# Northeast Offshore Wind Regional Market Characterization

## A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind

October 2017

Report Number 17-21

Cover Image: Block Island Wind Farm

# Northeast Offshore Wind Regional Market Characterization

## A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind

*Final Report*

Prepared for:

**New York State Energy Research and Development Authority**

**Massachusetts Clean Energy Center**

**Massachusetts Department of Energy Resources**

**Rhode Island Office of Energy Resources**

**Clean Energy States Alliance**

Prepared by:

**Sustainable Energy Advantage, LLC**

Framingham, MA

NYSERDA Report 17-21 October 2017

# DOE Disclaimer

This material is based upon work supported by the U.S. Department of Energy award number DE-EE0007220. This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

# NYSERDA Notice

This report was prepared by BVG Associates, LTD in the course of performing work contracted for by the New York State Energy Research and Development Authority (NYSERDA), and reflects collaboration between NYSERDA and representatives of the Massachusetts Department of Energy Resources, the Massachusetts Clean Energy Center and the Rhode Island Office of Energy Resources (the Participating States) and the assistance of the Clean Energy States Alliance. The opinions expressed in this report do not necessarily reflect those of NYSERDA, the State of New York, or any of the Participating States, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, the Participating States and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, the Participating States and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

# Project Support

This report was written under contract with the New York State Energy Research and Development Authority (NYSERDA). The report is part of A Roadmap for Multi-State Cooperation on Offshore Wind Development, a project by the States of Massachusetts, New York, and Rhode Island.

The Roadmap project seeks to identify opportunities for cooperative action to help deploy offshore wind (OSW) in the Northeast at the scale necessary to reduce costs and establish a regional supply chain. It is funded in part by a $592,683 grant from the U.S. Department of Energy's federally administered State Energy Program to NYSERDA.

A Steering Committee[1] with representatives of the participating states and coordination from the Clean Energy States Alliance set project directions and ensured that project work products will be useful to the states. Preliminary results were vetted with an external Advisory Committee representing a range of energy sector, economic, and environmental expertise. Among the project's activities is the publication of analysis that can inform the states' decisions on OSW and be useful to a wide range of stakeholders.

[1] Nils Bolgen and Bill White (Massachusetts Clean Energy Center); Eric Steltzer (Massachusetts Department of Energy Resources); Doreen Harris and Greg Matzat (NYSERDA); and Christopher Kearns (Rhode Island Office of Energy Resources).

# Report Team

**Organizations:** Sustainable Energy Advantage, LLC, AWS Truepower, Daymark Energy Advisors, Meister Consultants Group

**Project Manager**: Robert C. Grace, Sustainable Energy Advantage, LLC

**Primary Authors:** Robert C. Grace, Jordan R. P. Shoesmith, Deborah Donovan, Cara Goodman, Nicole Hamilton (Sustainable Energy Advantage, LLC)

Bruce Bailey, (AWS Truepower)

Carrie Gilbert (Daymark Energy Advisors)

Wilson Rickerson, Egan Waggoner (Meister Consultants Group)

# Acknowledgements

Doreen Harris and Greg Matzat of NYSERDA provided project management. Members of the Steering Committee for the Multi-State Offshore Roadmap project contributed to the development of this study and reviewed the drafts. The Steering Committee members and other staff of participating state agencies who contributed information and served as reviewers were Rachel Ackerman, Nils Bolgen, and Bill White (Massachusetts Clean Energy Center); Farhad Aminpour, Michael Judge, and Joanne Morin (Massachusetts Department of Energy Resources); Doreen Harris and Greg Matzat (NYSERDA); Christopher Kearns (Rhode Island Office of Energy Resources); Warren Leon and Val Stori (Clean Energy States Alliance); and Paul Gromer (Peregrine Energy Group).

# Table of Contents

# Table of Figures

# List of Tables

# Summary

The Atlantic coast of the northeastern United States has significant technical potential for the deployment of offshore wind power generation. The Northeast states are well positioned to benefit from the deployment of offshore wind (OSW) as a resource that can stabilize volatile energy costs, create clean energy at a scale that can contribute to replacing the region's retiring fossil-fueled and nuclear plants, diversifying the supply mix of a region heavily reliant on natural gas, meeting the region's ambitious goals for addressing climate change impacts from the energy sector, and creating significant numbers of local clean energy jobs.

The European experience with OSW has produced an industry that has over 12 gigawatts (GW) of installed capacity thus far and is expected to reach 24.6 GW by 2020 and up to 40 GW by 2024. In 2014, the European OSW industry supported 75,000 full-time equivalent (FTE) jobs. Based on the existing pipeline of projects in Europe, the industry is expected to support approximately 125,000 FTE jobs by 2019 (Ernst & Young, 2015; Ho, Mbistrova, Pineda, & Tardieu, 2017).

Although the OSW resource of the Northeast region has the potential to meet the needs of the region, successful deployment thus far has been limited. While the Cape Wind project in Massachusetts was vital in starting the conversation in the United States about the potential of offshore wind—which led to the development of the Federal OSW permitting process, after 15 years navigating previously unchartered waters of permitting, long-term contracting, and public acceptance—the project has stalled due to cancelled power purchase agreements (PPA) and litigation. In Maine, two proposed 12 megawatts (MW) pilot projects were selected for long-term contracts by the Maine Public Utilities Commission (ME PUC). Statoil suspended development of its Hywind Maine project (selected in 2011) in 2013, but pre-construction research and development is underway on the University of Maine's Aqua Ventus I, an innovative floating technology demonstration project (selected in 2013). This project was selected to receive up to $40 million of DOE support. New Jersey has established an offshore wind renewable energy credit (OREC) program to drive OSW deployment. Although Fishermen's Energy's project, a fully permitted 24 MW pilot-scale Atlantic City Windfarm, received DOE support, the project stalled without New Jersey BPU approval to participate in the state's OREC program and due to failure to reach a funding milestone to receive additional DOE funding (U.S. Department of Energy, 2016; Offshore Wind Hub, 2016).

However, encouraging recent state and regional policy and project development activities suggest increasingly favorable prospects for OSW in the United States. The nation's first OSW development, Deepwater Wind's 30 MW Block Island Wind project, became operational in December 2016 in Rhode Island's state waters. In January 2017, the Long Island Power Authority (LIPA) selected Deepwater Wind's 90 MW South Fork Wind Farm for a long-term PPA. The Bureau of Ocean Energy Management (BOEM) continues to oversee the auctioning of lease areas off the Atlantic coast, awarding to Statoil in December 2016 a hotly-contested lease in New York State's first Wind Energy Area that can support up to 1 GW of OSW capacity. In addition, legislation enacted in Massachusetts in 2016 requires the state's utilities to solicit 1.6 GW of OSW between 2017 and 2027. In early 2017, New York Governor Andrew M. Cuomo announced a statewide target of 2.4 GW of OSW capacity by 2030.

This report presents a Regional Market Characterization (RMC), one component of "A Roadmap for Multi-State Cooperation on Offshore Wind Development," a DOE-funded effort Massachusetts, New York, and Rhode Island to evaluate the potential for mutual action that could bring OSW to scale in the region. The report describes the context for OSW deployment in the region and seeks to answer the question: *What could the scale of near-term and long-term regional OSW deployment be, given the nature of regional OSW resources and supply chain, individual state policy drivers and initiatives, regional energy needs as well as the region's existing resource base?*

A project team consisting of Sustainable Energy Advantage, LLC (SEA) and its subcontractors, AWS Truepower, Daymark Energy Advisors, and Meister Consultants Group, was commissioned to develop a forward-looking estimate of the potential market for OSW, expressed in installed capacity and associated energy production. In the report, they present the OSW market potential as a range of likely regional OSW deployment bounded by low- and high-deployment trajectories in Atlantic waters off the northeastern U.S. coast through the year 2030. In addition, the project team compiled and summarized data and other background information on OSW development potential, electric system and market factors, and state and regional policies, and developed plans and other initiatives that are relevant to the future potential for building out the OSW resource in the Northeast.

## S.1 Analytical Approach

The assessment focused on potential generation from OSW projects in Atlantic waters for delivery to any of the individual participating states and other New England states, including potential OSW deployed off New Jersey's shores that might be delivered to New York State. To characterize the potential scale of the northeast OSW market, as it may ramp up over the study timeframe, the RMC examined the range of opportunities and constraints expected to shape the market for OSW through 2030.

The OSW Market Characterization analysis of the Northeast OSW market produced High Regional OSW Deployment and Low Regional OSW Deployment trajectories which, the authors believe, depict the range of the most likely OSW deployment in the future. The Regional OSW Deployment trajectories considered drivers influencing the regional market potential in the following categories:

- OSW characteristics
- Electric system and market characteristics
- Policies and plans that impact OSW

Within each of these categories, the authors researched and analyzed data and made assumptions for each of the factors listed in the second column of Table ES-1. The project team developed a spreadsheet model to assess the impacts of each of the identified drivers, opportunities and constraints, as well as their interactions. Baseline data and forecasts were combined in a bottom-up model with assumptions to test the impact of high- and low-assumptions for various unknowns to determine which factors were most likely to establish bounds on OSW deployment over time.

The potential range of future regional OSW deployment is restricted by factors that serve as a ceiling (or maximum range of penetration), an opportunity, or a floor (or minimum range of penetration) for each individual market driver category. Other factors analyzed serve as a comparative benchmark. The authors assumed that, for each category of market driver, the upper bound on OSW deployment would be constrained by the most binding constraint at any given time from among the factors within the category. For each component of the analysis, the factors that were determined to be most applicable in establishing the Low- and High-Regional OSW Deployment trajectories were composites of the individual factors analyzed. These factors are summarized as follows (and shown in the third column of Table ES-1):

- Development Pipeline and Buildout Potential as determined by OSW Characteristics
- OSW Share of the Maximum Integration of Variable Energy Resources (VER) into the Electric System Grid as determined by Electric System Characteristics
- OSW Share of the Policy-Driven Demand for Renewable Energy Generation as determined by Policy Drivers

**Table S-1. Overview of Market Analysis**

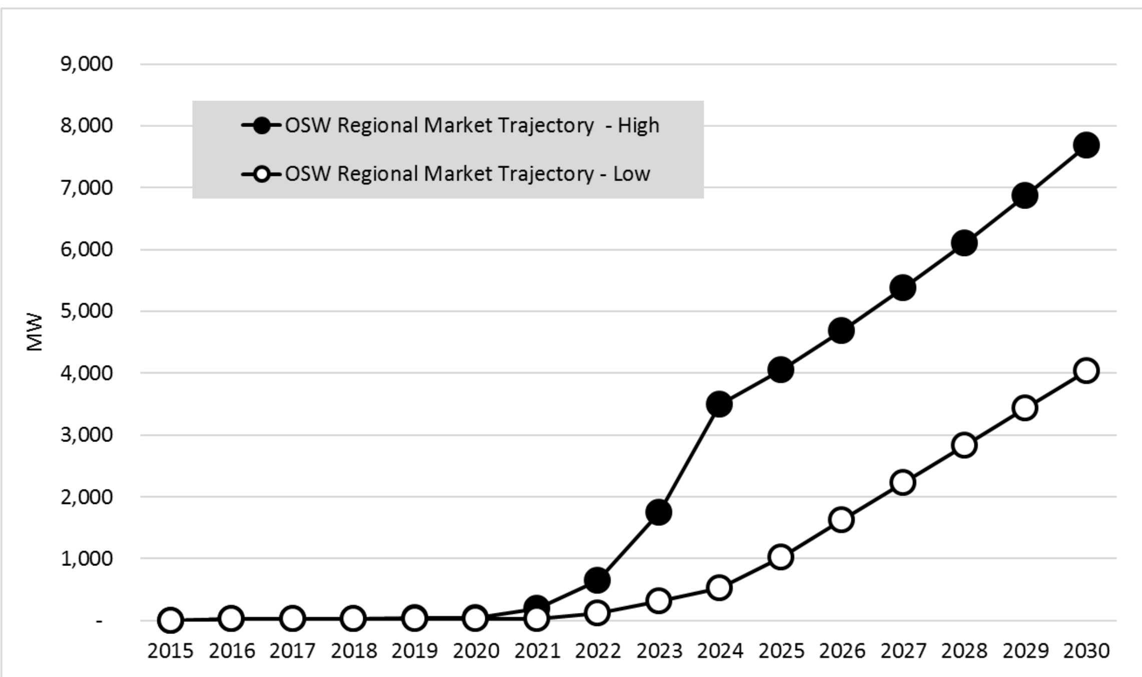
| Component of Analysis | Major Factors Analyzed | Constraining Factors |
|---|---|---|
| OSW Characteristics | • Resource potential<br>• Current development pipeline<br>• Current and future lease areas<br>• Feasible pace and density of OSW buildout<br>• Technology performance characteristics | Development Pipeline and Buildout Potential |
| Electric System and Market Characteristics | • Future electricity demand<br>• Future deployment of technologies that influence load<br>• Interconnection availability<br>• The current and evolving mix of generating capacity in the region, in particular the expected retirements of fossil and nuclear generation<br>• Physical limitations on integration of variable resources<br>• The feasible OSW share of VERs and of retiring generation | OSW Share of the Maximum Integration of Variable Energy Resources into the Electric System Grid |
| Policy Drivers | • Demand for renewable generation through Renewable Portfolio Standard (RPS) mandates<br>• Deployment of other renewable energy (RE) and traditional non-RE technologies through set-asides and procurement policies<br>• Resulting uncommitted incremental RPS demand available to OSW<br>• Greenhouse gas (GHG) reduction targets;<br>• Non-RPS renewable energy procurement policies and plans<br>• OSW-specific procurement policies and plans | OSW Share of the GHG Policy-Driven Demand for Renewable Energy Generation |

Of course, the relative cost competitiveness of OSW compared to other generation resources also impacts OSW's potential deployment. However, relative cost was explicitly defined as outside the scope of this analysis, which presumes that OSW will continue to have a cost premium during the study period, and assesses the possible role of OSW in the context of that premium.

## S.2 Findings

When examined in combination, the three component analyses form the low and high bounds of potential market penetration of OSW through 2030. The high and low bounds reflect expectations and assumptions about the course of development potential, market factors, and state and regional policies during the study period. The result is expressed as the range of likely scale of OSW deployment (MW) and energy production (GWh) over time. Based on the RMC's analytical approach, the Low- and High-Regional OSW Deployment trajectories are shown in Figure ES-1 (cumulative installed MW) and Figure ES-2 (GWh per year production). The high trajectory is constructed as a theoretical upper limit based on the high-end assumptions of the factors listed in Table ES-1. It is not presumed that the OSW industry will necessarily be able to achieve the high trajectory, but rather that actual deployment will likely fall between these bounds.

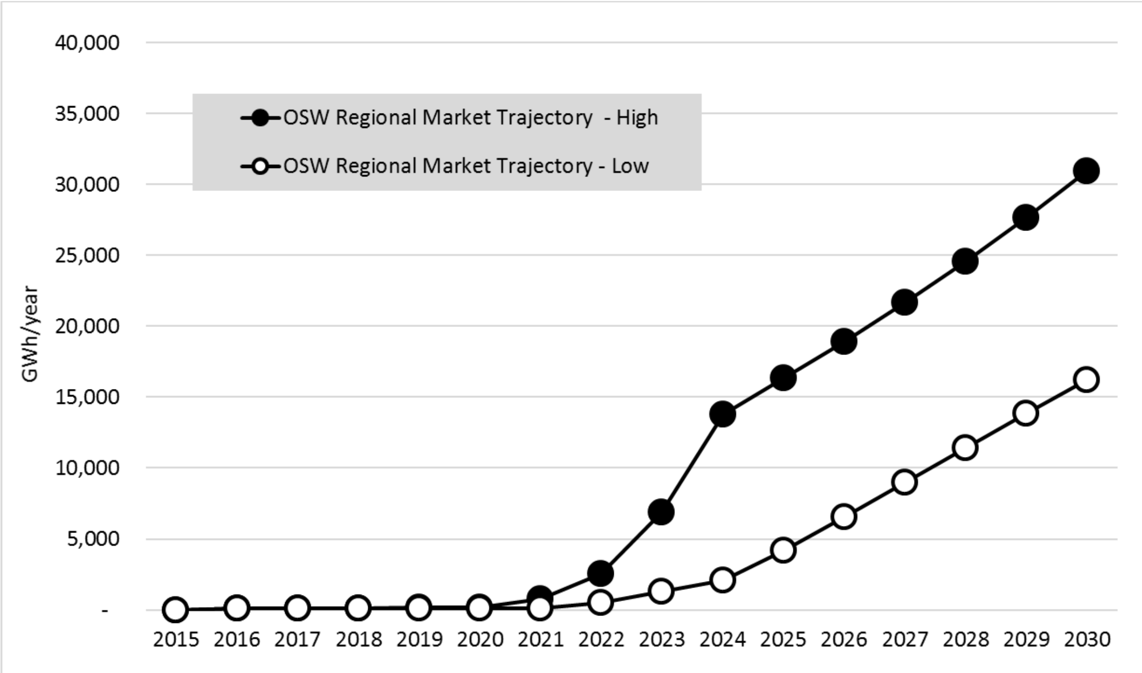
**Figure S-1. Low and High Regional OSW Deployment Trajectories (Cumulative MW)[2]**




---

2 Capacity in each year is assumed to be fully operational by end of given year.

**Figure S-2. Low and High Regional OSW Deployment Trajectories (GWh/year)**




## S.3 Areas for Further Study

As noted in Section 6.1, the analysis could be refined to consider the cost of OSW compared to other resources. Such an analysis would be particularly appropriate in the context of rapidly falling prices for OSW in Europe. Contract announcements during 2016–2017 for European projects have been in the range of $70-$140/MWh (Hundleby & Freeman, 2017). This trend reflects the well-established infrastructure and supply chain in Europe, the movement to larger wind turbines, and other project-specific factors. Given these factors, a direct comparison to potential prices in the U.S. market cannot yet be made. Nevertheless, lower prices for offshore wind would enable it to supply a larger share of the generation needed to compensate for power plant retirements and to address commitments to greenhouse gas reductions in the Northeast.

# 1 Introduction

## 1.1 Background

The Atlantic coast of the northeastern United States has significant technical potential for the deployment of offshore wind power generation. The Northeast states are well positioned to benefit from the deployment of offshore wind (OSW) as a resource that can stabilize volatile energy costs, create clean energy at a scale that can contribute to replacing the region's retiring fossil-fueled and nuclear plants, diversifying the supply mix of a region heavily reliant on natural gas, meeting the region's goals for reducing greenhouse gas (GHG) emissions from the energy sector, and creating significant numbers of local clean energy jobs. The robust deployment of OSW in coastal European waters demonstrates that the industry is rapidly advancing. To date over 12 gigawatts (GWs) of OSW projects are currently operating, supporting 75,000 jobs with industry expectations to grow to 40 GW by 2024 (Ernst & Young, 2015; Karst, 2016; Ho, Mbistrova, Pineda, & Tardieu, 2017). However, because OSW is still an emerging industry in the U.S., its cost at present exceeds that of natural gas, land-based wind (LBW) and utility-scale solar (Cole, et al., 2016).

While some areas of the Northeast have the potential for a significant amount of LBW development, many of the most favorable sites for LBW development are either far from coastal-load centers or located in transmission-constrained areas. Fully building out large amounts of LBW capacity in the Northeast is further constrained by limitations on transmission capacity and concerns about a range of potential local impacts of wind development.

The OSW resource of the Northeast region has the potential to overcome many of the obstacles that are influencing the development of LBW and to meet the other needs of the region, but successful deployment thus far has been limited. While the Cape Wind project in Massachusetts was vital in starting the conversation in the United States about the potential of offshore wind—which led to the development of the Federal OSW permitting process, after 15 years navigating previously unchartered waters of permitting, long-term contracting, and public acceptance—the project has stalled due to cancelled power purchase agreements (PPA) and litigation. In Maine, two proposed 12 MW pilot projects were selected for long-term contracts by the Maine Public Utilities Commission (ME PUC). Statoil suspended development of its Hywind Maine project (selected in 2011) in 2013, but pre-construction research and development is underway on the University of Maine's Aqua Ventus I, an innovative floating technology demonstration project (selected in 2013). This project was selected to receive up to $40 million of DOE support. New Jersey has established an offshore wind renewable energy credit (OREC) program to drive OSW deployment. Although Fishermen's Energy's project, a fully permitted 24 MW pilot-scale Atlantic City Windfarm, received DOE support, the project stalled without New Jersey BPU approval to participate in the state's OREC program and due to failure to reach a funding milestone to receive additional DOE funding (U.S. Department of Energy, 2016; Offshore Wind Hub, 2016).

However, encouraging recent state and regional policy and development activities suggest increasingly favorable prospects for OSW deployment, including the more streamlined auction process administered by the Bureau of Ocean Energy Management (BOEM)[3], opening up current unleased areas and new future lease areas off the coasts of Massachusetts, Rhode Island, New Jersey and New York. In addition, the following create substantial demand pull and market visibility for increased regional OSW deployment 1) the passage of an energy bill in Massachusetts that includes a provision for the solicitation of 1.6 GW of OSW between 2017–2027, 2) the announcement in New York of a Clean Energy Standard (CES) requiring 50% of power to be renewable by 2030 (explicitly including development by NYSERDA of a state program to maximize the potential and value of OSW), and 3) New York's statewide OSW target of 2.4 GW by 2030.. In late 2016, the nation's first OSW project—the 30-MW Block Island Wind Farm—reached commercial operation (Deepwater Wind, 2016), and in January 2017, the Long Island Power Authority (LIPA) selected Deepwater Wind's 90 MW South Fork Wind Farm for a long-term PPA. Collectively, these developments point to an emerging OSW market in the Northeast.

Market scale and visibility have been identified as major drivers to cost reduction for OSW (BVG Associates, 2015). Europe's most recent experience with OSW has demonstrated that a market of sufficient scale and duration can reduce costs. A central premise of the OSW Roadmap project is that the Northeast states can achieve cost reductions in OSW by working collaboratively to bring scale and cost reductions to OSW market. The OSW Roadmap project—a DOE-funded effort of Massachusetts, New York, and Rhode Island to examine barriers to OSW, identify opportunities that might benefit from regional collaboration and the potential for mutual action to bring OSW to scale in the region—is a manifestation of this premise. One of the components of the OSW Roadmap project is the development of a Regional Market Characterization Report (RMC) that supports, by summarizing the near and long-term regional OSW market in the Northeast, the development of the OSW Roadmap. This

[3] For more information on BOEM's offshore wind lease area auction process, see (Ausubel & Cramton, 2011).

RMC seeks to answer the question: *What could the scale of near-term and long-term regional OSW deployment be, given the nature of regional OSW resources and supply chain, individual state policy drivers and initiatives, regional energy needs as well as the region's existing resource base?* This report will serve as a foundation to later analyses that will be part of the development of a Regional OSW Roadmap.

The New York Energy Research and Development Authority (NYSERDA), the lead-contracting agency representing New York in the OSW Roadmap effort, commissioned Sustainable Energy Advantage, LLC (SEA) and its subcontractors, AWS Truepower, Daymark Energy Advisors, and Meister Consultants Group, (the "project team"), to develop the RMC.

In developing the RMC, the project team focused on assessing the market for OSW in the participating states of Massachusetts, New York, and Rhode Island, as well as the nonparticipating regional states of Connecticut, Maine, New Hampshire, and Vermont, because of the regional nature of the electricity market.[4]

## 1.2 Objectives of This Report

The primary objective of the RMC is to develop a forward-looking estimate of the potential market for OSW, expressed in installed capacity and associated energy production. The market potential is presented as an estimated range of the likely scale of OSW deployment, bounded by low- and high-deployment trajectories, in Atlantic waters off the Northeastern United States through the year 2030.

In preparing the RMC, the project team compiled and summarized data and other background information relevant to the future potential for building out the OSW resource in the northeast in the following categories:

- OSW deployment potential as determined by resource potential, current development activity, current and future lease areas, interconnection opportunities and constraints, and technology performance characteristics.
- Electric system and market factors such as future electricity demand, the current and evolving supply mix in the region, and physical limitations on integration of variable resources.

4 To the extent that markets in the Mid-Atlantic region will interact with the development of OSW in the region that is the primary subject of this report, the project team also generally characterized the market in that region and considered deployment in federal waters off of New Jersey which might deliver its output into New York.

- State and regional policies that create demand for low-carbon and renewable energy in general, and OSW in particular.

Some of this information, such as electric market factors and state and regional policies, directly supported development of the Low- and High-Regional OSW Deployment trajectories. Other information, such as general OSW development potential and electric system limitations, served as valuable reality checks on the overall feasibility of the deployment trajectories.

## 1.3 Limitations of This Report

Readers of this report should keep in mind the following important limitations:

- The characterization of the regional market for OSW does not represent a forecast of what is expected to be developed. Rather, it conveys a quantification of the potential size of the OSW market. The low and high bounds of that market size are determined by some assumptions about various opportunities and constraints.
- The trajectories derived make no presupposition about the responsibility for or support of OSW by any particular state within the region beyond the presumption that procurement targets recently adopted by Massachusetts and New York are fulfilled; rather, they represent the potential market scale that could be arrived at through future individual or collective state or regional actions.
- The inputs to the market characterization are based on desktop research and include available data. The project team did not generate any new data or conduct any original research solely for the purpose of this report.
- The opportunities and constraints reflected in the market characterization do not explicitly take into consideration the relative costs of OSW versus other renewable and non-renewables generation technologies. While studies indicate that, today, OSW projects produce energy at a higher cost than the lowest-cost renewable energy alternatives, studies also indicate that, over time and at scale, OSW costs would decrease dramatically. The OSW Roadmap project, of which this report is a part, is focused on how collective actions of states in the region can lower OSW costs and the pace of those reductions. Thus, the relative cost of OSW is an outcome of the study, and not an input assumption.
- Siting and permitting of OSW projects will determine the viable locations of, as well as the lead time and pace of development, and as such these factors are relevant to the market characterization. However, despite potential constraints on OSW location such as those suggested in a recent U.S. Coast Guard Study (U.S. Coast Guard, 2016)—because of the significant technical resource potential and BOEM's ability to offer additional leases to further build out that technical potential—this study assumes that siting and permitting will not limit the scale of the market between now and 2030.

## 1.4 Organization of Report

This report is organized as follows:

The factors influencing OSW market scale and timing are addressed in three chapters following this introduction:

- Information pertaining to OSW deployment as a function of resource potential and constraints (Chapter 2)
  Information dictating the potential demand for OSW as a function of Market Factors (Chapter 3)
- Information dictating the potential demand for OSW as a function of State and Regional Policies, Programs, and Plans (Chapter 4)

Chapter 5 presents the results of the collective market assessment, along with a description of the inputs, assumptions, and methodology used to develop the market assessment. The analysis details are included in Appendix A. Chapter 6 contains conclusions and recommendations for further analysis.

# 2 Offshore Wind Development Potential and Constraints

This chapter provides a broad assessment of the development potential for OSW resources in the region consisting of New England, New York, and New Jersey[5] as well as a discussion of significant economic and systemic barriers that could constrain OSW deployment and integration. The chapter focuses primarily on regional OSW resource potential, lease areas and projects currently under construction, planned or proposed. It also summarizes key constraining factors including economics, permitting, supply chain, as well as interconnection and transmission. It summarizes likely interconnection infrastructure, and highlights projected OSW energy production (i.e., capacity factors [CFs]) and peak coincidence.

## 2.1 Offshore Wind Resource Potential

Table 1 summarizes the gross OSW resource potential for New York State, the five coastal New England states, and New Jersey, according to a 2016 National Renewable Energy Laboratory (NREL) study (Musial, Heimiller, Beiter, Scott, & Draxl, 2016). The NREL study categorized gross resource potential by the following terms:

- wind speed at 100 meters hub height in 0.25 meters per second (m/s) (0.56 mph) intervals beginning with 7.0 m/s (16.7 mph)
- water depths in ranges of 0-30 m, 30-60 m, and 60-700 m, and 700-1,000 m[6]
- distance from shore at intervals of 0-3 nautical miles (nm), 3-12 nm, 12-50 nm and 50-200 nm

5 New Jersey is included in this summary because of the potential for delivery of electricity from projects in waters off New Jersey to New York. For the analysis underlying this report, we assumed that up to 50% of U.S. Wind's New Jersey lease area (OCS-A 0499) could be developed for delivery into New York State.

6 Resource potential in water depths greater than 60 m in the Great Lakes was excluded.

**Table 1. Gross Regional OSW Resource Potential between 12-50 nm from Shore**

*Source: (Musial, Heimiller, Beiter, Scott, & Draxl, 2016)*

| NREL Gross OSW Potential (MW) | |
|---|---|
| **State** | |
| CT | - |
| ME | 56,530 |
| MA | 82,704 |
| NH | 460 |
| NJ | 42,061 |
| NY | 42,888 |
| RI | 8,364 |
| **Total** | **233,007** |

The values in Table 1 represent a subset of the NREL data consistent with current trends in OSW development, which are focused on areas between 12 and 50 nm from shore and possess minimum average wind speeds of 8.5 m/s (19.0 mph).[7] Development potential, expressed in megawatts (MW) of installed capacity, was originally determined in the NREL study by multiplying the amount of water area by a uniform factor of 3 $MW/km^2$. This development density, which is reflected in Table 1, was applied in our analysis. The resource estimates summarized here were not reduced by any environmental or water-use exclusions (such as shipping lanes) and thus should be considered as theoretical maximum values.

The water depth intervals are intended to reflect the general types of foundation technologies used to develop a given OSW project (Musical W., 2007). Monopoles and gravity foundations are assumed for depths of 0-30 m while jacket and truss-type structures are assumed for depths of 30-60 m.[8] In deeper water, floating platforms instead of fixed bottom foundations are assumed. Floating platforms are currently in the precommercial phase of development. Water depth and foundation type are factors that have a bearing on the capital costs of OSW.

---

7 The purpose of Table 1 is to only illustrate the sizable resource of offshore wind that is available just off the Northeast Coast, not the amount of offshore wind that is expected to be developed.

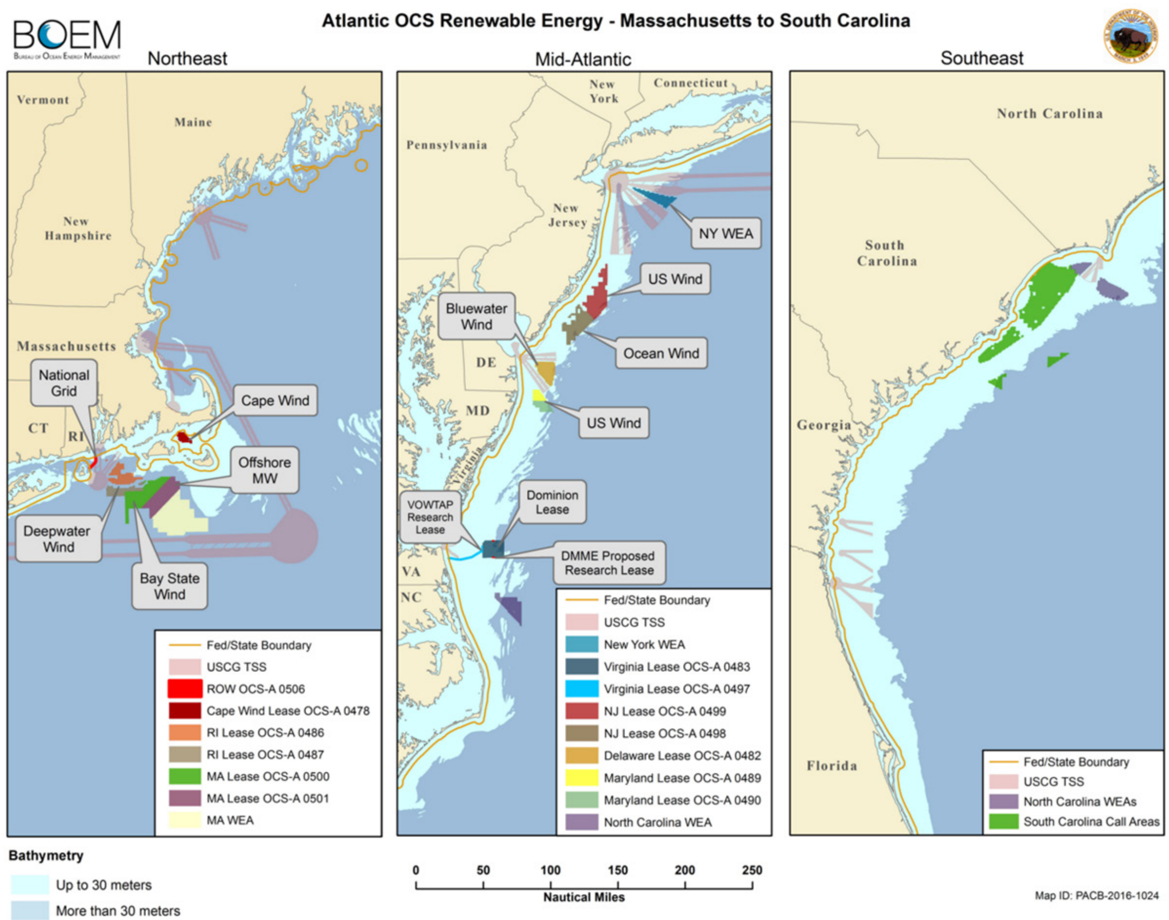
8 While many projects in waters deeper than 30 m still use monopoles, this assumption is a modeling simplification.

## 2.2 Offshore Wind Lease Areas

Deployment of OSW in federal waters requires that an OSW developer acquire a lease from the Bureau of Ocean Energy Management (BOEM). In recent years, BOEM has defined lease areas for OSW deployment in federal waters for four states within the region relevant to this study: Rhode Island, Massachusetts, New York, and New Jersey. Figure 1 shows the location of each of these lease areas, in addition to other lease areas identified by BOEM elsewhere along the Atlantic coast. With the exception of the Nantucket Sound area (Cape Wind project), all areas begin at a distance of least 12 nautical miles (13.8 statute miles) from shore and have water depths less than 60 m (BOEM, 2016a). As shown in Table 2, the lease areas identified in these states have a cumulative area of over 4,700 square kilometers ($km^2$) and a total resource potential of approximately 15 GW.

There are two unleased lease areas within the Massachusetts Wind Energy Area (WEA) (OCS-A 0502 and OCS-A 0503), which cover an area of 1,600 $km^2$ and have a cumulative resource potential of approximately 4,700 MW. In December 2016, Statoil, which recently won the lease auction for the first New York State WEA, and PNE Wind, a German-based developer that has participated in previous OSW lease auctions, each submitted unsolicited lease requests with BOEM for both unleased portions of the MA WEA (PNE Wind, 2016a; Statoil, 2016). Given that both developers nominated the same Massachusetts area, BOEM determined that competitive interest exists and announced that it will proceed with a competitive leasing process for lease areas OCS-A 0502 and OCS-A 0503 (BOEM, 2017a). In addition, on October 2, 2017, New York State announced that it submitted an Area for Consideration for OSW development off New York's Atlantic Coast to BOEM, requesting that BOEM identify and lease at least four new WEAs, each capable of accommodating at least 800 MW of OSW capacity (New York State, 2017).

**Figure 1. BOEM Atlantic OSW Lease Areas**[9]




There are currently no proposed OSW projects in federal waters off the coasts of New Hampshire and Maine. Table 2 summarizes the BOEM lease areas by area designation and by the maximum potential capacity (in MW). Assuming the NREL standard power density of 3 MW/km$^2$ for projects without specific associated MW, the lease areas comprise a total potential OSW buildout of nearly 15 GW.[10]

9 Updates to map: Statoil won the lease auction for the New York WEA. Bluewater Wind sold the rights to its lease area off the coast of Delaware to Deepwater Wind. Ocean Wind sold the rights to its lease area off the coast of New Jersey to DONG Energy. The lease area off the coast of North Carolina was recently won by Avangrid. OffshoreMW is now Vineyard Wind.

10 For illustrative purposes, based on the 3 MW/km$^2$ density factors, the 667 km$^2$ RI/MA lease area has a developable resource potential of 2001 MW (667 km$^2$ * 3 MW/km$^2$), which could support approximately 250 8-MW wind turbines or 200 10-MW wind turbines.

**Table 2. Northeast BOEM Lease Areas (MW)**

*Source: (BOEM, 2016a; DOE, 2017)*

| Lease Areas | Lease | MW[11] | Area ($km^2$) | Year Leased |
|---|---|---|---|---|
| Current Wind Energy Areas (portions entirely leased) | | | | |
| MA Nantucket Sound (Cape Wind) | OCS-A 0478 | 468 | 119 | 2010 |
| RI/MA WEA (Deepwater Wind) | OCS-A 0486 & 0487 | 2,001 | 667 | 2013 |
| MA WEA (DONG) | OCS-A 0500 | 2,277 | 759 | 2015 |
| MA WEA (Vineyard Wind) | OCS-A 0501 | 2,025 | 675 | 2015 |
| NY WEA (Statoil) | OCS-A 0512 | 1,000 | 321 | 2016 |
| NJ WEA (US Wind) | OCS-A 0499 | 2,226 | 742 | 2016 |
| NJ WEA (DONG)[12] | OCS-A 0498 | 1,947 | 649 | 2016 |
| Current Wind Energy Areas (unleased areas) | | | | |
| MA WEA | OCS-A 0502 | 3,012 | 1,004 | TBD |
| MA WEA | OCS-A 0503 | 1,707 | 569 | TBD |
| Total | | 16,663 | | |

## 2.3 Offshore Wind Projects under Construction, Planned or Proposed

Compared to Europe, which has 92 OSW projects (including sites under construction at the end of 2016), the OSW market in the northeastern U.S. is in its infancy (Ho, Mbistrova, Pineda, & Tardieu, 2017). Nonetheless, the region is experiencing an increasing level of OSW development activity. While most of the proposed OSW projects are in the early planning phases of development, the nation's first pilot-scale OSW plant, Deepwater Wind's 30-MW, five-turbine Block Island Wind Farm, became operational in December 2016, and the 12-MW Maine Aqua Ventus pilot-scale floating OSW project—recently selected

11 Each lease area's developable resource potential is based on NREL density assumption of 3 MW/$km^2$, unless otherwise specified.

12 For the purposes of this analysis, it is assumed that any output from a project within this lease area will not be delivered into New York State. As a result, the lease area is not included in the analysis.

as eligible for additional DOE funding—continues development activities (DOE, 2016). As for larger-scale OSW projects, while Cape Wind's development efforts in Nantucket Sound have stalled, Deepwater Wind, Vineyard Wind, DONG Energy[13] and Statoil have acquired the rights to expansive lease areas in the region and have proposed OSW projects of varying sizes. In January 2017, Deepwater Wind was selected to develop the first 90 MW from within its lease area, with output to be sold to LIPA under a long-term PPA. Table 3 below details all current or planned OSW projects at any stage of development in existing state or federal lease areas off the coasts of New England, New York, and New Jersey.

**Table 3. Regional Offshore Wind Projects at Any Stage of Development Within Existing State or Federal Lease Areas**

*Source(s): (Smith, Stehly, & Musial; Baranowski, Oteri, Baring-Gould, & Tegen, 2016; BOEM, 2016d; NYSERDA, 2016c; DOE, 2017; Deepwater Wind, 2017; U.S. Wind, 2017)*

| Project Name (Developer) | Capacity (MW) | State | Development Status | Notes |
|---|---|---|---|---|
| Aqua Ventus I **(Maine Aqua Ventus I GP LLLC)** | 12 | ME | Permitting / Initial Dev. | Floating technology demonstration project. ME PUC term sheet for $0.23/kWh, Project has received $10.7 m DOE funding since 2012. Eligible to receive up to $40 m in additional DOE funding.[14] |
| Atlantic City Windfarm – Phase I **(Fishermen's Energy)** | 24 | NJ | Dormant | Technology demonstration project. Has received $10.7 m in DOE funding since 2012. Missed milestone deadline to receive up to $40 m in additional DOE funding. |
| Bay State Wind **(DONG Energy and Eversource Energy)** | 1,000 | MA | Early Planning | Developer expected to bid into the 2017 Massachusetts Sec. 83C RFP. |
| Block Island Wind Farm **(Deepwater Wind)** | 30 | RI | Operational | PPA w/ National Grid, Cost capped at $0.24/kW. Operational as of December 2016. |
| Cape Wind **(EMI)** | 468 | MA | Dormant | Lease suspension expired July 24, 2017. |

[13] On October 2, 2017, DONG Energy announced that it would be changing its name to Ørsted, pending approval by the company's shareholders (DONG Energy, 2017). Given that the announcement postdated this analysis, in this report we still refer to the company as DONG Energy or DONG.

[14] In 2016, the Aqua Ventus I and Atlantic City Windfarm projects were both selected by the DOE for the next phase of its Offshore Wind Advanced Technology Demonstration (ATD) Projects Initiative, making them eligible to receive up to $40 million in additional funding. However, Atlantic City Windfarm missed the ATD milestone deadline for securing an offtake agreement and thus is no longer eligible for additional DOE funding (DOE, 2016).

**Table 3 continued**

| Project Name (Developer) | Capacity (MW) | State | Development Status | Notes |
|---|---|---|---|---|
| Deepwater ONE[15] **(Deepwater Wind)** | 210 - 1,200 | RI/MA | Early Planning | This lease area will be built out in phases beginning with the South Fork project and including Revolution Wind (see below). |
| **(US Wind)** | ~ 1,500 | NJ | Early Planning | - |
| Ocean Wind **(DONG Energy)** | 1,000 | NJ | Early Planning | - |
| Revolution Wind **(Deepwater Wind)** | 96 - 288 | RI/MA | Early Planning | Submitted bid under Massachusetts Sec. 83D RFP.[16] If selected, operational by Q4 2023. |
| South Fork Wind Farm **(Deepwater Wind)** | 90 | RI/MA | Permitting / Initial Dev. | Selected and approved by PSEG-LI and LIPA for long-term contract. Operational by 2020. |
| **(Statoil)** | 1,000 | NY | Early Planning | - |
| Vineyard Wind **(Vineyard Wind LLC, Copenhagen Infrastructure Partners, and Avangrid Renewables)** | 400 - 1,600 | MA | Early Planning | Developer filed Site Assessment Plan with BOEM in March 2017. Expected to bid into the 2017 Massachusetts Sec. 83C RFP. |

While many factors may dictate which of these efforts will result in operating OSW projects, this group of projects represents the front end of the development pipeline which will be used in this report to represent the outer-bounds of near-term market potential until other lease areas and development activities progress.

## 2.4 Barriers and Constraints to Offshore Wind Deployment

There are a number of factors that have the potential to constrain OSW deployment during the study period, including the cost-competitiveness of OSW, permitting timelines, the lack of a sufficient OSW supply chain in the U.S., as well as interconnection and transmission issues. Each topic is discussed in brief in this section.

15 Deepwater Wind has submitted a Site Assessment Plan to BOEM.

16 Deepwater Wind recently submitted a proposal for its 144 MW Revolution Wind project under the Massachusetts 83D RFP, which would be constructed within Deepwater Wind's OCS-A 0486 lease area (the Deepwater One area) (Deepwater Wind, 2017). This project was announced after the analysis conducted in this paper was complete and is thus not included in the analysis' existing pipeline assumptions.

### 2.4.1 Economics

Levelized cost of energy (LCOE) is a useful metric for comparing the cost of various technologies on a per-unit basis.[17] Recently published comparisons of LCOE for different technologies for projects built in 2015 (shown in Figure 2) reflect a wide range as a function of regional resource potential, regional cost differences, scale economies and variation in the cost to interconnect.[18] These recent published comparisons of LCOE estimates show that, for a hypothetical OSW project built in 2015, the LCOE is materially higher than that of LBW and also higher than utility-scale solar PV.[19]

However, recent studies show that LCOE for OSW in the Northeast is expected to decline over time as a function of global cost reductions, as well as greater scale and market visibility in the U.S. The University of Delaware's Special Initiative on Offshore Wind (SIOW) released a study titled *Massachusetts Offshore Wind Future Cost Study* in March of 2016 projecting that the LCOE of OSW built in coastal waters of Massachusetts (inclusive of transmission and interconnection) could be as low as $162/MWh for a project commencing commercial operation in 2023, $128/MWh for a project commencing commercial operation in 2026, and $108/MWh for a project commencing commercial operation in 2029. The analysis is in 2016 dollars and assumes an OSW project pipeline of 2000 MW deployed over 10 years (Kempton, McClellan, & Ozkan, 2016). In addition, NREL unveiled an analysis in the spring of 2016 projecting U.S. OSW costs of $125 to $150 per MWh for Massachusetts OSW projects in 2022 (Beiter, et al., 2016).

