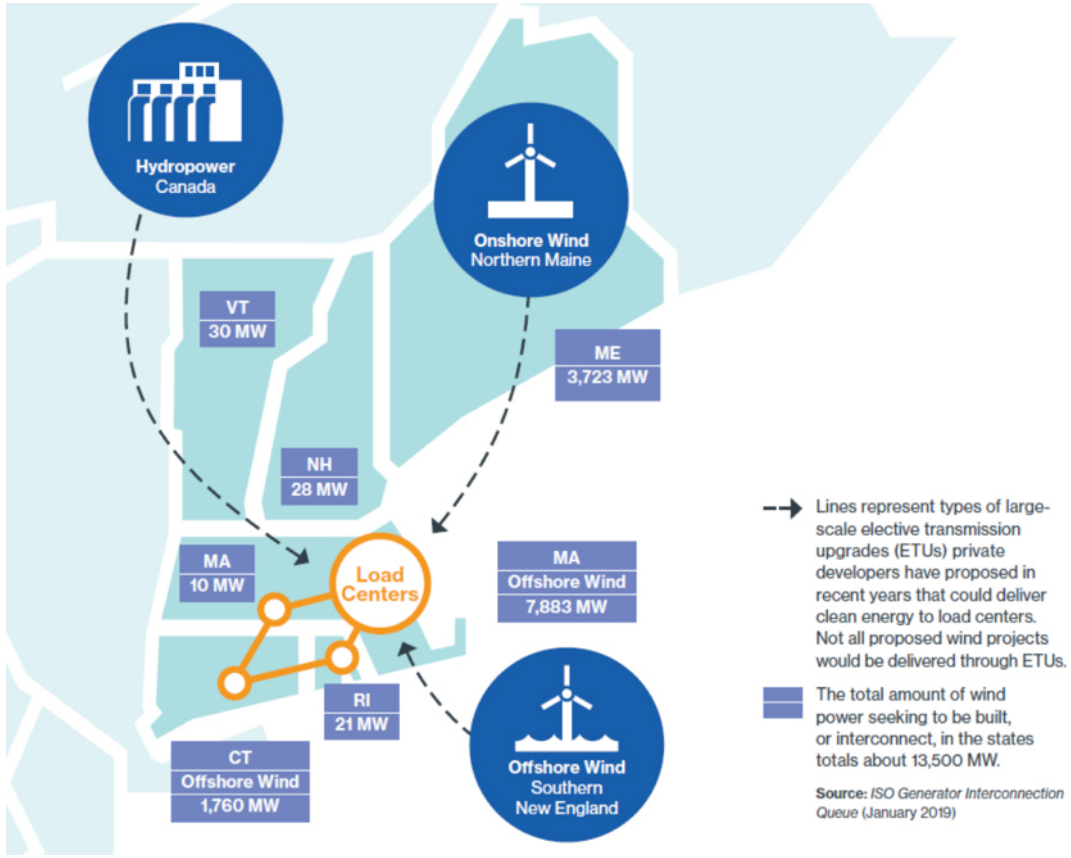
Source: ISO New England

Sources: BOEM; ISO-NE (https://www.iso-ne.com/about/key-stats/resource-mix/)

Renewables Integration (Cont'd)

Supply-Side Considerations: Elective Transmission Upgrades (ETUs)

- Investments in the regional transmission grid will facilitate the states' policy directives for renewable energy and enable the transportation of low-carbon electricity into the region. Because of the long 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 from these remote, weaker areas of the system to far-away consumers.
- In 2015, the ISO-NE improved its interconnection study process for elective transmission upgrades (i.e., not reliability-driven upgrades) and introduced new rules that ensure that renewable resources are able to deliver capacity and energy into the power markets.
- ETUs are transmission lines funded by private parties—not through regional cost-sharing. While not necessary from a reliability standpoint, they can help enhance generator deliverability or facilitate the integration of renewable resources, such as remote wind resources, by enhancing portions of the grid.
- Today, private developers are competing in state procurements to build transmission projects that would enable the delivery of thousands of megawatts of clean energy, mostly from wind resources in northern Maine and hydro resources in Canada (not all proposed wind projects in New England would be delivered through ETUs). As of June 2019, 14 ETU projects are under study, and three have received approval of their proposed plan applications. State procurement programs will be major deciders of which projects will move forward.
- In 2017, the ISO implemented a new "clustering" methodology that enables interconnection requests from multiple generators and ETUs in the same area to be studied together. This is helping to advance the requests in northern and western Maine where thousands of megawatts of proposed new resources, mostly wind, are seeking to interconnect to the regional grid.