The degree of OSW LCOE reductions and the pace of such declines in the northeastern U.S. is a key subject of the OSW Regional Roadmap Initiative. Until factors such as global cost reduction, regional supply chain development, economies of scale, and operational experience reduce the necessary premium for OSW over other sources of renewable and zero carbon electricity, the rate and scale of its deployment will largely depend upon state policies as well as federal incentives such as the extension of the 30% Investment Tax Credit (ITC).

---

17 We note however that a simple comparison of LCOE does not take into account the differences in value of the production of different types of facilities, accounting for issues such as time of production and contribution to peak. As noted in Section 2.6, OSW has a greater peak coincidence than land-based wind, and therefore its production has a higher expected market value.

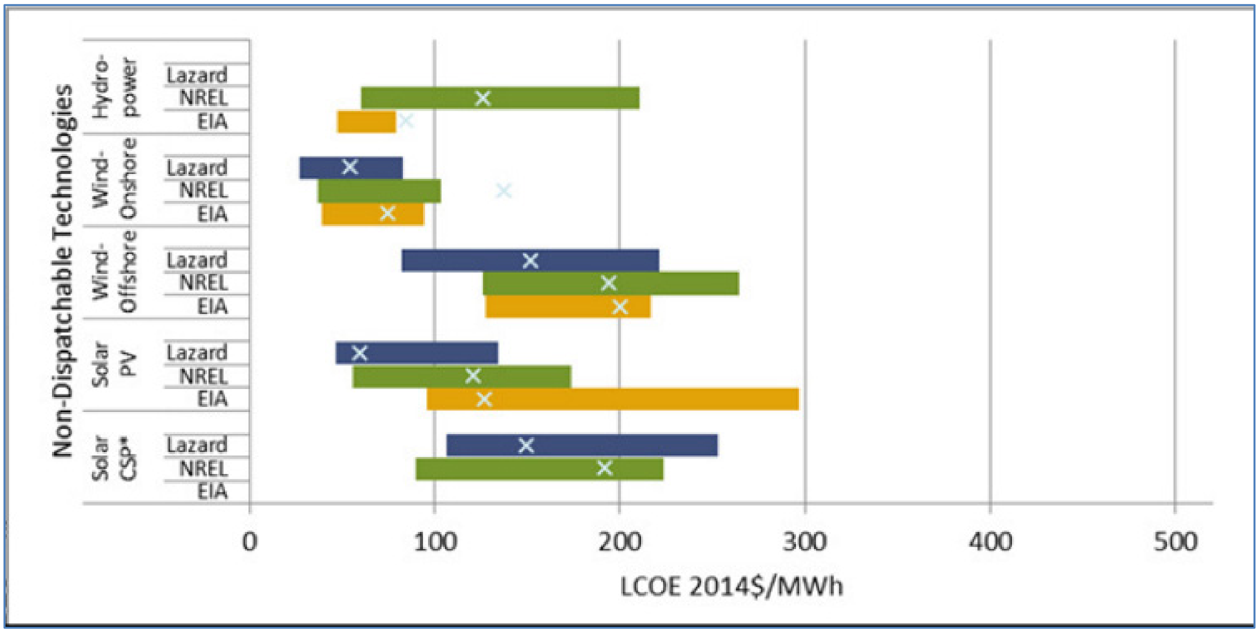
18 While the source – the 2016 NREL Annual Technology Baseline Discussion Draft (Cole, et al., 2016) – does not explicitly identify whether the OSW costs shown are national figures or representative of OSW projects in the Northeast, we assume that they are applicable to the Northeast as a benchmark for 2015.

19 We note that the 2015 LCOE figures are not forward-looking and reflect only historical data for generation technologies in 2015.

**Figure 2. LCOE Comparison of Offshore Wind versus Other Non-Dispatchable Renewable Energy Technologies for Systems Coming Online in 2015[20]**

*Source: (Cole, et al., 2016, p. 129).*

*Sources Shown in Table: (EIA (a), 2015; EIA (b), 2015; NREL, 2015b; Lazard, 2015)*




## 2.4.2 Permitting Timeline

An understanding of the regulatory challenges associated with OSW deployment in the United States is not complete without mention of the Cape Wind experience (Zeller, 2013). Initially proposed in 2001, the 468 MW-project proposed for federal waters in Massachusetts' Nantucket Sound sought approvals ahead of the development of any defined permitting process. It faced numerous legal challenges, local opposition and regulatory hurdles on the path toward receiving state and federal permits and the first OSW lease issued by BOEM. Because the project failed to secure financing, the power purchase agreements (PPAs) negotiated with utilities National Grid and NSTAR (now Eversource) expired in

[20] The ranges shown represent calculated values, while the average reported LCOE value is shown by the "x."

December 2014. The BOEM lease with Cape Wind is currently suspended, and since the Cape Wind lease location is ineligible for the Massachusetts Section 83C procurement, there are no apparent opportunities for a replacement PPA[21] (BOEM, 2016f; Hopper, 2015).

The shift of most development activity further offshore offers the promise of a less contentious process for those developers actively advancing projects at other lease areas throughout the region today. With respect to BOEM leases, there are several phases in the process, including planning and analysis; competitive bidding and leasing; site assessment; and construction and operations (Logan, 2015). A variety of federal and state permits are required to construct and operate an OSW facility.[22] Because the relevant authority is spread across numerous local, state and federal institutions, the regulatory process for the siting, permitting, and installation of OSW facilities can be time-consuming and expensive for developers. This is in part because few developers in the U.S. have progressed much farther through the regulatory process beyond acquiring rights to federal lease areas from BOEM. As such, the regulatory structure is underdeveloped and still adapting to a gradually emerging and new industry. As a result, the permitting process for new OSW projects could take up to approximately six years.[23] These activities occur contemporaneously with the process of arranging for interconnection and associated permits. For purposes of this RMC, the authors assume that, as a result of permitting and other factors, today it might take about six years after a lease is awarded for a WEA before an OSW project can begin construction. Pre-development activities such as the collection of baseline resource data, greater industry experience with the process, and efforts to further streamline the federal permitting process, could shrink to as little as five years from lease awards to completing construction.

---

21 In February 2015, BOEM approved a two-year lease suspension for Cape Wind. The initial lease awarded to Cape Wind by BOEM in April 2010 included a 33-year term, comprised of a 5-year site assessment term and a 28-year project operation term. The suspension enables Cape Wind to address its outstanding issues, including securing project financing, without affecting the operational term of the project, the period during which it could generate revenue. The lease suspension expires on July 24, 2017 (Hopper, 2015).

22 While a detailed description of the siting and permitting regime for OSW is beyond the scope of this RMC, a comprehensive description of the process can be found in (Thaler, Permitting and Leasing for Maine Offshore Wind Energy Projects - Offshore Wind Energy Project Roadmap, 2013).

23 For example, 30 CFR Part 585 (RENEWABLE ENERGY AND ALTERNATE USES OF EXISTING FACILITIES ON THE OUTER CONTINENTAL SHELF) provides a one-year preliminary term and a five-year site assessment term leading to an approved BOEM Construction and Operations Plan (COP). Project-specific issues could result in a request to BOEM for an extension, or alternatively, federal permitting could take less time.

## 2.5 United States Supply Chain

The European OSW industry, with over 12 GW of OSW facilities installed (Ho, Mbistrova, Pineda, & Tardieu, 2017), has matured mainly through industrialization and innovation on logistics to start aggressively driving down costs (Hannibal, 2016). In contrast—although there is substantial marine infrastructure in the region and nationally (such as the Gulf of Mexico offshore oil and gas industry supply chain)—the United States OSW industry supply chain, installation, and operations infrastructure is in its infancy. Supporting large-scale deployment of OSW in the northeastern U.S. will require, in the near-term, expansion of the supply chain for assembly, manufacturing of foundations and towers, electric infrastructure, operations and maintenance, and balance of plant. As the industry reaches critical mass, manufacturing of turbines and customized vessels—of the type currently deployed in Europe—is expected to expand. The extent to which the region can foster industry supply chain growth could be a key determinant of the rate and scale of OSW deployment, as well as a driver for achieving cost reductions, which in turn could further enable greater OSW deployment.

For example, the massive customized seagoing vessels, such as ships and jack-up barges that are today installing two turbines a day in Europe (Karst, 2016), are not currently available in U.S. waters. In June 2017, Zentech Inc. and Renewables Resources International (RRI) announced plans to build the U.S. OSW industry's first Jones Act-compliant, four-legged, self-propelled, dynamically positioned level 2 (DP2) jack-up vessel for OSW turbine installation, with delivery slated for no later than Q4 2018. The vessel will be designed to carry and install up to three 9-MW turbines with the ability for future modifications to accommodate four 8-MW turbines at a time and eventually 10-MW turbines (Zentech, Inc., 2017). It may still be difficult to attract additional investment in such vessels to be deployed before OSW development reaches an adequate scale. Furthermore, European vessels hired for construction of U.S. projects cannot be used optimally due to the Jones Act (The Merchant Marine Act of 1920 [Jones Act], 2012). The Jones Act effectively prohibits foreign-flagged vessels from transporting "merchandise" between any two points in the U.S. Vessels used to transport OSW turbine components from U.S. ports to their offshore sites must therefore be manufactured and registered in the U.S. and further must be owned and operated by U.S. citizens (Papavizas, 2011). Until purpose-built ships can be deployed in the region, the pioneers in the region's OSW industry have been creative in working within the constraints of the Jones Act. In the near-term, developers are exploring or using such tactics as (for example) using upgraded port facilities with heavy load capacity for a walking crane. Deepwater Wind has demonstrated the use of Jones Act compliant vessels to transport components to the project site, combined with deploying non-Jones Act-compliant, Jack-up vessels for installation at the site (Wittenberg, 2013).[24]

Another example of supply chain development is the lack of experienced trained crew and technical workers in the region to man crews for installation, operations, and maintenance. The number of crews operating in the region serves as a constraint to OSW deployment in the Northeast. In addition, it will take time and volume for the region to gain the experience and know-how that comes from repetition (and is honed by competition) to boost the installation rate and use the supply chain infrastructure efficiently, spreading fixed costs over more units.

Another supply chain component impacting costs and possibly limiting OSW deployment is limited port infrastructure (Kaubisch, 2013). The Commonwealth of Massachusetts has constructed the Marine Commerce Terminal in New Bedford, a first-in-the-nation facility designed for the assembly, construction, and deployment of OSW projects (Massachusetts Clean Energy Center, 2015). The Massachusetts Clean Energy Center (MassCEC) is conducting an Offshore Wind Ports and Infrastructure Assessment to "identify and assess additional waterfront sites in the Commonwealth that may be available for private investment by the offshore wind industry" (MassCEC, 2017a). The State of Rhode Island has also made investments at Quonset Point (Deepwater Wind, 2014) to support regional OSW development. But further public and private investment in supply chain networks and infrastructure will be required to facilitate and spur the large-scale deployment of OSW.

However, without increased development activity, the industry will be reluctant to invest heavily in the requisite supply chain components required to foster development. The European experience demonstrates that continuous market development over an extended period is essential for achieving the industrial scale that facilitates the development of cost-effective supply chain networks, an adequate supply of trained labor and market efficiencies gained from operational experience that enable OSW to compete with other more established energy sources.

---

24 The Multi-State Offshore Wind Roadmap Project has commissioned a study by GustoMSC on the potential to build a Jones Act-compliant vessel for offshore wind installation in the U.S.

### 2.5.1 Interconnection and Transmission

Instrumental to the deployment and integration of OSW is the expansion of existing and construction of new transmission infrastructure both onshore and offshore, first to bring output from OSW farms to points of interconnection (as described in Section 2.5) and second to deliver output from interconnection points to the region's load centers.

The cost associated with transmission and interconnection as well as the process for assigning transmission and interconnection costs also serve as a challenge to OSW deployment.[25] Because no OSW transmission backbone or infrastructure exists along the East Coast, it is likely that each OSW developer will identify its own least costly transmission solution. One shortcoming of such an approach is that if major network upgrades are needed, the project that triggers the cost will pay. Excess capacity enabled by such an investment might be used by competitors free-riding under open access tariffs.[26] Further, there is currently no process by which to consider more optimal interconnection and transmission facilities that could serve multiple projects at lower aggregate cost. While NYS performs group interconnection studies, sometimes referred to as cluster studies, on a 'class year' basis, ISO-NE currently considers each interconnection request individually, which precludes contemporaneous consideration of the facilities and upgrades required to interconnect multiple projects.[27]

An OSW transmission and interconnection study conducted for Massachusetts considered that OSW projects might not be sized to achieve transmission-related economies of scale in the near-term. Market and policy factors might influence the size of OSW projects developed in the region. The study observed that "projects in the 250 MW range could also be developed and are considered potentially more viable in the near term by some industry stakeholders due to the current status of policy, the market, and financing mechanisms" (ESS Group, 2014). Due to the structure of the existing interconnection process combined with competitive pressure, an OSW developer may be faced with a choice to build interconnection

---

25 As used here, these terms have the following meanings. Interconnection costs include the cost of radial transmission facilities from the offshore collector station to the region's existing transmission network, including offshore and onshore facilities; new substations or substation upgrades. Interconnection costs can also include transmission network upgrades upstream from the point of interconnection necessary to accommodate the injection of OSW power and energy. Relevant transmission includes network facilities, and upgrades thereto, that serve as common carriers. Transmission also encompasses high voltage offshore backbone facilities intended to serve multiple OSW projects.

26 This situation is most acute for OSW projects seeking to interconnect into Maine or New Hampshire, due to a large number of land-based wind projects seeking to interconnect within a constrained area of the grid. For OSW projects interconnecting in southern New England, where there are few projects seeking to interconnect and few transmission constraints, this situation is not a material impediment.

27 However, as of 2016, ISO New England has begun to evaluate best practices in interconnection studies in other regions to inform possible implementation of similar approaches in ISO-NE (Kay, 2016).

facilities capable of only carrying its own peak output—which may be suboptimal from a societal perspective compared to, for instance, building a trunk line capable also supporting an adjacent OSW project built at a later date—or incur the cost needed for facilities with additional capacity beyond that required to interconnect their immediate project. While a coordinated approach to interconnecting OSW could yield long-term cost savings and lower environmental impacts with fewer lines traversing through state waters, such options are today not generally available to OSW developers.[28]

In some locations, network upgrade investments necessary to interconnect and deliver OSW may be costly, while other areas have existing capacity for interconnection. For instance, preliminary results from ISO New England's recent OSW Economic Study indicate that the cost of additional system upgrades to integrate OSW off Massachusetts and Rhode Island would be very low (ISO New England, 2016). In contrast, interconnection of incremental generation in Maine is currently subject to material transmission constraints, which (unless relieved) may preclude access to capacity revenues and result in curtailment. The complexities of the New York City and Long Island grids may require material investment to reliably accommodate large quantities of OSW in some locations. A recent ISO New England study of transmission investments to enable southern New England OSW installations concluded that such investments will also provide substantial reliability benefits or market benefits (ISO New England, 2016). However, the process for allocating such costs to their beneficiaries (other than OSW developers) is untested, out of the control of individual developers, and may not align well with the development cycle.

In Europe, many facilities are interconnected to shared radials that are oversized for the first OSW facility constructed, with additional projects added in subsequent years, rather than each project building its own radial (Hamilton, et al., 2014). In addition, a number of entities in Europe are exploring development of a multi-terminal DC grid for OSW as an alternative to individual radials, bringing cost, reliability, and market benefits (Cardiff University, 2016). In the northeast U.S. OSW market, an offshore network

---

[28] In Germany, transmission system operators are required to fund all offshore wind grid connection via an offshore connection point. The OSW developer is responsible for connecting to this connection point. Thus, LCOE is much lower in Germany. In contrast, in the UK developers pay for transmission infrastructure and then transfer ownership of the assets post-commissioning (Hamilton, et al., 2014). While current transmission tariffs in the Northeastern U.S. do not provide a mechanism to socialize, or to share, OSW interconnection costs, it is possible that in the future, FERC Order 1000 may provide a path to OSW projects meeting public policy purposes having transmission costs socialized in network transmission rates. The most recent Order 1000 planning process ended in May 2017 after the New England States Committee on Electricity (NESCOE) concluded that there are currently no Public Policy Requirements (PPRs) driving the need for transmission within New England, and thus, a study of public policy transmission upgrades and/or expansions in the current planning cycle is not necessary (NESCOE, 2017).

might be most efficient from an aggregate long-term cost perspective, and from the perspective of lowered barriers to incremental deployment, but issues of who would build, fund, and own such a system, and how its costs might be allocated, remain unexplored.

Regional offshore transmission networks have been proposed in recent years for the U.S., none of which appear to be under active development at this time. In New England coastal waters, Anbaric Transmission proposed in 2011 to construct the Bay State Offshore Wind Transmission System, a 2,000-MW transmission network, designed to deliver output from OSW farms operating in the Rhode Island and Massachusetts (RIMA) WEA as well as the Massachusetts Wind Energy Area (MAWEA) to Massachusetts interconnection points (Wood, 2011).[29] The Atlantic Wind Connection—led by independent transmission company Trans-Elect, with Atlantic Grid Development as the project developer and Google, Bregal Energy, Marubeni Corporation and Elia as sponsors—was a proposal for a 6,000 MW subsea OSW transmission "backbone" network spanning from northern New Jersey to Virginia, with additional proposed interconnection points in Delaware and Maryland. The project was proposed to link to OSW lease areas and provide an efficient and cost-effective means of collecting and interconnecting the Mid-Atlantic's OSW production (Atlantic Grid Development LLC, 2014a; Atlantic Grid Development LLC, 2014b).

In addition to these regional offshore transmission networks, several inland transmission projects at various stages of development will increase the transfer capacity across major New England grid interfaces to facilitate the delivery of bottled-in generation sites in remote areas away from load centers as well as imports from Quebec and New Brunswick. One or more of these facilities, as illustrated in Figure 3, would be essential in delivering OSW energy off the coasts of Maine and New Hampshire to the region's primary load centers. Projects in the MAWEA and RIMA have the advantage of being able to interconnect directly into load centers. It is worth noting that preliminary results of ISO New England's 2015 Offshore Wind economic study show that transmission constraints across the SEMA/RI Import Interface and the North-South Interface are "less binding" with the addition of OSW interconnected to southeast Massachusetts and Rhode Island substations (ISO New England, 2016).[30]

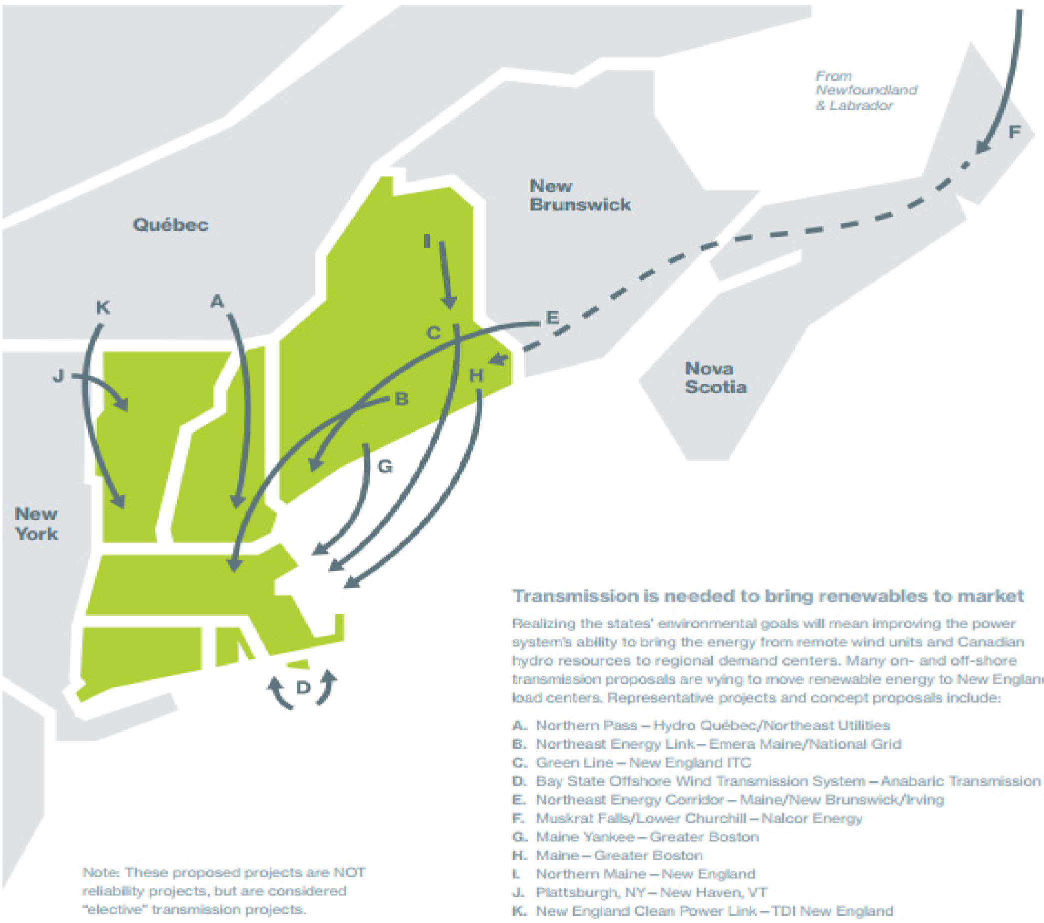
---

29 Anbaric filed an interconnection request with ISO New England in 2011, but the project has since been withdrawn from the interconnection queue after Anbaric shelved the project.

30 "Offshore wind at $0/MWh added to southern New England results in reduced total constrained hours on the North-South Interface. With the addition of 2000 MW offshore wind, the constraint is almost eliminated (<5 hours per year) under the Business as Usual scenario.)"

**Figure 3. Proposed New England Transmission Projects**

*Source: (ISO New England, 2015)*




## 2.6 Interconnection Infrastructure

As a general notion, one of the oft-stated advantages of OSW is that project output can be injected directly into load centers, compared to far-away LBW, which may need substantial transmission infrastructure investments to get generation to load centers (Henson, 2010).

The load centers in coastal states in the Northeast are near locations with ample OSW resource potential. A number of locations proximate to potential OSW areas are also the sites of large baseload generators (both operating and retired), which could provide ready-made and potentially robust points of interconnection (POIs). This section provides a high-level overview of potential interconnection infrastructure at POIs in New York and New England.

The decision to add generation in a particular location is driven by project economics. While there are few (if any) potential POIs for OSW that will not require *some* level of upgrades elsewhere on a system to balance injection of additional capacity, all else being equal, the lowest cost places to interconnect OSW may often be locations that are close to load and have access to high voltage transmission lines and infrastructure designed to carry significant amounts of energy to load. Retired coastal power plants make good candidates.[31] High-level studies of several potential interconnection points have been conducted, as discussed further below. However, the interconnection process requires a study for each additional generator to determine what upgrades are required.

In summary, many potential opportunities exist for interconnecting material quantities of OSW generation and absorbing that output into load centers in the Northeast. Existing studies for New York State and Southern New England show potential for between approximately 10,000 to 14,000 MW, and POIs in Maine or New Hampshire could likely absorb up to several thousand additional MW of OSW capacity once network transmission constraints are relieved.

### 2.6.1 New York City

New York City and Long Island are high-load areas, which are proximate to locations considered for OSW deployment, and could handle injection of a large quantity of OSW supply. The LI-NYC Offshore Wind Collaborative published an assessment (Con Edison & LIPA, 2009) of transmission infrastructure necessary to facilitate up to 700 MW of OSW that included the evaluation of six single points of interconnection. The collaborative proposed using 138 kV voltage lines and existing LIPA and Con Edison transmission infrastructure in the Rockaways and Northern Queens to interconnect the first 350 MW. The second 350 MW of capacity would be interconnected by expanding the Northern Queens and Rockaway substations as well as by constructing a new Eastern Queens substation. A 2012 internal study conducted for NYSERDA identified higher voltage potential points of interconnection capable of handling between approximately 2,000 and 5,000 MW of OSW in NYISO Zones I (J and K). The study concluded some material network upgrades might be required to accommodate the injection within a portion of the grid with considerable reliability-driven operating constraints. In addition, Deepwater Wind hopes to deliver up to 600 MW to the east end of Long Island, (Plummer, 2016), the first phase of which is the recently proposed 90 MW Deepwater One – South Fork project to be interconnected at East Hampton (Deepwater Wind, 2015). While the New York Offshore Wind Cost Reduction Study

---

31 Although conditions may have changed since their retirement. For example, a new resource may have been added elsewhere that changes the amount of generation that can be accommodated at a particular spot.

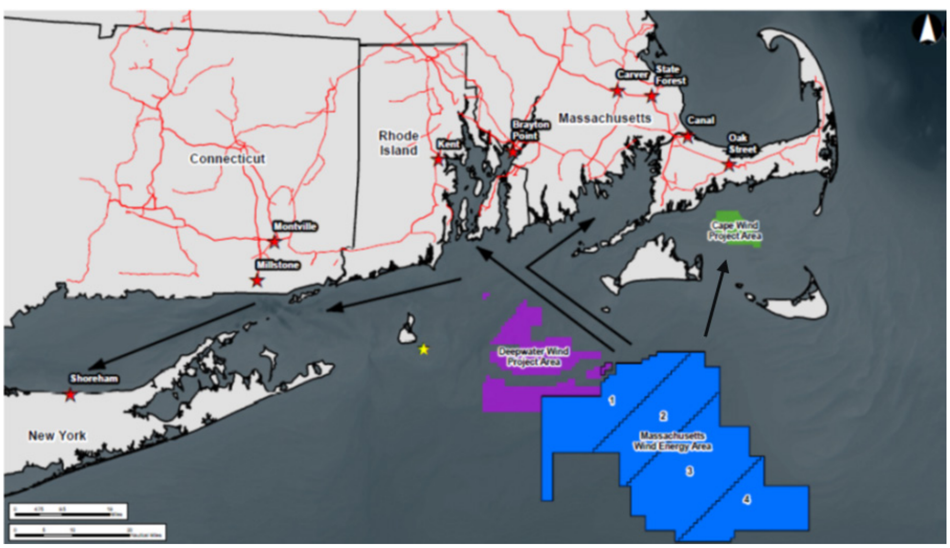
(McClellan, Ozkan, Kempton, Levitt, & Thomson, 2015) also considered potential POIs in New York City, it assumed interconnection to nearest onshore locations on the Long Island 138 kV network. However, the scope of that study did not include any transmission analysis.

While the New York City and Long Island areas have substantial load with transmission import constraints from all directions on land—making them appealing locations to inject OSW—the New York City area is also a highly operationally-constrained and somewhat inflexible system from a reliability perspective. In addition, siting new transmission on Long Island could be quite challenging. For this reason, additional study is required regarding optimal interconnection points, and the costs of dealing with such issues—through network upgrades or otherwise—will impact the ultimate cost of injecting OSW into this region.

### 2.6.2 New England

In New England, the Massachusetts Clean Energy Center commissioned a report published in September 2014 examining potential interconnection points for OSW from the MAWEA and the RIMA (ESS Group, 2014). The potential POIs identified in the report are mapped in Figure 4.

**Figure 4. Potential Points of Interconnection in Southern New England Source: (ESS Group, 2014)**



The POIs screened and examined—ISO-NE 345 kV substations—are shown in Table 4. Several of these sites currently have robust transmission infrastructure due to the existence of large, retired, or retiring generation facilities, such as Millstone and Montville (CT) as well as Brayton Point and Canal (MA). The study concluded that it is technically feasible to interconnect 500 to 1,000 MW, and in certain cases up to 2,000 MW, of OSW at each potential 345 kV interconnection point. In total, these sites were found to "likely have the collective ability to interconnect and integrate up to 6,000 MW of wind energy capacity from the RIMA WEA and MAWEA" (ESS Group 2014, p. 40). Sites were ranked on various criteria, including cost of substation upgrades; approximate total undersea cable length (as a proxy for cost); approximate length of upland cable (as a proxy for stakeholder resistance); proximity of space available for converter stations; and competition for transmission resources. Tier 1 interconnection sites—those deemed most attractive in this study—are identified as Kent, Brayton Point, and Canal. In addition to the POIs identified in this study, the Cape Wind project proposed to interconnect to the Barnstable Switching Station (115 kV), which is near the Oak Street substation studied.

**Table 4. Summary of Southern New England Interconnection Points**

*Source: (ESS Group, 2014)*

| | State | Owner | Approximate Total Cable Route Length (Miles) | Approximate Land Cable Route Length[32] | Approximate Submarine Cable Route Length | Substation Improvement for a 1,000 MW Project | Proximity of Potential Converter Station Parcel | Rank |
|---|---|---|---|---|---|---|---|---|
| **Brayton Point** | MA | National Grid | 45 – 95 | <1 | 45 – 95 | $10M | Close | Tier 1 |
| **Canal** | MA | NSTAR | 60 – 100 | 10 | 50 – 90 | $2.5M | Close | Tier 1 |
| **Kent County** | RI | National Grid | 51 – 96 | 1 | 40 – 95 | $2.5M | Close | Tier 1 |
| **Carver** | MA | NSTAR | 65 – 105 | 20 | 45 – 85 | $2.5M | Not Close | Tier 2 |
| **Oak Street** | MA | NSTAR | 50 – 60 | 10 | 45 – 60 | $2.5M | Not Close | Tier 2 |
| **Millstone** | CT | Northeast Utilities | 60 – 120 | <1 | 60 – 120 | $2.5M | Close | Tier 3 |
| **Montville** | CT | Northeast Utilities | 65 – 130 | <1 | 65 - 130 | $2.5M | Close | Tier 3 |

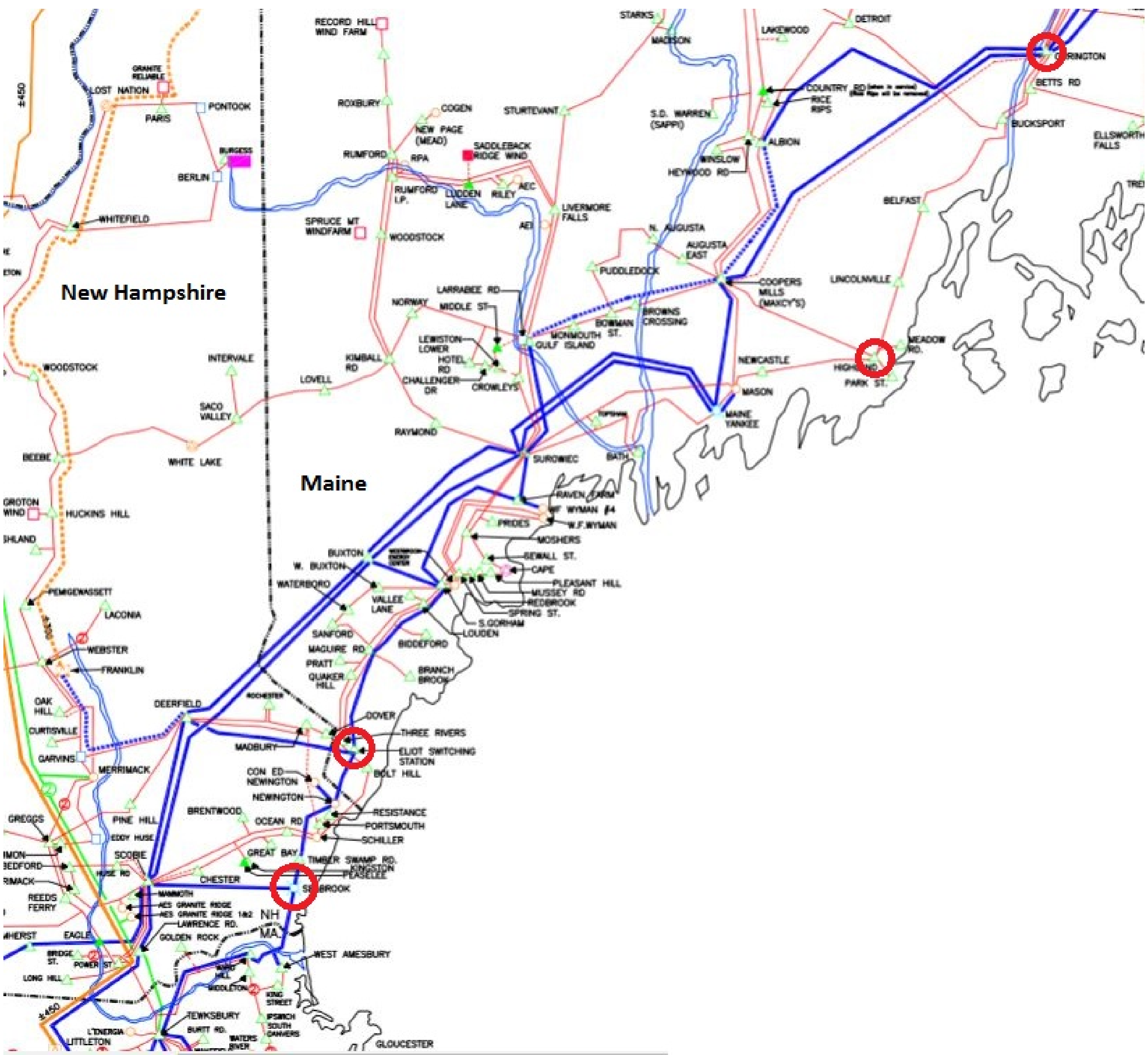
32 Land Cable Routes were estimated based on existing upland transmission rights-of-way and the assumption that space was available to accommodate the required lines. Detailed assessments of available space within the existing rights-of-way or possible limitation (e.g. congestion) that might prohibit the use any given right-to-way for a proposed HVDC transmission cable are beyond the scope of this study.

### 2.6.3 Northern New England

Potential POI sites accessible to projects in the Gulf of Maine are located in Maine and New Hampshire, and have been identified in recent studies (The University of Maine, 2012; NH Committee to Study Offshore Wind Energy, 2014; Daniel, et al., 2014). As shown in Figure 5, these sites include the Elliot 345 kV, Highland 345 kV, and Orrington 345 kV substations in Maine and the Seabrook substation in New Hampshire. Other possible POI sites may be found at the location of retired plants (Maine Yankee) or plants at risk of retiring (Wyman 1 – 4). Maine Aqua Ventus is looking at a variety of lower-voltage substations to interconnect its planned 12 MW floating OSW pilot installation (The University of Maine, 2012).

**Figure 5. Potential Points of Interconnection in Northern New England**

*Source: (ISO New England, 2016d)*



At present, transmission from these states to load centers in Southern New England are constrained, as many of these sites are north of major transmission constraints in export-constrained areas. A variety of studies (ISO New England, 2016) and transmission proposals (such as those discussed in Section 2.4.4) could ultimately mitigate these constraints at some point during the study period. Nonetheless, there is less proximate load to absorb OSW generation developed in these areas than the potential locations off Massachusetts, Rhode Island, or New York.

## 2.7 Energy Production and Peak Coincidence

Capacity factors (CFs) attainable from OSW projects are significantly higher than LBW because of the stronger average wind speeds available offshore. Modeled average wind speeds at 90 m for the OEM Lease Areas and for the NYSERDA areas identified in Table 1 are in the range of 8.5-9.0 m/s (Schwartz, Heimiller, Haymes, & Musial, 2010). Applying annual speed distributions to the power curves of commercial OSW turbines results in gross CFs of 50-55% and net CFs of 40-45% or higher after subtracting estimated losses of 21%. In comparison, LBW projects in New York and New England generally report net CFs of 25-35% (Wiser & Bolinger, 2014 Wind Technologies Market Report, 2015).[33]

Studies have shown that the diurnal pattern of OSW differs from that experienced at typical inland sites (Bailey & Wilson, The Value Proposition of Load Coincidence and Offshore Wind, 2014). In the marine environment, wind speeds normally reach a maximum in the afternoon and evening hours while winds at inland elevated terrain sites tend to peak at night. The significance of this contrast is that the OSW pattern more closely matches the region’s electric demand patterns than LBW. This stronger load coincidence can have positive implications for how the output of OSW plants is valued. Figure 6 shows greater peak coincidence for OSW during extreme cold days when load tends to peak above average seasonal days.

Figure 7 for NYISO shows examples of greater peak coincidence compared to LBW. It has been shown that the value of energy production from an OSW plant within the NYISO market can be 2.6 times that from on inland wind plant in terms of coincident hourly LMP prices (Bailey & Wilson, The Value Proposition of Load Coincidence and Offshore Wind, 2014). Likewise, the capacity value (or credit) for energy from OSW energy projects interconnected to NYISO or ISO New England is significantly higher than from inland projects (Hinkle & Piwko, 2010; NYISO, 2010). For example, in both the NYISO and New England ISO regions, OSW’s capacity credit would be approximately 45% of the project’s

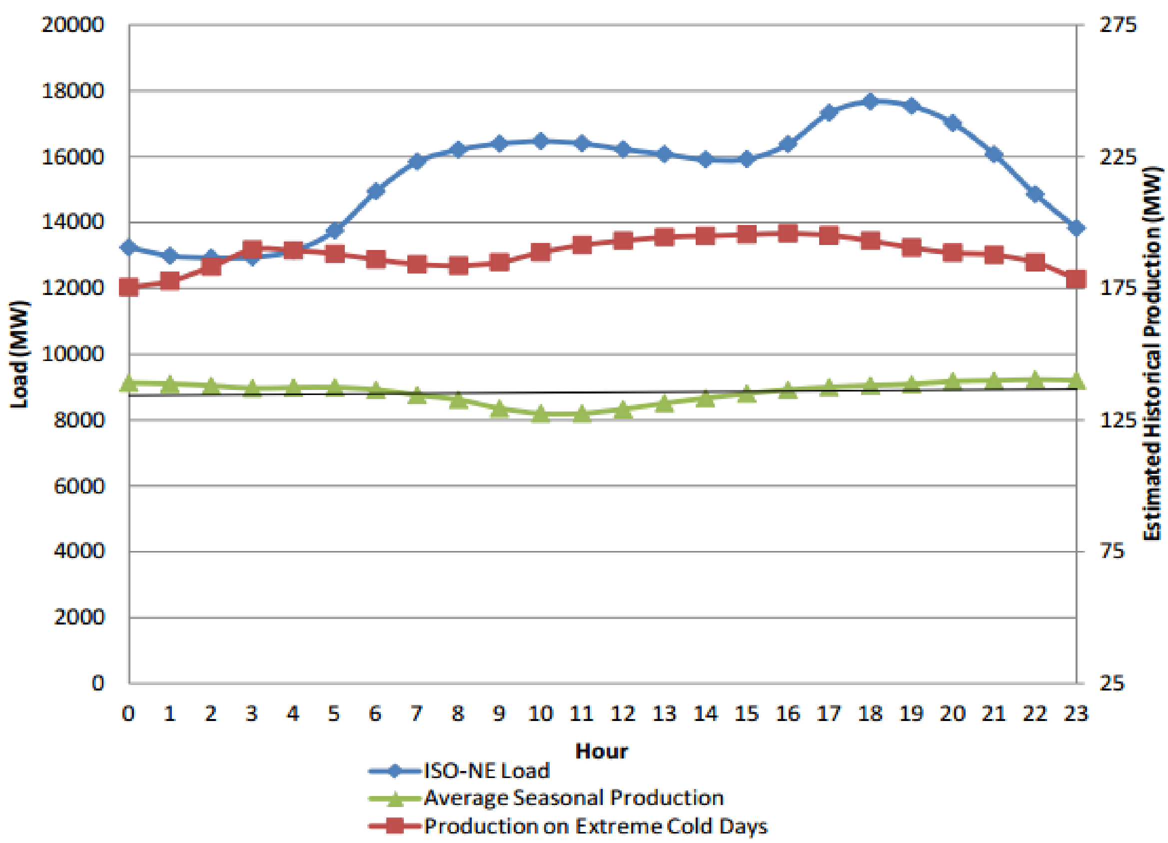
---

33 Note that both OSW and LBW are expected to increase relative to these assumptions, due to technology advances (Wiser, et al., 2016).

nameplate capacity, compared to only 15-18% typically earned by an inland project (Bailey, 2015).[34] OSW, which realizes maximum seasonal CFs in winter, has been shown to also have the potential for mitigating natural gas price spikes and associated wholesale electricity price increases (Wilson, 2014).

**Figure 6. ISO-NE Comparison of Average Offshore Wind Production Levels on Average Winter Days and During Extreme Cold Weather Events (for 252 MW MAWEA Project)**

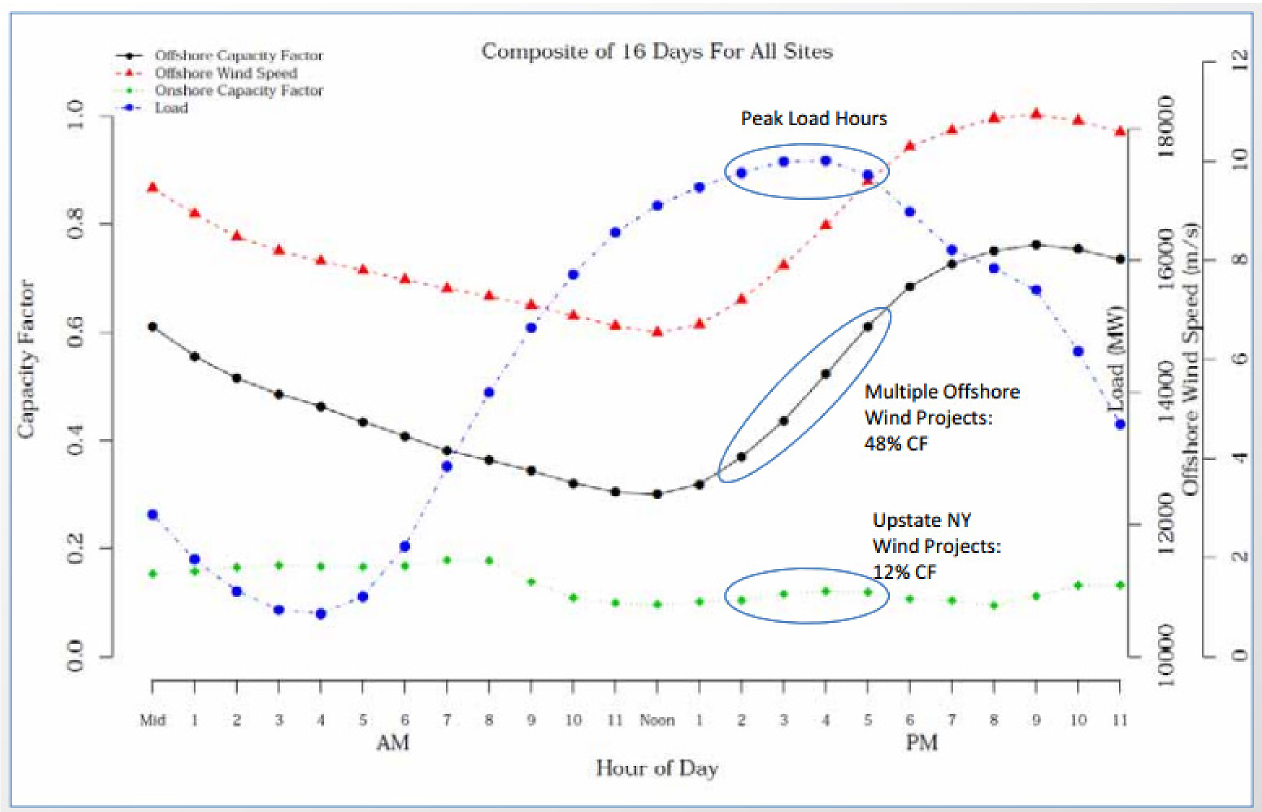
*Source: (Baker & Wilson, 2014)*




34 Note that the more recent draft ISO New England Offshore Wind Economic Study estimated a range of 30 to 35% of project nameplate capacity for OSW. (ISO New England, 2016)

**Figure 7. Offshore and Onshore Capacity Factors, Offshore Wind Speed and NYC Load (with Sea Breeze)**

*Source: (Bailey, Wilson, & Tareila, 2013)*




OSW is characterized by significantly higher capacity factors, greater scalability, as well as higher peak coincidence than other variable renewable energy resources. These factors suggest that OSW may contribute as an important part of a portfolio approach to the replacement of retiring baseload power resources throughout the region—the potential of which is analyzed in Section 3.3. It also suggests that a simple LCOE comparison such as that reflected in Section 2.4.1, may undervalue OSW relative to LBW.

### 2.7.1 Capacity Market

Another aspect of peak coincidence is represented and valued in the region's wholesale markets through the capacity markets. Capacity markets in ISO New England and NYISO provide revenue to generators to incentivize capacity investment and to assure that capacity is available at times of system peak demand. A baseload or dispatchable generator can qualify for a capacity value—seasonal claimed capability, in ISO New England, and Unforced Capacity (UCAP) in NYISO that can approach its nameplate capacity. While variable energy resources (VERs) are eligible to participate in capacity markets—the Forward

Capacity Market (FCM) in ISO New England and the Installed Capacity (ICAP) market in NYISO. Market rules attribute a lower capacity value per MW of nameplate to VERs to reflect the projected probability that they will be generating during peak hours.

The ability for OSW to "replace" retiring thermal generation, as discussed in Section 3.3, is limited in part by the lower capacity value earned by VERs. Because of the central role of capacity markets in ensuring reliability, there are evolving features in capacity markets which may further limit the amount of capacity contributed by VERs.[35] On the other hand, co-located or virtually-aggregated energy storage deployment may be able to increase the value, which OSW can deliver in capacity markets by increasing OSW's on-peak availability.

---

35 Examples include ISO New England's (1) **Pay for Performance** (PFP) program, which subjects projects with a $5,500/MWh fee if it fails to perform during 'reliability hours', and (2) **Offer Review Trigger Prices (ORTP)**, which are intended to prevent uneconomic or subsidized new entry from distorting market prices by setting a price floor below which new entrants must demonstrate their costs or be withdrawn from the capacity auction. While 200 MW of intermittent generators are exempt from ORTP in each auction, the remainder will be subject to additional scrutiny if their bids are below the ORTP.

# 3 Potential Demand for Offshore Wind: Market Factors

The wholesale energy market is another key factor that bounds the potential rate and scale of OSW deployment in the region, or more generally, the potential demand for OSW. Broadly speaking, the defining features of wholesale energy markets include its resource mix, energy demand, pending and at-risk unit retirements and its development pipeline. The market aims to meet demand as cost-effectively as possible, replace retiring units and maintain system reliability all while achieving various policy goals, which today primarily involves phasing out aging, inefficient and carbon-intensive resources and increasing the supply of renewable energy. Overall, wholesale energy markets in New York and New England are currently characterized by reduced fuel supply costs, significant imminent baseload unit retirements, concern about a growing overreliance on natural gas-fueled generation, as well as related efforts to increase the supply of low carbon and renewable energy.

This chapter is divided into four primary sections, each describing a key component of the market that bounds the development potential of OSW. Section 3.1 discusses the region's energy mix and the market factors that led to its current state. Section 3.2 provides an overview of current and future energy demand based on ISO New England and New York ISO forecasts. Section 3.3 examines pending and at-risk retirements and the opportunity these retirements present for OSW development. Lastly, Section 3.4 assesses the penetration potential for VERs both nationally and regionally.

## 3.1 Regional Energy Mix

After several years of natural gas price volatility and high oil prices, the region is now experiencing a large change in generating resource mix in response to favorable natural gas market prices and environmental/economic pressures on older fossil steam generators and nuclear plants. More stable and lower gas prices and a decline in oil prices have altered fuel use patterns in the region. Natural gas is still the dominant fuel by far, and most incremental planned thermal capacity is fired by natural, with several new combined cycle and combustion turbine units clearing capacity markets in recent years. But fuel use, particularly in the winter, has been impacted by lower oil prices and natural gas pipeline constraints.

The northeast continues to pursue developments in natural gas infrastructure in order to access new supply from the Marcellus shale region. After experiencing natural gas price spikes for several winters, New York and New England have made efforts to expand pipeline capacity into the region (ISO New England, 2016b; ICF International, 2015; Krohn & Teller, 2016).

New York's Constitution Pipeline was scheduled for completion in 2016, but further development of portions of the pipeline halted after the New York Department of Environmental Conservation decided not to issue the necessary water quality permits to continue construction in April 2016, a challenge to which was recently rejected by the U.S. District Court for the Northern District of New York (Hurdle, 2017). The Algonquin Incremental Markets (AIM) project in New England was placed fully into service in January 2017 (Bradley, 2017). Additional projects are under development as well. Despite favorable market prices, however, due primarily to growing political and public opposition, the future of the proposed projects is unclear. In May 2016, Kinder Morgan cancelled its Northeast Energy Direct natural gas pipeline from Pennsylvania to Massachusetts due to insufficient demand and public opposition (Chesto, Kinder Morgan Shelves $3 Billion Pipeline Project, 2016) and in June 2017, Enbridge put the Access Northeast pipeline on hold, withdrawing their application from FERC, after the Massachusetts Supreme Judicial Court's rejected a proposal to have pipeline costs passed on to ratepayers and the lack of political support for legislation allowing them to do so (Chesto, 2017).

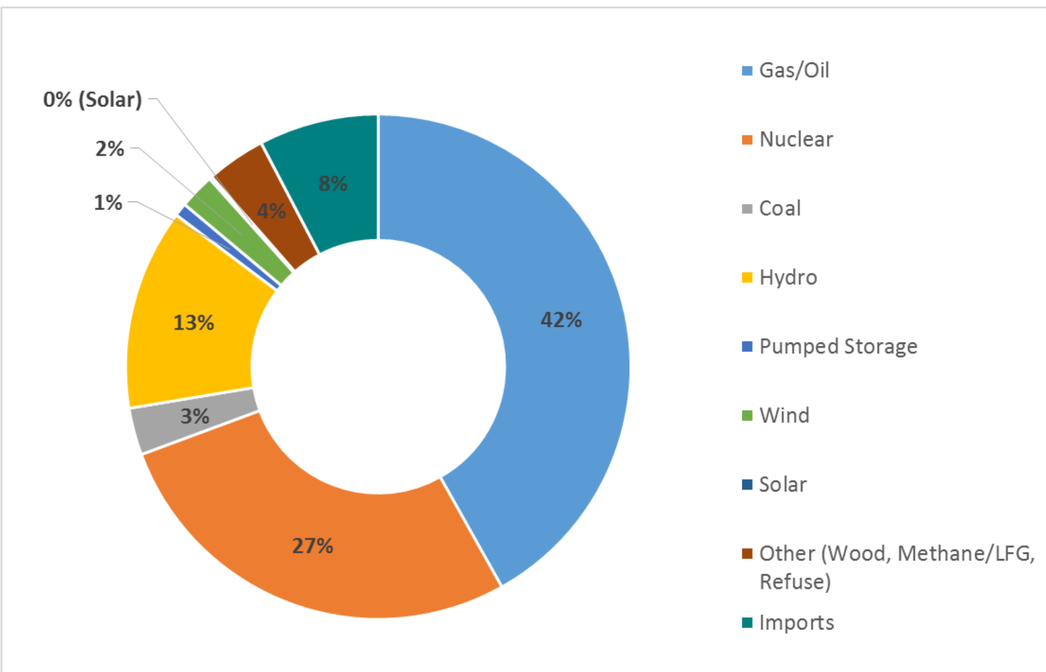
As discussed in Section 2.4.4 several large scale electric transmission projects have been proposed for the northeast which could impact the regional market and opportunities for OSW development. Many of the proposed transmission projects are focused on providing access between load centers and renewable energy sources—particularly Canadian hydro, and wind projects in Maine and New York. Proposals vary in size and both AC and DC projects have been proposed. Several of these projects were bid into the New England Clean Energy RFP in January 2016 (CT DEEP, MA DOER, Eversource, National Grid and Unitil, 2016). This RFP was jointly offered by Connecticut, Massachusetts, and Rhode Island with the goal of supporting more cost-effective new clean energy (hydro and wind) and is discussed in further detail in Section 4.

As illustrated in Figure 8, these market dynamics have resulted in a regional energy mix currently dominated by natural gas. Nuclear power has largely maintained its share of generation regionally over the last decade. However, due to the recent retirement and possible retirements of plants, nuclear energy's share of the region's resource mix is expected to decline significantly, potentially deepening the region's dependence on natural gas and undermining the region's greenhouse gas reduction efforts

(Vermont Yankee nuclear facility; the planned 2019 retirement of the Pilgrim nuclear power station in Massachusetts; the 2020-2021 staged retirement of both Indian Point nuclear power generating units, in addition to the possible retirements of New York State's remaining nuclear power plants following the conclusion of the New York's Zero-Emissions Credit [ZEC] requirement in 2030 [see Section 3.3][36]) New York State has begun implementing its CES that includes financial assistance for three of the State's nuclear power plants (see Section 4.1.1.3). Renewables, on the other hand, despite many consecutive years of significant growth, still only account for a small fraction of total generation. As depicted in Figure 8 and Table 5, wind and solar account for less than 3% of total generation. However, renewable energy supply comprises a far larger share of the near-term development pipeline and interconnection queue, and the statistics shown do not fully capture the contribution of distributed renewable energy generation.

**Figure 8. Regional Energy Production by Fuel Type (New York and New England)**

*Sources: (NYISO, 2015, p. 61; ISO New England, 2016a)*




[36] The ZEC requirement establishes an obligation for New York's load-serving entities (LSEs) to purchase ZECs, from NYSERDA in an amount proportional to their load (NYS Public Service Commission, 2016b).

**Table 5. Generation by Fuel Type (GWh)**

*Source: (NYISO, 2015, p. 61; ISO New England, 2016a)*

| | New York (2014) | New England (2015) |
|---|---|---|
| **Gas/Oil** | 59,767 | 54,329 |
| **Nuclear** | 43,041 | 31,890 |
| **Coal** | 4,325 | 3,884 |
| **Hydro** | 28,525 | 6,615 |
| **Pumped Storage** | 849 | 1,453 |
| **Wind** | 3,986 | 2,169 |
| **Solar** | 51 | 463 |
| **Other (Wood, Methane/LFG, Refuse)** | 3,194 | 7,114 |
| **Imports** | | 20,905 |

Table 6 and 7 below show the contribution of different resource types to meeting peak demand in the summer and winter of 2015 for New York State and New England.[37] For non-dispatchable generation types whose production is limited during summer-peak periods, these figures are materially lower than nameplate capacity. For example, as can be seen from Table 5 and 6, the capacity market 'capability' of over 800 MW of New England LBW capacity is only 79 MW in the summer and 200 MW in the winter, indicating its limited peak coincidence. Due to the greater summer-peak coincidence for OSW compared to LBW, discussed in Section 2.6, a sharp decline of capability from winter to summer is not expected for OSW.

**Table 6. 2016 Summer Capability by Fuel Type (MW)**

*Source: (ISO New England, 2016e; NYISO, 2016)*

| | New York | New England |
|---|---|---|
| **Gas** | 3,788 | 8,506 |
| **Oil** | 2,578 | 3,938 |
| **Gas & Oil Dual Fuel** | 18,211 | 7,340 |
| **Coal** | 1,017 | 1,947 |
| **Nuclear** | 5,402 | 4,010 |
| **Pumped Storage** | 1,406 | 1,677 |
| **Hydro** | 4,315 | 1,467 |
| **Wind** | 1,446 | 79 |
| **Solar** | 32 | 5 |
| Other | 381 | 918 |

37 NYISO and ISO New England have different summer and winter capability periods and each ISO employs a different methodology for calculating capacity values for their control area's capacity resources. For example, NYISO's Summer Capability period is from May 1 to October 31, whereas ISO New England's is from June 1 to September 30.

**Table 7. 2016 Winter Capability by Fuel Type (MW)**

*Source: (ISO New England, 2016e; NYISO, 2016)*

| | New York | New England |
|---|---|---|
| **Gas** | 4,140 | 8,511 |
| **Oil** | 2,982 | 3,962 |
| **Gas & Oil Dual Fuel** | 19,850 | 7,365 |
| **Coal** | 1,032 | 1,947 |
| **Nuclear** | 5,425 | 4,010 |
| **Pumped Storage** | 1,404 | 1,677 |
| **Hydro** | 4,291 | 1,640 |
| **Wind** | 1,446 | 200 |
| **Solar** | 32 | 0 |
| **Other** | 382 | 923 |

The share of the regional energy mix derived from renewable energy, particularly from variable sources like wind and solar, is relatively small both in terms of its share of actual generation as well as its capacity contribution to meeting peak summer demand. The region's current energy mix, and in particular the small but growing contribution of VERs to regional capacity, highlight the constrained development potential of variable resources like wind and solar—several of which are discussed further below. These resources are deployed to meet the region's demand for energy, the future of which could affect the development potential of OSW.

## 3.2 Regional Energy Demand

The development potential for OSW is bounded by a number of market factors, starting with total demand for energy. As discussed in Section 3.1, a variety of market dynamics ultimately determine a region's energy mix, but a market's demand for energy effectively represents the ceiling or maximum supply potential of any single energy resource. Furthermore, forecasts of future energy demand in addition to the capacity retirements (discussed in Section 3.3 below) provide a framework for assessing the potential for OSW to supply New England and New York State markets. The regional load drives the GWh demand from renewable energy resources under regional renewable portfolio standard and clean energy standard policies discussed below. It also influences the degree to which low-carbon supply is needed to meet regional greenhouse gas goals. Both ISO-New England and the NYISO publish forecasts for energy and peak demand annually in the form of the ISO-NE Forecast Report of Capacity, Energy, Loads, and Transmission (CELT Report) and the NYISO Gold Book. Below, Figures 9 through 11 illustrate the combined NYISO and ISO-New England Base, low- and high-case forecasts for regional energy demand from 2015 to 2030.

In the base case scenario depicted in Figure 9, total regional load (net of energy efficiency and passive demand response), which includes all six New England states and New York, is projected to be relatively flat, decreasing from 288,300 GWh in 2015 to 287,481 GWh by 2030. Total regional load in the low case, shown in Figure 10, is projected to decrease more significantly from 282,081 GWh in 2015 to 267,219 GWh in 2030, an average annual decrease of 0.35%. In the high-case scenario illustrated in Figure 11, however, regional load is projected to increase from 294,509 GWh in 2015 to 308,453 GWh in 2030, an average annual increase of 0.32%.

**Figure 9. Regional Base Case Load Forecast 2015-2030**

*Sources: (NYISO, 2015; ISO New England, 2015)*

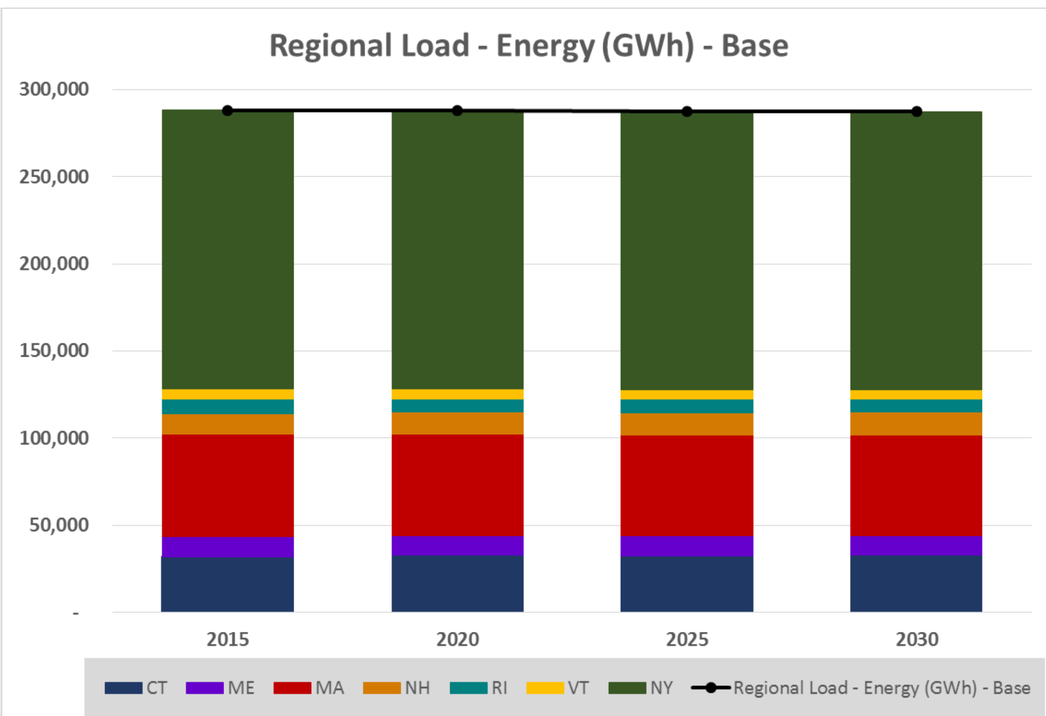


**Figure 10. Regional Low-Case Load Forecast 2015-2030**

*Sources: (NYISO, 2015; ISO New England, 2015)*

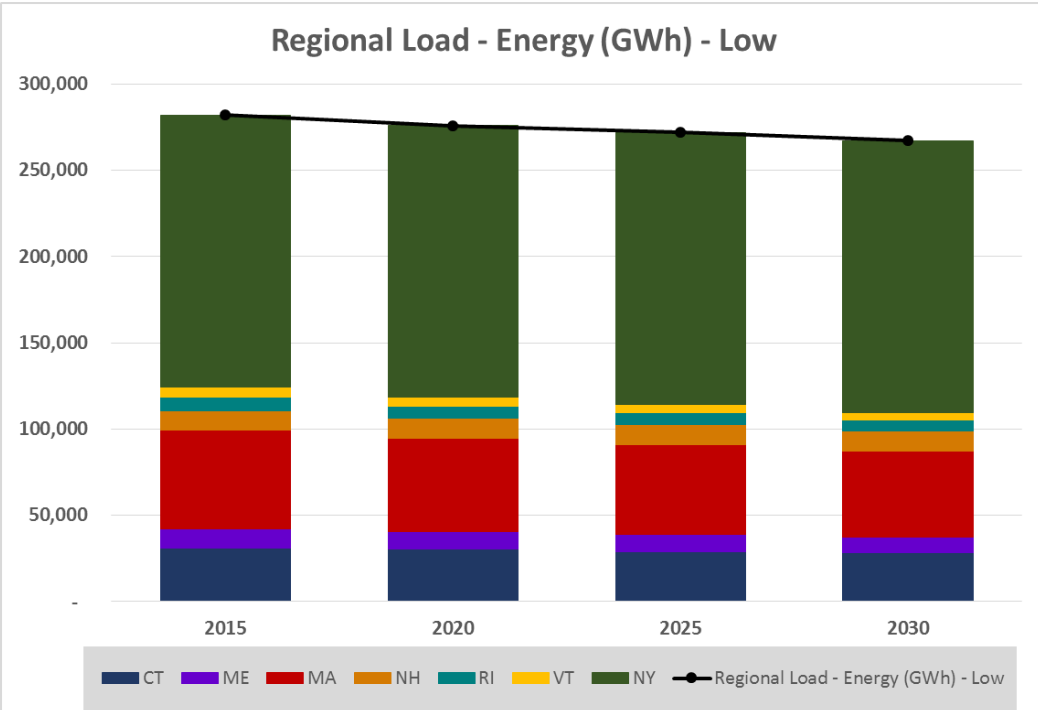



**Figure 11. Regional High-Case Load Forecast 2015-2030Sources: (NYISO, 2015; ISO New England, 2015)**

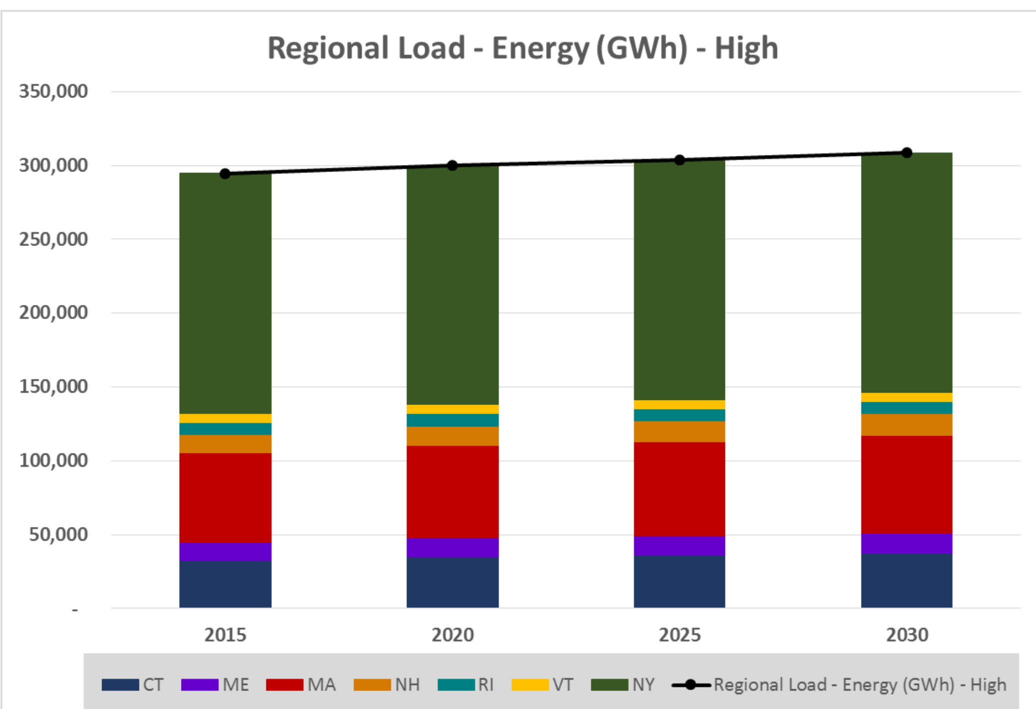


Table 8 and 9 present regional summer-peak and winter-peak [net of energy efficiency and behind-the-meter production (NY) and passive demand response (NE)] in 2016, as well as projections for 2030 by state and region. The low- and high-case projections for regional summer-peak demand in 2030 range from 57,219 to 65,293 MW, with a base case projection of 61,778 MW. The low- and high-case projections for regional winter-peak demand in 2030 range from 42,379 to 49,089 MW, with a base-case projection of 45,775 MW.

**Table 8. State and Regional Summer-Peak Demand net of Energy Efficiency (EE)/Behind-the-Meter (BTM) (MW)**

*Source: (ISO New England, 2016e; NYISO, 2016), extrapolated*

| | 2016+ | | | | 2030 | | |
|---|---|---|---|---|---|---|---|
| States | High | Base | Low | | High | Base | Low |
| **CT** | 7,105 | 7,051 | 6,998 | | 7,331 | 7,132 | 6,935 |
| **ME** | 2,078 | 2,017 | 1,956 | | 2,407 | 2,141 | 1,877 |
| **MA** | 12,437 | 12,326 | 12,215 | | 12,918 | 12,489 | 12,063 |
| **NH** | 2,553 | 2,531 | 2,509 | | 2,981 | 2,947 | 2,732 |
| **RI** | 1,861 | 1,855 | 1,849 | | 1,994 | 1,919 | 1,849 |
| **VT** | 937 | 924 | 911 | | 916 | 853 | 803 |
| ISO-NE | **26,970** | **26,704** | **26,438** | | **30,506** | **28,786** | **27,106** |
| **NY** | 35,683 | 33,360 | 33,250 | | 36,877 | 34,363 | 30,959 |
| Regional | **62,654** | **60,064** | **56,688** | | **65,293** | **61,778** | **57,219** |

**Table 9. State and Regional Winter-Peak Demand net of Energy Efficiency (EE)/Behind-the-Meter (BTM) (MW)**

*Source: (ISO New England, 2016e; NYISO, 2016), extrapolated*

| | 2016 | | | | 2030 | | |
|---|---|---|---|---|---|---|---|
| States | **High** | **Base** | **Low** | | **High** | **Base** | **Low** |
| **CT** | 5,530 | 5,459 | 5,389 | | 5,430 | 5,152 | 4,881 |
| **ME** | 1,868 | 1,826 | 1,786 | | 1,964 | 1,800 | 1,638 |
| **MA** | 9,965 | 9,803 | 9,647 | | 9,869 | 9,212 | 8,572 |
| **NH** | 2,039 | 2,001 | 1,964 | | 2,484 | 2,122 | 1,773 |
| **RI** | 1,307 | 1,286 | 1,266 | | 1,176 | 1,110 | 1,048 |
| **VT** | 984 | 965 | 946 | | 1,071 | 992 | 917 |
| ISO-NE | **21,693** | **21,340** | **20,998** | | **21,994** | **20,338** | **18,828** |
| **NY** | 26,049 | 24,445 | 22,841 | | 27,096 | 25,385 | 23,551 |
| Regional | **47,742** | **45,785** | **43,839** | | **49,089** | **45,775** | **42,379** |

Table 10 shows the regional electric load [net of energy efficiency and behind-the-meter production (NY) and passive demand response (NE) in 2015, as well as projections for 2030 by state and region. As can be seen, regional load is expected to stay relatively flat, decreasing slightly in the base forecast, increasing slightly in the high forecast, and decreasing slightly in the low forecast.

**Table 10. State and Regional Load Net of EE/BTM (GWh)**

*Source: (ISO New England, 2015; NYISO, 2015), extrapolated*

| | 2015 | | | | 2030 | | |
|---|---|---|---|---|---|---|---|
| State | High | Base | Low | | High | Base | Low |
| **CT** | 32,674 | 31,729 | 30,784 | | 37,504 | 32,732 | 28,136 |
| **ME** | 12,016 | 11,531 | 11,041 | | 13,672 | 11,370 | 9,181 |
| **MA** | 60,800 | 59,120 | 57,440 | | 65,932 | 57,642 | 49,656 |
| **NH** | 12,097 | 11,777 | 11,452 | | 14,847 | 13,205 | 11,614 |
| **RI** | 8,371 | 8,151 | 7,931 | | 8,126 | 7,234 | 6,377 |
| **VT** | 6,016 | 5,871 | 5,726 | | 5,959 | 5,261 | 4,594 |
| ISO-NE | 131,974 | 128,179 | 124,374 | | 146,040 | 127,444 | 109,558 |
| **New York** | 162,535 | 160,121 | 157,707 | | 162,412 | 160,037 | 157,662 |
| Regional | 294,509 | 288,300 | 282,081 | | 308,452 | 287,481 | 267,220 |

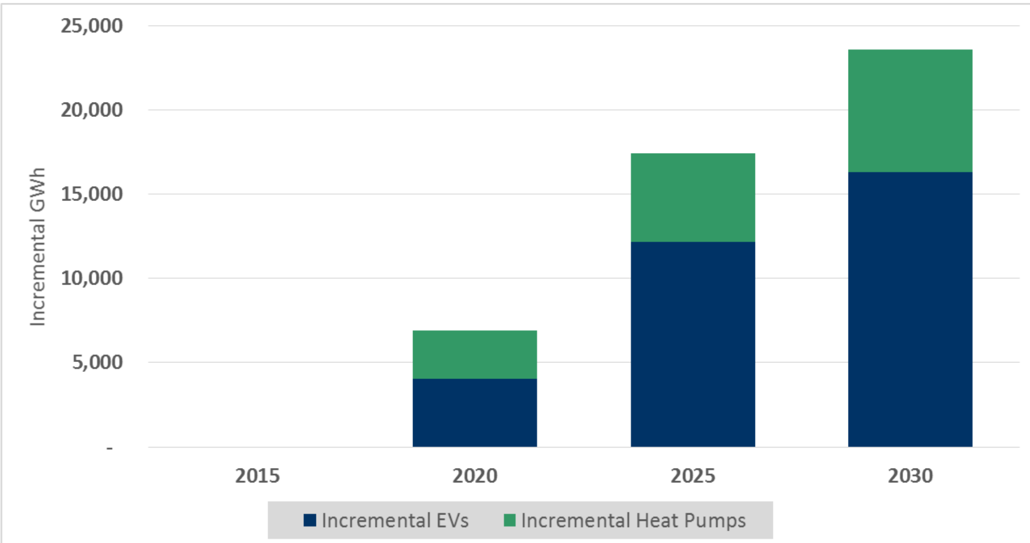
Regional and state efforts to meet aggressive greenhouse gas reduction targets (discussed further in Chapter 4), often rely upon electrification to decarbonize the transportation and heating sectors. This section presents an additional regional-load forecast under certain electrification assumptions made by Synapse Energy Economics, Inc. as part of a report in which it assessed various strategies that could be employed to achieve a 40% reduction in $CO_2$ emissions from 1990 levels by 2030 under the Regional Greenhouse Gas Initiative (RGGI) (Stanton, et al., 2016). In the report, Synapse assumes that 35% of light vehicle trips under 100 miles are replaced by electric vehicles (EVs) and 44% of residential consumption of petroleum is replaced by electric heat pumps by 2030. Based on these rates of electrification and a number of other strategies[38] proposed to achieve a 40% reduction in RGGI-wide $CO_2$ emissions by 2030, incremental load from EVs and heat pumps would reach 23,569 GWh by 2030 as shown in Figure 12 below, all of which the report assumes would be served by incremental renewable generation.

---

[38] According to the report, under the RGGI baseline scenario, energy efficiency measures save 45,000 GWh of electricity by 2030 and under its 40% emission reduction scenario, the adoption of additional efficiency measures saves a total of 81,000 GWh of electricity by 2030 (Stanton, et al., 2016, pp. 9-10).

**Figure 12. Regional *Incremental* Load Forecast 2015-2030 w/ Electrification of Transportation and Residential Heating to Achieve 40% Reduction in $CO_2$ Emissions by 2030 (GWh)**

*Source: (Stanton, et al., 2016)*




OSW could therefore find opportunity in either contributing to meeting the load growth necessitated by electrification of the transportation and home heating sector, contributing to filling a gap created by retiring generation resources (as discussed in the following section), or competing to displace other operating resources.

In addition, we note that Table 8 and 10 together show that summer-peak demand is expected to grow relative to overall net load, resulting in a degradation of the region's load factor. This trend underscores an increasing regional need for generation supply that produces at times of peak demand, and suggests limits to the ability of intermittent generation supply to (by itself) replace retiring baseload generation.

## 3.3 Market Opportunity Created by Regional Base Load Retirements

The Northeast region is in the midst of a series of significant generation unit retirements. As previously mentioned, the recent or potential planned retirement of nuclear units in New England (Vermont Yankee and Pilgrim) and in New York State (Indian Point) would result in a substantial loss of carbon-free generation. Moreover, aging and inefficient coal and oil-fired units continue to retire, based on competition from newer, more efficient plants using natural gas as well as additional regulatory and societal pressure to reduce emissions. Table 11 below shows confirmed planned retirements for New England and New York State. If all the facilities listed in Table 11 retire as expected, the region will have to replace nearly 6,000 MW of generation capacity (a combination of baseload and cycling) by 2021.

**Table 11. Planned Retirements in New England and New York**

*Sources: (ISO New England, 2016a; PSEG Power Connecticut, 2016; NYISO, 2016)*

| Unit Name | Date | Type | Capacity |
|---|---|---|---|
| New England | | | |
| Brayton Point | 2017 | Coal | 1,125 |
| Brayton Point | 2017 | Oil | 475 |
| Pilgrim | 2019 | Nuclear | 670 |
| Bridgeport Harbor | 2021 | Coal | 485 |
| New York | | | |
| Niagara Bio-Gen | 2016 | Biomass | 51 |
| Astoria GTs 5, 7, 8, 10, 11, 12, 13 | 2016 | Oil | 142 |
| Dunkirk 2 | 2016 | Coal | 100 |
| Huntley 67 & 68 | 2016 | Coal | 436 |
| Ravenswood GTs 4, 5, 6 | 2016 | Gas | 64 |
| Cayuga 1 & 2[39] | 2017 | Coal | 323 |
| Indian Point Unit 2 | 2020 | Nuclear | 1,028 |
| Indian Point Unit 3 | 2021 | Nuclear | 1,041 |

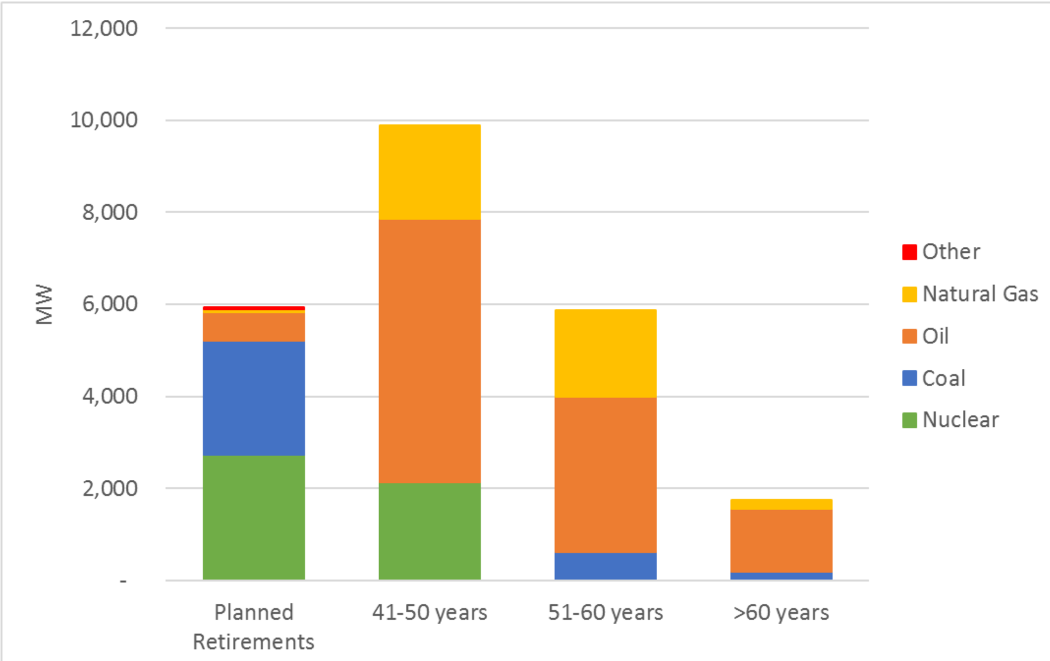
In addition to the planned retirements listed above, a significant amount of capacity is at risk for retirement throughout New England and New York by 2030. ISO-NE developed a list of facilities it considered to be at risk as a part of its Strategic Transmission Analysis (Sheilendranath, 2012). No such list has been developed for New York. In lieu of a list of at-risk retirements for New York State, Figure 13 includes (in addition to facilities at risk for retirement in New England) all baseload generating units in New York State greater than 50 MW whose operational age will be 40 or older by the year 2020, based on 2015 NYISO Gold Book data (NYISO, 2015). Figure 13 illustrates all regional planned and at-risk retirements by fuel source and age group (based on age in 2020). As shown, the oldest generating units in the region are primarily coal and oil units, followed by natural gas-fired plants and a relatively younger core of large nuclear generation facilities. Regionally, there are 42 at-risk generation units with approximately 15,000 MW of cumulative capacity. Approximately 67% of these at-risk units will have been operating for 60 years or more by 2030.

---

39 For this analysis, Cayuga 1&2 were assumed to retire in 2017 after the reliability agreement between the plant and NYSEG ended; however, the owners have since announced that they plan to continue to operate past the expiration of the agreement (Prager, 2017). Governor Cuomo has called for the elimination of coal fired generation by 2020 (Cuomo A. M., Letter Directing Department of Public Service to Commence Proceeding to Establish a Clean Energy Standard, 2015).

**Figure 13. Regional Planned and At-Risk Retirements by Fuel Source (MW)[40]**

*Sources: (Sheilendranath, 2012; NYISO, 2015; ISO New England, 2016c)*




As demonstrated above, the region is facing significant retirements that together could require the replacement of up to approximately 23 GW of capacity over the course of the next several decades. The generally constant levels of demand projected for the region along with the need to replace a substantial amount of capacity presents a considerable opportunity for OSW to play a potentially significant role in the region's energy mix. Practically speaking, because variable renewable generation sources have lower capacity factors than the retiring generation and less capacity value per unit of nameplate capacity, a quantity of variable generation sufficient, in nameplate capacity rating, to replace all the retiring generators' energy would fall short of meeting the retiring generators' contribution to meeting peak. OSW has a higher capacity factor and greater peak coincidence than other variable renewables, as discussed in Section 2.6, and therefore can be more effective as part of a portfolio contributing to replacing such generation, MW for MW, than LBW or solar. Nonetheless, OSW should not be expected to replace all the region's retiring capacity.

---

40 The FitzPatrick, Ginna and Nine Mile Point nuclear power plants in New York, which have a cumulative nameplate capacity of approximately 2,140 MW, are not considered at risk during the study period due to the financial assistance they will receive under the New York ZEC program. Following the conclusion of the 12-year ZEC contracts for these facilities' in 2029, the plants may be considered at risk for retirement. These three facilities are nonetheless included in the above graph under the '41-50 year' category to reflect their operating age.

The analysis in Chapter 5 considers a range of potential contributions of OSW to filling needs created by retirements in assessing the market potential for OSW. The extent to which OSW can be deployed to meet the region's energy demand and replace its retiring capacity is further bound by the ability of the NYISO and ISO-New England to accommodate and integrate increasing levels of OSW as a variable energy resource. This ability to integrate OSW can evolve over time as the grid evolves to accommodate the changing mix of supply and energy storage deployment increases. These factors are discussed in the following section, and are considered in Chapter 5 in estimating the potential proportion of market opportunities that can be met by OSW.

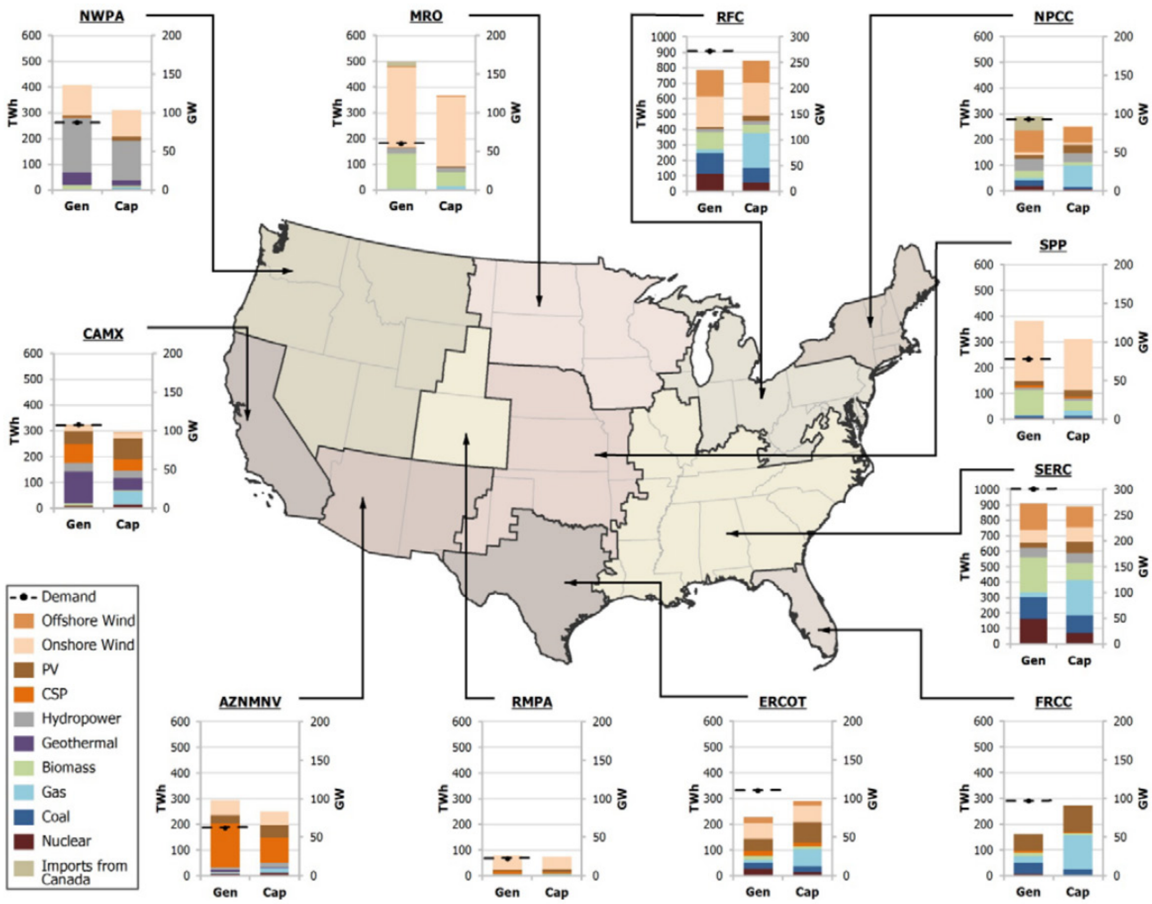
## 3.4 Variable Energy Resource Penetration

The scale and rate of OSW deployment and integration is limited by the bulk power system's ability to absorb its intermittent output. This section provides a snapshot of recent analysis of potential limits to VER penetration over time, which provides a basis for estimates developed in Section 5.2. In 2012, NREL published the *Renewable Electricity Futures Study*, which examines the potential for high penetrations of various renewable energy technologies both nationally and regionally, taking into account geographic, temporal and operational factors and constraints (Mai, et al., 2012b). Volume 1 of the report examines a series of 80% renewable energy (RE) penetration by 2050 scenarios.[41]

[41] The core of the scenarios varied primarily based on the assumptions made for technological improvements over time. For more information on the variations in model assumptions for the core 80% RE and High-Demand RE scenarios, see (Mai, et al., 2012b, pp. 3-2).

**Figure 14. Renewable Generation and Capacity by Region in 2050 Under 80% RE-ITI Scenario**

*Source: (Mai, et al., 2012b, pp. 3-6)*




Under the Incremental RE Technology Improvement (80% RE-ITI) scenario, which NREL used as the base case in its analysis, VERs nationally account for roughly 27% of total generation by 2030 and nearly 50% of total generation by 2050 (Mai, et al., 2012b, p. xvii; NREL, 2012a). In the Northeast Power Coordinating Council (NPCC) region, which encompasses New England and New York State, the study showed VERs accounting for approximately 18% of total generation by 2030 and 39% of total generation by 2050. As illustrated in Figure 14, under NREL's 80% RE-ITI scenario, OSW achieves significant market penetration, accounting for roughly 30% of regional generation in 2050. These scenarios represent NREL's detailed exploration through modeling of potential high end for VER penetration (recognizing the constraints imposed by stability, reliability, and the need to meet load as incurred cost-effectively). In addition, they present an examination of the potential for feasible VER penetration to increase over time with, for example, changes in the grid and increased energy storage deployment. These NREL modeling results inform the development of scenarios considering the potential for VER penetration limitations to bound the scale of the OSW market over time, as discussed further in Section 5.2

## 3.5 Summary

Overall, the extent to which OSW can contribute to the regional energy supply is bounded by the demand for electricity, the opportunity provided by retirements, and the penetration potential of variable energy resources. At current costs, OSW would not be supported solely by revenues from the wholesale energy and capacity markets. As with other renewable technologies such as LBW and solar, OSW costs are expected to decline over time. However, until these resources can be deployed solely based on wholesale market revenues, local, state, and federal policies will be necessary to drive demand for OSW and establish a market suitable for its development.

Policy initiatives can also dictate how much of demand can be supplied by renewables in general, and by OSW in particular. In theory, Renewable Portfolio Standards and/or greenhouse gas and carbon reduction targets can and will drive renewable energy adoption and zero-carbon adoption, respectively. Initiatives to stimulate increased deployment of energy storage can increase the potential penetration of VERs. While OSW is the zero-emission renewable energy generation option best able to contribute to replacing retiring generation. However, so long as it remains more costly than other renewables, its deployment at scale will depend on dedicated state policy supports, such as mandated procurements, carve-outs or other policy-driven finance mechanisms during the study period.

The next chapter examines current state and regional policies and plans regarding renewable energy and greenhouse gas reduction, as well as initiatives targeted at OSW. They provide context for examination in Chapter 5 of the role (if any) of these factors in proscribing the OSW market potential.