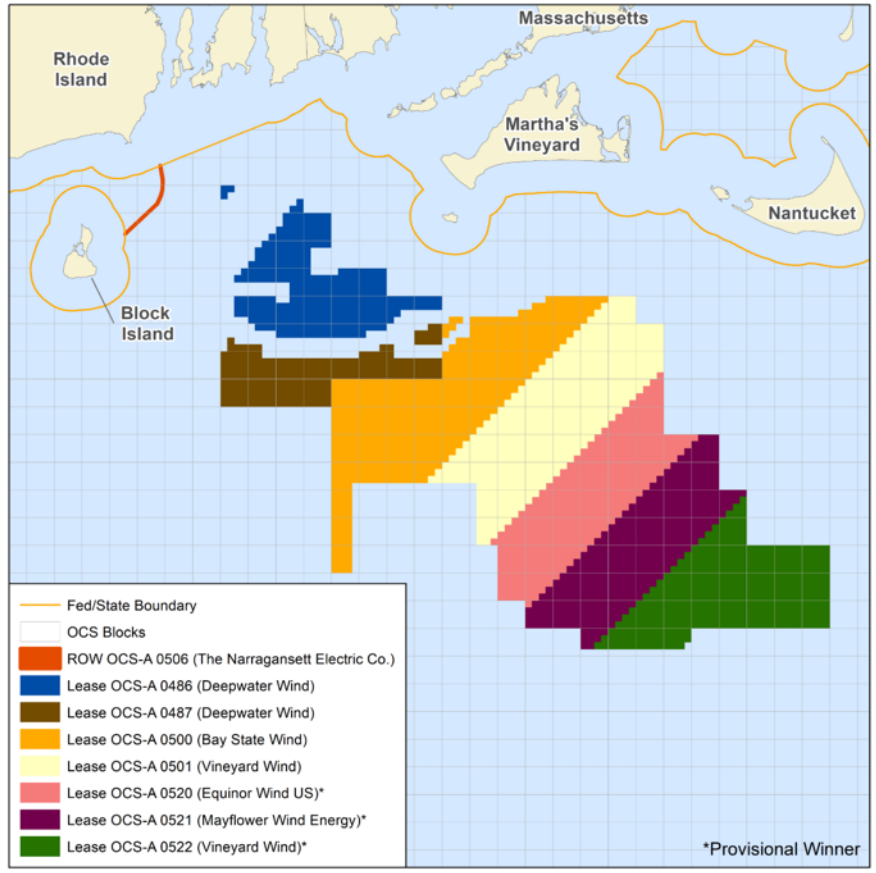
Source: ISO-NE (https://www.iso-ne.com/about/key-stats/transmission/)

Renewables Integration (Cont'd)