# 4 Potential Demand for Offshore Wind: State and Regional Policies and Plans

The potential demand for OSW in the northeastern United States will likely be driven by a range of state and regional policies focused on increasing the deployment of renewable energy generation and reducing greenhouse gas emissions. In this chapter, we provide a high-level summary of state and regional policies that have the greatest potential to influence the market for large-scale renewables in general, or OSW specifically, over the next 15 years and beyond. The main focus of this chapter is Massachusetts, New York State and Rhode Island, the states participating in the Offshore Wind Roadmap. Because policies and goals for renewable energy and addressing climate change within the region will also influence the regional market for OSW, we provide brief presentations of relevant policies and plans in Connecticut, New Hampshire, and Vermont as well. Lastly, this chapter presents a limited discussion of similar OSW-related activities and policies in the Mid-Atlantic states, given their proximity to the Northeast and the potential for those activities to influence the market for OSW in the region. We summarize state and regional policies that have the potential to influence demand for OSW and other large-scale renewables, including the following:

- Procurement policies for renewable energy and other resources (e.g., transmission)
- Renewable energy and environmental regulations, laws and policies (including RPS, greenhouse gas goals,)
- Plans (including State Energy Plans, Climate Action Plans, etc.)
- OSW-specific:
  - Goals
  - Laws
  - Policies
  - Regulatory proceedings,
  - Proposals under consideration
  - Economic development activities (including ancillary industry support such as port facilities, testing facilities)
- Proposed legislation
- Notable metropolitan/municipal renewable energy goals and initiatives (e.g., New York City, Portland, Boston, Providence, etc.)

This chapter is organized into seven geographically-specific subsections, each of which summarizes, where applicable, the information listed above for a designated state or region. Sections 4.1 through 4.4 address the relevant state-specific policies, as well as significant past and ongoing OSW-related activities in the three primary states participating in the Roadmap for Multistate Cooperation on Offshore Wind—New York, Massachusetts and Rhode Island. Section 4.5 focuses on the remaining New

England states, Connecticut, Maine, New Hampshire and Vermont. Section 4.6 discusses regional programs, such as the Regional Greenhouse Gas Initiative (RGGI) and regional system planning specific to the Northeast that could affect regional cooperation on OSW development. Lastly, Section 4.7 provides a brief overview of relevant OSW development activities and initiatives in the Mid-Atlantic region focusing on New Jersey as well as the and the Mid-Atlantic region's OSW transmission planning.

## 4.1 New York State

There are several ongoing renewable energy policy, planning, and procurement initiatives underway or being considered or pursued concurrently in the state of New York that will stimulate demand for OSW. Each of these initiatives builds upon a robust recent history of renewable energy procurement and greenhouse gas emission reduction goals, successive state policies aimed at reducing greenhouse gas emission. In addition they also build on OSW specific initiatives, such as OSW resource potential assessments and feasibility studies for proposed and potential projects off Long Island, in Lakes Erie and Ontario and in the Atlantic Ocean south of New York City and Long Island.[42] In January 2017, Governor Cuomo announced a statewide commitment to developing 2.4 GW of offshore by 2030 and directed NYSERDA to complete the State's Offshore Wind Master Plan by the end of 2017 (Cuomo A. M., 2017c).

### 4.1.1 Renewables Procurement and Targets

#### *4.1.1.1 PSEG-Long Island (LIPA)*

The Long Island Power Authority, has committed to procure 280 MW of on-island renewable energy generation. It issued its first request for proposals in October of 2013. Deepwater Wind ONE was one of nearly 40 proposals submitted in response to the RFP, but it was not selected.

In the fall of 2015, on behalf of the Long Island Power Authority, PSEG-Long Island issued a request for proposals for resources to serve the South Fork of Long Island (PSEG Long Island LLC (a), 2016). Following the release of the RFP, Deepwater Wind announced that its response to the RFP is a combination of 90 MW of capacity from the Deepwater Wind ONE lease area combined with 15 MWs of on-shore battery storage systems (Deepwater Wind, 2015). In January 2017, LIPA unanimously voted to approve Deepwater Wind's South Fork Wind Farm. The total cost for the project is estimated at

[42] As the scope of this RMC is offshore wind in the Atlantic, it will not address development potential in the Great Lakes.

$740 million and could include up to 15 turbines (Cuomo A. M., 2017a). LIPA is expected to purchase all of the energy, capacity, renewable attributes, and ancillary services produced by the facility through a 20-year PPA with the option of a five-year extension at a discounted price (Long Island Power Authority, 2017a). The project is expected to reach commercial operation by December 2022.

Late in 2015, PSEG-Long Island issued an additional request for proposals for up to and potentially more than 210 MW of new renewable capacity and energy [PSEG Long Island LLC (b), 2015]. OSW is an eligible technology under the RFP. Deepwater Wind submitted a bid for a 210-MW offshore wind farm from within their Deepwater One lease area in response to the RFP, but was not selected.

In April 2017, LIPA released its 2017 Long Island Integrated Resource Plan (IRP) and Repowering Studies, which among other issues considered and addressed, details how LIPA plans to meet its requirement under the New York CES's statewide 50% by 2030 goal. The plan noted that peak-load reduction appears to be driven by increasing amounts of energy efficiency and rooftop solar development. LIPA's CES requirement is 12.3% of the statewide requirement of 29,000 GWh of renewables by 2030, which, according to LIPA, will require it to acquire 800 MW of new renewable capacity. LIPA's IRP suggests it will rely almost entirely on offshore wind to meet its requirements (Long Island Power Authority, 2017b).

#### *4.1.1.2 New York Main Tier RPS*

The New York State RPS includes a Main Tier for large-scale generators and a customer-sited tier. The Main Tier RPS includes a target for 30% of the State's total electricity consumption to come from renewable generation by 2015. Under the Main Tier RPS framework, New York State's major investor-owned utilities collect from their customers an RPS fee. The revenue is transferred to a fund administered by NYSERDA, which NYSERDA in turn uses to directly incentivize large renewable energy projects through its Main Tier by issuing periodic solicitations for long-term RPS Attribute (REC) purchase agreements. NYSERDA issued its final Main Tier solicitation in 2016 and announced the selected projects in January 2017. Under the procurement, 11 large-scale clean energy projects with a cumulative capacity of 260 MW were selected for 20-year PPAs with a weighted average REC award price of $24.24 per MWh (Cuomo A. M., 2017b).

Governor Cuomo's Reforming the Energy Vision (REV) announced in 2015 includes replacing the RPS with a CES. In a letter dated December 2, 2015, Governor Cuomo directed the New York Department of Public Service (DPS) to initiate a proceeding to develop and implement a new CES and ordered that it be presented to the Public Service Commission (PSC) by June 2016 in order to achieve the 2015 State Energy Plan's long-term goal of providing 50% of the State's electricity from renewable sources by 2030 (Cuomo A. M., 2015).

#### *4.1.1.3 Clean Energy Standard*

On February 26, 2015, the PSC instituted the Reforming the Energy Vision large-scale renewables track, the implementation of which was initiated in a new proceeding, Case 15-E-0302 (New York Department of Public Service, 2015). On June 1, 2015, NYSERDA issued a paper titled Large Scale Renewable Energy Development in New York: Options and Assessment (NYSERDA, 2015), which focused on the successor program to the current Main Tier RPS program slated to end after 2016. The paper explored and compared different approaches for procurement and financing of new renewables through long-term REC purchases, bundled power purchase agreements (PPAs), or utility-owned generation. On January 21, 2016, the PSC issued an order expanding the proceeding to include the consideration of the 50% by 2030 CES, and further directing the preparation of a Staff White Paper on the Clean Energy Standard (New York Department of Public Service, 2016). The paper and subsequent comments guided development of a new large-scale renewables program in New York State.

On January 25, 2016, PSC released the White Paper outlining a CES that includes a combination of short-term and long-term targets, a proposed load-serving entity CES obligation, and discussion of possible future long-term REC contracting and PPA options to support CES project financing (New York Department of Public Service, 2016). The proposed CES is comprised of tiers to support renewable energy generation built after January 2015 (Tier I); resources built out under other State programs (including NY-Sun, RPS and Clean Energy Fund—instigated resources) and operating renewable energy generation (Tier II).

The PSC published a cost study (NYSERDA, Sustainable Energy Advantage, LLC, 2016a) in April 2016 to fulfil the requirement that State policies result in just and reasonable rates and provide input to the PSC's implementation of a cost-effective program. The cost study devoted Appendix A.2.2 to the examination of OSW resource potential and projected costs. The study included a base case and alternative scenarios and sensitivities which modeled potential OSW deployment quantities of between 1,200 and 2,000 MW under base cases and up to 4,000 MW in sensitivity analyses.

On August 1, 2016, the PSC formally issued the order adopting a CES (NYS Public Service Commission, 2016b). As adopted, the CES is divided into two programs: a Renewable Energy Standard (RES) that is further subdivided into two tiers, and a Zero-Emissions Credit (ZEC) requirement. The RES will be used as a major vehicle to achieve the state's "50 by 30" renewable goal. Tier 1 of the RES requires a load-serving entity (LSE) to supply an increasing percentage of retail sales in State with eligible renewables, mirroring in most respects the "Class I" RPS of most surrounding states. It is intended to create demand for new resources in support of the State's incremental renewable targets. The CES will also include long-term REC contract procurement of supply by NYSERDA to support financing of new renewables. While the PSC did not create an explicit carve-out tier for offshore wind, it envisioned that offshore wind resources will be contributing to the CES targets. In its order, the PSC requested that staff identify appropriate mechanisms to achieve the "objective of maximizing the potential for offshore wind."
The New York State Offshore Wind Master Plan, which is expected to be released by the end of 2017, will include recommendations on what mechanism(s) the State should use for OSW procurement and offtake (NYSERDA, 2016g).

### 4.1.2 Statewide Plans for GHG Reductions and Renewable Energy Targets

On August 6, 2009, then Governor David A. Paterson signed Executive Order No. 24, establishing a goal to reduce statewide greenhouse gas emission 80% by 2050 compared to 1990 levels (Paterson & Schwartz, 2009). The order also created a Climate Action Council which was further required to prepare a Climate Action Plan (Council, 2010) that would establish how New York State would meet its GHG emissions reduction goal.

The State of New York issued the 2015 New York State Energy Plan (New York State Energy Planning Board Members, 2015) on June 25, 2015. The plan lays out the policy options that guide the State's Reforming the Energy Vision effort in order to advance its clean energy economy. The plan includes targets for reducing GHG emissions by 40% from 1990 levels by 2030, and by 80% by 2050, as well as obtaining 50% of the State's electricity from renewable energy sources by 2030. The plan discusses various steps the State could take to facilitate its renewable energy market. The Plan addresses the planned development of the next phase of the large-scale renewables (LSR) policy through the REV initiative and the State's continuing support for OSW development. The plan outlined the State's commitment to produce a series of studies focusing on OSW siting and cost reduction.

In January 2017, New York Governor Cuomo also directed the Department of Environmental Conservation and NYSERDA to determine a cost-effective pathway toward reaching 100% renewable energy in New York State (Cuomo A. M., 2017c).

### 4.1.3 Clean Energy Fund and Other Initiatives

In addition to the development of the CES, New York State has several other programs that support the development of large-scale renewables that OSW is eligible for, including the Clean Energy Fund. The Public Service Commission approved a $5 billion, 10-year Clean Energy Fund to “accelerate the growth of New York’s clean energy economy, address climate change, strengthen resiliency in the face of extreme weather and lower energy bill for New Yorkers starting in 2016” (Cuomo A. M., 2016a). The fund will allocate $2.7 billion to market development as well as $782 million to the NY Green Bank to facilitate market investment and stimulate consumer demand for renewable energy resources, including onshore and offshore wind (Clean Energy Fund Investment Plan: Large-Scale Renewables Chapter, 2016).

### 4.1.4 The New York State Offshore Wind Master Plan

New York State has launched a number of related OSW initiatives to facilitate the deployment of OSW and provide environmental benefits at the lowest cost, while minimizing impacts on offshore habitats and wildlife, coastal communities, fisheries and maritime industries. In January 2017, New York Governor Cuomo delivered a series of Regional State of the State addresses across New York State. On January 10, 2017, Governor Cuomo announced a wide-ranging set of environmental initiatives and directives, including a statewide commitment to developing 2.4 GW of offshore wind by 2030. He called on NYSERDA to ensure that the New York Wind Energy Area, the lease for which was subsequently awarded at auction by Statoil, "is developed cost-effectively and responsibly to customers” (Cuomo A. M., 2017c) and further called for the execution of the OSW Master Plan by NYSERDA. The plan will provide a comprehensive State roadmap for advancing development of OSW in a cost effective and responsible manner and will coordinate all involved agencies including DEC, DOS, DPS and NYSERDA. In addition, on October 2, 2017, New York State announced that it submitted an Area for Consideration for OSW development off New York’s Atlantic Coast to BOEM, requesting that BOEM identify and lease at least four new WEAs, each capable of accommodating at least 800 MW of OSW capacity

(New York State, 2017). Under the Clean Energy Fund, NYSERDA will also undertake targeted pre-development initiatives including in-field resource assessments, baseline environment studies and site characterization to reduce overall project and ratepayer costs for OSW sites (NYSERDA, 2016d). These initiatives and their $15 million budget were described in Clean Energy Fund investment plans.

Pursuant to the Blueprint for the New York State Offshore Wind Master Plan—in coordination with other state agencies and the Market Advisory Group—an advisory group consisting of 19 different industry experts and organizations intended to actively inform and contribute to the development of the OSW Master Plan. NYSERDA continues to advance a series of studies aimed at informing the OSW Master Plan and advancing the development of OSW in New York. OSW Master Plan-related studies and surveys that have been completed or are otherwise ongoing include the following:

- Data Review and Gap Analysis (Ecology and Environment, Inc., 2017)
- Regulatory Review and Stakeholder Perceptions (NYSERDA, 2015c)
- Aerial Baseline Survey of Marine Wildlife (Normandeau Associates, 2017)
- Aviation and Radar
- Benthic Environment: Sediment Profile Imaging and Multi-Beam Echo Sounder Survey
- Birds and Bats
- Cumulative Effects
- Environmental Sensitivity and Permitting Risk Analysis
- Fish and Fisheries
- Grid Interconnection
- Health and Safety
- Jobs and Economic Benefits
- Marine Archeology and Cultural Resources
- Marine Mammals and Sea Turtles
- Metocean Characterization Report (NYSERDA, 2017)
- Onshore Permitting Constraints
- Pipelines, Cable, and Third-party Infrastructure
- Ports and Supply Chain
- Project Cost Projections
- Recreational Uses
- Sand and Gravel Resources
- Shipping and Navigation
- Vessels
- Visual Simulation

#### *4.1.4.1 NY Wind Energy Areas*

In September 2011, the Long-Island/New York City Offshore Wind Collaborative filed a lease application with BOEM (BOEM, 2016b). Following discussions between BOEM and a New York task force aimed at identifying potential lease areas within the New York Bight, it was determined that other companies were interested in developing the same area proposed by the collaborative. As a result, BOEM initiated a competitive leasing process in 2014.

On March 16, 2016, the U.S. Department of Interior announced that BOEM identified and designated a new 81,130-acre (approximately 328 $km^2$ or 127 $mi^2$) wind energy area (WEA), approximately 11 nautical miles offshore south of Long Beach, New York. The designation, however, does not approve the construction and operation of a wind energy facility, which would require a separate application requiring BOEM review and approval (BOEM, 2016c). On June 6, 2016, the Department of Interior issued a Proposed Sale Notice for Commercial Leasing for Wind Power on the Outer Continental Shelf Offshore New York, as well as an Environmental Assessment, for the 79,350-acre New York WEA (BOEM, 2016d; BOEM, 2016e).

Following the issuance of the proposed sale notice, NYSERDA announced that it would participate in the BOEM auction for the commercial OSW energy lease for the New York WEA as it sought "to ensure OSW in New York [is] developed at the lower possible cost for electricity consumers" (NYSERDA, 2016c). Notably, NYSERDA stated that as part of its pre-development work, it would "produce environmental studies and a resource assessment and site characterization to further reduce project costs and impacts," and "package this work with a power purchase mechanism and select a project developer through a competitive process." NYSERDA suggested the strategy would minimize project risks, maximize competition and facilitate financing certainty for developers. The lease auction concluded on December 16, 2016 with Statoil ultimately winning with a final bid price of approximately $42.5 million (BOEM, 2016g).

Prior to the auction, NYSERDA issued their draft Metocean Plan aimed to "set out the parameters for the wind resource assessment that NYSERDA intends to carry out" in evaluating the NY WEA (NYSERDA, 2016e). A metocean study is conducted to assess the meteorological and environmental considerations of completing a project (in this case, an offshore wind installation within the NY WEA). NYSERDA noted that if the authority were to be unsuccessful in acquiring the BOEM lease for the NY WEA, the plan would be adapted to evaluate additional sites suitable for wind energy development.

The identification of the New York WEA was initially the result of an unsolicited lease application submitted by the New York Power Authority (NYPA) on behalf of the Long Island (LI) – New York City (NYC) Offshore Wind Collaborative, which, as discussed in the following section, included a proposal for a 700-MW OSW project consisting of up to 194 3.6-MW wind turbines (NYPA, 2011). As identified, however, the lease area could support up to approximately 1000 MW of OSW capacity given current turbines and project development approaches.

In December 2016, PNE Wind submitted an unsolicited application for an OCS renewable energy commercial lease to BOEM, requesting a commercial lease for an offshore lease area approximately 41,000 acres in size, where PNE proposed to develop the NY4-Excelsior Wind Park with a preliminary capacity of 400 MW (PNE Wind, 2016b). BOEM will determine whether competitive interest for the proposed lease area exists. If competitive interest does exist, BOEM will hold a competitive lease auction for the area. If none exists, BOEM will negotiate and execute a lease with PNE (BOEM, 2017b).

#### *4.1.4.2 The Long Island – New York City Offshore Wind Collaborative*

The LI-NYC Offshore Wind Collaborative, once a public-private collaboration between ConEdison, the Long Island Power Authority (LIPA) and the New York Power Authority (NYPA), was originally established in 2008 to assess the feasibility and advance the development of an OSW wind project off the Atlantic Coast of New York State. The collaborative generated a series of reports in support of its proposed 700-MW OSW wind project, including:

- Offshore Wind Power Integration Project Feasibility Assessment (Con Edison & LIPA, 2009)
    - The report found that a 350-MW OSW farm operating at a 30% capacity factor would generate 920 GWh of electricity annually.
- Offshore Wind Technology Overview (AWS Truewind, 2009)
- Economic Impact Assessment: Long Island – New York City Offshore Wind Project (AWS Truepower, LLC & Camoin Associates, Inc., 2010)
- NYSERDA Physical and Environmental Qualities Studies (2010), a pre-development assessment of which suggested a project would be economically and environmentally beneficial as well as technically feasible:
    - Summary of Physical and Environmental Qualities of the Proposed Long Island – New York City Offshore Wind Project Area (NYSERDA, 2010)
        - The report applied five different turbine models with a 90-meter hub height assumption, each in a 350 MW and a 700 MW turbine array. The report estimated that annual net energy production could range from 1,069.5 GWh to 1,324.5 GWh, based on an assumed net capacity factor range of 34.9% to 43.4%.

The collaborative is no longer actively working to advance a project.

### 4.1.5 Other Studies Paving the Way for Offshore Wind

New York State has commissioned additional studies in support of OSW development. The studies include the following:

- In July 2013, the New York Department of State published the New York Offshore Atlantic Ocean Study (New York State Department of State, 2013), which details the physical, biological, geographic and socioeconomic characteristics of offshore activities in the Atlantic Ocean off the coasts of New York. The study sought to inform and support, among other activities and ocean industries, the future siting of OSW facilities.
- In addition to its involvement in facilitating and supporting many of the assessments and feasibility studies mentioned above, NYSERDA commissioned the New York Offshore Wind Cost Reduction Study (University of Delaware - Special Initiative on Offshore Wind, 2015)
- NYSERDA has also partnered with the Biodiversity Research Institute (BRI) on a two-phase project to help pave the way for potential OSW developers by more clearly defining the environmental permitting process. In addition, the project aims to identify the research needed to fully understand the impacts that OSW development could have on wildlife (NYSERDA, 2016f).

### 4.1.6 New York City Initiatives

The City of New York has initiated the following programs to address clean energy and climate change:

- The One New York: The Plan for a Strong and Just City (OneNYC) (The City of New York, 2015) *Initiative* is overseen by the Mayor’s Office of Long-Term Planning and Sustainability (Mayor's Office of Recovery and Resiliency, 2016). OneNYC is a citywide initiative to address the challenges posed by climate change, poor air quality, aging infrastructure and a changing economy that calls for an 80% reduction in citywide emissions by 2050 and by 35% within government operations by 2025 compared to 2005.
- On July 31, 2015, the City of New York issued a Request for Information (RFI) “to gather input regarding new sources of renewable energy to supply electricity for City government operations” to reach 100% renewable energy and to reduce greenhouse gas emissions 80% by 2050 (DCAS and MOS 2015).

## 4.2 Massachusetts

### 4.2.1 Renewables Procurement and Targets

#### *4.2.1.1 Renewable Portfolio Standard*

The Massachusetts Class I RPS established targets for load-serving entities to supply a specified percentage of retail load with new renewable resources. As amended by the Green Communities Act of 2008 (Massachusetts Legislature, 2008), its targets reach 15% of load by 2020 and increase by 1% per year indefinitely thereafter (Executive Office of Energy and Environmental Affairs, 2016). As noted in

Section 4.3.5 below, recent legislative proposals could, if passed, increase the rate of growth of annual RPS targets.

### *4.2.1.2 Long-Term Renewable Energy Procurement*

On August 8, 2016, Massachusetts Governor Charlie Baker signed An Act to Promote Energy Diversity, 2016), Section 83C of which requires the state's investor-owned utilities to solicit 1,600 MW of OSW between 2017 and 2027 and allows the state's investor-owned utilities to enter into long-term contracts with OSW developers. The first solicitation was required to occur no later than June 30, 2017 and all 1,600 MW must be contracted by June 30, 2027.[43] Each solicitation shall be no less than 400 MW and allows for remuneration to utility companies of up to 2.75% of the annual payments under the contract (Chapter 188 of Session Laws 2016 - An Act to Promote Energy Diversity, 2016). Section 83D of the same legislation requires the same utilities to issue a solicitation for long-term contracts with a combination of firm hydroelectric supply, Class I RPS-eligible supply firmed by hydroelectric, or Class I RPS supply alone. An RFP under Section 83D was issued on March 31, 2017 (MA Clean Energy, 2017). Among numerous proposals for LBW, utility-scale solar and hydroelectric, Deepwater Wind proposed 96 MW, 144 MW, and 288 MW variations of the Revolution Wind project from its Deepwater One lease area into the Section 83D RFP (Deepwater Wind, 2017).

Pursuant to Section 83C, on June 29, 2017, the Massachusetts electric distribution companies (EDCs) issued a Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects, seeking to procure a total of 400 MW of OSW. In addition to a 400 MW proposal, bidders are allowed to offer proposals for 200 MW up to approximately 800 MW of OSW. The proposals are due by December 20, 2017 and the selected project(s) will be submitted to the Department of Public Utilities for approval by July 31, 2018 (Unitil, et al., 2017).

Massachusetts has had some previous success using long-term contracts to enable the financing of grid-scale renewable energy sources. Section 83 (adopted in 2008) and Section 83A (adopted in 2012) of M.G.L. Chapter 169, An Act Relative to Green Communities, contained requirements for the state's EDCs to enter into long term PPAs with Class I RPS-eligible renewable energy generators. Section 83

---

[43] The enabling legislation requires the proposals submitted by developers to be cost-effective and reasonable. If following their review of the proposals, the Department of Energy Resources, in consultation with the utilities and the independent evaluator, determines that the proposals received were unreasonable, they may terminate the solicitation and require additional solicitations to fulfill the requirements of the legislation. All final contracts entered into by OSW developers and the utilities must be approved the Department of Public Utilities (DPU).

allowed for EDCs to enter either competitively-procured or negotiated bilateral PPAs with Class I RPS resources constituting 3% of retail load over a five-year period commencing in 2009. Competitive procurements under this section have led to construction of 148 MW across four operating LBW projects, as well as a small hydroelectric project. Section 83 procurement and contracting was fulfilled by the EDCs early, prompting passage of Section 83A. Section 83A obliged the EDCs to procure PPAs from another 4% of load from 2013 to 2016 (Massachusetts Legislature, 2012). One round of procurement commencing in 2013 led to six power purchase agreements with LBW farms. Although four of these were ultimately terminated, Section 83A has so far led to construction of the majority of the contracted supply, about 333 MW of wind capacity. Pursuant to its remaining authority under Section 83A, Massachusetts also participated in the New England Clean Energy RFP (discussed in Section 4.6.1) in 2016, through which 11 solar and LBW energy projects with a cumulative nameplate capacity of 461.2 MW were selected to advance to contract negotiation (Geschiere & Pande, 2016). The remaining unused procurement authority under Section 83A was sunset at the end of 2016.

There was also a long-term contract component to the Cape Wind OSW project. Negotiated PPAs covering 72.5% of the proposed 468 MW Cape Wind OSW project were executed by the state's two largest EDCs. Although the Cape Wind project secured the permits and leases necessary to move forward, it failed to secure financing before missed contractual milestones led to the EDCs terminating these PPAs.[44]

### 4.2.2 Greenhouse Gas Reductions Targets and Plans

The state's Global Warming Solutions Act (GWSA) contains a greenhouse gas emission reduction target of 25% below 1990 levels by 2020 and an 80% reduction by 2050. The GWSA was enacted in 2008, and spurred the development of the Massachusetts Climate Implementation Plan.

The MA Clean Energy and Climate Plan for 2020, updated in 2015, presents a set of strategies that the state will implement to reach the GWSA goal of 20% below 1990 levels of GHG emissions by 2020. Reductions necessary to reach the goal are planned to come from the electric generating sector with strategies of Clean Energy Imports (4.2%), Coal Fired Power Plant Retirements (2.9%), and the RPS

44 A condition of the Eversource merger settlement requires Eversource to solicit a replacement for the Cape Wind PPA (MA DOER, NSTAR and Northeast Utilities, 2016)

(1.1%) totally 8.2% (Massachusetts Executive Office of Energy and Environmental Affairs, 2016). The plan points to OSW as a potential future option that is not included in the plan's explicit 2020 goals (Massachusetts Executive Office of Energy and Environmental Affairs, 2016).

On May 17, 2016, the Massachusetts Supreme Judicial Court ruled that greenhouse gas reduction targets set by the GWSA were binding and that the Massachusetts Department of Environmental Protection (DEP) is responsible for the development of new regulations and programs to ensure that the greenhouse gas emissions targets set by the GWSA are actually met (Massachusetts Supreme Judicial Court, 2016). Following the ruling, in September 2016, Governor Baker signed Executive Order 569—"Establishing an Integrated Climate Change Strategy for the Commonwealth", which directed the Secretary of Energy and Environmental Affairs to coordinate efforts to "mitigate and reduce greenhouse gas emissions and to build resilience and adapt to the impacts of climate change" by establishing specific 2030 and 2040 emissions limits, cutting emissions from government operations, reducing emissions from transportation and electricity sectors, and publishing a comprehensive energy plan (Baker C. D., 2016). The order further directed the DEP to promulgate regulations, through a public process, to ensure that the state achieves the emissions reductions. In response to the Governor's executive order, the DEP issued a memorandum to stakeholders, in which it outlined proposed changes to its regulations in order to comply with the GWSA (Massachusetts Department of Environmental Protection, 2016). Of potential relevance to the demand for incremental renewable energy, one of the key strategies put further by DEP was the adoption, effective in 2018, of a Clean Energy Standard (CES). The proposed CES would establish escalating targets for energy supply from low-carbon resources including Class I RPS-eligible supply as well as large hydroelectric supply, which would encompass, but go beyond the Class I RPS. In August 2017, the DEP issued six regulations to limit or reduce greenhouse gas emissions, among them 310 CMR 7.75 establishing a CES. As promulgated, the CES requires retail sellers of electricity to provide a minimum of 80% clean energy for each retail electric product sold by 2050 (310 CMR 7.75 Clean Energy Standard, 2017). Beginning in compliance year 2018, EDCs and competitive suppliers must provide 16% of their electricity sales from clean generation. In 2018 this represents an incremental 3% of load above the Class I RPS obligations. The obligation ratchets up by 2% each year and maxes out at 80% by 2050 and thereafter. To be considered an eligible clean energy generator, a facility must:

- be qualified as a Massachusetts RPS Class I renewable generation unit, or
- have "net lifecycle GHG emissions, over a 20-year life cycle, that yield at least a 50% reduction of greenhouse gas emissions per unit of useful energy relative to the lifecycle greenhouse gas emissions from the aggregate use of the operation of a new combined cycle natural gas electric generating facility using the most efficient commercially available technology as of the date of the statement of qualification application for the portion of electricity delivered by the generation unit," and have begun commercial operations after December 31, 2010, or
- be a hydroelectric generator with a capacity over 30 MW, which meets both the emissions and 2010 vintage requirements previously identified.

### 4.2.3 Offshore Wind Initiatives

The MassCEC initiated several studies and initiatives to support the responsible and expedited development of future OSW projects:

- **Transmission**–an OSW transmission project to assess the most cost-effective cable routes and interconnection locations for incorporating OSW electricity into the regional grid (ESS Group, 2014)
- **Wildlife Surveys**–in partnership with BOEM, multi-year (2011-2017) marine wildlife surveys (underwater acoustical buoys and aerial surveys) to provide baseline data for the offshore permitting process (Veit, White, Perkins, & Curley, 2016; Kraus, et al., 2016)
- **Metocean Data**–collection of metocean data in partnership with the Woods Hole Oceanographic Institution (WHOI) and AWS Truepower on a WHOI-owned platform located near federal offshore wind energy areas (MassCEC, 2015)
- **Supply Chain**–a supply chain analysis to connect Massachusetts manufacturers, suppliers, and services companies to OSW developers and contractors
- **Ports and Infrastructure**–an engineering assessment of 18 waterfront sites with potential to be redeveloped by private industry investment to support offshore wind component manufacturing, staging, and long-term O&M (MassCEC, 2017)
- **Research**–funding for academic and research institutions to advance research and innovation in offshore wind development, technology and operations (MassCEC, 2017)
- **Workforce**–workforce training programs aimed at preparing Massachusetts workers with the skills necessary to work in this emerging industry (MassCEC, 2015)

Massachusetts has also published an Ocean Management Plan, which was issued by the Executive Office of Energy and Environmental Affairs in 2009 and updated in 2015. The Plan sets standards for ocean-based development that aim to protect wildlife and existing ocean uses and ensure that development is done in a sustainable way (MA EEA, 2015).

According to the Massachusetts Clean Energy Center, Massachusetts has already or will be

- establishing a public-private partnership to collect metocean data near the Federal OSW planning areas south of Martha's Vineyard in ways that support research and advance project planning and permitting
- funding a series of pilot research projects jointly identified by Massachusetts research institutions and OSW developers
- completing the Massachusetts Offshore Wind Ports and Infrastructure Assessment[45], a comprehensive evaluation of 18 potentially available waterfront sites in Massachusetts that could be used for parts of the offshore wind supply chain (MassCEC, 2017a)
- conducting OSW transmission route survey work
- identifying approaches for optimizing long-term offshore transmission built-out

### 4.2.4 Infrastructure Initiatives

Massachusetts has made several major investments in infrastructure and research designed to support the development of OSW. The Massachusetts Clean Energy Center (MassCEC) invested $113 million in the construction of the Marine Commerce Terminal in New Bedford. While the facility was designed as a multi-purpose terminal, it was purposely built to support construction, assembly and deployment of OSW projects. The terminal has the capacity to accommodate mobile cranes and storage loads across the entire 26-acre facility, rivalling the highest load-bearing ports in the U.S. (Massachusetts Clean Energy Center, 2016). In September 2016, the Baker-Polito Administration signed letters of intent with DONG Energy, Deepwater Wind and OffshoreMW (now Vineyard Wind), three offshore wind developers that currently hold the federal leases comprising the MAWEA and RIMA WEA, "to lease the New Bedford Marine Terminal as a staging and deployment location for future wind projects" (Baker & Polito, 2016).

In addition, MassCEC partnered with the U.S. Department of Energy and NREL to construct and operate the Wind Technology Testing Center (WTTC), the largest indoor wind blade test facility in North America. The WTTC offers wind turbine blade testing to blade manufacturers as a way to advance the technology, drive down costs, and ensure that new turbine blades are fully evaluated and certified for reliability and performance (MassCEC).

45 The Phase One – Existing Conditions Report was completed in May 2017 (MassCEC, 2017b). Phase Two, the Final Ports Assessment is expected for release at the end of Summer 2017.

### 4.2.5 Complementary Developments and Initiatives

Massachusetts has launched an Energy Storage Initiative (Massachusetts Executive Office of Energy and Environmental Affairs, 2015), and in the fall of 2016 released a study detailing recommendations to expand storage markets and craft supportive policies and regulations (Massachusetts DOER, MassCEC, Customized Energy Solutions, Alevo Analytics, Sustainable Energy Advantage, Daymark Energy Advisors, and Strategen, 2016). Massachusetts also runs programs designed to support innovative and/or local clean energy technologies, including energy storage technologies. Resilient power and energy storage-specific grant programs are currently operating, and other programs are in development. There is also work underway to make storage eligible to participate in existing state clean energy programs, including the state's alternative energy portfolio standard and long-term utility procurement. The Massachusetts Energy Diversity Act of 2016, which calls for the state's utilities to procure 1600 MW of OSW, allows OSW to be paired with energy storage systems and allows utilities to own energy storage systems in Massachusetts. The state has also announced an "aspirational" target for utility procurement of 200 MWh of energy storage by 2020. Material expansion of the role of energy storage would enable increased penetration of variable resources such as OSW (see Section 3.4), and thereby enable OSW to play a greater role in replacing retired or retiring baseload and cycling resources (see Section 3.3).

In 2014, Boston City Mayor Martin J. Walsh released the Greenovate Boston 2014 Climate Action Plan Update, which set an interim target of reducing citywide GHG emissions by 25% below 2005 levels by 2020 and a long-term target of reducing GHG emissions by 80% below 2005 levels by 2050 (Walsh, 2014).

## 4.3 Rhode Island

### 4.3.1 Renewables Procurement and Targets

#### *4.3.1.1 Renewable Energy Standard*

After being extended in 2016 (S.2185 - Substitute A, 2016), Rhode Island's Renewable Energy Standard (RES) requires load-serving entities to supply a percentage of their sales to retail customers from eligible renewables which ramp up to 38.5% renewable energy by 2035, with at least 36.5% coming from “new” renewable resources.[46] Wind is an eligible resource, but no specific amounts are required, and OSW is not mentioned.

#### 4.3.1.2 Long-Term Renewable Energy Contracting

In 2010, with certain amendments in 2012, the Rhode Island General Assembly established under Chapter 26.1 of Title 39 of the Rhode Island General Laws a Long-Term Contracting Standard for Renewable Energy (Rhode Island Legislature, 2009). Under § 39-26.1-3, and the PUC’s corresponding regulations, National Grid, the state’s investor-owned EDC, is required to solicit and procure a minimum ‘long-term contract capacity’ of 90 MW from RES-eligible new renewables (corresponding to a nameplate capacity target adjusted by a generator’s capacity factor, i.e., a 100 MW wind farm operating at a 30% capacity factor counts as 30 MW of contract capacity). This section of the law does not distinguish between eligible renewables, and as National Grid has now fulfilled its procurement obligations under this section, the 90 MW is foreclosed to future OSW support. However, the same statute contains two additional provisions dedicated to OSW.

Section (§) 39-26.1-7 (Town of New Shoreham Project) was established to “facilitate the construction of a small-scale OSW demonstration project off the coast of Block Island, including an undersea transmission cable that interconnects Block Island to the mainland, in order to position the state to take advantage of the economic development benefits of the emerging OSW industry; promote the development of renewable energy sources that increase the nation's energy independence from foreign sources of fossil fuels; reduce the adverse environmental and health impacts of traditional fossil fuel energy sources; and provide the Town of New Shoreham with an electrical connection to the mainland.” It required National Grid to enter into a long-term PPA, subject to PUC approval, for an OSW demonstration of up to 30 MW (Rhode Island Legislature, 2009). The Block Island Wind Farm is counted against the § 39-26.1-3 requirement.

Further, § 39-26.1-8 (Utility-scale offshore wind project – Separate proceedings) provides for a long-term PPA between a developer selected by the state to develop a utility-scale OSW farm, and National Grid of between 100 and 150 MW in nameplate capacity, separate from the § 39-26.1-3 requirement. A developer may bring an application for a PPA before the PUC for approval, subject to a PUC determination

---

[46] These ultimate targets account for a 1-year delay in target ramp-up ordered by the PUC as a result of the second resource adequacy evaluation; future resource adequacy evaluations could potentially alter these targets further.

regarding "(1) the economic impact and potential risks, if any, of the proposal on rates to be charged by the electric distribution company; (2) the potential benefits of stabilizing long-term energy prices; (3) any other factor the commission determines necessary to be in the best interest of the rate payers" (Rhode Island Legislature, 2009).

In addition, in 2014 the General Assembly passed the Affordable Clean Energy Security Act. Under § 39-31-5 (Regional energy procurement), National Grid, in consultation with the Office of Energy Resources (OER) and the Division of Public Utilities and Carriers (serving as ratepayer advocate), is authorized to voluntarily participate in multistate or regional efforts to procure domestic or international large- or small-scale hydroelectric power and eligible renewable energy resources, including wind (as well as natural gas pipeline capacity). It is through this authority that National Grid and the OER participated in the CERFP described in Section 4.6.1., through which 11 renewable energy projects with a cumulative nameplate capacity of 461.2 MW were selected to advance to contract negotiation (Geschiere & Pande, 2016). Rhode Island did not specify its procurement targets under the CERFP and the statute imposes no time limits on procurement authority, so that its application to OSW in the future remains a possibility (RI General Assembly, 2014).

#### *4.3.1.3 Renewable Energy in State Plans*

The Rhode Island State Energy Plan "Energy 2035" (Rhode Island Division of Planning, 2015) touts OSW as the state's largest renewable resource, but does not set any specific targets, other than mentions of existing activities with Deepwater Wind detailed below. It also outlines three different expansion scenarios for the RES, with 2035 targets of 25%, 40%, and 75% being considered (as compared to the current 16% target). These scenarios call for 180 MW of OSW deployment in-state (corresponding to the maximum targets under § 39-26.1), and the higher scenarios also call for purchasing a large number of RECs from out-of-state wind resources, up to 1,000 MW. In March 2017, Governor Raimondo announced a nonbinding strategic goal of achieving 1,000 MW of renewable energy supply by 2020 (Raimondo, 2017).

### 4.3.2 Greenhouse Gas Reductions Targets and Plans

The Resilient Rhode Island Act, (Ch. 42-6.2, Resilient Rhode Island Act of 2014–Climate Change Coordinating Council) was passed by the General Assembly in 2014. It established a Rhode Island Executive Climate Change Coordinating Council and required that, by no later than December 31, 2016, the council submit to the governor and General Assembly a plan that includes strategies, programs, and actions to meet the following targets for greenhouse gas emissions reductions:

- Ten percent (10%) below 1990 levels by 2020
- Forty-five percent (45%) below 1990 levels by 2035
- Eighty percent (80%) below 1990 levels by 2050

(Rhode Island General Assembly, 2014).

### 4.3.3 Offshore Wind Development Support Initiatives

#### *4.3.3.1 Ocean SAMP*

The State of Rhode Island in 2007 identified that its largest renewable energy resources opportunity was OSW. In 2008, the Rhode Island Ocean Special Area Management Plan, or Ocean SAMP, was launched by the University of Rhode Island (URI), the Rhode Island Coastal Resource Management Council and Rhode Island Sea Grant. A number of other state agencies participated in this research project, including the Department of Environmental Management and the Office of Energy Resources. The effort was funded by the State of Rhode Island Office of Energy Resources, the Rhode Island Economic Development Corporation, the U.S. Department of Energy, and the Rhode Island Sea Grant College Program.

The Ocean SAMP examined the opportunities, challenges and locations within state and federal waters off the Rhode Island coastline to construct OSW projects (R.I. Coastal Resources Management Council, n.d.). The SAMP served as a regulatory and management tool to help develop ocean-based resources. The upfront comprehensive SAMP work accelerated the permitting and siting time for Deepwater Wind's Block Island Wind Farm, and reduced costs associated with these activities overall and for the developer. This SAMP investment should also pay off in the same manner for projects in federal waters off Rhode Island. In 2015, URI launched an effort to update the SAMP with new scientific data and enhanced policies.

### 4.3.3.2 Block Island Wind Farm

The state released a Request for Proposals to partner with a renewable energy developer to build the state project. The state selected Deepwater Wind (DWW) in late 2008 as its preferred OSW development partner and the partner to develop and build the 30-MW project provided for under the long-term contracting statute discussed in Section 4.4.1.2. DWW's Block Island Wind Farm (BIWF), located entirely within state waters off the Town of New Shoreham is the first OSW installation in the U.S. In 2010, the Public Utility Commission approved a 20-year power purchase agreement (PPA) between National Grid and DWW for the 5-turbine, 30 MW project. In 2013 and 2014, DWW secured the necessary state and federal permits to construct the Block Island project (Rhode Island Public Utilities Commission, n.d.).

DWW began construction of the BIWF in July 2015. The project became operational in December 2016. The project and associated interconnection cable are connected to Block Island and to Narragansett, RI (Deepwater Wind, 2016).

### 4.3.3.3 Port Development

In 2010, Rhode Island received a grant through ARRA Stimulus funds to develop a staging area for OSW development through the redevelopment of the Quonset Point Business Park (the State of Rhode Island, 2010). Quonset received infrastructure improvements that include two piers that can accommodate the size and weight of OSW components as well as large wind construction vessel access.

### 4.3.3.4 Complementary Developments and Initiatives

Increased deployment of energy storage can help support widespread deployment of variable renewables, and thus can help increase the potential for OSW to contribute to filling a baseload/cycling energy gap, created by retirements of older plants in the regional generation fleet. OER, the Energy Efficiency and Resource Management Council (EERMC), the Distributed Generation Board and National Grid have assembled a Systems Integration Rhode Island (SIRI) working group to identify significant issues with respect to the future of Rhode Island's electric grid and thereafter develop recommendations. The final "vision document" was released in January 2016 and mentions storage as a "non-wires alternative" (NWA) factor in distribution planning, system reliability procurement. Recommendations include promotion of cost-effective, comprehensive NWA distribution planning, and acceleration of EV use (Rhode Island Office of Energy Resources, 2016). In addition, the State Energy Plan includes consideration of energy storage as a means for increasing energy security/resiliency, grid modernization, and interstate coordination to reduce high and volatile regional energy costs. It modeled deployment of 200 and 150 MW of storage, which it found “would represent a significant investment in power system resiliency, providing substantial energy security benefits but likely at a significant cost” (Rhode Island Division of Planning, 2015, p. 130).

### 4.3.4 City of Providence Initiatives

On April 22, 2016, the Mayor of Providence, Jorge Elorza, in commemorating Earth Day, signed an Executive Order adopting, among other goals, a citywide goal of achieving carbon neutrality by 2050. The goal has been added to the city's Sustainable Providence Plan, the most recent of which was released in September 2014 (Elorza, 2016).

## 4.4 Rest of New England

### 4.4.1 Connecticut

The high-marine vessel traffic and low-wind speeds in Long Island Sound, which represents the majority of Connecticut’s ocean coastline, significantly limit the state’s focus on policies and other activities associated with OSW.

#### *4.4.1.1 Renewable Energy Standard*

In Connecticut’s Renewable Portfolio Standard, the target for Class I resources, including wind, increases from 14% of end-use load in 2016 to 20% by 2020, with amounts not yet set thereafter (CT DEEP - PURA, n.d.).

#### *4.4.1.2 Long-Term Renewable Energy Contracting*

The Connecticut General Assembly has adopted several long-term contracting provisions since 2011, with the most relevant adopted in 2013 (Public Act 13-303) and 2015 (Public Act 15-107). Some of these provisions pertain to distributed energy generation or large hydroelectric, which are not detailed here. Procurement relevant to large-scale, RPS Class I resources (which encompass OSW) include the following:

- PA 15-107 grants the Connecticut Department of Energy and Environmental Protection (DEEP) Commissioner authority to engage in procurement of a range of regional utility-scale and local distributed-scale renewable energy sources. The Act also requires solicitation of natural gas resources, and distributed generation sources including Class I and Class II RPS resources, energy storage and demand response, through long-term contracts which in aggregate (across

3 distinct procurements) can represent up to 10% of the load equivalent of the state's EDCs (with the split between the categories to be determined based on the relative valuation of proposals received).

- Under PA-13-303 Section 6, DEEP is authorized to solicit long-term contracts for RPS Class I renewables in aggregate up to 4% of EDC load. In September 2013, DEEP selected through a competitive procurement two renewable energy projects—EDPR's 250 MW Number 9 wind project and the 20 MW Fusion Solar Center—to enter into long-term contracts with the state's electric distribution companies. However, a modest amount of this procurement authority remains unfilled. In addition, under PA-13-303 Section 7, DEEP is authorized to procure either Class I renewables or large hydro resources under long-term contracts representing up to 5% of EDC load (Connecticut Legislature).

Connecticut also participated in the CERFP (discussed in Section 4.6.1) in 2016, through which 11 renewable energy projects with a cumulative nameplate capacity of 461.2 MW were selected to advance to contract negotiation (Geschiere & Pande, 2016). Connecticut currently has the following remaining procurement authority:

- 1890 GWh per year of Qualified Clean Energy under Section 1(c) of Public Act 15-107
- 1130 GWh per year of Qualified Clean Energy under Section 7 of Public Act 13-303
- 125 GWh per year of Class I Qualified Clean Energy under Section 6 of Public Act 13-303 (CT DEEP, MA DOER, Eversource, National Grid and Unitil, 2016)

In June 2017, Governor Malloy signed Public Act 17-144—an Act Promoting the Use of Fuel Cells for Electric Distribution System Benefits and Reliability and Amending Various Energy-Related Programs and Requirements into law—which among other provisions, expands DEEP's procurement authority under Section 8 of Public Act 13-303 to a broader set of resources, including offshore wind, and extend offered contract durations to up to 20 years. Under Section 8 of Public Act 13-303, DEEP may solicit and select proposals from qualified resources to meet up to 4% of the load distributed by the state's EDCs (State of Connecticut, 2017). Only 3% of the load may be procured from offshore wind resources.

#### *4.4.1.3 Renewable Energy in State Plans*

Connecticut's 2013 Comprehensive Energy Strategy does not give any specific considerations to offshore wind (CT DEEP, 2013). In July 2017, CT DEEP issued a draft of the 2017 Comprehensive Energy Strategy (CES), which includes a series of recommendations for the state's energy policy "guided by the goal of cheaper, cleaner, [and] more reliable energy," including the alignment of the state's renewable targets and renewable energy procurement with the state's carbon reduction goals under the Global Warming Solutions Act (CT DEEP, 2017). Among other recommendations, the draft CES recommended the following:

- Increasing Class I RPS requirements to 30% by 2030
- Encouraging new Class I resources by phasing down the value of biomass and landfill gas resources in meeting Class I RPS requirements
- Undertaking additional procurement to match the 1% annual RPS escalation using existing and (if needed) new statutory authority, and prioritizing “grid-scale” Class I development by allocating up to 0.75% of such procurement each year to grid-scale resources

The draft CES also recognized offshore wind as being a resource that “can result in grid scale renewables without the renewable siting concerns raised in DEEP’s recent grid scale solicitations.” Connecticut also conducts a biennial Integrated Resources Plan (IRP) process, the last of which was developed in 2014. Under the IRP process, the DEEP may make determinations of procurement activity under existing authority and potentially highlight future actions requiring additional statutory authority.

In 2004, Connecticut Governor John G. Rowland signed Executive Order No. 32 establishing a goal of increasing the renewable energy share of electricity consumption by state government and public university load to 20% by 2010, 50% by 2020 and 100% by 2050 (Rowland, 2004). Greenhouse Gas Reductions Targets and Plans, Connecticut’s Global Warming Solutions Act of 2008 (Connecticut Legislature, 2008) established GHG reduction targets of 10% below 1990 levels by 2020, and 80% below 2001 levels by 2050. The Act requires CT DEEP to establish a baseline emission inventory, develop modeling scenarios for strategies that contribute to attaining the goals, and “…a schedule of recommended regulatory actions by relevant agencies, policies and other actions necessary to show reasonable further progress towards achieving the greenhouse gas emission levels specified in the GWSA.” The Governor’s Council on Climate Change is tasked with monitoring the state’s process and making recommendations for achieving the state’s goals.

### 4.4.2 Maine

#### *4.4.2.1 Renewable Portfolio Standard*

Wind (including OSW) is an eligible resource under Maine’s Class I RPS. The Maine Class I RPS targets reach their maximum of 10% of retail sales from eligible renewables in 2017, and remain constant thereafter (C.M.R. 65-407, Ch. 311, §3[A]). Without further target increases in the timeframe in which OSW will be available, it is unlikely that this policy will drive any new OSW.

### Plans that Include Renewable Energy Targets

The Maine Comprehensive Energy Plan 2015 Update (State of Maine Governor's Energy Office, 2015) includes the goals set by the Ocean Energy Act, detailed in Section 4.2.4, and notes that OSW could be an economically productive export for Maine, given their large resource levels and low electricity loads. The plan also notes that the siting requirements for OSW development are less strict than those for onshore projects.

## *4.4.2.2 Greenhouse Gas Reductions Targets and Plans*

In 2003 the Maine Legislature passed 38 MRSA §576, which requires a reduction of greenhouse gas emissions by 10% below 1990 levels by 2020, and an unspecified long-term reduction goal which is "sufficient to eliminate any dangerous threat to the climate." The law acknowledges that reductions of up to 80% below 2003 levels may be necessary (Maine Legislature, 2003).

Portland developed a Municipal Climate Action Plan in 2008 to frame initiatives that would help bring the city closer to meeting the goal of lowering emissions to 10% below 1990 levels by 2020 (Portland Municipal Climate Change Working Group, 2008).

## *4.4.2.3 Procurement Policies*

### Long-Term Renewable Capacity

Maine Law 35-A M.R.S. Section 3210-C (enacted in 2006) describes the authority of the Public Utilities Commission (the Commission) to direct transmission and distribution utilities to sign long-term contracts for capacity resources, and the energy and RECs associated with the capacity resources. The law further notes that capacity resources shall be selected first on merit of their competitive prices. The second priority is to choose resources such as demand response, new renewable energy resources, and new resources with zero-net greenhouse gas emissions (Maine Legislature, 2006).

There is currently a proceeding in Maine PUC Docket 2015-0058 to inquire into the goals and objectives for long-term contracting under 35-A M.R.S. Section 3210-C (Maine Public Utilities Commission, 2015). No actions have been taken in the docket since June 2015, but the outcome has the potential to establish whether the OSW market will in the future have access to long-term utility contracts under this law. The central issue considered under this proceeding is the use of long-term contracts to support renewable energy generation.

## Offshore Wind Procurement and Floating Pilot Offshore Wind PPA

Ocean renewable energy procurement through long-term contracting is authorized by Section A-6 of the 2010 Ocean Energy Act (discussed further in Section 4.2.4 below). The Act directed the Public Utility Commission (MPUC) to conduct a competitive solicitation for proposals for 30 MW of capacity, energy and Renewable Energy Certificates (RECs) from OSW or tidal energy projects. The Act authorizes the PUC to enter into contracts for up to 30 MW total, from deep-water OSW energy pilot projects and tidal energy demonstration projects, with a 5 MW total limit on tidal projects. The Act limits the customer bill impact of the contracts to 0.145 cent per kilowatt-hour for any customer class (Maine Legislature, 2010).

In response to the RFP issued by the Maine PUC in September of 2011, Statoil North America, Inc., an international energy company, submitted a proposal that was selected by the PUC (Statoil North America, Inc). In addition, Statoil submitted an unsolicited request for a commercial lease to the Bureau of Ocean Energy Management (BOEM) for a pilot-scale wind power project in deep water south of Boothbay. The proposed project, named Hywind Maine, was a multi-turbine wind park with the world's first full-scale floating wind turbines. After reopening of the RFP for OSW, in October 2013 Statoil removed its proposal from consideration from the PUC.

Following Statoil's departure, in 2013 and 2014, the Commission approved a long-term contract for the Maine Aqua Ventus OSW project proposed by a University of Maine consortium that includes Cianbro Corp. and Emera (Maine Public Utilities Commission, 2010). Aqua Ventus is a 12-MW pilot project aimed at demonstrating a floating platform design. The University of Maine has focused research on floating technologies which the State of Maine has supported through research and development bonds (University of Maine, n.d.). The University of Maine continues to have a term sheet in place for a 20-year PPA and has received $7.7 million in funding from the Department of Energy for refinement of cost estimates and design. The Aqua Ventus project was one of several projects selected by the Department of Energy in May 2016 as eligible to receive up to $40 million in additional Federal funding under the Offshore Wind Demonstration Projects program, subject to Congressional appropriations and the achievement of development milestones. Subsequent to the selection, D.O.E. committed $3.7 million to fund the next phase of project development (DOE, 2016).

### Offshore Wind Specific Policies and Programs: 2010 Offshore Energy Act

Following completion of Governor Baldacci's Ocean Energy Task Force in 2009 (Ocean Energy Task Force, 2009), in 2010, the Ocean Energy Act was signed into law. The purpose of the Act to Implement the Recommendations of the Governor's Ocean Energy Task Force is "to encourage development of OSW and tidal energy." The legislation both authorized above-market contracts for electricity generated from tidal energy and OSW and established OSW energy goals (Maine Legislature, 2010). The Act sets nonbinding goals for future development of renewable energy in Maine, including OSW goals as follows:

- 2,000 MW installed by 2015
- 3,000 MW installed by 2020, including at least 300 MW from offshore sources
- 8,000 MW installed by 2030, including at least 5,000 MW from offshore sources

Due to the depth of waters in the Gulf of Maine, the focus of these goals is on floating foundations.

## 4.4.3 New Hampshire

### *4.4.3.1 Renewable Energy Standard*

The New Hampshire RPS includes wind as a Class I resource, and requires that 6.90% of electricity in 2016, rising to 15% of electricity in 2025 come from Class I (NH PUC, 2016).

### *4.4.3.2 Long-Term Renewable Energy Contracting*

The Public Utilities Commission (PUC) considers for approval long-term PPAs between the state's utilities and electricity generators on an ad hoc basis, but no target for achieving RPS targets with long-term PPAs has been set or is anticipated.

### *4.4.3.3 Renewable Energy and OSW in State Plans*

New Hampshire's State Energy Strategy notes a significant potential for contributions from OSW in the long term (NH OEP, 2014).

New Hampshire formed a Legislative Committee to Study Offshore Wind Energy and the Development of Other Ocean Power Technology, which released its report in 2014. This report stated that there is significant OSW potential, and the best locations would be over three miles offshore, where floating platforms would be optimal (NH Committee to Study Offshore Wind Energy, 2014).

#### 4.4.3.4 Legislation

NH is considering HB 626—an Act Authorizing Energy Infrastructure Development and Designating Energy Infrastructure Corridor that would determine statutory energy infrastructure corridors within which energy infrastructure could potentially be sited underground. It would also direct the Site Evaluation Committee to evaluate and approve proposals for the development of energy infrastructure such as electric transmission facilities and natural gas projects. This could increase the likelihood of electric transmission projects necessary for LBW and OSW projects to deliver their output to load centers in southern New England (See discussion of transmission constraints in Section 2.4.4.).

### 4.4.4 Vermont

#### 4.4.4.1 Renewable Energy Standard

Vermont is implementing a renewable energy standard (RES), which was enacted through Act 56 of 2015. The minimum obligation of total renewable energy is set at 55% of each retail electricity provider's electricity sales during the year beginning January 1, 2017, increasing by an additional 4% every three years, until reaching 75% in 2032. The target will maintain at 75% thereafter. The minimum obligation for distributed generation is set at 1% beginning January 1, 2017, increasing by 0.6% per year thereafter until reaching 10% in 2032. The target will maintain at 10% thereafter. The total renewable energy target does not require new renewable energy generation, and can be met from a surplus of legacy renewables throughout the region. As a result, the RPS program is designed primarily to support in-state DG development, and provides negligible support for new utility-scale resources, such as LBW, OSW, or large biomass plants (Vermont Legislature, 2015).

#### 4.4.4.2 Long-Term Renewable Energy Contracting

Under Vermont's Sustainably Priced Energy for Economic Development ("SPEED") (30 V.S.A. Chapter 89) goals, some of the state's regulated utilities have brought forward for approval by the Vermont Public Service Board (PSB) several long-term PPAs with (or proposals for utility ownership of) large-scale renewables (featuring commercial-scale wind projects in Vermont and New Hampshire). With the advent of the RES, the authors do not anticipate any further out-of-state contracting with new renewables including OSW.

#### 4.4.4.3 Renewable Energy in State Plans

Vermont: The 2016 Vermont Comprehensive Energy Plan indicates that Vermont utilities are likely to purchase OSW if it becomes cost-competitive. Although no specific amounts are set as goals for OSW, the overall renewable energy goals are to “Meet 25% of the remaining energy need from renewable sources by 2025, 40% by 2035, and 90% by 2050” (Vermont Department of Public Service, 2016). Given Vermonters’ general opposition to large scale in-state wind and solar projects, it is possible that OSW could play a part in meeting their goals. However, given the RES targets, which would (if attained) meet the lion’s share of these targets, the incremental appetite for OSW would be quite limited.

#### 4.4.4.4 Greenhouse Gas Reductions Targets and Plans

Section 578 of Vermont’s Title 10 Conservation and Development statute set GHG emission reduction targets of 25% below 1990 levels by 2012, 50% below 1990 levels by 2028, and, if practicable, 75% by 2050 (Vermont General Assembly, 2016).

## 4.5 Regional Activities

### 4.5.1 Procurement Policies

Since 2009, the New England Governors’ Conference has authorized the New England States Committee on Electricity (NESCOE)—which represents the collective perspective of the six New England states in regional electricity matters—to develop and implement a work plan for the competitive coordinated procurement of regional renewable energy generation (Shumlin, 2012). The objective of these efforts has been to coordinate efforts to drive procurement in sufficiently large quantities to support procurement of the largest renewables projects with best-scale economies, and to support construction of large-scale transmission facilities necessary to tap remote sources of clean energy, neither of which was likely through individual state’s smaller-scale procurement efforts. This initiative, which has progressed through numerous stages of concerted effort by NESCOE staff and representatives to NESCOE of each state, has culminated in the issuance of the New England Clean Energy Request for Proposals (CERFP) (CT DEEP, MA DOER, Eversource, National Grid and Unitil, 2016).

In November of 2015, the state agencies and distribution companies in Massachusetts, Connecticut, and Rhode Island issued the CERFP seeking proposals for clean energy and transmission (Connecticut, Massachusetts, and Rhode Island, 2015). Under the joint solicitation, Massachusetts' distribution companies, Connecticut Department of Energy and Environmental Protection (DEEP) and National Grid in Rhode Island were seeking to procure a combination of Class I RPS renewables, large hydro, and supporting transmission facilities under long-term contracts or "Qualified Clean Energy Delivery Commitments" under various existing authorities (detailed further below, where relevant). Bids were submitted in late January 2016 consisting of submissions representing 23 responses consisting of various combinations of LBW, utility-scale solar, fuel cell, and large-scale hydroelectric supply, many combined with supporting transmission proposals.

No bids from OSW projects were submitted. Many proposed projects are in very early stages of development and issues around siting and interconnection delays and timing of delivery were major factors in terms of their viability to serve the needs of the procuring states as they seek to replace retiring coal and nuclear capacity. In October 2016, the participating states announced that 11 renewable energy projects—consisting of solar and LBW—with a cumulative nameplate capacity of 461.2 MW located in Connecticut, Maine, New Hampshire, and New York State were selected to advance to contract negotiation under the CERFP (Geschiere & Pande, 2016). The approach taken for coordinated action under individual state statutory authority is a capability that many states in the region have been working on for several years, which has culminated in a working model now being executed for how to advance individual states' interests while seeking scale through coordinated action.

### 4.5.2 Regional Greenhouse Gas Reduction Targets

The Regional Greenhouse Gas Initiative (RGGI) is a program established in 2005 to limit carbon emissions in a region that includes the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Implemented through a cap-and-trade regime, RGGI allowances have a market price and periodic auctions. Each state has its own $CO_2$ emissions budget for the electric sector, supported by enabling statute and regulations for implementing the program. The regional cap was reduced from its original value of 165 million short tons by 2013 to 91 million short tons in 2014, and declines annually by 2.5% from 2015 to 2020. The RGGI program is currently undergoing a program review, and the program cap may be reduced further through this process, particularly in the face of the aggressive state goals described above. On August 23, 2017, RGGI announced that the participating states had agreed on a proposal for an additional 30% reduction in emissions by 2030, relative to 2020 (RGGI, 2017a). That proposal is now being circulated for stakeholder comments. Current individual state caps within RGGI are shown in Table 12 below, and the individual states' commitments are discussed further under each individual state.

**Table 12. 2017 Adjusted $CO_2$ Allowance Allocation by State**

*Source: (RGGI, 2017b)*

| State | 2017 Adjusted $CO_2$ Allowance Budget (Short Tons) | Share of Total Adjusted Budget |
|---|---|---|
| Connecticut | 4,042,095 | 6.5% |
| Delaware | 2,858,274 | 4.6% |
| Maine | 2,249,216 | 3.6% |
| Maryland | 14,179,851 | 22.7% |
| Massachusetts | 10,079,934 | 16.1% |
| New Hampshire | 3,259,302 | 5.2% |
| New York | 24,315,220 | 38.9% |
| Rhode Island | 1,005,431 | 1.6% |
| Vermont | 463,472 | 0.7% |
| Total | **62,452,795** | **100%** |

In August of 2015, the New England Governors and Eastern Canadian Premiers (NEG/ECP) adopted a Resolution Concerning Climate Change (Conference of the New England Governors and Eastern Canadian Premiers, 2015). Building on earlier commitments made by the group, the resolution set reduction targets of 35%-45% below 1990 emission levels by 2030, and a target reduction of 75-85% below 2001 levels by 2050. The resolution also committed the states and provinces to update the 2013 Regional Climate Change Action Plan to develop possible joint action to achieve the 2030 target. As discussed in Section 2.1, the region has substantial OSW potential. If this potential can ultimately be realized at a palatable cost, OSW can become a major contributor to meeting these targets.

### 4.5.3 Wholesale Market Planning and Operations

The increasing participation by VERs such as wind in the region's electric markets have prompted FERC and wholesale market operators like ISO-NE and NYISO to implement market rule changes and other policies that address a range of issues, including planning, interconnection, integration, economic dispatch, transmission constraints, reliability, capacity market participation and generator curtailment. Addressing these issues is critical to enabling the widespread deployment and maximizing the feasible integration of VERs. Examples of the approaches regulators, policymakers, system operators, and market participants are taking include the following:

- Wind generation studies (NYISO, 2010)
- Renewable energy integration studies (Hinkle & Piwko, 2010; Piwko, et al., 2005)
- Wind power forecasts
- Negative LMP bidding and dispatch rules changes

- Establishing working groups like the ISO-NE Variable Resource Working Group[47]

In addition, transmission planning and cost allocation initiatives to support the interconnection and integration of large-scale renewables are also underway. Examples include the following:

- FERC Order 1000: The Federal Energy Regulatory Commission's Order 1000 brings far-reaching changes to the process governing transmission planning and cost allocation. Specifically, it requires each "public utility transmission provider" to "work within its transmission planning region to create a regional transmission plan that identifies transmission facilities needed to meet reliability, economic, and public-policy requirements...." Each plan must "include fair consideration of lines proposed by non-incumbents, with cost allocation mechanisms in place to facilitate lines moving from planning to development." The order will have significant implications for future renewables deployment in New England and New York, in particular in relation to efforts to build out the transmission system to enable greater access to Northern New England or Upstate New York wind power facilities, as well as potential expansions to enable increased large hydro imports from Canada. Order 1000 can change how new transmission projects are evaluated, prioritized and selected. With the CERFP also under development (see discussion in Section 4.6.1), the consideration of policy goals in transmission planning is integral to the successful bidding by generating resources dependent on additional transmission infrastructure development. However, the most recent New England Order 1000 planning process ended in May 2017 after the New England States Committee on Electricity (NESCOE) concluded that there are currently no Public Policy Requirements (PPRs) driving the need for transmission within New England. Thus, a study of public policy transmission upgrades and/or expansions in the current planning cycle is not necessary (NESCOE, 2017).
- ISO-NE OSW Economic Study: In 2016, ISO-NE issued the results of three requested economic studies of transmission expansion to integrate the region's large-scale renewable energy resources, one of which focused on interconnection and transmission of OSW resources. ISO-NE studied the impact of integrating large-scale OSW into the ISO-NE grid from a reliability perspective and its potential effect on energy prices. The study was not intended to quantify capital cost of requirements for the purchase and installation of OSW turbines nor the cost of submarine transmission to bring power ashore. OSW developers will expect to recover all capital investment and operating expenses through energy and renewable energy credit revenues under long-term power purchase agreements (PPAs). The Offshore Wind Study explored the effects of the addition of 1000 MW and 2000 MW of OSW capacity in southern New England on production cost savings, its impact on load-serving entity (LSE) energy expense, and annual energy revenue available to OSW generators and the expected overall emissions reductions. The key findings included annual production cost savings ranging from \$104 million to \$807 million a year, resulting in \$56 million to \$491 million a year in LSE energy purchase cost reductions. Expected annual revenue to OSW generators from the sale of energy and RECs is expected to range from \$83 million to \$732 million. Additionally, the study

---

47 For more information on the Variable Resource Working Group, visit http://www.iso-ne.com/committees/reliability/variable-resource.

analyzed potential transmission constraints and found that "transmission constraints on the major interfaces are less binding with the addition of OSW interconnected to the Barnstable, Brayton Point, and Kent County substations," in Massachusetts and Rhode Island, respectively, resulting in a reduction of constrained hours on the SEMI/RI Import and the North-South Interfaces (ISO New England, 2016).

- New York State is also undertaking a planning initiative to modernize the State's energy system, including electric transmission construction, development of renewable energy sources, and upgrades to electric and infrastructure. The October 2012 Energy Highway Blueprint (as updated in 2013) presents proposed actions and measures to provide up to 3,200 MW of additional electric generation and transmission capacity and clean power generation through up to $5.7 billion in private- and public-sector investments (Cuomo A. , 2013). Among the proposed actions are characterization of OSW resources and initiating transmission upgrades to move excess power from upstate to downstate.

## 4.6 New Jersey

To the extent that policies in New Jersey will interact with the development of OSW in the region that is the primary subject of this report, those policies are summarized here.

New Jersey's Offshore Wind Economic Development Act of 2010 established a system of "Ocean Renewable Energy Credits" (ORECs) to support OSW deployment, with the goal of installing 1,100 MW of OSW as part of the broader RPS, which requires that New Jersey receive 22.5% of its energy from renewable sources by 2021[DSIRE (a), 2015]. The New Jersey Board of Public Utilities opened Docket EX11060353 to get stakeholder input on a proposed rule covering an OREC funding mechanism in February of 2013, but has not taken further action since then.

New Jersey currently has three proposed OSW projects in various stages of the development process. According to the developers' proposals, the three projects combined could bring 1,525 MW of renewable electricity to the region. Based on the size and location of the lease sites (see Section 2.2), however, it is estimated that as much as 4,200 MW could be generated by New Jersey OSW arrays. Despite this potential, it is unclear whether the projects will be able to move forward as the New Jersey Board of Public Utilities has yet to issue Offshore Renewable Energy Credits (ORECs) to the developers. The projects include the following:

- **Fishermen's Atlantic City Windfarm**. Fishermen's Energy planned to install 5 turbines on a 494-acre area off the coast of Atlantic City. The project would have a 24 MW capacity and was intended as a pilot project for the New Jersey OSW industry. The state's BPU twice rejected Fishermen's petition for approval of ORECs to support financing and construction of the project, saying that Fishermen's had failed to demonstrate a net economic benefit to New Jersey (O'Sullivan, 2016). New legislation provided an avenue to revive the project, with passage of Senate 988 after its predecessor, S2711, was dismissed by Governor Chris Christie in January 2016. However, S988, which would have required the BPU to reopen a 30-day period for Fishermen's to again submit its proposal, was vetoed by Governor Christie in early May 2016 (OffshoreWind.biz, 2016). After failing to meet a funding milestone, which required the project to finalize a PPA by the end of 2016, the project lost eligibility for additional DOE funding under the ATD program (Weston & Davidson, 2017).

- **US Wind Project.** In November 2015, U.S. Wind Inc. secured a lease to develop an 183,353-acre area off the southern coast of New Jersey. The exact details of the project are not yet firmly established as US Wind continues to conduct surveys of the area. The leased area, however, is estimated to have the capacity to produce as much as 2,230 MW (Moriarty, 2015).

- **Dong Energy - Ocean Wind**. DONG Energy acquired the lease from RES Offshore Developments to a 160,480-acre zone off the southern coast of New Jersey. The company intends to install 30 to 35 turbines for a proposed project capacity of 1,000 MW, though the zone is estimated to be capable of producing up to 1,950 MW. DONG has not established an estimated date of completion due to the lack of progress with the OREC application pending before the New Jersey Bureau of Public Utilities.[48]

[48] For the purposes of this analysis, it is assumed that no projects developed in DONG Energy's New Jersey lease area (OCS-A 0498) will deliver energy into the NYISO or ISO New England control areas.

# 5 Market Assessment

The market assessment addresses the question: What could the scale of near-term and long-term regional OSW deployment be, given the nature of regional OSW resources and supply chain, individual state policy drivers and initiatives, regional energy needs as well as the region's existing resource base? Analyzing the drivers examined in Chapters 1 through 4, the project team assessed the regional OSW market scale, as it might unfold between the present and 2030 in MW installed as well as gigawatt hours (GWh) of generation by year. The potential sources of OSW generation considered include potential generation deliverable from OSW projects in Atlantic waters adjacent to any of the states in the New England/New York region, including potential OSW deployed off New Jersey's shores that might be delivered to New York.

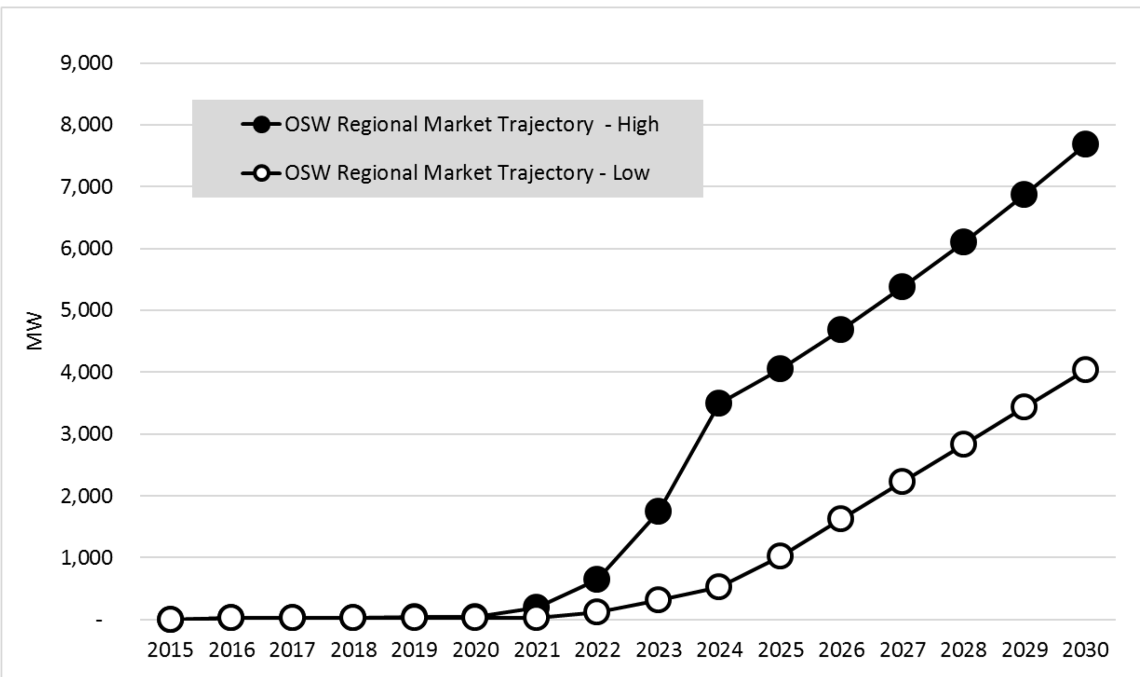
To bound the scale of the future regional market for OSW, the project team considered each of the following factors and the associated analytical perspectives described further in this chapter and in the Appendices:

- OSW characteristics, including
  - OSW resource potential (areas, wind regimes and conversion technology)
  - OSW development pipeline, lease areas and plans
  - the pace at which OSW could be deployed
- Characteristics of the region's electric system, including
  - the ability to connect OSW installations to onshore interconnection points for delivery to load centers
  - the region's electric energy consumption characteristics, as expected and as they may be influenced by factors such as deployment of emerging energy storage technologies, shifts in transportation and heating sector energy supply to electric vehicles and heat pumps
  - the electric system's ability to integrate large volumes of variable energy resources, including how it may be influenced by increased penetration of energy storage
  - the evolving resource base as influenced by planned and potential generator retirements throughout the region
- Policy drivers for renewables and OSW, including
  - RPS mandates
  - greenhouse gas reduction targets
  - renewables procurement policies and plans
  - OSW procurement legislation, policies and plans

- Competition from other renewable energy technologies or traditional non-renewable technologies, including the likely deployment of other renewable generation as a result of both DG set-asides and development and procurement of non-OSW renewables fulfilling portions of the policy and market opportunity prior to OSW's readiness to contribute at scale

The potential scale of the OSW regional market can be assessed by considering the factors identified above, and considering, in combination, each of these analytical perspectives. The assessment yielded High-Regional OSW Deployment and Low-Regional OSW Deployment trajectories which, the authors believe, bound the most likely OSW deployment futures under a range of potential future circumstances. These trajectories are shown in Figure 15 (installed MW) and Figure 16 (GWh per year production) [49] and the corresponding data is provided in Table 13.

**Figure 15. Low- and High-Regional OSW Deployment Trajectories (MW)**




49 Where analysis results were derived in units of nameplate MW OSW installed, or as GWh per year, Massachusetts average capacity factors were applied as a representative proxy in order to estimate the approximate corresponding GWh per year production, or MW OSW installed, respectively, in the absence of any particular geographical deployment associated with these trajectories.

**Figure 16. Low- and High-Regional OSW Deployment Trajectories (GWh/year)**

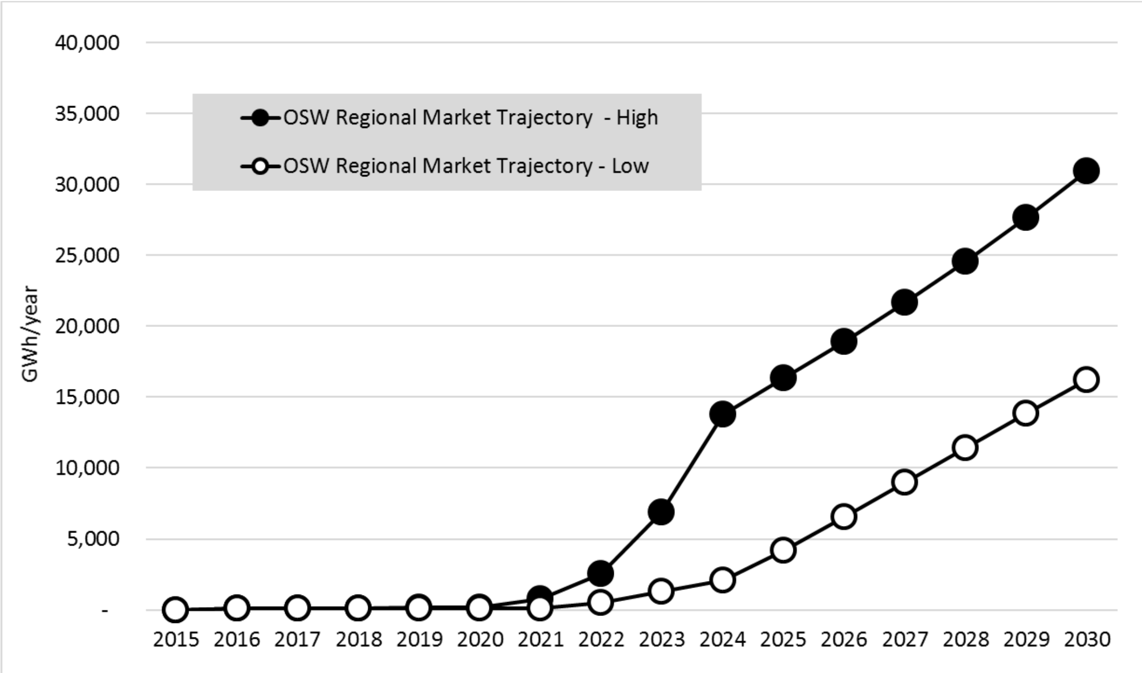



**Table 13. Low and High Regional OSW Deployment Trajectories**

| Year | Installed Capacity (MW) | | Annual Production (GWh/year) | |
|---|---|---|---|---|
| | High | Low | High | Low |
| 2016 | 30 | 30 | 116 | 116 |
| 2017 | 30 | 30 | 116 | 116 |
| 2018 | 30 | 30 | 116 | 116 |
| 2019 | 42 | 30 | 162 | 116 |
| 2020 | 42 | 30 | 166 | 118 |
| 2021 | 192 | 30 | 757 | 118 |
| 2022 | 642 | 120 | 2,531 | 473 |
| 2023 | 1,742 | 320 | 6,867 | 1,261 |
| 2024 | 3,491 | 520 | 13,763 | 2,050 |
| 2025 | 4,049 | 1,030 | 16,315 | 4,150 |
| 2026 | 4,687 | 1,630 | 18,886 | 6,568 |
| 2027 | 5,372 | 2,230 | 21,646 | 8,986 |
| 2028 | 6,099 | 2,830 | 24,577 | 11,404 |
| 2029 | 6,868 | 3,430 | 27,676 | 13,822 |
| 2030 | 7,679 | 4,030 | 30,944 | 16,239 |

The trajectories in Figure 15 and 16 were assembled based on a combination of component analyses described in the remainder of this chapter. The High-OSW Deployment trajectory was derived by treating the ceiling as the lesser of the Development Pipeline and Buildout Potential, VER penetration, and GHG policy-driven demand, each of which was derived from their own individual analyses. After considering each of the other analytical perspectives, the authors based the Low-OSW Deployment trajectory on the trajectory of planned procurements and procurement targets for OSW in the region, because the target exceeded the results of the other analytical perspectives. Along the way, other components of the analysis discussed in this chapter were examined for their potential role as limiting factors to the region's buildout potential. Other quantitative factors, such as the OSW share of generation retirement replacements, were overlaid for scale to illustrate the relationship between the indicated trajectories and the potential scale of retirement replacements possible. The results of the assembly of the Low- and High-Regional OSW Deployment trajectories according to these decision rules are shown in Figure 17 and 18, respectively. In Figure 17, which shows the derivation of the low trajectory, the black dotted line traces a trajectory based on operational OSW projects (i.e., Block Island Wind Farm) plus planned procurements and procurement targets in Massachusetts and New York. All other analytical perspectives considered in developing the low trajectory are included in the graph for illustrative purposes, including incremental VER penetration. It represents the cumulative VER capacity the grid is technically capable of supporting based on analysis described in Section 3.4. In Figure 18, which shows the derivation of the high trajectory, the black dotted line traces the lesser of the Development Pipeline and Buildout Potential, the OSW Share of VER penetration, and the OSW Share of GHG policy-driven demand. The high trajectory is also always greater than the incremental RPS-driven demand[50].

[50] We note that the analysis conducted for this report revealed that current RPS-driven demand is unlikely to represent a binding constraint on OSW, because state-specific RPS requirements alone are insufficient to meet the level of zero-emission electricity generation required for each state in the region to achieve its GHG emissions reduction targets. Consistent with this observation, as noted in Chapter 4, in 2016 Rhode Island increased their RES targets and an increase is being contemplated in 2015 and 2016 legislative proposals in Massachusetts.

**Figure 17. Derivation of Low-Regional OSW Deployment Trajectory**[51]

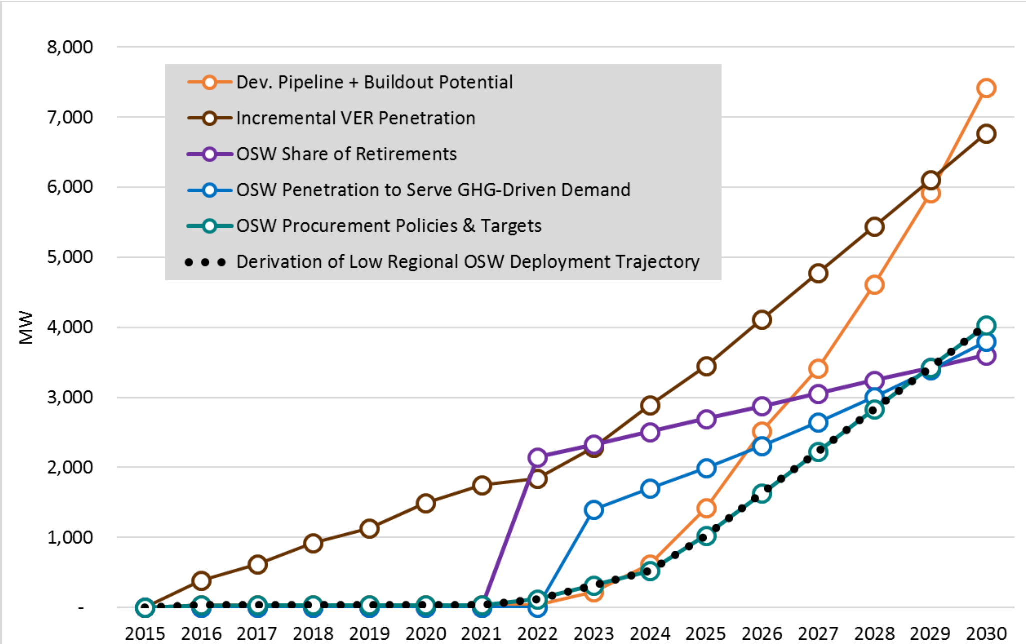
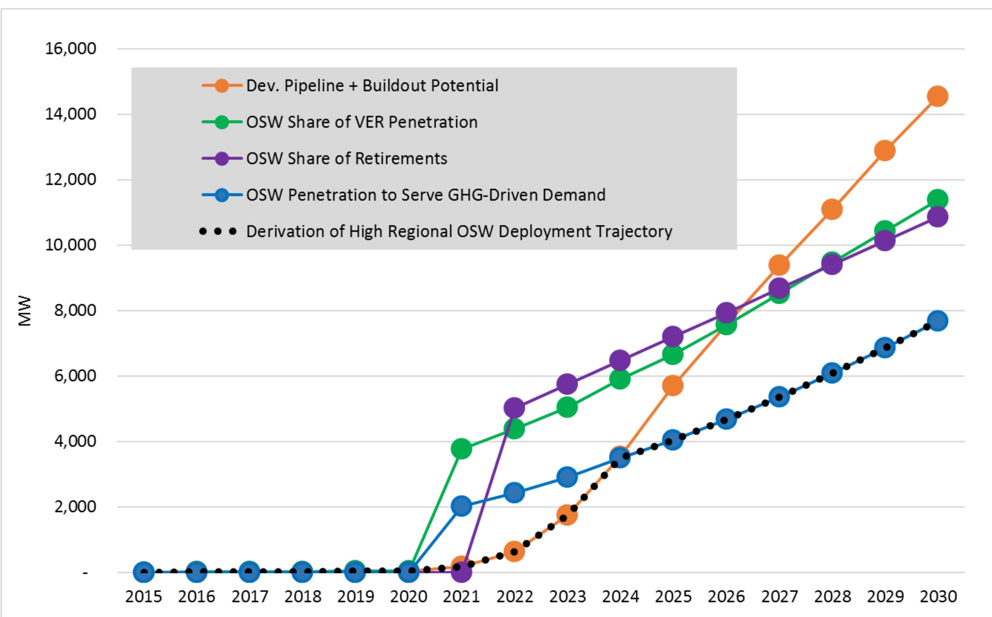



**Figure 18. Derivation of High-Regional OSW Deployment Trajectory**




---

51 In Figure 17, the Development Pipeline and Buildout Potential is shown to be slightly lower in 2022-2023 than the trajectory of current OSW Procurement Policies and Targets, suggesting that the Low trajectory could be slightly lower during that period.

Many of the perspectives considered in this chapter reinforced the general scale of the OSW market. Several were found likely to establish the bounds to OSW deployment in the region through 2030, while others were found unlikely to be binding in that timeframe.

In summary:

- **OSW Characteristics**. Within this category, the potential saturation of overall resource potential was found unlikely to be a limiting factor. A much more important and constraining factor during the study period was the Buildout Potential. Put simply, the OSW industry cannot expand faster than the industry's infrastructure and supply chain can support. While this is a real constraint in the short term, it can be addressed over time by building out the necessary supply chain to support a larger market. A further discussion of these factors is found in Appendix A.1. This category of issues was found to be binding in the High-Regional OSW Deployment trajectory only.
- **Electric System and Market Characteristics.** Within this category, the lesser of two factors—transmission and interconnection (T&I), and electric market constraints—can serve as a limit to OSW deployment, but only one was found to be *potentially* binding within the study period. A third factor, the scale of electric market opportunities, serves as a benchmark for comparison, and validation of the scale, proscribed by the lesser of the T&I and electric market constraints.
    - **Transmission and Interconnection (T&I)**. The potential capability to interconnect OSW projects and transmit their output to load centers was examined, and found not to be constraining during the study period. A discussion of the analysis of T&I potential can be found in Appendix A.2.
    - **Electric Market Constraints**. The total quantity of VER penetration that can be integrated into the region's electric systems should serve as a binding constraint in all cases. An OSW share of total VER penetration was assumed, as described in Section A.3.1. This figure could be, and was found to be, a factor that could *potentially* serve as a ceiling to the Regional OSW Deployment trajectories in the low case. However, procurement policies, such as those adopted by New York and Massachusetts, can serve to alter the assumed share of VERs, between LBW, solar and OSW, that otherwise might be dictated by other market forces. In the low case, the assumed OSW share of VER penetration that otherwise would have been found to be a binding constraint was effectively relaxed by the policy decision to deploy OSW in quantities to meet the policy goal. Such policy goals effectively substitute OSW for other VERs. This substitution is reasonable so long as the total VER penetration limit—the truly binding constraint—is not exceeded. A discussion of electric market constraints is found in Appendix A.3.
    - **Electric Market Opportunities**. An analysis of planned and potential retirements suggests there will be a need for substantial new energy production, part of which can be met by OSW. The quantity of retirement replacement that is estimated to be servable by OSW was found to be on a similar order of magnitude to the trajectories determined considering other drivers, and therefore can be considered as an alternative or supportive rationale for these trajectories. A discussion of OSW's potential to fill such 'market gaps' can be found in Appendix A.4.