Supply-Side Considerations: Demand for Offshore Wind Developments

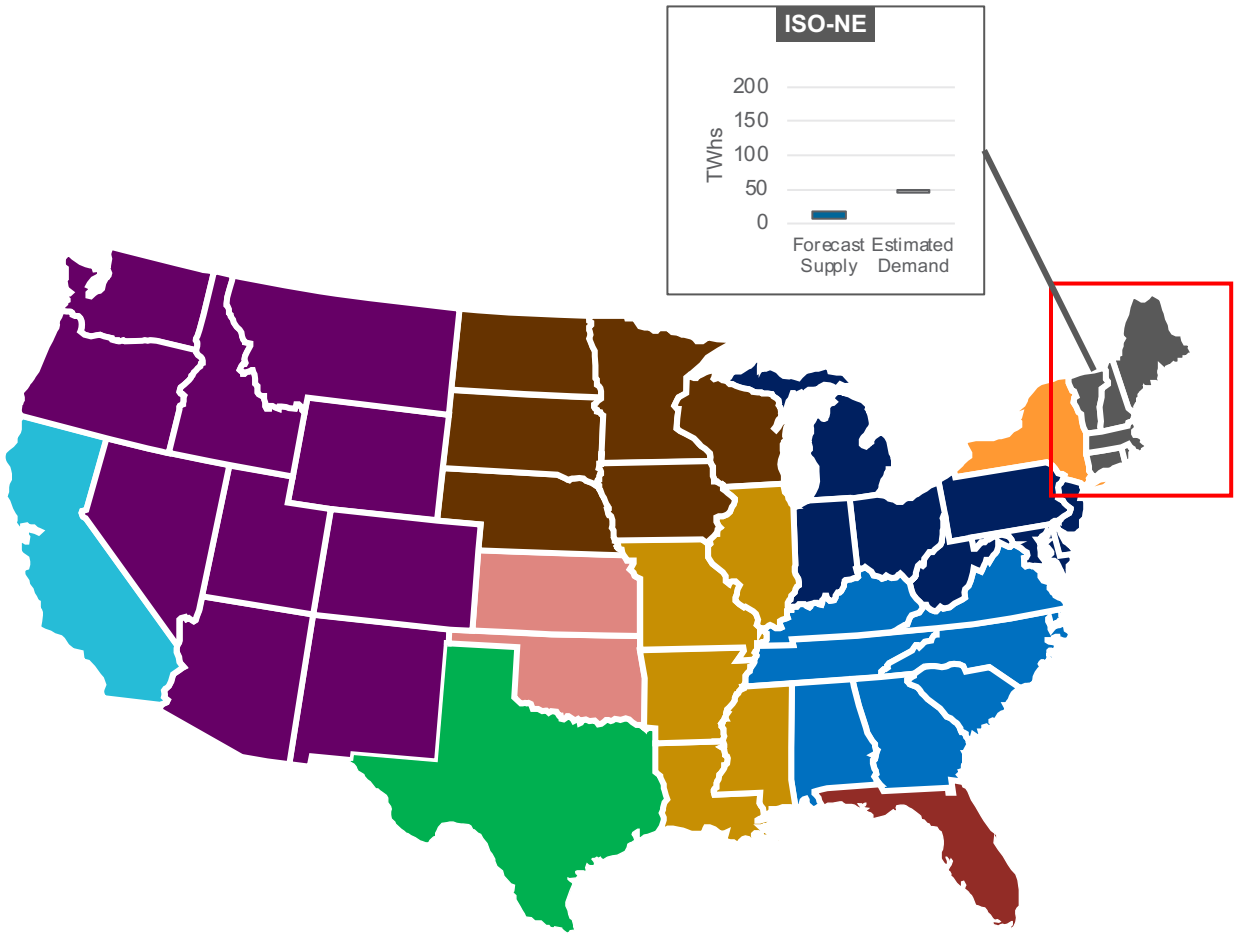
- **Rhode Island:** In 2011, BOEM published a "Call for Information and Nominations for Commercial Leasing for Wind Power on the OCS Offshore Rhode Island and Massachusetts." A call area was then identified in consultation with Rhode Island, and two leases were ultimately signed in 2013 for more than 164,000 acres, representing the first commercial leases in the United States.
  - In 2016, the 30 MW Block Island Offshore Wind, developed by Deepwater Wind New England, became the first offshore wind project in the United States.
  - Rhode Island subsequently joined the solicitation process led by Massachusetts (described below).
- **Massachusetts:** After receiving positive responses to an initial request for interest (RFI) in offshore commercial wind leases in 2010, BOEM worked with Massachusetts to identify a wind energy area. In 2014, it was announced that 742,000 acres would be made available for commercial wind energy leasing, and two leases were ultimately signed in 2015.
  - In 2016, Massachusetts Governor Charlie Baker signed into law a bill that committed the state to offshore wind. An Act Relative to Energy Diversity (H. 4568) requires Massachusetts electricity distribution companies to procure 1,600 MWs of cost-effective offshore wind energy by 2027, with the first solicitation taking place in June 2017.
  - Two projects, Bay State Wind and Vineyard Wind, were selected in the first solicitation, and both are proceeding with environmental and site reviews with the goal of having projects online in 2022–2023. On November 20, 2019, Massachusetts selected Mayflower Wind to supply the Commonwealth with an additional 804 MWs, satisfying the balance of the 1,600 MWs requirement.
- **Maine:** In 2011, BOEM received an unsolicited bid for a commercial lease for a wind energy project off the coast of Maine. Though BOEM determined that there was no commercial interest in the lease, thereby proceeding with the non-competitive lease process, Statoil since withdrew its lease request.
- **Connecticut:** Connecticut, in June 2019, passed a bill to enable solicitations for offshore wind beginning in 2019, with the first solicitation expected to total 2,000 MWs, all of which must be achieved by 2030, with the estimated year of first commissioning expected in 2023.