- **Policy Drivers**. Within this category, the *current* regional RPS policies were found insufficient to drive material demand for OSW, and thus (if there is to be an OSW market), they would either need to be altered, or they would otherwise not serve as a binding constraint. In contrast, the regional GHG policies are likely to subsume the RPS demand, drive future RPS demand, or replace RPS demand as a driving force for OSW deployment. Existing OSW procurement policies and procurement targets were also compared to the ultimate deployment trajectories and served as the basis for the Low-OSW Deployment trajectory.
  - **Regional RPS and NY CES Demand for OSW**. The existing and potential RPS policies (including the New York CES) provide only limited demand for OSW in their current form. An important observation is that the amount of incremental RPS-driven demand is modest after accounting for DG set-asides and policies, procurement committed to non-OSW renewables, and other Class I RPS renewables that come online prior to OSW. Together, these sources of competing supply are either already contracted, under construction or operating, or are already committed through existing statute or policy, thereby effectively consuming much of the potential incremental market otherwise available to OSW. From this perspective, RPS policies alone as currently conceived, without increased targets or other drivers, may be inadequate to support a market at sufficient scale to drive down OSW costs.
  - **Regional GHG-Driven Demand for OSW**. Meeting the region's GHG targets and mandates drives a materially greater need for zero-emission generation than current and planned RPS targets alone. In that respect, GHG-driven demand can be thought of as subsuming RPS demand, and providing a more material driver than RPS alone. The portion of GHG-driven demand likely available to be met by OSW, likely caps the scale of OSW market potential.
  - **OSW Procurements.** OSW procurement policies are beginning to be adopted to drive OSW deployment, and may ultimately dictate the scale and pace of OSW deployment until OSW reaches a cost versus value parity with other RPS-eligible and/or low-GHG resources. Procurement policies and targets have been adopted by New York and Massachusetts, and they are likely to dictate the scale of near-term OSW deployment as well as provide a floor for the scale of the OSW market during the study period. The analytical process and individual components of this portion of the analysis are described in greater detail in Appendix A.5.3. Additional procurement policies could be adopted in other states and it is clear that OSW-specific procurements, or improved OSW economics that allow successful competition head-to-head with other RPS supply, could either carve out portions of incremental RPS demand for OSW, or surpass RPS targets as a tool to meet GHG reduction targets.

## 5.1 Offshore Wind Characteristics

The broad category of OSW characteristics, is characterized by five component factors, including the following:

- the region's developable OSW resource potential (Appendix A.1.1)
- the current OSW development pipeline (Appendix A.1.2)
- the development potential of current and future OSW lease areas (Appendix A.1.3)
- the pace at which OSW projects can be developed (the temporal buildout pace) (Appendix A.1.4)
- state-specific capacity factors for OSW, which are applied throughout the analysis unless otherwise specified (Appendix A.1.5)

In analyzing the interaction of these factors, the resultant trajectory that reflects the binding constraints is referred to here as the "OSW Development Pipeline and Buildout Potential." While the overall OSW resource potential was not found to be binding, the consideration of the remainder of these factors each contributed to the Low- and High-Case OSW Development Pipeline and Buildout Potential trajectories. The low trajectory is depicted in Figure 19 (MW) and Figure 20 (GWh/year), while the high trajectory is depicted in Figure 21 (MW) and Figure 22 (GWh/year). The potential buildout of current and future lease areas is dictated by assumptions for the feasible temporal buildout pace and are additive to the existing pipeline of OSW projects that are in the advanced stages of development and construction. A detailed description of the analytical process used to derive the OSW Development Pipeline and Buildout Potential, each component of the analysis, and their associated assumptions can be found in Appendix A.1.

Based on these assumptions, the regional OSW Development Pipeline and Buildout Potential reaches up to approximately 7,400 MW (29,700 GWh/year) in the low case by 2030 and up to approximately 14,500 MW (57,900 GWh/year) in the high case by 2030. These results suggest that the region's buildout potential, while a near-term constraining factor, is not likely to be a limiting factor over the course of the study period as the market responds to regional OSW development activities by developing the necessary supply chain to support a larger market.

**Figure 19. Regional OSW Development Pipeline and Buildout Potential – Low Case (MW)**

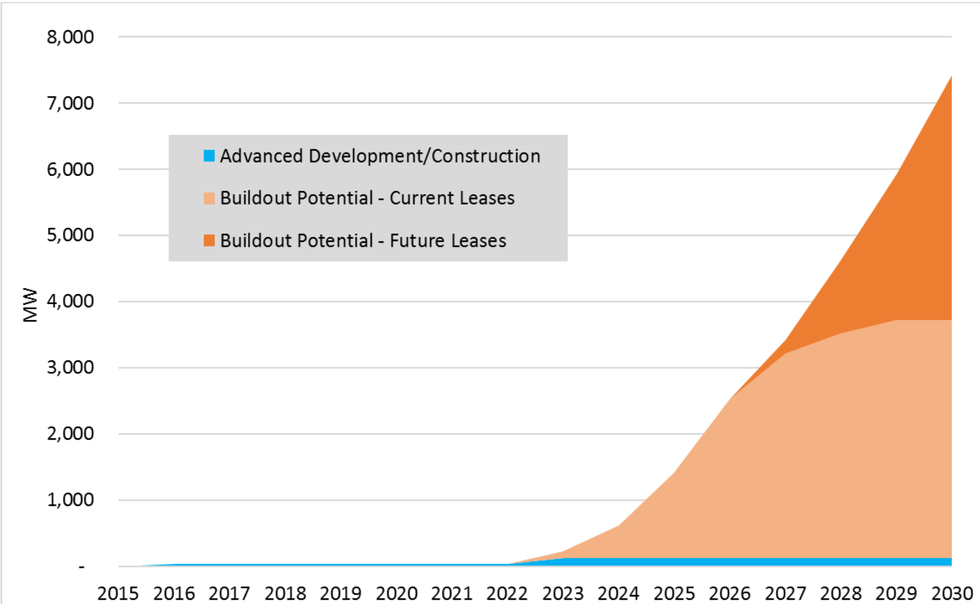



**Figure 20. Regional OSW Development Pipeline and Buildout Potential– Low Case (GWh/year)**

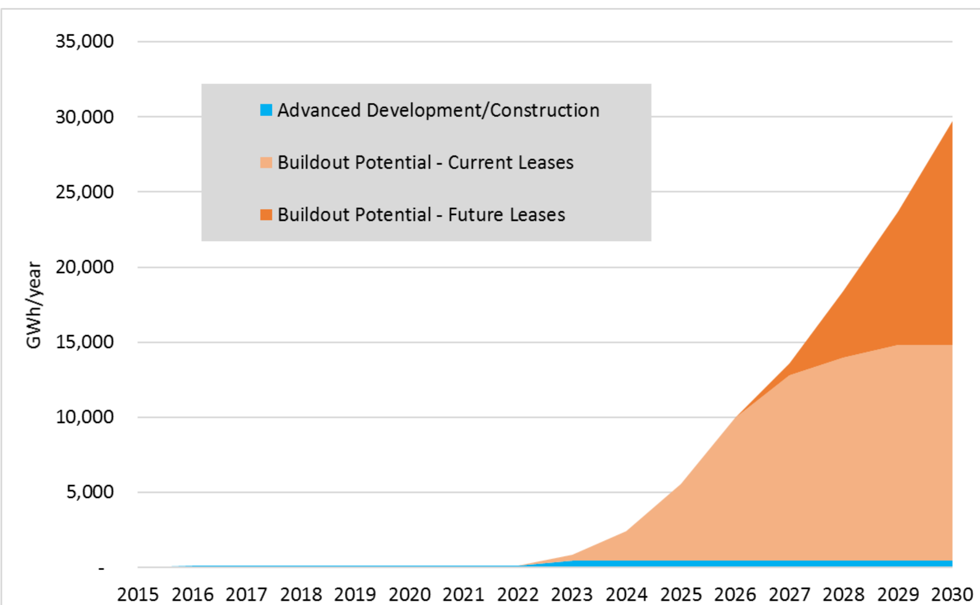


**Figure 21. Regional OSW Development Pipeline and Buildout Potential – High Case (MW)**

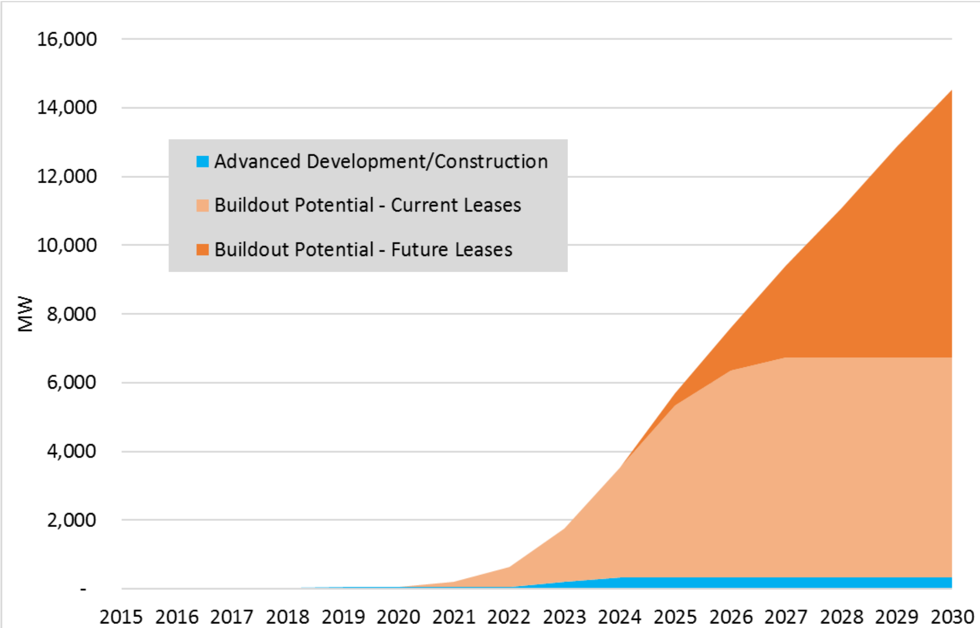
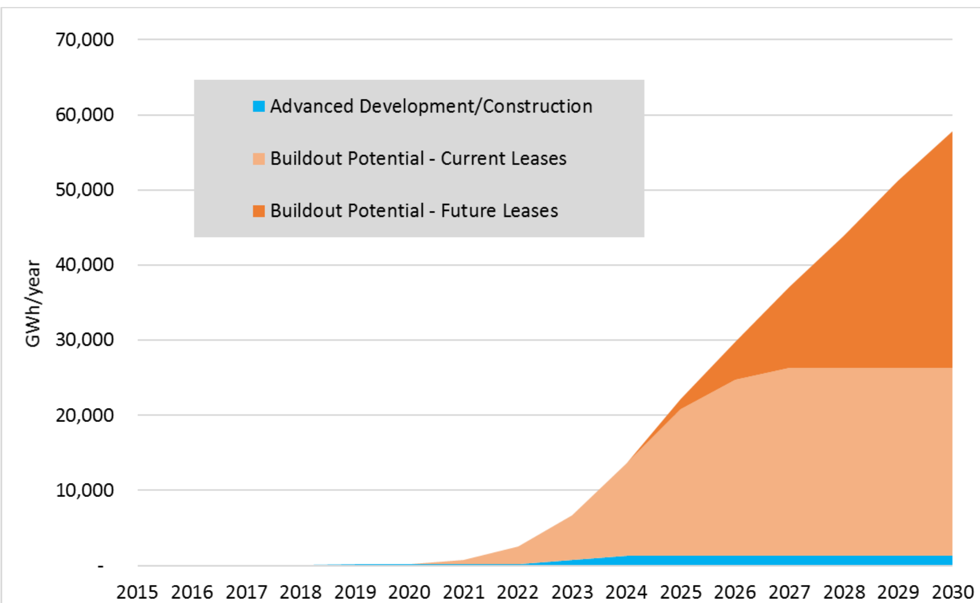



**Figure 22. Regional OSW Development Pipeline and Buildout Potential – High Case (GWh/year)**



## 5.2 Electric System and Market Components: Constraints and Opportunities

For the purposes of this analysis, the region's electric system and electric market are characterized by three component factors, including the following:

- transmission and interconnection infrastructure (T&I) (Appendix A.2)
- the bulk power system's and electricity market's ability to successfully and cost-effectively integrate VERs including OSW (Appendix A.3)
- regional market opportunities for OSW deployment, primarily created by planned and at-risk retirements (Appendix A.4)

The estimated OSW Share of VER Penetration was found to be most constraining of the factors considered. A low and high trajectory of the region's OSW electric market penetration, as depicted in Figure 23 (GWh/year) and Figure 24 (MW) was established by analyzing each of these components. A detailed description of the analytical process used to derive the region's low- and high-case trajectories of OSW Electric Market Penetration, as well as each component of the analysis and their associated assumptions can be found in Appendix A.2 - A.4.

Based on these assumptions, the region's ability to successfully and cost-effectively integrate OSW reaches up to approximately 6,800 GWh/year (1,700 MW) in the low case and up to 45,900 GWh/year (11,400 MW) in the high case by 2030. These results suggest that the electric market could potentially be a significant constraint to regional OSW wind deployment, but this ultimately depends on regional demand for renewable energy, the rate and scale of non-OSW development, and policy support for OSW. Notably, the low-case trajectory for OSW's Share of VER Penetration is lower than the trajectory of planned procurements and procurement targets, which cumulatively will drive up to 4,000 MW of OSW development by 2030. Total incremental VER penetration (Non-OSW and OSW) greatly exceeds the current OSW procurement trajectory with a low-case trajectory of approximately 6,800 MW by 2030 (see Appendix A.3). The OSW procurement trajectory, thus establishes the floor in the Low-Case OSW Deployment trajectory (see Figure 17).

**Figure 23. OSW Electric Market Penetration (GWh/year)**

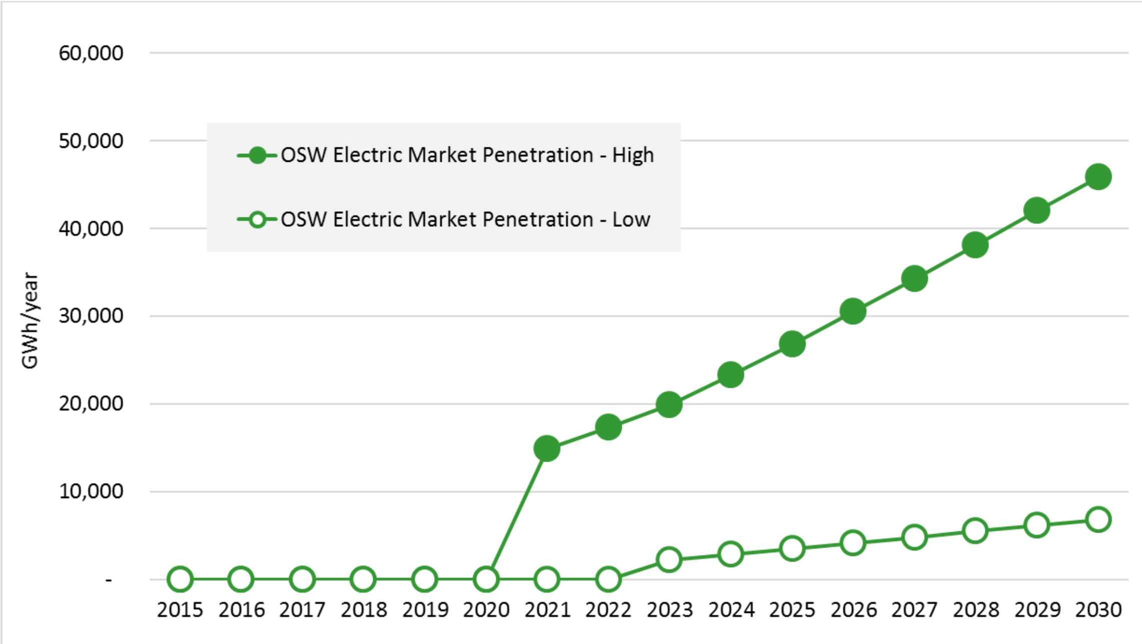
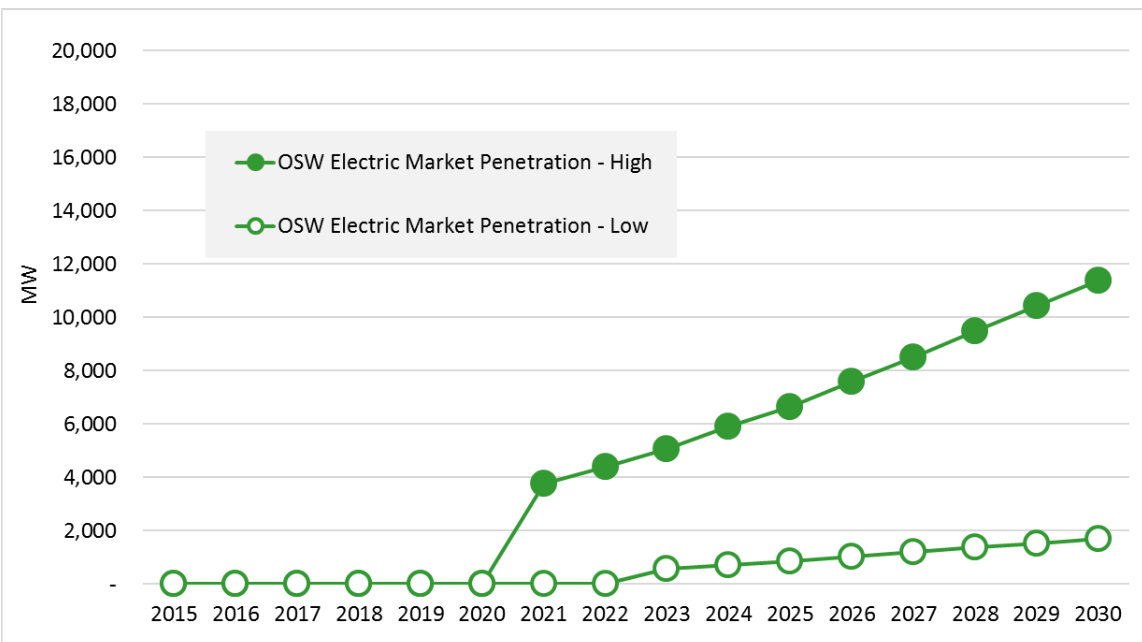



**Figure 24. OSW Electric Market Penetration (MW)**



## 5.3 State and Regional Policies and Plans

The regional policy drivers consist of four component factors, including the following:

- State-specific RPS policy-driven demand
- GHG emissions reduction policy-driven demand
- Other renewable energy policies and plans
- OSW procurement policies and plans

The analytical process used to derive GHG policy-driven demand for OSW, which is the primary regional policy driver and primary binding constraint in the High-Case Regional OSW Deployment trajectory, is described in depth in Appendix A.5.2. The estimated OSW Share of GHG Policy-Driven Demand for VERs was found to be most constraining of the factors considered. The region's aggressive GHG emissions reduction policies create a likely upper bound on the potential OSW market as they subsume and surpass the potential influence that current RPS targets could have in driving demand for OSW. A low and high trajectory of the region's GHG policy-driven demand for OSW, as depicted in Figure 25 (GWh/year) and Figure 26 (MW), was established by analyzing each of these components. A detailed description of each component of this analysis and their associated assumptions can be found in Appendix A.5.

Based on these assumptions, the region's GHG policy-driven demand for OSW reaches up to approximately 15,300 GWh (3,800 MW) in the low case and up to approximately 31,000 GWh/year (7,680 MW) in the high case by 2030.

**Figure 25. GHG Policy-Driven Demand for OSW (GWh/year)**

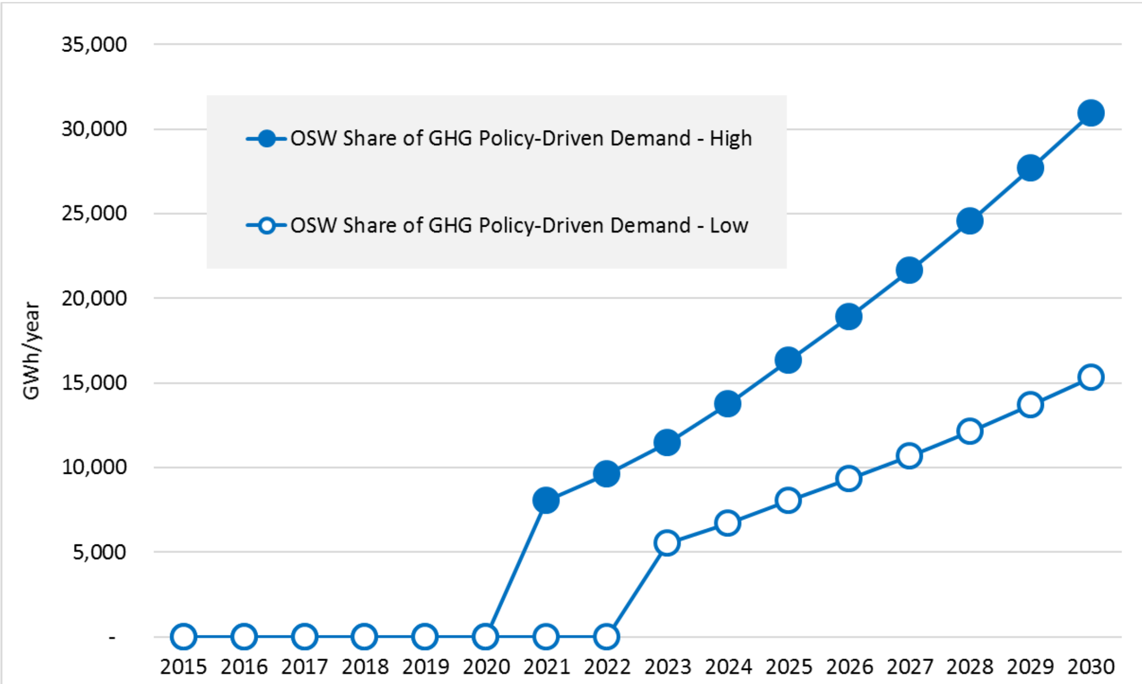
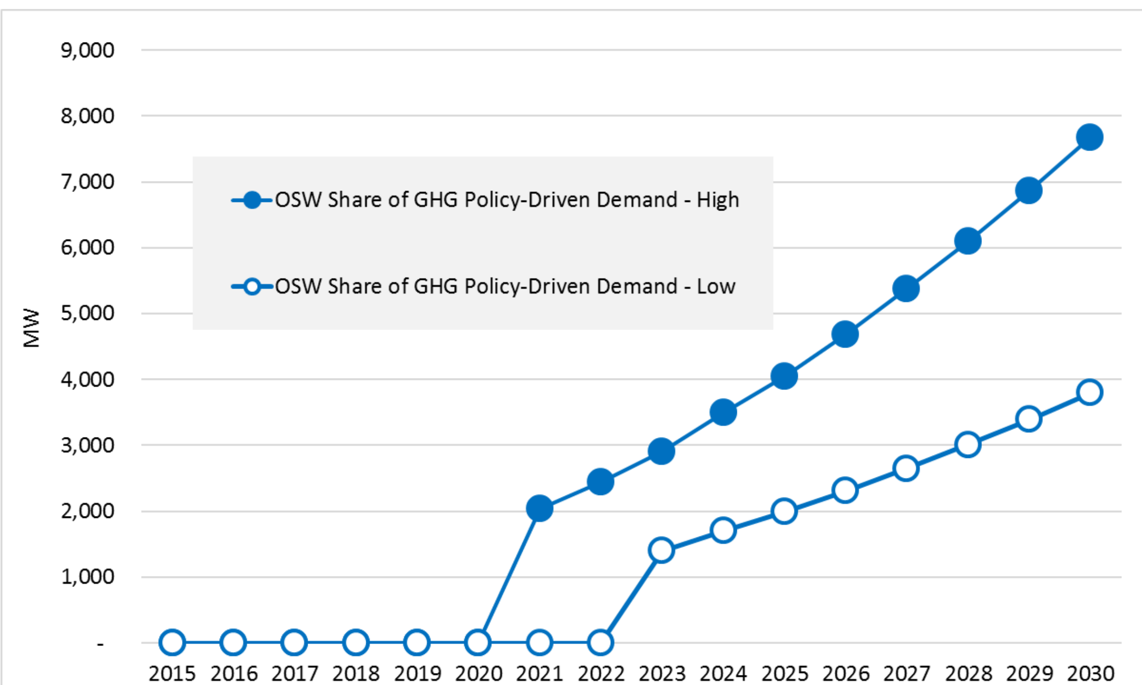



**Figure 26. GHG Policy-Driven Demand for OSW (MW)**



# 6 Conclusion

The central results of this OSW Regional Market Characterization report—the Low- and High-Regional OSW Deployment trajectories detailed in Chapter 5—present a broad range of potential future OSW deployment, which the authors believe bounds the potential regional OSW deployment volumes between the present and 2030. By 2030, the trajectories reach approximately 4 GW to 7.7 GW, respectively, in the low and high cases. These trajectories presume some degree of policy intervention. Due to the current relative and absolute costs of OSW and the critical importance of scale and market visibility in reducing costs of OSW over time, in the absence of any policy initiatives, even the low trajectory could be infeasible before 2030. However, states throughout the region have begun implementing policies and are considering further policies individually, in support of OSW deployment. Further, regional collaboration, as might be guided by the results of the OSW Roadmap project, could increase the probability of achieving OSW penetration within the indicated range.

**Table 14. OSW Procurement Volumes in the Northeast**

| Contracting State | MW | Notes: |
|---|---|---|
| Rhode Island | 100 - 150 | Existing long-term procurement statute could lead to contracts for 100 MW to 150 MW of OSW deployment in Federal waters (although such contracting is not automatic)[52] |
| Massachusetts | 1,600 | In August 2016, Governor Baker signed an Act Relative to Energy Diversity, Section 83C of which requires the state's EDCs to solicit 1,600 MW of OSW by 2030. |
| New York | 2,400 | In January 2017, Governor Cuomo announced a statewide commitment to developing 2.4 GW of offshore wind by 2030. |
| Total | 4,100 - 4,150 | |

While the timing of procurements under the above-referenced policies could vary, the comparison reinforces that currently discussed OSW procurement volumes within the Northeast region fall within the trajectories developed for this report, lending some credence to the appropriateness of the projections.

[52] A contract would need to be brought forward by the developer and EDC, meet a number of statutory requirements, and receive PUC approval. We are unaware of any plans to bring forth such a proposed contract at present.

## 6.1 Areas for Future Study

The scope of this study is based on desktop research and includes available data sources, and because there is limited data available on many of the parameters used, it has limitations. Further, the analysis is not a forecast of what is expected to be developed, but rather a consideration of OSW market-scale drivers intended to estimate the potential OSW market scale under a range of cost, electric market, and policy future conditions. The analysis performed in completing this study has revealed a number of potential areas for further study. These include but are not limited to the following:

- The analysis does not consider the relative cost of OSW versus other alternatives. With projections of OSW cost as a function of time and volume, the deployment analysis could be enhanced to consider the relative costs and commodity market values of OSW as compared to other renewable energy generation types and non-renewables. This data could be utilized in a supply curve-based analysis or capacity expansion model to refine the assessment of the relative market share of OSW. Such an analysis would be particularly appropriate in the context of rapidly falling prices for OSW in Europe. Contract announcements during 2016-2017 for European projects have been in the range of $70-$140/MWh (Hundleby & Freeman, 2017).
- This study's assumptions for low- and high-range of installation rates (turbines per year) are based on examination of past and expected European experience. Development of installation vessel and supply chain studies specific to the northeastern U.S. could in turn allow a more context appropriate set of assumption for OSW installation rates.
- For the proportion of the total OSW resource potential that is developable, the authors made assumptions regarding high- and low-percentages of total OSW resource potential in various depths that would ultimately be developable. Based on these assumptions, resource potential was found to not be a binding constraint on OSW deployment. A comprehensive and detailed regional analysis of the siting and permitting regime, including (for example) the degree to which United States Coast Guard shipping lane restrictions might limit the proportion of resource potential ultimately developable, would provide a more robust estimate of quantity of OSW that could be successfully sited and permitted in the region, and could determine whether siting constraints would be a limiting factor.
- In addition, the study assumed a relatively static lag between OSW lease execution and commercial operation. A study of the potential for streamlining the lag between lease execution to commercial operation to allow for faster growth could shed insight on the potential for a greater acceleration of OSW deployment.
- Furthermore, as an immature technology, there is limited information available of feasibility and cost of siting floating OSW technology. A study of the feasibility and relative cost of floating platforms in available Gulf of Maine water depths would provide greater insight into the truly developable potential in that region.

- This study relied on available prior analysis of OSW interconnection and other generic information on the region's electric system, none of which were specific to any particular assumed OSW project. A detailed transmission flow model is required to accurately assess the capability for interconnecting, and the associated cost, for any *specific* project deployment. Consideration and modeling of detailed, specific OSW project deployments would provide more accurate insight into interconnection feasibility. Further, the potential for shared radials or an offshore network collection system to both address any interconnection constraints, as well as to minimize OSW cost, could be assessed through a full engineering analysis of interconnection options and their associated network upgrade implications.
- As noted above, data on deployment of floating platforms is limited. A supply chain and engineering study of floating technology to assess whether buildout constraints differ materially would serve to sharpen assumptions that were based primarily on fixed-foundation experience for this study.
- This study assumed a high- and low-share of the market gap created by retiring generation was available to OSW in order to estimate OSW's potential to replace such generation. Detailed production cost modeling of a least-cost mix of supply between VERs and other resources could provide a more refined insight as to the potential for OSW to fulfill the gap.
- While a national NREL study was used to establish a higher-end VER penetration, with increased energy storage deployment over time, a sensitivity analysis to a regional production cost model incorporating a reasonable additional energy-storage deployment would yield refined estimates of how high an electric market penetration of OSW may be feasible.

In addition, there are other topics of study, outside of the scope of this study, that could be useful in considering and evaluating future state policies and initiatives. Such further analysis might pursue quantification of impacts of OSW development under both the Low- and High-Regional OSW Deployment trajectories:

- the total economic impacts (in job creation, economic development, and ratepayer impacts) of OSW deployment
- the impact that emissions reductions have on productivity/gross domestic product, and associated health outcomes

# 7 References


(n.d.).

30 V.S.A. Chapter 89. (n.d.). *Vermont Statutes Annotated; Title 30: Public Service; Chapter 89: Renewable Energy Programs.* Montpelier, VT: State of Vermont. Retrieved June 23, 2016, from http://legislature.vermont.gov/statutes/chapter/30/089

310 CMR 7.75 Clean Energy Standard. (2017, August). Boston, MA, USA: Massachusetts Department of Environmental Protection. Retrieved from http://www.mass.gov/eea/docs/dep/air/climate/3dregf-ces.pdf

4C Offshore. (2016, February 24). *Maryland - US Wind Inc Offshore Wind Farm*. Retrieved May 1, 2016, from 4C Offshore: http://www.4coffshore.com/windfarms/maryland---us-wind-inc-united-states-us4x.html

Analysis Group. (2013). *Planning for Offshore Energy Development.*

Atlantic Grid Development LLC. (2014a). *About Us*. Retrieved May 1, 2016, from Atlantic Wind Connection: http://atlanticwindconnection.com/about-us

Atlantic Grid Development LLC. (2014b). Retrieved April 29, 2016, from Atlantic Wind Connection: http://atlanticwindconnection.com/awc-projects/atlantic-wind-connection

Ausubel, L., & Cramton, P. (2011). *Auction Design for Wind Rights.* Washington, D.C.: Bureau of Ocean Energy Management. Retrieved May 30, 2016, from http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/Regulatory_Information/AusubelCramtonPaper1.pdf

AWS Truepower. (2014). *Energy Production Assesment and Load Coincidence Analysis for the Massachusetts and Rhode Island/Massachusetts Wind Energy Areas.*

AWS Truepower, LLC, & Camoin Associates, Inc. (2010). *Economic Impact Assessment: Long Island - New York City Offshore Wind Project.* New York Power Authority.

AWS Truewind, L. (2009). *Offshore Wind Technology Overview.* Long Island - New York City Offshore Wind Collaborative.

Bailey, B. (2015, September 18). *Energy Price Suppression Benefits of Offshore Wind Energy.* Albany, NY: AWS Truepower. Retrieved May 1, 2016, from AWS Truepower: https://www.awstruepower.com/blogs/smarter-power/energy-price-suppression-benefits-offshore-wind-energy/

Bailey, B., & Wilson, W. (2014). The Value Proposition of Load Coincidence and Offshore Wind. *10*(12). Retrieved April 28, 2016, from http://nawindpower.com/online/issues/NAW1401/FEAT_03_The-Value-Proposition-Of-Load-Coincidence-And-Offshore-Wind.html

Bailey, B., Wilson, W., & Tareila, C. (2013). Understanding Offshore Wind's Enhanced Peak Load Coincidence for East Coast Transmission Systems. *AWEA Windpower 2013 Conference & Exhibition.* Chicago, IL: AWS Truepower. Retrieved from https://www.awstruepower.com/assets/OffshoreLoadCoincidence-Bailey-AWST-Windpower2013.pdf

Baker, C. D. (2016, September 16). Executive Order No. 569 - Establishing An Integrated Climate Change Strategy for the Commonwealth. Boston, MA, USA: Office of the Governor. Retrieved from http://www.mass.gov/eea/docs/executive-order-climate-change-strategy.pdf

Baker, C. D. (n.d.). EXECUTIVE ORDER NO. 562. Boston, Massachusetts. Retrieved from http://www.mass.gov/governor/legislationexecorder/execorders/executive-order-no-562.html

Baker, G. C., & Polito, L. (2016). *Baker-Polito Administration, Offshore Wind Developers Announce Agreement for New Bedford Marine Commerce Terminal.* Commonwealth of Massachusetts. Boston, MA: The Office of the Governor of Massachusetts. Retrieved September 10, 2016, from http://www.mass.gov/governor/press-office/press-releases/fy2017/offshore-wind-developers-sign-agreement-in-new-bedford.html

Baker, M., & Wilson, W. (2014). *Energy Production Assessment and Load Coincidence Analysis.* Prepared by AWS Truepower. Boston, MA: Massachusetts Clean Energy Center. Retrieved May 1, 2016, from http://images.masscec.com/MassCEC_MassWEAs_EnergyAssessment-LoadCoincidenceAnalysis_03-Dec-2014.pdf

Baranowski, R., Oteri, F., Baring-Gould, I., & Tegen, S. (2016). *U.S. Department of Energy Regional Resource Centers Report: State of the Wind Industry in the Regions.* Golden, CO: National Renewable Energy Laboratory. Retrieved 29 April, 2016, from http://www.nrel.gov/docs/fy16osti/62942.pdf

Beiter, P., Musial, W., Smith, A., Lantz, E., Kilcher, L., Damiani, R., . . . Scott, G. (2016). Estimating the Economic Potential of Offshore Wind in the United States. *2016 AWEA Windpower.* New Orleans, LA: National Renewable Energy Laboratory. Retrieved June 14, 2016, from http://www.nrel.gov/docs/fy16osti/66288.pdf

Benjamin Riggs, Laurence Ehrhardt, and Rhode Island Manufacturers Association v. R.I Public Utilities Commission, National Grid, and Deepwater Wind Block Island, 1:15-cv-00343-S-LDA (United States District Court of Rhode Island August 14, 2015).

Black, J. (2016). *Draft 2016 PV Forecast.* Distributed Generation Forecast Working Group. Westborough, MA: ISO New England. Retrieved May 1, 2016, from http://www.iso-ne.com/static-assets/documents/2016/03/2016_draftpvforecast_20160224revised.pdf

BOEM. (2016a). *Lease and Grant Information*. Retrieved April 30, 2016, from Bureau of Ocean Energy Management: http://www.boem.gov/Lease-and-Grant-Information/

BOEM. (2016b). *New York Activities*. Retrieved April 30, 2016, from Bureau of Ocean Energy Management: http://www.boem.gov/New-York/

BOEM. (2016c, March 16). Bureau of Ocean Energy Management. *Announcement of Area of Identification: Commercial Wind Leasing on the Outer Continental Shelf Offshore New York*. Washington, D.C.: BOEM. Retrieved May 1, 2016, from http://www.boem.gov/NY-Area-ID-Announcement/

BOEM. (2016d). *Atlantic Wind Lease Sale 6 (ATLW-6) for Commercial Leasing for Wind Power on the Outer Continental Shelf Offshore New York - Proposed Sale Notice.* Washington, D.C.: Burea of Ocean Energy Management. Retrieved June 3, 2016, from http://www.boem.gov/PSN-NY/

BOEM. (2016e). *Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore New York: Environmental Assessment.* U.S. Department of Interior. Washington, D.C.: Bureau of Ocean Energy Management. Retrieved June 3, 2016, from http://www.boem.gov/NY-Public-EA-June-2016/

BOEM. (2016f). *Cape Wind*. Retrieved June 28, 2016, from Bureau of Ocean Energy Management: http://www.boem.gov/Renewable-Energy-Program/Studies/Cape-Wind.aspx

BOEM. (2016g, December 16). Interior Department Auctions Over 79,000 Acres Offshore New York for Wind Energy Development. Washington, D.C., USA. Retrieved from https://www.doi.gov/pressreleases/interior-department-auctions-over-79000-acres-offshore-new-york-wind-energy

BOEM. (2017a, March 10). BOEM Receives Lease Requests for Offshore Wind. Washington, D.C., USA: Department of Interior. Retrieved June 2, 2017, from https://www.boem.gov/note03102017/

BOEM. (2017b, January 224). Wind Energy Commercial Leasing Process. Washington, D.C.: BOEM. Retrieved from https://www.boem.gov/Commercial-Leasing-Process-Fact-Sheet/

Bradley, D. (2017, January 13). Remaining AIM Facilities Up And Running, Algonquin Gas Transmission Says. *Natural Gas Intelligence*. Dulles, VA. Retrieved from http://www.naturalgasintel.com/articles/109045-remaining-aim-facilities-up-and-running-algonquin-gas-transmission-says

BVG Associates. (2015). *Approaches to cost-reduction in offshore wind.*

C.M.R. 65-407, Ch. 311, §3(A). (n.d.). Public Utilities Commission Rules, Portfolio Requirement, New Renewable Resources: Class 1. *Maine Public Utilities Commission Rules*. Augusta, ME. Retrieved from http://www.maine.gov/sos/cec/rules/65/407/407c311.doc

Cardiff University. (2016). *MEDOW - Multi-Terminal DC Grid for Offshore Wind*. Retrieved May 1, 2016, from Cardiff University: http://sites.cardiff.ac.uk/medow/about-medow/

Chesto, J. (2016, April 20). Kinder Morgan Shelves $3 Billion Pipeline Project. *Boston Globe*. Retrieved May 2, 2016, from https://www.bostonglobe.com/business/2016/04/20/kinder-morgan-shelves-billion-new-england-pipeline-project/iEafnAP2P41o0B9tmM0lEI/story.html

Chesto, J. (2017, June 29). Lacking financing, utilities put $3 billion natural gas pipeline plan on hold. Boston, MA: The Boston Globe. Retrieved from https://www.bostonglobe.com/business/2017/06/29/utilities-withdraw-plan-for-billion-natural-gas-pipeline-expansion/o07zbTYmUIMWVmpjNItQ3H/story.html

Clean Energy Fund Investment Plan: Large-Scale Renewables Chapter, 14-M-0094 (April 29, 2016). Retrieved from http://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Large-Scale-Renewable.pdf

Coalition for Competitive Electricity, Dynegy Inc., Eastern Generation LLC, Electric Power Supply Association, NRG Energy Inc., Roseton Generating LLC, & Selkirk Cogen Partners L.P. (2016). *Complaint.* New York, NY: United States District Court - South District of New York. Retrieved October 20, 2016, from https://statepowerproject.files.wordpress.com/2014/03/ny-ces-complaint.pdf

Cole, W., Kurup, P., Hand, M., Feldman, D., Sigrin, B., Lantz, E., . . . Waldoch, C. (2016). *2016 Annual Technology Baseline - Discussion Draft.* Golden, CO: National Renewable Energy Laboratory. Retrieved May 2, 2016, from http://www.nrel.gov/analysis/pdfs/ATB_2016_summary_draft_public_2016-03-18.pdf

Cole, W., Mai, T., Logan, J., Steinberg, D., McCall, J., Richards, J., . . . Porro, G. (2016, November). 2016 Standard Scenarios Report: A U.S. Electricity Sector Outlook. Golden, CO: NREL. Retrieved from https://www.nrel.gov/docs/fy17osti/66939.pdf

Con Edison, & LIPA. (2009). *Offshore Wind Power Integration Project Feasibility Assessment.*

ConEd and LIPA. (2009). *Joint Con Edison - LIPA Offshore Wind Power Integration Project Feasibility Assessment.* New York, NY: ConEdison and the Long Island Power Authority. Retrieved June 28, 2016, from http://www.linycoffshorewind.com/pdf/feasibility%20study.pdf

Conference of New England Governors and Eastern Canadian Premiers. (2013, September 9). *Resolution 37-4 - Resolution on Climate Change*. Retrieved May 2, 2016, from Canadian Intergovernmental Conference Secretariat: http://www.scics.gc.ca/english/conferences.asp?a=viewdocument&id=2023

Conference of the New England Governors and Eastern Canadian Premiers. (2015, August 31). *New England Governors / Eastern Canadian Premiers.* Retrieved from Coalition of Northeast Governors: http://coneg.org/negecp

Connecticut Legislature. (2008, June 2). AN ACT CONCERNING CONNECTICUT GLOBAL WARMING SOLUTIONS. Hartford, Connecticut: State of Connecticut. Retrieved from https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm

Connecticut Legislature. (n.d.). AN ACT CONCERNING CONNECTICUT'S CLEAN ENERGY. Hartford, Connecticut. Retrieved from https://www.cga.ct.gov/2013/act/pa/pdf/2013PA-00303-R00SB-01138-PA.pdf

Connecticut, Massachusetts, and Rhode Island. (2015). Retrieved from New England Clean Energy RFP: https://cleanenergyrfp.com/

Council, N. Y. (2010). *Climate Action Plan Interim Report.* New York State.

CT DEEP - PURA. (n.d.). *Connecticut Renewable Portfolio Standards*.

CT DEEP. (2013). *Comprehensive Energy Strategy.*

CT DEEP. (2017, July 26). 2017 Comprehensive Energy Strategy (Draft). New Britain, CT, USA: Connecticut Department of Energy and Environmental Protection. Retrieved from http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/14ab20853a72aded85258169006769a5/$FILE/Connecticut%20Comprehensive%20Energy%20Strategy%20Draft%20v2.pdf

CT DEEP, MA DOER, Eversource, National Grid and Unitil. (2016). New England Clean Energy RFP. Connecticut Department of Energy and Environmental Protection, Massachusetts Department of Energy Resources, Eversource Energy, National Grid and Unitil. Retrieved May 1, 2016, from New England Clean Energy RFP: https://cleanenergyrfp.com/

Cuomo, A. (2013). *New York Energy Highway Blueprint Update.* Albany, NY: State of New York. Retrieved June 23, 2016, from http://www.nyenergyhighway.com/PDFs/BP2013/EHBPuploadpt2013/

Cuomo, A. M. (2015). *Letter Directing Department of Public Service to Commence Proceeding to Establish a Clean Energy Standard.* State of New York, Executive Chamber. Albany, NY: State of New York. Retrieved June 21, 2016, from https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/Renewable_Energy_Letter.pdf

Cuomo, A. M. (2016a, January 21). *Governor Cuomo Launches $5 Billion Clean Energy Fund to Grow New York's Clean Energy Economy*. Retrieved from New York State: https://www.governor.ny.gov/news/governor-cuomo-launches-5-billion-clean-energy-fund-grow-new-york-s-clean-energy-economy

Cuomo, A. M. (2016b, January 13). Built to Lead: Governor Cuomo's 2016 State of the State and Budget Address. Albany, NY: New York State Governor's Press Office. Retrieved October 18, 2016, from https://www.governor.ny.gov/news/video-transcript-built-lead-governor-cuomos-2016-state-state-and-budget-address

Cuomo, A. M. (2017a, January 25). Governor Cuomo Announces Approval of Largest Offshore Wind Project in the Nation. Albany, NY, USA: NYSERDA. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-01-25-Governor-Cuomo-Announces-Approval-of-Largest-Offshore-Wind-Project

Cuomo, A. M. (2017b, January 12). Governor Cuomo Announced $360 Million for 11 New Large-Scale Renewable Energy Projects in State of the State. Albany, NY, USA. Retrieved April 10, 2017, from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-01-12-Governor-Cuomo-Announced-360-Million-for-Large-Scale-Renewable-Projects

Cuomo, A. M. (2017c, January 10). Governor Cuomo Presents 25th Proposal of 2017 State of the State: Nation's Largest Offshore Wind Energy Project Off Long Island Coast and Unprecedented Commitment to Develop up to 2.4 Gigawatts of Offshore Wind Power by 2030. Albany, NY, USA.

Retrieved from https://www.governor.ny.gov/news/governor-cuomo-presents-25th-proposal-2017-state-state-nations-largest-offshore-wind-energy

Daniel, J. P., Liu, S., Ibanez, E., Pennock, K., Reed, G., & Hanes, S. (2014). *National Offshore Wind Energy Grid Interconnection Study.*

Daniel, J. P., Liu, S., Ibanez, E., Pennock, K., Reed, G., & Hanes, S. (2014). *National Offshore Wind Energy Grid Interconnection Study Final Technical Report.* Washington, D.C.: DOE.

Deepwater Wind. (2014, November 11). Deepwater Wind Names Block Island Wind Farm Foundation Fabricator — Work Slated for Early 2015. Providence, RI. Retrieved May 1, 2016, from Deepwater Wind: http://dwwind.com/press/deepwater-wind-names-block-island-wind-farm-foundation-fabricator-work-slated-early-2015/

Deepwater Wind. (2015, December 8). Deepwater Wind Proposes Innovative Offshore Wind, Energy Storage Solution to Meet Growing Energy Demand on Long Island's South Fork. Providence, RI. Retrieved April 28, 2016, from http://dwwind.com/press/deepwater-wind-proposes-innovative-offshore-wind-energy-storage-solution-to-meet-growing-energy-demand-on-long-islands-south-fork/

Deepwater Wind. (2016). Retrieved from Deepwater Wind: http://dwwind.com/

Deepwater Wind. (2017, July 31). Deepwater Wind Proposing World's Largest Offshore Wind, Energy Storage Combination: Revolution Wind Farm Bid into Massachusetts Clean Energy RFP. New Bedford, MA: Deepwater Wind. Retrieved from http://dwwind.com/press/deepwater-wind-proposing-worlds-largest-offshore-wind-energy-storage-combination/

DGFWG. (2016). *Draft 2016 PV Forecast.* ISO-NE.

DOE. (2016). *Offshore Wind Advanced Technology Demonstration Projects*. Retrieved May 30, 2016, from Office of Energy Efficiency & Renewable Energy: http://energy.gov/eere/wind/offshore-wind-advanced-technology-demonstration-projects

DOE. (2017). *2016 Offshore Wind Technologies Market Report.* Washington, D.C. Retrieved August 16, 2017, from https://energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf

Dominion. (2016, May 1). *Virginia Offshore Wind Technology Advancement Project*. Retrieved 2016, from Dominion: https://www.dom.com/corporate/what-we-do/electricity/generation/wind/virginia-offshore-wind-technology-advancement-project

DONG Energy. (2017). *We change our company name to Ørsted.* DONG Energy. Retrieved from http://www.dongenergy.com/en/media_/news-articles/Pages/171002ANN.aspx

Douglas-Westwood. (2013). *Assessment of Vessel Requirements for the US Offshore Wind Sector.*

DSIRE (a). (2015, May 20). *New Jersey Renewables Portfolio Standard*. Retrieved May 1, 2016, from Database of State Incentives for Renewables & Efficiency/NC Clean Energy Technology Center: http://programs.dsireusa.org/system/program/detail/564

DSire (b). (2015, February 18). *Virginia Voluntary Renewable Energy Portfolio Goal*. Retrieved May 1, 2016, from DSire/NC Clean Energy Technology Center: http://programs.dsireusa.org/system/program/detail/2528

DSire (c). (2016, March 7). *Maryland Renewable Energy Portfolio Standard*. Retrieved May 3, 2016, from DSire/NC Clean Energy Technology Center: http://programs.dsireusa.org/system/program/detail/1085

DSire (d). (2015, February 3). *North Carolina Renewable Energy and Energy Efficiency Portfolio Standard*. Retrieved May 3, 2016, from DSire/NC Clean Energy Technology Center: http://programs.dsireusa.org/system/program/detail/2660

DSire (e). (2015, February 11). *Delaware Renewables Portfolio Standard*. Retrieved May 3, 2016, from DSire/NC Clean Energy Technology Center: http://programs.dsireusa.org/system/program/detail/1231

Dvorak, M., Corcoran, B., Ten Hoeve, J., McIntyre, N., & Jacobson, M. (2012). *US East Coast offshore wind energy resources and their relationship to peak-time electricity demand.* Wiley Online Library.

Ecology and Environment, Inc. (2017, May). *Data Review and Gap Analysis for the New York State Energy Research and Development Authority Offshore Wind Planning Area.* Albany: NYSERDA. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Programs/offshore-wind/Offshore-Wind-Data-Review-and-Gap-Analysis-May-2017.pdf

EIA (a). (2015). *Annual Energy Outlook 2015.* Washington, D.C.: U.S. Energy Information Administration. Retrieved May 1, 2016, from http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf

EIA (b). (2015). *AEO 2015: Cost and Performance Characteristics of New Central Station Electricity Generating Technologies.* Washington, D.C.: U.S. Energy Information Administration. Retrieved May 1, 2016, from https://www.eia.gov/forecasts/aeo/assumptions/pdf/table_8.2.pdf

EIA (c). (2015, June 3). *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015*. Retrieved May 2, 2016, from U.S. Energy Information Administration: https://www.eia.gov/forecasts/aeo/electricity_generation.cfm

EIA. (2014). *Maryland State Profile and Energy Estimates*. Retrieved from U.S. Energy Information Administration: http://www.eia.gov/state/?sid=MD

Elorza, M. J. (2016, April 22). Executive Order 2016-3: Commitment to Eliminating City-Wide Carbon Emissions and Preparing for the Long-Term Impacts of Climate Change. Providence, Rhode Island, United States of America.

Ernst & Young. (2015). *Offshore Wind in Europe: Walking the Tightrope to Success.* Paris: EY. Retrieved October 14, 2016, from http://www.ewea.org/fileadmin/files/library/publications/reports/EY-Offshore-Wind-in-Europe.pdf

ESS Group. (2014). *Offshore Wind Transmission Study: Final Report.* Massachusetts Clean Energy Center. Boston, MA: Prepared for Massachusetts Clean Energy Center. Retrieved April 28, 2016, from http://files.masscec.com/research/MassCECOSWTransmissionStudy.pdf

Executive Office of Energy and Environmental Affairs. (2016). RPS and APS Program Summaries. Boston, Massachusetts. Retrieved from http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-program-summaries.html

Geschiere, A., & Pande, H. (2016). In With a Bang, Out with a Whimper: New England Clean Energy RFP. ICF. Retrieved from file:///C:/Users/jshoesmith/Downloads/energy-new-england-clean-energy-rfp.pdf

GL Garrad Hassan. (2014). *Assessment of Ports for Offshore Wind Development in the United States.*

Hamilton, B., Bielecki, M., Bloch, C., Decker, T., Frantzis, L., Midura, K., . . . Zhao, F. (2014). *Offshore Wind Market and Economic Analysis.* Prepared by Navigant Consulting. U.S. Department of Energy. Retrieved April 30, 2016, from http://energy.gov/sites/prod/files/2014/08/f18/2014%20Navigant%20Offshore%20Wind%20Market%20&%20Economic%20Analysis.pdf

Hand, M. M., Baldwin, S., DeMeo, E., Reilly, J. M., Mai, T., Arent, D., . . . Sandor, D. (2012). *Renewable Electricty Futures Study: Volume I.* Golden, CO: NREL.

Hannibal, M. (2016, March 1). Comments on the European Offshore Industry. *2016 U.S. Offshore Wind Leadership Conference*. Boston, MA: Siemens Wind Power.

Henson, B. (2010, November 16). *New England Wind Integration Study Final Results.* Westborough, MA: ISO New England. Retrieved April 28, 2016, from http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2010/nov162010/newis_iso.pdf

Hinkle, G., & Piwko, R. (2010). *New England Wind Integration Study.* Prepard by GE Energy, EnerNex Corporation and AWS Truepower. ISO New England. Retrieved April 28, 2016, from http://www.uwig.org/newis_report.pdf

Ho, A., Mbistrova, A., & Corbetta, G. (2016). *The European Offshore Wind Industry - Key Trends and Statistics 2015.* Brussels, Belgium: European Wind Energy Association. Retrieved from http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2015.pdf

Ho, A., Mbistrova, A., Pineda, I., & Tardieu, P. (2017). *The European offshore wind industry: Key trends and statistics 2016.* Brussels, Belgium: Wind Europe. Retrieved from https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2016.pdf

Hopper, A. R. (2015). *Cape Wind Lease Suspension Order.* Washington, D.C.: BOEM. Retrieved October 31, 2016, from http://www.boem.gov/Lease-Suspension-Order/

Hundleby, G., & Freeman, K. (2017). *Unleashing Europe's offshore wind potential: A new resource assessment.* BVG Associates. WindEurope. Retrieved from https://windeurope.org/wp-content/uploads/files/about-wind/reports/Unleashing-Europes-offshore-wind-potential.pdf

Hurdle, J. (2017, March 17). Federal judge rejects permits challenge in new setback to Constitution Pipeline. *StateImpact Pennsylvania*. PA: NPR. Retrieved from https://stateimpact.npr.org/pennsylvania/2017/03/17/federal-judge-rejects-permits-challenge-in-new-setback-to-constitution-pipeline/

ICF International. (2015). *New England Market Outlook: Demand for Natural Gas Capacity and Impact of the Northeast Energy Direct Project.* Kinder Morgan, Inc. Retrieved May 30, 2016, from http://www.kindermorgan.com/content/docs/NED_CapacityOutlook.pdf

Isabel Kain & others vs. Massachusetts Department of Environmental Protection, SJC-11961 (Massachusetts Supreme Judicial Court October 7, 2015).

ISO New England. (2015). *2015 Regional Electricity Outlook.* Holyoke, MA: ISO New England. Retrieved April 29, 2016, from http://www.iso-ne.com/static-assets/documents/2015/02/2015_reo.pdf

ISO New England. (2015). *2015-2024 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT) Report.* Holyoke, MA: ISO-NE. Retrieved June 20, 2016, from http://www.iso-ne.com/static-assets/documents/2015/05/2015_celt_report.pdf

ISO New England. (2016, March 28). *2015 Economic Study - Offshore Wind: Draft Results.* Planning Advisory Committee. Westborough, MA: ISO New England. Retrieved March 20, 2016, from ISO New England Planning Advisory Committee Meeting: http://www.iso-ne.com/static-assets/documents/2016/03/a3_2015_economic_study_off_shore_wind_presentation.pdf

ISO New England. (2016a). *Resource Mix*. Retrieved May 2, 2016, from ISO New England: http://www.iso-ne.com/about/key-stats/resource-mix

ISO New England. (2016b). *2016 Regional Electricity Outlook.* Holyoke, MA: ISO New England. Retrieved May 30, 2016, from http://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf

ISO New England. (2016c). *State of the Grid: 2016.* Holyoke, MA: ISO-NE. Retrieved October 18, 2016, from https://www.iso-ne.com/static-assets/documents/2016/01/20160126_presentation_2016stateofthegrid.pdf

ISO New England. (2016d). *2015 Economic Study: Evaluation of Offshore Wind Deployment.* Holyoke, MA: ISO New England. Retrieved February 17, 2017, from https://www.iso-ne.com/static-assets/documents/2016/09/2015_economic_study_offshore_wind_development_final.docx

ISO New England. (2016e). *2016-2025 Forecast Report of Capacity, Energy, Loads, and Transmission.* Holyoke, MA: ISO New England. Retrieved February 24, 2017, from https://www.iso-ne.com/static-assets/documents/2016/05/2016_celt_report.xls

Karst, T. (2016, March 1). Comments on OSW Economics in Europe. *2016 U.S. Offshore Wind Leadership Conference*. Boston, MA: MHI Vestas Offshore Wind.

Kaubisch, I. (2013). Combining On- and Offshore Logistics: Finding a Suitable Harbor for an Offshore Wind Jack-Up Vessel. *AWEA Offshore Windpower Conference & Exhibition.* Somerville, MA: Clarendon Hill Consulting. Retrieved 29 2016, April, from http://www.offshorewindhub.org/sites/default/files/resources/Study%20on%20suitable%20harbors%20for%20Offshore%20wind%20traffic.pdf

Kay, B. (2016, March 28). Interconnection Cluster Studies: Summary and discussion of interconnection group study processes in the NYISO, CAISO, PJM, SPP, MISO and ISO-NE. *Planning Advisory Committee*. Westborough, MA: ISO New England. Retrieved from https://www.iso-ne.com/static-assets/documents/2016/03/a2_summary_of_clustering_approaches.pptx

Kempton, W., McClellan, S., & Ozkan, D. (2016). *Massachusetts Offshore Wind Future Cost Study.* University of Delaware.

Kraus, S. D., Leiter, S., Stone, K., Wikgren, B., Mayo, C., Hughes, P., . . . Tielens, J. (2016). *Northeast Large Pelagic Survey Collaborative Aerial and Acoustic Surveys for Large Whales and Sea Turtles: Final Report.* Sterling, Virginia: US Department of the Interior, Bureau of Ocean Energy Management.

Krohn, J., & Teller, K. (2016, January 28). New Pipeline Projects Increase Northeast Natural Gas Takeaway Capacity. *Today In Energy*. Retrieved May 30, 2016, from http://www.eia.gov/todayinenergy/detail.cfm?id=24732

Lau, J., & Coste, W. (2016). *2015 Economic Study Strategic Transmission Analysis - Onshore Wind Integration Draft Results.* Planning Advisory Committee. Westborough, MA: ISO New England. Retrieved May 1, 2016, from http://www.iso-ne.com/static-assets/documents/2016/03/a3_2015_economic_study_on_shore_wind_presentation.pdf

Lazard. (2015). *Lazard's Levelized Cost of Energy Analysis - Version 9.0.* Lazard. Retrieved May 1, 2016, from https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf

Logan, T. (2015, June 3). Overview of BOEM's Leasing Process. *BOEM-HI Task Force Meeting*. Honolulu, HI: Bureau of Ocean Energy Management. Retrieved May 1, 2016, from http://www.boem.gov/Lease-Process-06-15/

Long Island Power Authority. (2017a, January 25). Long Island Power Authority (LIPA) Minutes of the 266th Meeting Held on January 25, 2017. Uniondale, NY, USA: LIPA. Retrieved from http://www.lipower.org/pdfs/company/papers/board/01252017/APPROVED%20Board%20Minutes%20of%20January%2025,%202017%20Meeting.pdf

Long Island Power Authority. (2017b). *Energy Guide: 2017 Long Island Integrated Resource Plan and Repowering Studies.* New York, NY: LIPA. Retrieved from www.lipower.org/pdfs/company/trans/LIPA_EnergyGuide%206x9%204_22_17%20FINAL.pdf

MA Clean Energy. (2017). *83D*. Retrieved from Massachusetts Clean Energy: https://macleanenergy.com/83d/

MA DOER, NSTAR and Northeast Utilities. (2016). *Settlement Agreement.* NSTAR Electric Company, NSTAR Gas Company and Western Massachusetts Electric Company (WEMCO), Department of Public Utilities Docket No. 10-170. Boston, MA: Massachusetts Department of Energy Resources (DOER). Retrieved June 23, 2016, from http://web1.env.state.ma.us/DPU/FileRoomAPI/api/Attachments/Get/?path=10-170%2f21512doerst.pdf

MA EEA. (2015, January 6). *Massachusetts Ocean Management Plan*. Retrieved May 3, 2016, from Massachusetts Executive Office of Energy and Environmental Affairs: http://www.mass.gov/eea/waste-mgnt-recycling/coasts-and-oceans/mass-ocean-plan/

Mai, T., Wiser, R., Sandor, D., Brinkman, G., Heath, G., Denholm, P., . . . Strzepek, K. (2012b). *Volume 1: Exploration of High-Penetration Renewable Electricity Futures. Vol. 1 of Renewable Electricity Futures Study.* Golden, CO: National Renewable Energy Laboratory. Retrieved May 2, 2016, from http://www.nrel.gov/docs/fy12osti/52409-1.pdf

Maine Governor's Energy Office. (2007). *Energy Efficiency and Renewable Energy*. Retrieved from http://www.maine.gov/energy/initiatives/efficiency_renewable.html

Maine Legislature. (2003). *Title 38: Section 576. Reduction Goals*. Retrieved May 3, 2016, from Maine Revised Statutes: http://legislature.maine.gov/legis/statutes/38/title38sec576.html

Maine Legislature. (2006). *Long Term Contracting Statute.* Retrieved May 3, 2016, from Maine Public Utilities Commission: http://www.maine.gov/mpuc/legislative/documents/Long%20term%20contracting%20statute.pdf

Maine Legislature. (2010, April 7). An Act To Implement the Recommendations of the Governor's Ocean Energy Task Force: PUBLIC Law, Chapter 615, LD 1810. Retrieved from http://www.mainelegislature.org/legis/bills/bills_124th/chappdfs/PUBLIC615.pdf

Maine Public Utilities Commission. (2010). *Docket 2010-00235*. Retrieved from https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2010-00235&FRM=0

Maine Public Utilities Commission. (2011). *Docket 2011-00138*. Retrieved from https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2011-00138

Maine Public Utilities Commission. (2015). *Docket 2015-00058*. Retrieved from https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2015-00058

Maine Public Utilities Commission. (2015). *Docket 2015-00157*. Retrieved from https://mpuc-cms.maine.gov/CQM.Public.WebUI/Common/CaseMaster.aspx?CaseNumber=2015-00157

Maine State Legislature. (2010, April 7). PUBLIC Law, Chapter 615, LD 1810, An Act To Implement the Recommendations of the Governor's Ocean Energy Task Force (The Ocean Energy Act). Maine. Retrieved from http://www.mainelegislature.org/legis/bills/bills_124th/chappdfs/PUBLIC615.pdf

MARCO. (2014, March 1). *MARCO Overview*. Retrieved May 1, 2016, from Mid-Atlantic Regional Council on the Ocean: http://midatlanticocean.org/about/marco-overview/

Massachusetts Clean Energy Center. (2016). *New Bedford Marine Commerce Terminal*. Retrieved May 1, 2016, from Massachusetts Clean Energy Center: http://www.masscec.com/marine-commerce-terminal-new-bedford

Massachusetts Department of Environmental Protection. (2016, December 16). Memo to Greenhouse Gas Stakeholders. Boston, MA, USA. Retrieved from http://www.seadvantage.com/Documents/Eyes_and_ears_Library/MA/DEP_CES_Memo_121616.pdf

Massachusetts Department of Public Utilities. (2014). *Energy and Environmental Affairs* . Retrieved from http://web1.env.state.ma.us/DPU/FileRoom/dockets/bynumber

Massachusetts DOER, MassCEC, Customized Energy Solutions, Alevo Analytics, Sustainable Energy Advantage, Daymark Energy Advisors, and Strategen. (2016). *State of Charge: Massachusetts Energy Storage Initiative.* Boston, MA: Massachusetts Department of Energy Resources. Retrieved October 18, 2016, from http://www.mass.gov/eea/docs/doer/state-of-charge-report.pdf

Massachusetts Executive Office of Energy and Environmental Affairs. (2008). *Global Warming Solutions Act Background*. Retrieved from http://www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/global-warming-solutions-act-background.html

Massachusetts Executive Office of Energy and Environmental Affairs. (2009). *RPS and APS: Statutes, Regulations and Guidelines*. Retrieved from http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-statutes-and-regulations.html

Massachusetts Executive Office of Energy and Environmental Affairs. (2015). *Energy Storage Initiative*. Retrieved from http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/energy-storage-initiative/

Massachusetts Executive Office of Energy and Environmental Affairs. (2016). *Massachusetts Clean Energy and Climate Plan for 2020.*

Massachusetts Executive Office of Energy and Environmental Affairs. (2017). *Reducing GHG Emissions under Section 3(d) of the Global Warming Solutions Act (GWSA)*. Retrieved from Mass.gov: http://www.mass.gov/eea/agencies/massdep/air/climate/section3d-comments.html

Massachusetts General Court. (2016). *Chapter 188 of Session Laws 2016 - An Act to Promote Energy Diversity.* Boston, MA: 189th General Court of the Commonwealth of Massachusetts. Retrieved October 18, 2016, from https://malegislature.gov/Laws/SessionLaws/Acts/2016/Chapter188

Massachusetts Legislature. (2008). Green Communities Act of 2008. Boston, Massachusetts. Retrieved from https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169

Massachusetts Legislature. (2012). AN ACT RELATIVE TO COMPETITIVELY PRICED ELECTRICITY IN THE COMMONWEALTH. Boston, Massachusetts. Retrieved from https://malegislature.gov/Laws/SessionLaws/Acts/2012/Chapter209

Massachusetts Legislature. (2015). H.2851 - An Act to Promote Offshore Wind Energy.

Massachusetts Legislature. (2015). H.2881 - An Act to Promote Energy Diversity.

Massachusetts Legislature. (2016). S.2121 - An Act Relative to 2030 and 2040 Emissions Benchmarks.

Massachusetts Legislature. (n.d.). 310 CMR 7.75 CLEAN ENERGY STANDARD . Boston, Massachusetts. Retrieved from http://www.mass.gov/eea/docs/dep/air/laws/ces-dreg.pdf

Massachusetts State House of Representatives. (2016). *H.4385.* Boston, MA: 189th General Court of the Commonwealth of Massachusetts. Retrieved June 28, 2016, from https://malegislature.gov/Bills/189/House/H4385

Massachusetts State Senate. (2016). *S.2372.* Boston, MA: 189th General Court of the Commonwealth of Massachusetts. Retrieved June 28, 2016, from https://malegislature.gov/Bills/189/Senate/S2372

Massachusetts Supreme Judicial Court. (2016). *Isabel Kain & Others vs. Department of Environmental Protection.* Boston, MA. Retrieved from http://www.seadvantage.com/Documents/Eyes_and_ears_Library/MA/2016-sjc-11961.pdf

MassCEC. (2015). *Offshore Wind*. (Massachusetts Clean Energy Center) Retrieved from http://www.masscec.com/offshore-wind

MassCEC. (2017a). Massachusetts Offshore Wind Ports & Infrastructure Assessment. MA: MassCEC. Retrieved July 12, 2017, from http://www.masscec.com/massachusetts-offshore-wind-ports-infrastructure-assessment

MassCEC. (2017b, May). *Phase One – Existing Conditions Reports*. Retrieved from Massachusetts Clean Energy Center: http://www.masscec.com/phase-one-%E2%80%93-existing-conditions-reports

MassCEC. (n.d.). Wind Technology Testing Center. Boston, Massachusetts: Massachusetts Clean Energy Center. Retrieved from http://files.masscec.com/about-masscec/facilities/wind-technology/WTTCFactSheet.pdf

Mayor's Office of Recovery and Resiliency. (2016). *Mayor's Office of Recovery and Resiliency*. Retrieved from http://www.nyc.gov/html/oltps/html/home/home.shtml

McClellan, S., Ozkan, D., Kempton, W., Levitt, A., & Thomson, H. (2015). *New York Offshore Wind Cost Reduction Study.* Albany, NY: NYSERDA.

Moriarty, T. (2015, September 17). *BOEM Announces Major Step for Renewable Energy Offshore North Carolina*. Retrieved May 2, 2016, from Bureau of Ocean Energy Management: http://www.boem.gov/press09172015/

Musial, W. (2007, Fall). Offshore Wind Electricity: A Viable Energy Option for Coastal USA. *Marine Technology Society Journal, 41*(3), 32-43. Retrieved April 26, 2016

Musial, W., Elliot, D., Fields, J., Parker, Z., & Scott, G. (2013). *Analysis of Offshore Wind Energy Leasing Areas for the Rhode Island/Massachusetts Wind Energy Area.* Technical Report, National

Renewable Energy Laboratory, Golden, CO. Retrieved April 28, 2016, from http://www.nrel.gov/docs/fy13osti/58091.pdf

Musial, W., Elliot, D., Fields, J., Parker, Z., Scott, G., & Draxl, C. (2013). *Assessment of Offshore Wind Energy Leasing Areas for the BOEM New Jersey Wind Energy Area.* Golden, CO: National Renewable Energy Laboratory. Retrieved May 3, 2016, from http://www.nrel.gov/docs/fy13osti/60403.pdf

Musial, W., Heimiller, D., Beiter, P., Scott, G., & Draxl, C. (2016, September). *2016 Offshore Wind Energy Resource Assessment for the United States.* Golden, CO: NREL. Retrieved from https://www.nrel.gov/docs/fy16osti/66599.pdf

National Renewable Energy Laboratory . (2013). *Analysis of Offshore Wind Energy Leasing Areas for the Rhode Island/Massachusetts Wind Energy Area.*

NEG/ECP. (2017, February 16). Regional Strategies, Policies and Measures: Potential Options for Consideration. *Regional Climate Change Action Plan Development*. New England Governors and Eastern Canadian Premiers. Retrieved from http://coneg.org/Data/Sites/1/media/neg-ecp---comprehensive-draft-options.170216.pdf

NESCOE. (2017). *NESCOE Submission Regarding Transmission Needs Driven by State and Federal Public Policy Requirements.* Westborough, MA: NESCOE. Retrieved from https://www.iso-ne.com/static-assets/documents/2017/05/nescoe_submission_public_policy_transmission_upgrades.pdf

New York Department of Public Service. (2015). *Case 15-E-0302*. Retrieved from DPS: http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=15-e-0302

New York Department of Public Service. (2016). *Staff White Paper on Clean Energy Standard.* Retrieved from file:///C:/Users/cgoodman/Downloads/%7B930CE8E2-F2D8-404C-9E36-71A72123A89D%7D%20(1).pdf

New York State. (2017). *New York State Submits Offshore Areas for Potential Wind Devleopment Off Atlantic Coast.* NYSERDA. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-10-02-NYS-Submits-Offshore-Areas-for-Potential-Wind-Development-Off-Atlantic-Coast

New York State Assembly (b). (2015, January 12). An Act to amend the public service law, in relation to New York state. Albany, New York: State of New York. Retrieved from http://assembly.state.ny.us/leg/?default_fld=%0D%0A&bn=A01396&term=2015&Summary=Y&Actions=Y&Text=Y

New York State Assembly (b). (2016, January 13). An Act to Amend the Public Service Law and the Public Authorities Law, In Relation to Establishing a Clean Energy Fund and Requiring NYPA and LIPA to Establish Clean Energy Initiatives. Albany, New York: New York State. Retrieved from http://assembly.state.ny.us/leg/?default_fld=&bn=A01924&term=2015&Summary=Y&Actions=Y&Votes=Y&Text=Y

New York State Assembly (c). (2016, January 30). An Act to Amend the Public Service Law, In Relation to Enacting the "New York Renewable Portfolio Act of 2016". Albany, New York: New York State Assembly. Retrieved from http://assembly.state.ny.us/leg/?default_fld=&bn=S02893&term=2015&Summary=Y&Actions=Y&Text=Y

New York State Assembly (d). (2016). Albany, NY: New York State Assembly. Retrieved June 21, 2016, from http://assembly.state.ny.us/leg/?default_fld=&leg_video=&bn=S08005&term=2015&Summary=Y&Actions=Y

New York State Department of State. (2013). *New York Offshore Atlantic Ocean Study.* Albany, NY: New York Department of State. Retrieved from http://docs.dos.ny.gov/communitieswaterfronts/ocean_docs/NYSDOS_Offshore_Atlantic_Ocean_Study.pdf

New York State Energy Planning Board Members. (2015). *2015 New York State Energy Plan.* Albany, New York: New York State. Retrieved May 2016, from http://energyplan.ny.gov/Plans/2015

NH Committee to Study Offshore Wind Energy. (2014). *Report of the Committee to Study Offshore Wind Energy and he Development of Other Ocean Power Technology.*

NH OEP. (2014). *New Hamshire 10 Year State Energy Strategy.*

NH PUC. (2016). *Electric Renewable Portfolio Standard*.

Normandeau Associates. (2017). *NYSERDA: Remote Marine and Onshore Technology*. Retrieved from Normandeau Associates: Environmental Consultants: https://remote.normandeau.com/nys_overview.php

NREL. (2012a). *Renewable Electricity Futures Scenario Viewer*. (Alliance for Sustainable Energy, LLC) Retrieved May 2, 2016, from National Renewable Energy Laboratory: http://www.nrel.gov/analysis/re_futures/data_viewer/

NREL. (2015a). *2014-2015 Offshore Wind Technologies Market Report.*

NREL. (2015b). *Annual Technology Baseline and Standard Scenarios.* Golden, CO: National Renewable Energy Laboratory. Retrieved May 2, 2016, from http://www.nrel.gov/analysis/data_tech_baseline.html

NYISO. (2010). *Growing Wind: Final Report fo the NYISO 2010 Wind Generation Study.* Albany, NY: New York ISO. Retrieved May 2, 2016, from http://www.nyiso.com/public/webdocs/media_room/press_releases/2010/Child_New_York_Grid_Ready_for_More_Wind_093010/GROWING_WIND_-_Final_Report_of_the_NYISO_2010_Wind_Generation_Study.pdf

NYISO. (2011). *Installed Capacity Manual.* Rensselaer, N.Y.: New York Independent System Operator.

NYISO. (2015). *"Gold Book" - 2015 Load & Capacity Data.* NYISO. Retrieved from http://system.suny.edu/media/suny/content-assets/documents/capital-facilities/energy/2015-Load-and-Capacity-Data-Report.pdf

NYISO. (2016). *"Gold Book" - 2016 Load & Capacity Data.* Rensselaer, NY: New York Independent System Operation. Retrieved from http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Documents_and_Resources/Planning_Data_and_Reference_Docs/Data_and_Reference_Docs/2016_Load__Capacity_Data_Report.pdf

NYISO. (2016). *Generator Deactivation Assessment: James A. FitzPatrick Nuclear Generating Facility.* Albany, NY: New York ISO. Retrieved May 2, 2016, from http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Planning_Studies/Reliability_Planning_Studies/Generator_Deactivation_Assessments/FitzPatrick_Generator_Deactivation_Assessment_2016-04-22.pdf

NYPA. (2011, September 8). *Request for Commercial Lease.* Bureau of Ocean Energy Management. New York, NY: New York Power Authority (NYPA). Retrieved June 28, 2016, from http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/State_Activities/BOEM%20LI-NYCApplication09082011(2).pdf

NYS Public Service Commission. (2016a, January 21). Order Authorizing the Clean Energy Fund Framework. Albany, NY.

NYS Public Service Commission. (2016b). *Order Adopting a Clean Energy Standard.* Albany, NY: State of New York Public Service Commission. Retrieved August 1, 2016, from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b1A8C4DCA-E2CC-449C-AA0D-7F9C3125F8A5%7d

NYS Public Service Commission. (2016c). *Order Expanding Scope of Proceeding and Seeking Comments.* Albany, NY: NYS PSC.

NYSERDA. (2010). *Summary of Physical and Environmental Qualities for the Proposed Long Island - New York City Offshore Wind Project Area.* Albany, NY: NYSERDA.

NYSERDA. (2012). *Unpublished Offshore Wind Cost-Benefit Report.*

NYSERDA. (2013). *Operating Plan for Technology and Market Development Programs (2012-2016).* Albany, NY: NYSERDA.

NYSERDA. (2015). *Large Scale Renewable Energy Development in New York: Options and Assessment.* Retrieved from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={26BD68A2-48DA-4FE2-87B1-687BEC1C629D}

NYSERDA. (2015b). *System Benefits Charge*. Retrieved from New York State: http://www.nyserda.ny.gov/About/System-Benefits-Charge

NYSERDA. (2015c). *Advancing the Environmentally Responsible Development of Offshore Wind Energy in New York State: A Regulatory Review and Stakeholder Perceptions.* Albany, NY: NYSERDA. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/Advancing-Environmental-Response-Development-Off-Shore-Wind-New-York.pdf

NYSERDA. (2016a). *Regional Greenhouse Gas Initiative*. Retrieved from New York State: http://www.nyserda.ny.gov/About/Regional-Greenhouse-Gas-Initiative

NYSERDA. (2016b). *Renewable Portfolio Standard Program Purchase of Renewable Energy Attributes Request for Proposals No. 3257.* Albany, NY: New York State Energy Research and Development Authority. Retrieved May 5, 2016, from http://www.seadvantage.com/Documents/Eyes_and_ears_Library/ISO/3257_Main_tier_RFP_NY_PSC_April_2016.pdf

NYSERDA. (2016c, June 2). *New York State to Participate in Offshore Wind Lease Auction*. Retrieved June 3, 2016, from New York State Energy Research and Development Authority: http://www.nyserda.ny.gov/About/Newsroom/2016-Announcements/2016-06-02-New-York-State-to-Participate-in-Offshore-Wind-Lease-Auction

NYSERDA. (2016d). *Clean Energy Fund Investment Plan: Large-Scale Renewables Chapter.* Albany, NY: NYSERDA. Retrieved October 18, 2016, from http://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Large-Scale-Renewable.pdf

NYSERDA. (2016e, November). Draft Metocean Plan for the New York Wind Energy Area. Albany, NY, USA. Retrieved from http://seadvantage.com/Documents/Eyes_and_ears_Library/NY/metocean-plan-draft.pdf

NYSERDA. (2016f). *New York Wildlife and Marine Wind Energy Project*. Retrieved May 3, 2016, from New York State Energy Research and Development Authority: http://www.nyserda.ny.gov/Cleantech-and-Innovation/Power-Generation/Wind/Offshore-Wind/Marine-Wind-Energy-Project

NYSERDA. (2016g). *Blueprint for the New York State Offshore Wind Master Plan.* Albany, NY: NYSERDA. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/New-York-State-Offshore-Wind-Blueprint.pdf

NYSERDA. (2017). *Metocean Plan for the New York Offshore Study Area.* NYSERDA, Carbon Trust Advisory Limited and Frazer Nash Consultancy. NYSERDA. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/16-35-Metocean-Plan-Wind-Energy.pdf

NYSERDA, Sustainable Energy Advantage, LLC. (2016a). *Clean Energy Standard White Paper - Cost Study Supplement.* Albany, NY: New York Department of Public Service. Retrieved May 4, 2016, from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={6C2629FF-3562-4C34-A773-C5EEACE86BE0}

NYSERDA, Sustainable Energy Advantage, LLC. (2016b). *Clean Energy Standard White Paper - Cost Study.* Albany, NY: NYS Department of Public Service. Retrieved June 27, 2016, from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={7B564AD9-E6E9-4FA9-93B6-1AA85B1719E2}

Ocean Energy Task Force. (2009). *Final Report of the Ocean Energy Task Force to Governor John E. Baldacci.* Retrieved from http://www.maine.gov/dacf/mcp/downloads/finalreport_123109.pdf

Offshore Wind Hub. (2016). *New Jersey State Resources*. Retrieved October 28, 2016, from Offshore WInd Hub: http://www.offshorewindhub.org/states/new-jersey

OffshoreWind. (2012, November 18). *Bluewater Wind Offshore Wind Project*. Retrieved May 4, 2016, from OffshoreWind.net: http://offshorewind.net/bluewater-wind-offshore-wind-project/

OffshoreWind.biz. (2016, February 12). Fishermen's Atlantic City OWF Gets Another Chance. *Offshore Wind Biz*. Retrieved 1 2016, May, from http://www.offshorewind.biz/2016/02/12/fishermens-atlantic-city-owf-gets-another-chance/

O'Sullivan, J. (2016, January 8). NJ Offshore Wind Farm Bill Pending Christie's Signoff. *Law360*. Retrieved May 1, 2016

Papavizas, C. (2011). Clarifying the Jones Act for Offshore Wind. *North American Wind Power*(June). Retrieved May 1, 2016, from http://cdn2.winston.com/images/content/1/0/v2/107/Jones-Act-Wind-Article-North-American-Wind-Power-June-2011.pdf

Paterson, D. A., & Schwartz, L. (2009). Establishing a Goal to Reduce Greenhouse Gas Emissions Eighty Percent by the Year 2050 and Preparing a Climate Action Plan. Albany, NY: Department of Environmental Conservation. Retrieved from http://www.dec.ny.gov/energy/71394.html

Paterson, G. D. (2009). Executive Order No. 24. Albany, NY: Department of Environmental Conservation.

Piwko, R., Bai, X., Clark, K., Jordan, G., Miller, N., & Zimberlin, J. (2005). *The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations.* Prepared by GE Energy. Albany, NY: New York Energy Research and Development Authority. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/wind-integration-appendix.pdf

Plummer, C. (2016, April 4). Interview with Deepwater Wind. (B. Grace, Interviewer)

PNE Wind. (2016a, December 30). Unsolicited Application for an Outer Continental Shelf Renewable Energy Commercial Lease. Washington, D.C., USA: Bureau of Ocean Energy Management. Retrieved from https://www.boem.gov/PNE-MA4-502-Lease-Application/

PNE Wind. (2016b, December 30). Unsolicited Application for an Outer Continental Shelf Renewable Energy Commercial Lease under 30 CFR 585.230. Washington, D.C.: Bureau of Ocean Energy Management. Retrieved from https://www.boem.gov/PNE-NY4-excelsior-Lease-Application/

Portland Municipal Climate Change Working Group. (2008, March). *Portland Maine*. Retrieved May 3, 2016, from Climate Action Plan: http://www.portlandmaine.gov/1294/Climate-Action-Plan

Prager, P. B. (2017, June 30). Letter Regarding Retirement of Cayuga Units 1 and 2 to NY PSC. Lansing, NY. Retrieved from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={8924778D-7E52-4A7A-B76F-5F2EA707FBBB}

PSEG Long Island LLC (a). (2016, November 10). Request for Proposals: South Fork Resources. Riverhead, NY. Retrieved May 5, 2016, from https://www.psegliny.com/files.cfm/SFRFP11102015Clean.pdf

PSEG Long Island LLC (b). (2015). *Request for Proposals: New Renewable Capacity and Energy.* Riverhead, NY. Retrieved May 5, 2016, from http://pseglirenrfp.com/2015RenewableRFPFinal2015-12-22.docx

PSEG Power Connecticut. (2016, February 11). PSEG Power 485-MW Combined-Cycle Gas Plant Clears ISO-New England Forward Capacity Auction. *PR Newswire*. Retrieved May 2, 2016, from http://www.prnewswire.com/news-releases/pseg-power-485-mw-combined-cycle-gas-plant-clears-iso-new-england-forward-capacity-auction-300218764.html

R.I. Coastal Resources Management Council. (n.d.). Retrieved from Rhode Island Ocean Special Area Management Plan: http://seagrant.gso.uri.edu/oceansamp/

Raimondo, G. M. (2017, March). Raimondo Announces "1,000 by '20" Clean Energy Goal-- 1,000 megawatts of clean energy by 2020. North Kingtown, RI. Retrieved from http://www.ri.gov/press/view/29766

RGGI. (2016, March 18). *2016 Allowance Allocation.* Retrieved May 2, 2016, from Regional Greenhouse Gas Initiative: https://www.rggi.org/docs/CO2AuctionsTrackingOffsets/Allocation/2016_Allowance-Allocation.pdf

RGGI. (2017a, August 23). RGGI States Announce Proposed Program Changes: Additional 30% Emissions Cap Decline by 2030. New York, NY, USA. Retrieved from http://rggi.org/docs/ProgramReview/2017/08-23-17/Announcement_Proposed_Program_Changes.pdf

RGGI. (2017b, June 16). Distribution of 2017 CO2 Allowances. New York, NY, USA: Regional Greenhouse Gas Initiative. Retrieved from http://www.rggi.org/docs/CO2AuctionsTrackingOffsets/Allocation/2017_Allowance-Distribution.pdf

Rhode Island Division of Planning. (2015). *Energy 3035 - Rhode Island State Energy Plan.* Retrieved from http://www.planning.ri.gov/documents/LU/energy/energy15.pdf

Rhode Island General Assembly. (2014). *Chapter 42-6.2: Resilient Rhode Island Act of 2014 - Climate Change Coordinating Council.* Retrieved May 3, 2016, from Rhode Island Statutes: http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-6.2/INDEX.HTM

Rhode Island General Assembly. (2015). *SB 89 & HB 5079 - An Act Relating to Public Utilities and Carriers - Renewable Energy Standard.*

Rhode Island General Assembly. (2016). *H 7413 - An Act Relating to Public Utilities and Carriers - Renewable Energy.*

Rhode Island Legislature. (2009). *Chapter 39-26.1: Long Term Contracting Standard for Renewable Energy*. Retrieved May 3, 2016, from Rhode Island Statutes: http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26.1/INDEX.HTM

Rhode Island Legislature. (2016). *H 7514 - An Act Relating to Public Utilities and Carriers - Public Utilities Commission.* Retrieved from http://webserver.rilin.state.ri.us/BillText/BillText16/HouseText16/H7514.pdf

Rhode Island Office of Energy Resources. (2016). *Systems Integration Rhode Island Vision Document.* Retrieved from http://www.energy.ri.gov/siri/

Rhode Island Public Utilities Commission. (2014). *Annual RES Compliance Report 2012.* Retrieved May 3, 2016, from http://www.ripuc.org/utilityinfo/PUC-RES-AnnualReport2012-Rev(3-25-14).pdf

Rhode Island Public Utilities Commission. (2014). *Docket No. 4491*. Retrieved from http://www.ripuc.org/eventsactions/docket/4491page.html

Rhode Island Public Utilities Commission. (2016, March 3). *Docket 4600 - PUC's Investigation Into the Changing Electric Distribution System*. Retrieved from http://www.ripuc.org/eventsactions/docket/4600page.html

Rhode Island Public Utilities Commission. (n.d.). *Docket 4185 - Review of Amended PPA Between National Grid and Deepwater Wind Block Island*. Retrieved from http://www.ripuc.org/eventsactions/docket/4185page.html

RI General Assembly. (2014). Chapter 39-31 Affordable Clean Energy Security Act. Retrieved from Chapter 39-31: http://webserver.rilin.state.ri.us/Statutes/title39/39-31/INDEX.HTM

Rowland, J. (2004). *Executive Order No. 32.* Hartford, CT: Office of the Governor. Retrieved June 23, 2016, from http://www.ctenergy.org/pdf/ExOrder32.pdf

Schwartz, M., Heimiller, D., Haymes, S., & Musial, W. (2010, June). *Assessment of Offshore Wind Energy Resources for the United States.* Technical Report, National Renewable Energy Laboratory, Golden, CO. Retrieved April 28, 2016, from http://www.nrel.gov/docs/fy10osti/45889.pdf

SEA. (2016). *MA Solar Market Study Model Analysis (Not Public).* Framingham, MA: Sustainable Energy Advantage, LLC.

Services, D. o., & Sustainability, M. O. (2007, September 15). Request for Information: Supply New York City With Renewable Power. New York, NY.

Sheilendranath, A. (2012). *Strategic Transmission Analysis: Generation Retirements Study.* Planning Advisory Committee. Westborough, MA: ISO New England. Retrieved May 2, 2016, from http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2012/dec132012/retirements_redacted.pdf

Shumlin, G. P. (2012, July 30). A Resolution Directing the New England State Committee on Electricity (NESCOE) to Implement a Work Plan for the Competitive Coordinated Procurement of Regional Renewable Power. *New England Governors Conferences, Inc.* Montpelier, VT: NESCOE. Retrieved May 2, 2016, from http://nescoe.com/uploads/CP_Resolution_July_2012.pdf

Smith, A., Stehly, T., & Musial, W. (2015). *2014-2015 Offshore Wind Technologies Market Report.* Golden, CO: National Renewable Energy Laboratory. Retrieved April 28, 2016, from http://www.nrel.gov/docs/fy15osti/64283.pdf

Staff, N. D. (2016). *Staff White Paper on Clean Energy Standard.* Albany: DPS.

Stanton, E. A., Knight, P., Allison, A., Comings, T., Horowitz, A., Ong, W., . . . Takahashi, K. (2016). *The RGGI Opportunity 2.0: RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets.* Cambridge, MA: Synapse Energy Economics, Inc. Retrieved April 1, 2016, from http://www.synapse-energy.com/sites/default/files/RGGI_Opportunity_2.0.pdf

State of Connecticut. (2017, June 27). Public Act No. 17-144 - An Act Promoting the Use of Fuel Cells for Electric Distribution System Benefits and Reliability and Amending Various Energy-Related Programs and Requirements. Hartford, CT. Retrieved from https://www.cga.ct.gov/2017/ACT/pa/pdf/2017PA-00144-R00HB-07036-PA.pdf

State of Maine Governor's Energy Office. (2015, February). Maine Comprehensive Energy Plan Update 2015.