Commercial Wind Energy Areas Off the Coasts of Rhode Island and Massachusetts



Sources: ISO-NE; BOEM; MassCEC Offshore Wind

Renewables Integration (Cont'd)

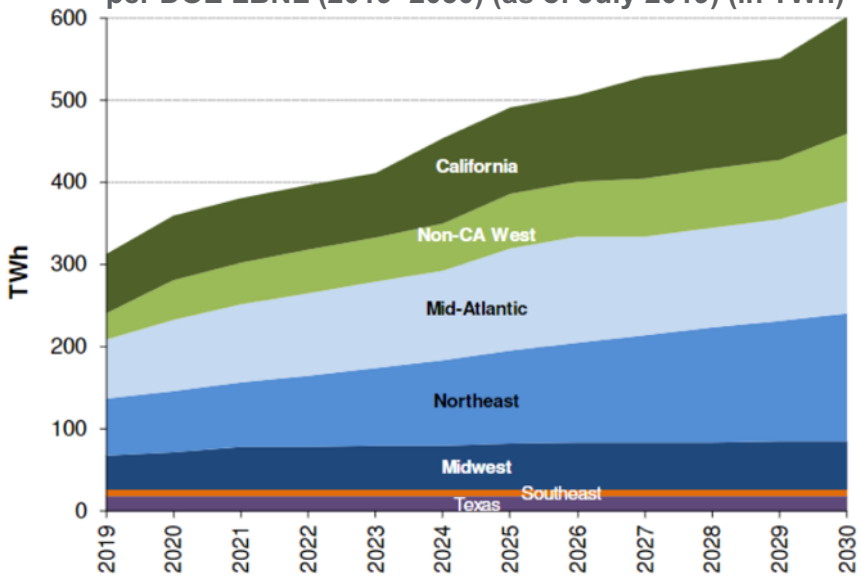


Sources: EIA; regional, NERC demand forecasts; NREL; LBNL; ScottMadden analysis

Integration Challenges – Renewable Portfolio Standard (RPS) Supply and Demand

- As seen in the map at left and the Northeast section of the chart below, the estimated demand for renewable resources in the ISO-NE region is expected to significantly outpace the forecast supply of renewables in the region, suggesting that future demand, at least in part, will need to be met by resources from outside the ISO-NE region.
- According to the Lawrence Berkeley National Laboratory (LBNL), while the Northeast (including New England) is a relatively small market, almost all renewable energy capacity additions are serving RPS demand.

Projected U.S. RPS Demand (Total Compliance Requirements) per DOE LBNL (2019–2030) (as of July 2019) (in TWh)



Source: LBNL

Sources: LBNL 2019 RPS Analysis; EIA; regional, NERC demand forecasts; NREL Standard Scenarios; LBNL; ScottMadden analysis

Implications for Transmission

	Resilience	Integration of Renewables	Other Factors	Transmission Opportunities
New England ISO	▪ Severe weather is the largest cause of electrical disturbances, particularly due to system stress sustained during severe winter weather events in recent years ▪ Growing concerns about "fuel security" due to retirements of baseload nuclear, coal, and oil-fired units (5.2 GWs retired since 2013 or retiring soon) and increasing reliance on gas-fired generation capacity and variable renewable energy (3.2 GWs of gas and 13.5 GWs of wind generation in the queue) ▪ Thirteen (13) interconnections with neighboring regions in New York and eastern Canada used to meet 17% of the region's demand in 2018, and interconnection with different time zones provides additional diversity ▪ Retirement of oil-fired and dual-fuel capacity that has served as a lifeline for the region during recent winter weather events	▪ Current capacity and penetration of wind/solar is modest ▪ Significant growth in renewable capacity in the region will be needed to meet RPS-driven demand ▪ State procurement initiatives for large-scale clean energy resources have included significant capacity targets for new and existing capacity from solar, wind (including offshore), fuel cells, energy storage, biomass, and hydro imports ▪ Currently, 20 ETU interconnection requests in the queue, many to deliver zero- or low-carbon resources to or within the region ▪ More than 150,000 behind-the-meter solar PV installations, with a combined nameplate capacity of 2.9 GWs, with favorable state policies incentivizing continued growth of distributed solar	▪ More than 30 GWs of new distributed solar PV expected by 2023 may impact planning assumptions ▪ 20 MWs of grid-scale storage online since 2015, with proposals for 1.3 more by 2022, in addition to existing 1,800 MWs of pumped storage capacity in the region ▪ Most recent capacity auction cleared 4,040 MWs of efficiency and demand response, including 654 MWs of new resources ▪ Congestion considered to be minor concern in most areas, and mitigation by additional transmission upgrades is not currently warranted; uplift and congestion charges have been low since 2011 ▪ Fairly consistent state policies across the footprint, all with aggressive renewable energy goals and mandates	▪ Focus on moving hydropower from Canada, onshore wind from northern Maine, and offshore wind from southern New England ▪ Growing potential opportunity for offshore wind, with expected co-benefit to resilience to a point (wind resources may be curtailed below certain design temperatures during severe winter weather events) ▪ Investment of $10.9 billion from 2002 to 2019 in reliability-driven, regional cost-shared projects, and $1.3 billion planned over the planning horizon (as of June 2019) ▪ Opportunity to enhance degrading system frequency response capability from declining inertia

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