State of Rhode Island General Assembly. (2016). *S.2185 - Substitute A.* Providence, RI: State of Rhode Island General Assembly. Retrieved June 28, 2016, from http://webserver.rilin.state.ri.us/BillText/BillText16/SenateText16/S2185A.pdf

Statoil. (2016, December). Unsolicited Request for an Outer Continental Shelf Renewable Energy Commercial Lease. Washington, D.C., USA. Retrieved from https://www.boem.gov/Statoil-0502-0503/

Statoil North America, Inc. (n.d.). Unsolicited Application for an OCS Renewable Energy Commercial Lease. Maine. Retrieved from http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/State_Activities/Statoil%20Unsolicited%20Lease%20Request%20Public%20Version.pdf

Stromsta, K.-E. (2017, February 13). *Deewpater eyes 'seamless' move into 210MW proejct after South Fork.* Retrieved April 10, 2017, from RECHARGE: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjmuqn4t5rTAhUL0oMKHT40A5gQFggcMAA&url=http%3A%2F%2Fwww.rechargenews.com%2Fwind%2F1215058%2Fdeepwater-eyes-seamless-move-into-210mw-project-after-south-fork&usg=AFQjC

Tetra Tech EC. (2010). *Port and Infrastructure Analysis for Offshore Wind Energy Development.*

Thaler, J. (2013). *Permitting and Leasing for Maine Offshore Wind Energy Projects.* University of Maine. Portland, ME: Enviromental and Energy Technology Council of Maine. Retrieved May 1, 2016, from http://www.e2tech.org/Resources/Documents/MOWII_Offshore_Wind_Roadmap_JAN2013.pdf

Thaler, J. (2013, January). *Permitting and Leasing for Maine Offshore Wind Energy Projects - Offshore Wind Energy Project Roadmap.* Maine Composites Alliance (MCA), Maine Wind Industry Initiative (MWII), and Environmental and Energy Technology Council of Maine. Retrieved May 1, 2016, from http://www.e2tech.org/Resources/Documents/MOWII_Offshore_Wind_Roadmap_JAN2013.pdf

The Brattle Group. (2013). *A Learning Investment-based Analysis of the Economic Potential for Offshore Wind: the case of the United States.*

The City of New York. (2015). *One New York: The Plan for a Strong and Just City.* New York, NY: the City of New York. Retrieved from http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf

The Crown Estate. (2012). *Offshore Wind Cost Reduction.*

The Merchant Marine Act of 1920 (Jones Act). (2012). *46 U.S.C. § 55102*. Retrieved from http://www.upa.pdx.edu/IMS/currentprojects/TAHv3/Content/PDFs/Jones_Act_1920.pdf

the State of Rhode Island. (2010). *State of Rhode Island Receives $22.3 Million Stimulus Grant to Support Improvements at Quonset Point.* Office of Economic Recovery and Reinvestment. Retrieved from http://www.ri.gov/press/view/10777

The University of Maine. (2012). *Maine Deepwater Offshore Wind Report.* DOE.

U.S. Coast Guard. (2016). *Atlantic Coast Port Access Route Study.* ACPARS Workgroup. Washington, D.C.: United States Coast Guard. Retrieved from http://www.uscg.mil/lantarea/ACPARS/docs/ACPARS_Final_Report_08Jul2015%20Combined%20Appendix-Enclosures%20-%20Final%20After%20LMI%20Review-Corrected%20Date.pdf

U.S. Department of Energy. (2016). *Offshore Wind Advanced Technology Demonstration Projects*. Retrieved October 28, 2016, from Office of Energy Efficiency and Renewable Energy: http://energy.gov/eere/wind/offshore-wind-advanced-technology-demonstration-projects

U.S. Department of Energy Wind and Water Power Technologies Office. (n.d.). *Offshore Wind Projects: Fiscal Years 2006 - 2015.*

U.S. Wind. (2017). *Our Projects*. Retrieved October 3, 2017, from U.S. Wind: http://www.uswindinc.com/our-projects/

Unitil, National Grid, Eversource Energy, Massachusetts Department of Energy Resources, , & . (2017, June 29). Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects. Boston, MA: MA DOER. Retrieved from https://macleanenergy.files.wordpress.com/2017/02/section-83c-request-for-proposals-for-long-term-contracts-for-offshore-wind-energy-projects-june-29-2017.pdf

University of Delaware - Special Initiative on Offshore Wind. (2015). *New York Offshore Wind Cost Reduction Study.*

University of Maine. (n.d.). *R&D Fast Facts - Offshore Wind Energy*. Retrieved from UMaine Energy: http://umaine.edu/energy/rd-energy-fast-facts/offshore-wind-energy/

Veit, R. R., White, T. P., Perkins, S. A., & Curley, S. (2016). *Abundance and Distribution of Seabirds off Southeastern Massachusetts, 2011-2015: Final Report.* Sterling, Virginia: U.S. Department of the Interior, Bureau of Ocean Energy Management.

Vermont Department of Public Service. (2016). *2016 Vermont Comprehensive Energy Plan.*

Vermont General Assembly. (2016, May 1). *Title 10: Conservation and Development, Chapter 023: Air Pollution Control*. Retrieved 2016, from Veront General Assembly: http://legislature.vermont.gov/statutes/section/10/023/00578

Vermont Legislature. (2015). An Act Relating to Establishing a Renewable Energy Standard. Vermont: Vermont. Retrieved from http://psb.vermont.gov/sites/psb/files/Act%2056.pdf

Walaska, W. A., Sosnowski, V. S., Conley, Jr., W. J., & Kettle, N. D. (2016). SB 2181 - An Act Relating to Public Utilities and Carriers - Renewable Energy Growth Program (2016 Regular Session). Providence, RI.

Walsh, M. (2014). *Greenovate Boston 2014 CLimate Action Plan Update.* Boston, MA: City of Boston. Retrieved June 23, 2016, from http://www.cityofboston.gov/eeos/pdfs/Greenovate%20Boston%202014%20CAP%20Update_Full.pdf

Weston, D., & Davidson, R. (2017, January 5). Fishermen's Energy funding pulled - updated. *Windpower Offshore*. Retrieved from https://www.windpoweroffshore.com/article/1419926/fishermens-energy-funding-pulled-updated

Wilson, W. (2014). Offshore Wind: Mitigation of Natural Gas Based Market Price Spikes During Extreme Cold Weather Conditions. *AWEA Offshore Wind Conference.* Albany, NY: AWS Truepower. Retrieved April 28, 2016, from https://www.awstruepower.com/assets/Offshore-Wind-Mitigation-of-Natural-Gas-Based-Market-Price-Spikes-During-Extreme-Cold-Weather-Conditions_Wilson_Oct2014.pdf

Wilson, Whitney J. - AWS Truepower. (2014). *Offshore Wind: Mitigation of Natural Gas Based Market Price Spikes During Extreme Cold Weather Conditions.*

Wiser, R., & Barbose, G. (2008). *Renewable portfolio standards in the United States: A status report with data through 2007 (LBNL-154E).* Berkeley, CA: Lawrence Berkeley National Laboratory.

Wiser, R., & Bolinger, M. (2015). *2014 Wind Technologies Market Report.* Washington, D.C.: U.S. Department of Energy. Retrieved April 28, 2016, from http://energy.gov/sites/prod/files/2015/08/f25/2014-Wind-Technologies-Market-Report-8.7.pdf

Wiser, R., Jenni, K., Seel, J., Baker, E., Hand, M., Lantz, E., & Smith, A. (2016). *Forecasting Wind Energy Costs and Cost Drivers: The Views of the World's Leading Experts.* Lawrence Berkeley National Laboratory. Retrieved 2016, from https://emp.lbl.gov/sites/all/files/lbnl-1005717.pdf

Wittenberg, A. (2013). Offshore Wind Developers Outsmart Century-Old Federal Law. *SouthCoast Today*. Retrieved May 1, 2016, from http://www.southcoasttoday.com/article/20131229/NEWS/312290321

Wood, L. (2011, November 14). Massachusetts Company Proposes 2,000-MW Offshore Transmission Project. *Platts*. Retrieved April 30, 2016, from http://www.platts.com/latest-news/electric-power/charlottesvillevirginia/massachusetts-company-proposes-2000-mw-offshore-6676784

Zeller, T. J. (2013, March 1). Cape Wind: Regulation, Litigation And The Struggle To Develop Offshore Wind Power In The U.S. *Huffington Post*. Retrieved April 30, 2016, from http://www.huffingtonpost.com/2013/02/23/cape-wind-regulation-liti_n_2736008.html

Zentech, Inc. (2017, June 28). First US Offshore Wind Installation Vessel to be Built with Oil and Gas Expertise. Houston, TX, USA: Zentech, Inc. . Retrieved from http://zentech-usa.com/first-us-offshore-wind-installation-vessel-to-be-built-with-oil-and-gas-expertise/

# Appendix A

## A.1 Offshore Wind Resource Potential Components

The resource potential of OSW is characterized by five component factors, each of which is described in succession in this section. These include the region's developable resource potential, current and future OSW lease areas, the current OSW development pipeline, OSW's buildout potential and state-specific capacity factors for OSW, which are applied throughout the analysis. As depicted in Figure A-1 and Figure A-2, the consideration of each of these factors presented an outlook for the buildout of current and future lease areas in addition to the existing pipeline of OSW projects that are in the advanced stages of development and construction.

**Figure A-1. Low Regional OSW Development Pipeline and Buildout Potential**

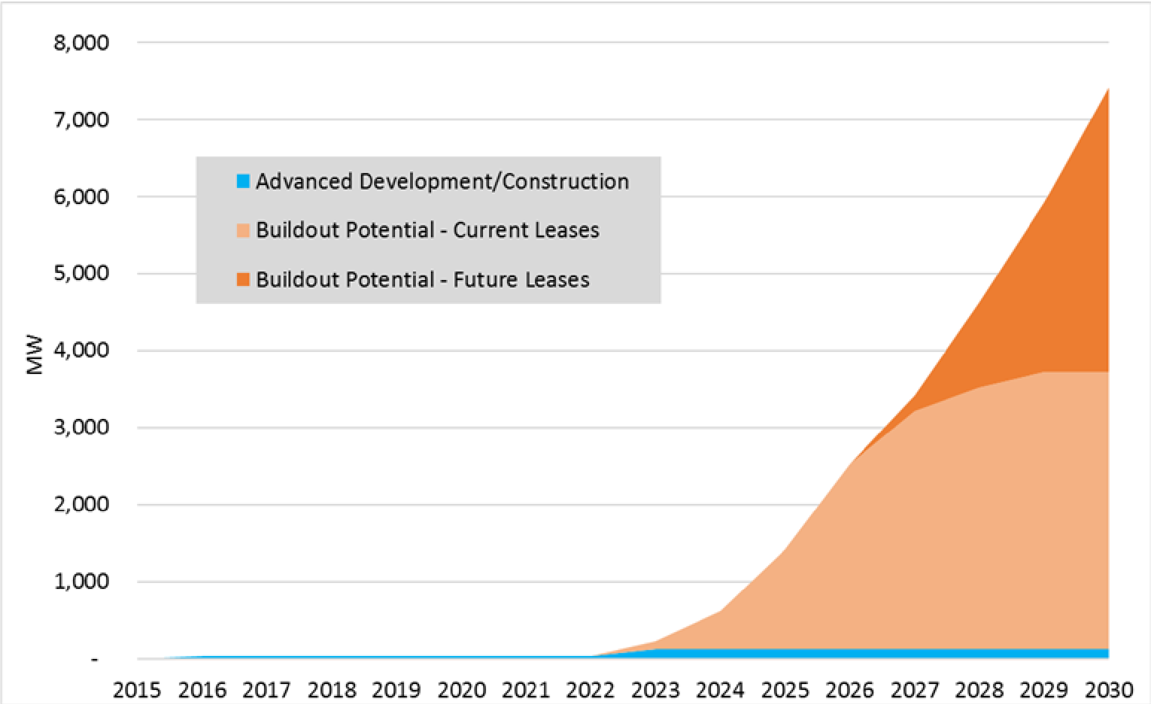
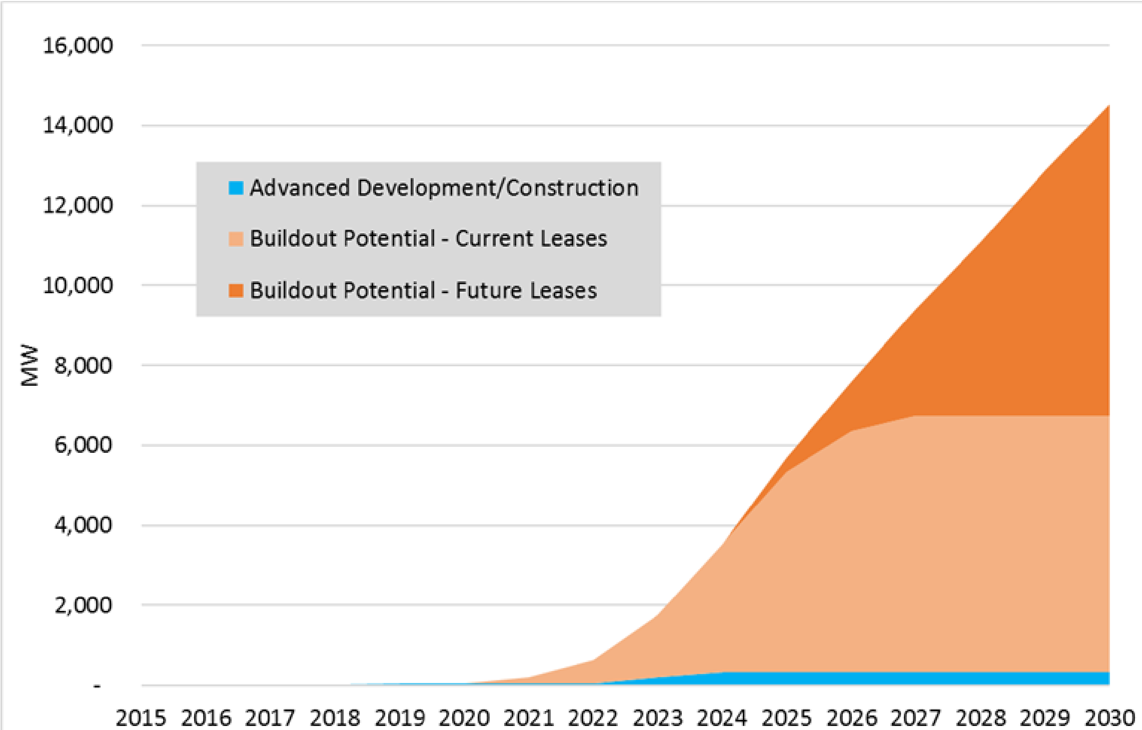


**Figure A-2. High Regional OSW Development Pipeline and Buildout Potential**




## A.1.1 MW Developable Resource Potential

The gross OSW resource potential limits the possible regional OSW market. However, data on the gross potential, without consideration of whether it is ultimately developable due to factors such as permitting or competing uses, is vast, and as discussed in Chapter 5, is ultimately not a material constraint. While there is no data available to precisely conclude how much of this potential is truly available to be developed, the various ocean planning initiatives referenced in Chapter 4 suggest a fraction of the area identified in Section 2.4 would be developable. For purposes of characterizing the OSW market scale, the project team made the following assumptions to illustrate the range of potentially developable OSW:

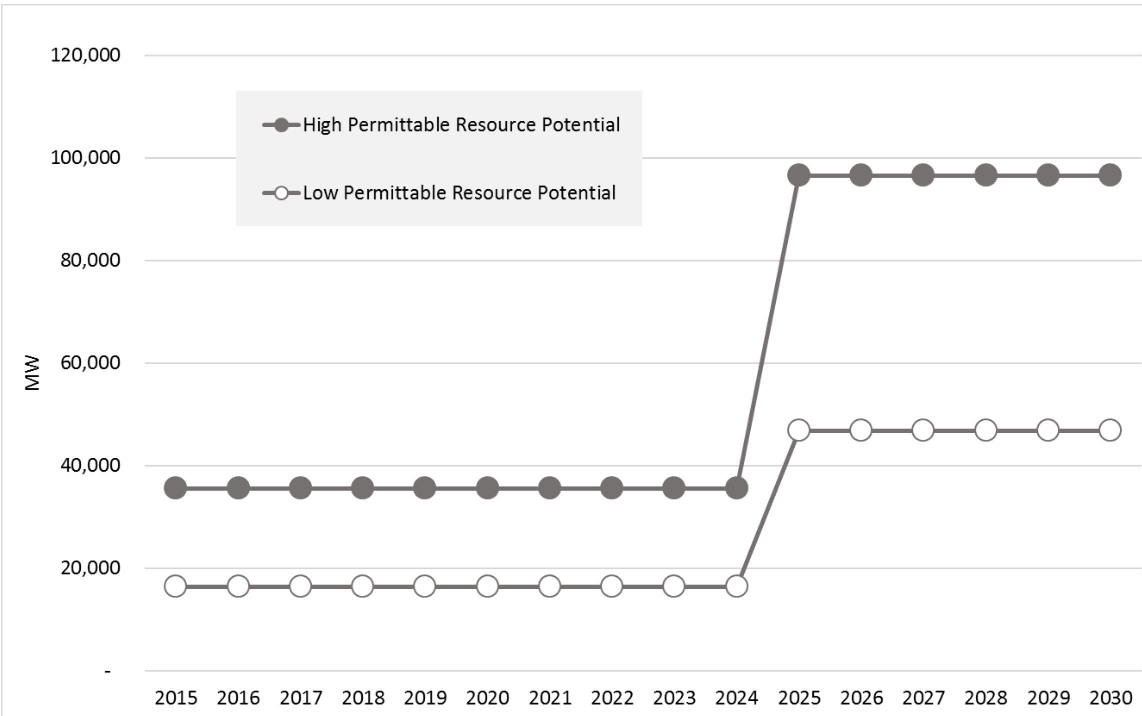
- the percentages of resource potential shown in Table A-1 are developable, after excluding area for issues such as competing uses or infeasible permitting
- commercial development of sites in depths in excess of 60m is not feasible until 2025
- the development density equals of OSW farms is 3 $MW/km^2$ (Musial, et al., 2013, p. vii)

For illustrative purposes, Figure A-3 (in MW) and Figure A-4 (GWh/year) depicts an estimate of OSW's resource potential based upon the following assumptions:

**Table A-1. Percent of Total Resource Potential Assumed Developable, by Depth**

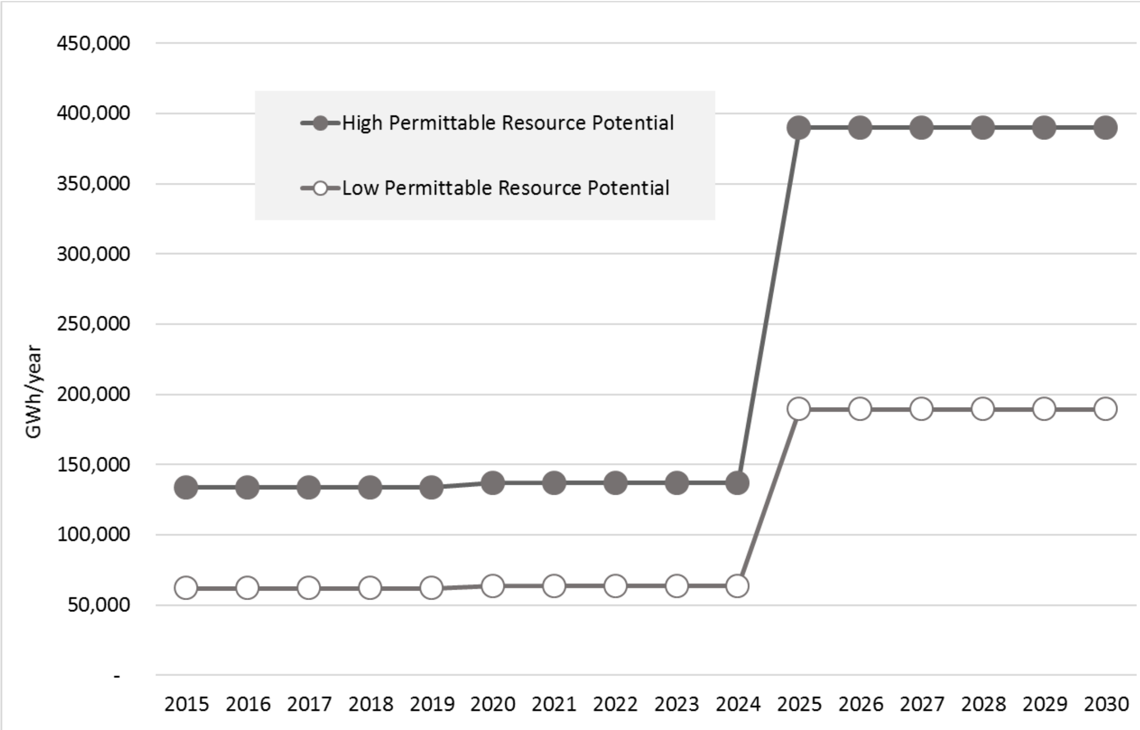
| Water Depth/Category | Low | High |
|---|---|---|
| **0-30 m** | 25% | 50% |
| **30-60 m** | 25% | 50% |
| **>60 m** | 25% | 50% |
| **NJ Area Available to Study Area** | 15% | 30% |

**Figure A-3. OSW Developable Resource Potential (MW)**




Based upon these assumptions, the developable OSW resource potential through 2024 is in the low-case scenario about 16,400 MW and in the high-case scenario about 35,500 MW; thereafter, when development in depths greater than 60m is commercially viable, the developable OSW potential grows to between 46,800 MW and 96,600 MW by 2030. Figure A-4 shows the annual production (GWh/year) associated with this MW resource potential.

**Figure A-4. OSW Developable Resource Potential (GWh/year)**




## A.1.2 Development Pipeline

Development activity has progressed materially for a handful of OSW projects. This existing development pipeline establishes the front end of the trajectories, due to the time necessary to move OSW projects to fruition. It includes all regional OSW projects that are operational, under construction or in the advanced stages of development. With one notable exception, these are primarily small (pilot, or demonstration) projects. The development pipeline includes the following projects, all of which are listed and described in Table 3:

- Block Island Wind Farm (RI) – 30 MW
- Deepwater ONE – South Fork – 90 MW
- Deepwater ONE (LIPA Expansion) – 210 MW
- Aqua Ventus (ME) – 12 MW
- Atlantic City Wind Farm – Phase I (NJ) – 25 MW

low and high cases were developed with varying assumptions. In the low case, it is assumed that the Block Island Wind Farm, which became operational in December 2016, and the Deepwater ONE – South Fork project, become operational during the study period. The high case assumes additionally that the 210-MW expansion within Deepwater Wind's Deepwater ONE project area and the Aqua Ventus project become operational within the study period. Each project faces barriers before their completion is assured. The analysis assumes that Cape Wind (Horseshoe Shoals) does not get developed during the study period, in part due to the historical barriers the project/area has faced and in part because the project is ineligible for the Massachusetts 83C OSW procurement. Each project faces barriers before their completion is assured. The Atlantic City Wind Farm was excluded from the high case based on the assumption that the most likely path to its development—securing New Jersey ORECs—would also assure its delivery to New Jersey.

Based on these assumptions, Figure A-5 shows that the 120 MW in the development pipeline in the low case and 342 MW of OSW capacity are in the development pipeline in the high case. As illustrated in Figure A-6, these projects would generate approximately 460 GWh/year of electricity in the low case and up to 1,318 GWh/year in the high case.

**Figure A-5. OSW Development Pipeline (MW)**

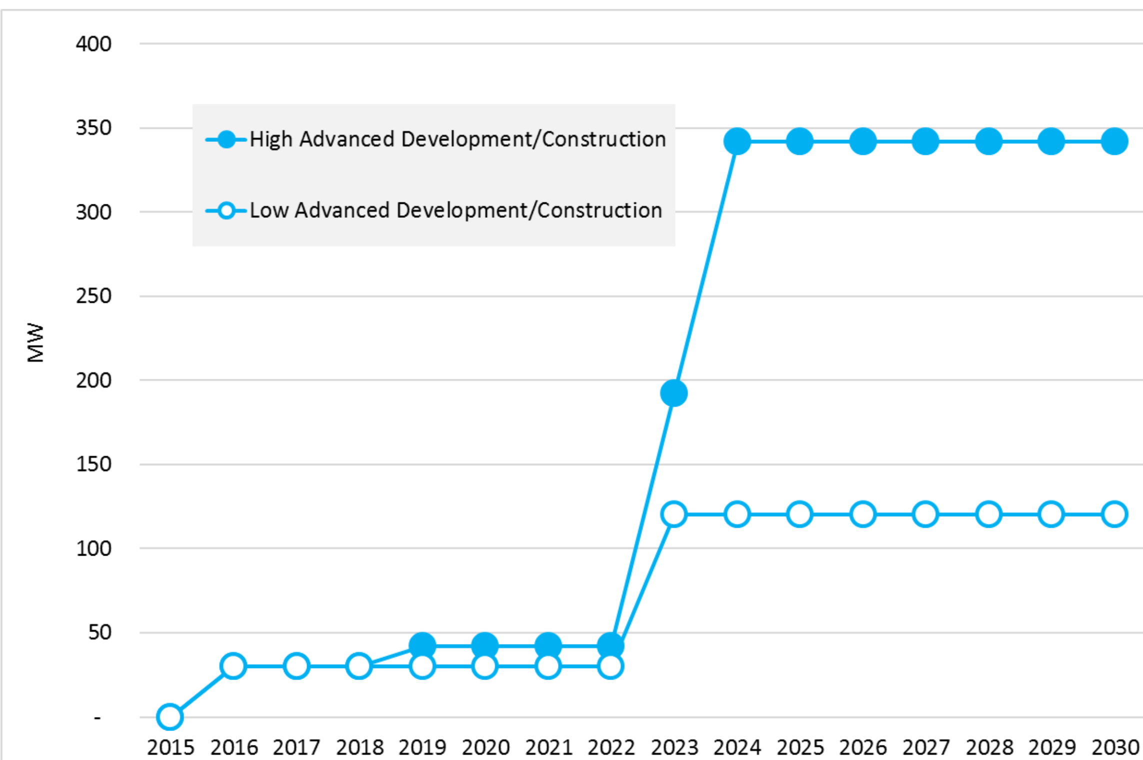
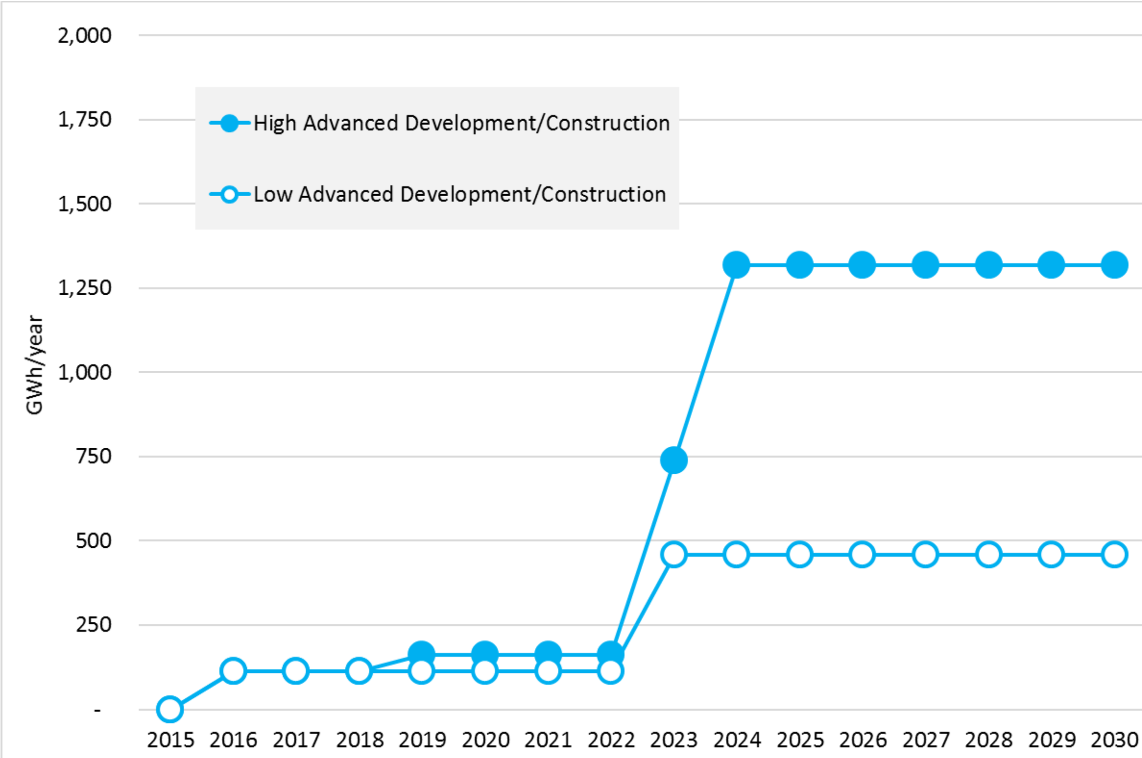


**Figure A-6. OSW Development Pipeline (GWh/year)**




## A.1.3 Lease Areas

The potential OSW market scale will expand over time as additional lease areas are brought into play. discussed in Chapter 2, OSW development activity in the region has primarily been confined to the identification of OSW lease areas and leasing thereof. Within identified lease areas, several OSW projects have been proposed and are planned to be developed. The availability and size of lease areas as they are added over time bound the scale of future OSW development potential. The current lease areas are comprised of those listed in Table 2, and included two categories of areas, those entirely leased and those with incremental lease potential. The total resource potential of the current lease areas (including incremental lease potential and the Nantucket Sound area) has been assessed at over 14,700 MW (BOEM, 2016a). In addition to these lease areas, a number of other areas have been identified as potential future lease areas, including areas off of the coasts of Maine, New York, and New Jersey. The cumulative resource potential of these future lease areas is an additional 6,000 MW. To establish low and high estimates of total resource potential of OSW lease areas, depicted in Figure A-7, the following assumptions were made:

- 100% of current lease areas that have been leased in their entirety are included in both the low case and the high case

- 75% of incremental lease potential in current lease areas is included in low case and 100% of incremental lease potential is included in the high case
- 50% of the future potential lease areas are included in the in the low case and 100% of the future potential lease areas are included in the high case
- 0% of the U.S. Wind lease area (OCS-A 0499) off New Jersey is available to New York in the low case and 50% is available to New York in the high case

Based on these assumptions, the current and future lease areas would facilitate about 14,600 MW of OSW capacity in the low case and up to about 21,600 MW of OSW capacity in the high case. Figure A-8 shows the energy production potential of these lease areas, with approximately 58,700 GWh/year in the low case and 86,700 GWh/year in the high case.

**Figure A-7. Current and Future OSW Lease Areas (MW)**

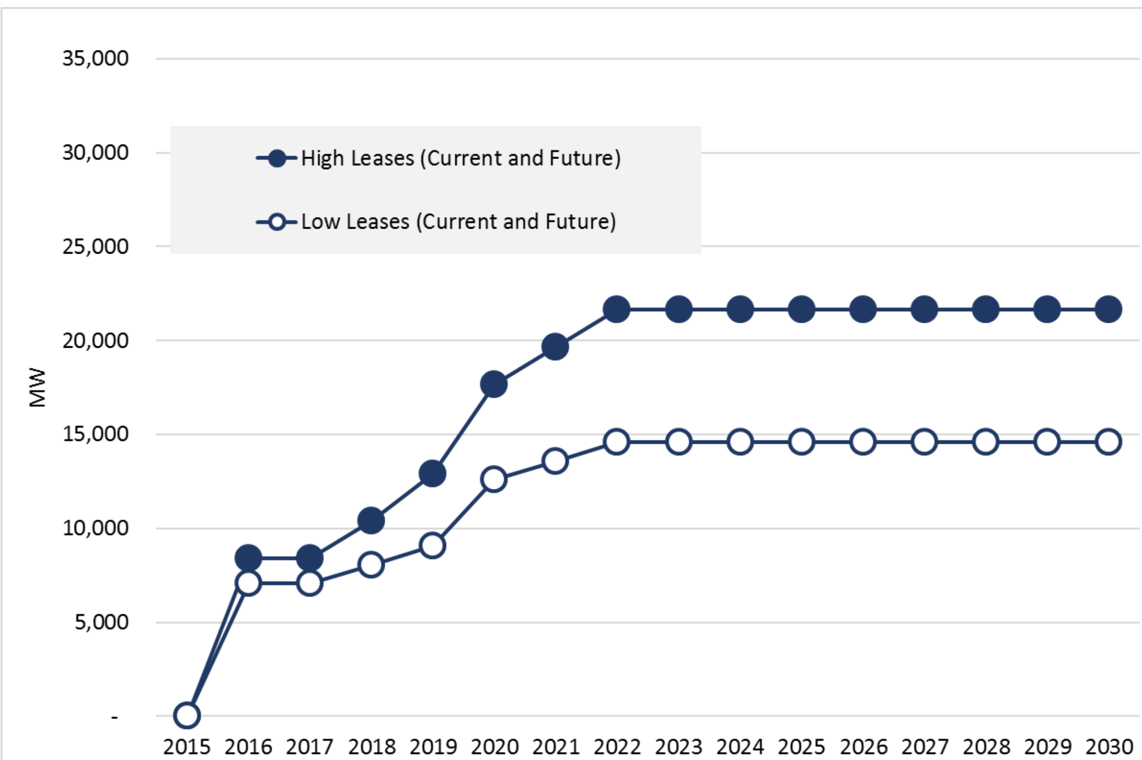
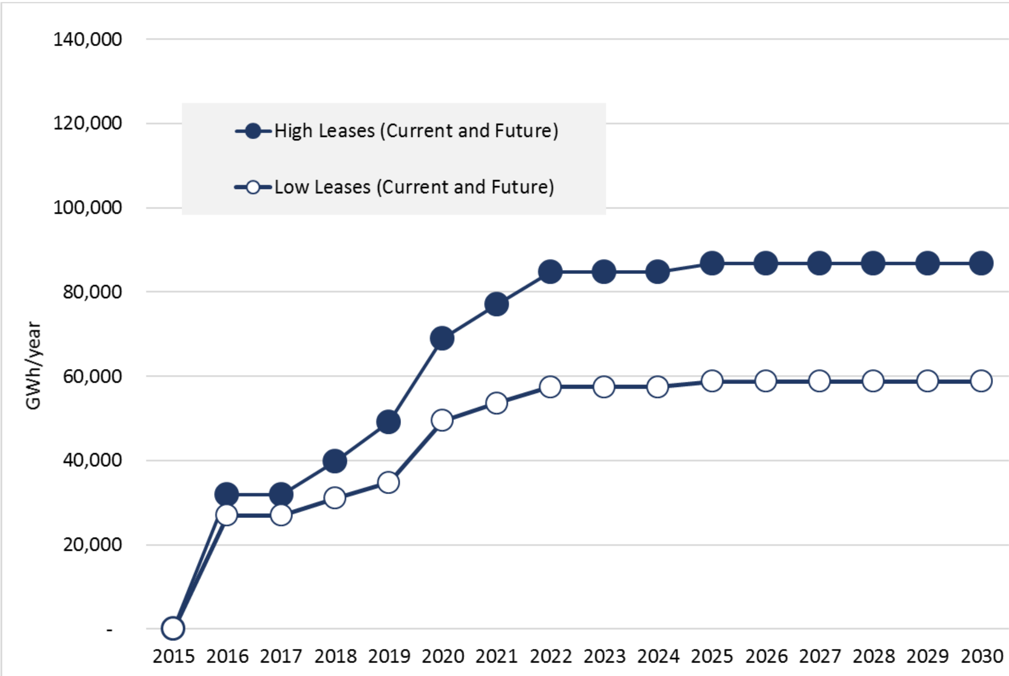


**Figure A-8. Current and Future OSW Lease Areas (GWh/year)**




### A.1.4 Temporal Buildout (Feasible Timing)

The scale and rate of regional OSW deployment is constrained, albeit moderately, by the infrastructure and supply chain available for its facilitation and integration. As discussed in Section 2.4.3, there are several factors that affect how quickly and at what scale OSW projects can be constructed and installed. The buildout potential of OSW is influenced, for example, by the type and number of ships, crews and facilities available, by the methods employed for the construction, transportation and installation of turbine foundations and components, as well as by industry experience. The annual throughput of turbines (i.e., how many turbines can be installed in a year) will increase over time as regional infrastructure improves and expands, as supply chain capacity grows and matures and as developers gain further industry experience.[53] With technological advances, turbine capacities will increase as well.

53 Ideally, a U.S./Northeast regional vessel and supply chain study would be used as a basis for developing the assumptions used for how the pace of turbine installation and deployment capabilities evolve over time. Unfortunately, no such (public) studies yet exist. The authors' experience, complemented by research into current and expected trends in Europe, has been used to craft the projections used herein. The assumptions used here are consistent with a near-term future combining the use of U.S. feeder vessels and EU heavy-lift vessels operating offshore, initially. Eventually heavy lift vessels may begin to be built in the U.S.; they would service U.S. OSW projects but could also be deployed abroad if there is a lull in the U.S. market. U.S.-sourced vessels may be triggered by a market scale approaching approximately 700 MW/yr. combined with confidence in a development pipeline of five years or longer.

The assumptions used to develop the low-case and high-case scenarios for the regional OSW buildout potential account for each of these factors. The process began by constructing a baseline buildout scenario from which the low-case and high-case scenarios were developed. The first step in the process was to define the overall pool of potential projects, in terms of both spatial area ($km^2$) and megawatts (MW). The maximum capacity density is assumed to be 3 MW per $km^2$ of area. The potential project pool currently consists of a mix of (1) discrete proposed and under-construction projects (see Table 3), (2) BOEM-designated Wind Resource Areas, leased and to-be-leased (see Table 2), and (3) assumed new Wind Resource Areas to be determined by BOEM by 2024.

As noted in Section 2.4.2, this analysis assumes that it requires at least six years after a lease is awarded for a Wind Resource Area before an OSW project can begin construction, with construction spanning (at least) two years. This lead time accounts for all development activities inclusive of physical/engineering studies, permitting and other regulatory approvals, acquiring a power purchase agreement and financing as well as equipment procurement. Additionally, due to startup and staging preparations, fewer MW are commissioned in the first year of construction. Given that the construction season in the region is roughly six months (mid-April to mid-October), the MW are not commissioned until approximately the end of the third quarter of a given year.

Additional assumptions specific to the development of the low-case and high-case buildout scenarios are as follows:

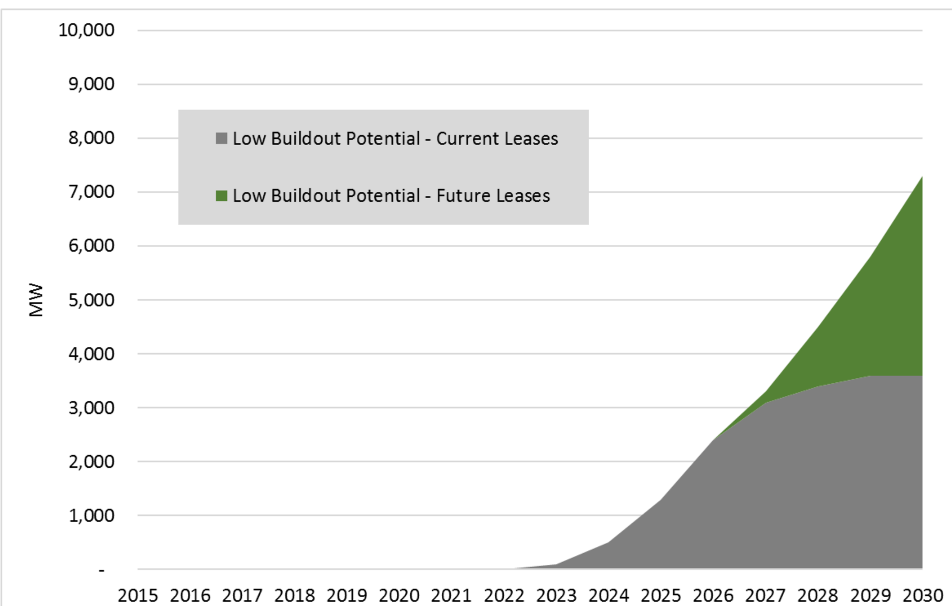
- The buildout potential for the high-case scenario was assumed to be 75% of the maximum area potential, while the buildout potential for the low-case scenario was assumed to be 50% of the maximum area potential.
- The maximum buildout rate for each lease area for the high-case scenario begins at 300/MW per year, increasing to 400 MW/year beginning in 2024 and to 500 MW/year beginning in 2027. For the low case, the increases in these buildout rates are delayed by two years.
- In the low-case scenario, it is assumed that the beginning of construction for projects in most wind areas begins two to three years later than for the high case.
- With regard to the lease area identified in New Jersey, because private developers acquiring these lease areas could decide to respond to a New York market opportunity and deliver their output into the New York City area, the high-case scenario assumes 50% of energy production from the area would be delivered to the New York grid, while the low case assumes 0%.

The regional OSW buildout is assumed to proceed as follows:

- Block Island Wind Farm
- The Deepwater RI/MA area is developed in stages beginning with 90 MW from the South Fork project and the first phase (60 MW) of the expansion of the Deepwater One project area in 2023, and then the remainder of the expansion (150 MW) being completed in 2024. All 300 MW supply LIPA
- In Massachusetts, the MA-500 area (which is closest to shore) is the first to begin operation with continuous construction over three years. In sequential (seaward) order, the MA-501, MA-502 and MA-503 areas are then developed
- In NY, the Statoil held lease area is the first project, which is followed by other projects in areas yet to be designated
- In Maine[54], project development is assumed in areas yet to be designated

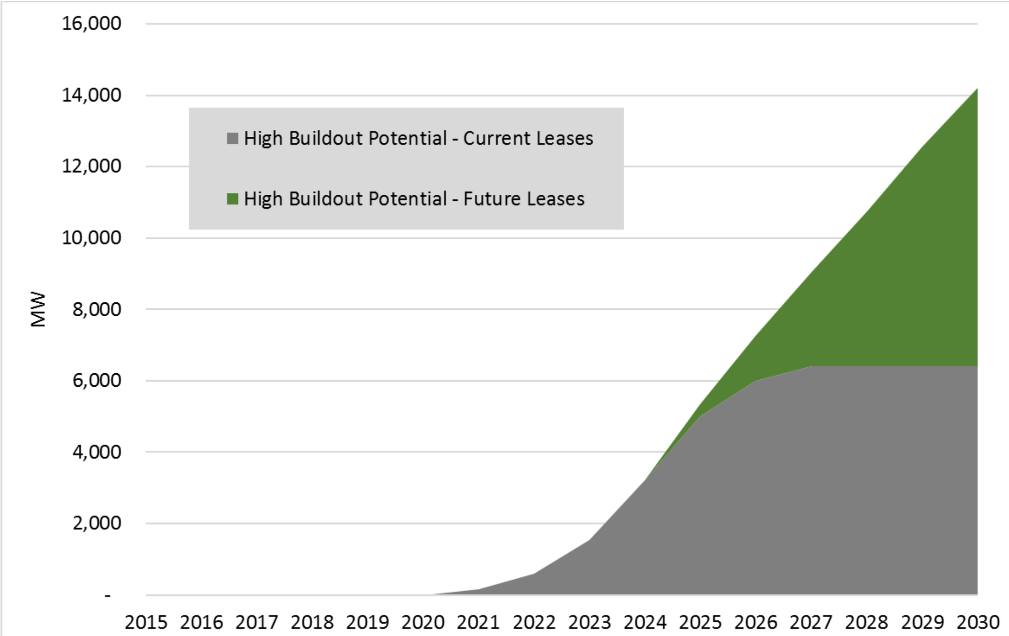
For illustrative purposes, Figure A-9 and Figure A-10 show the low-case and high-case rate and scale of regional development potential based on the assumptions described above. In the low case, the cumulative buildout potential for current and future leases reaches 7,300 MW by 2030 and in the high case, the cumulative buildout potential for current and future leases reaches 14,200 MW by 2030.

**Figure A-9. Low-OSW Buildout Potential - Current and Future Leases (MW)**




54 Although discussions between Maine and BOEM have not formally begun, it is reasonable to conclude that one or more lease areas will eventually be designated within the planning horizon. The area estimate for Maine was equivalent to 10% of the technical development potential determined by a 2010 NREL study for areas possessing average annual wind speeds >8.5 m/s at 100 m beyond 12 miles from shore.

**Figure A-10. High-OSW Buildout Potential - Current and Future Leases (MW)**



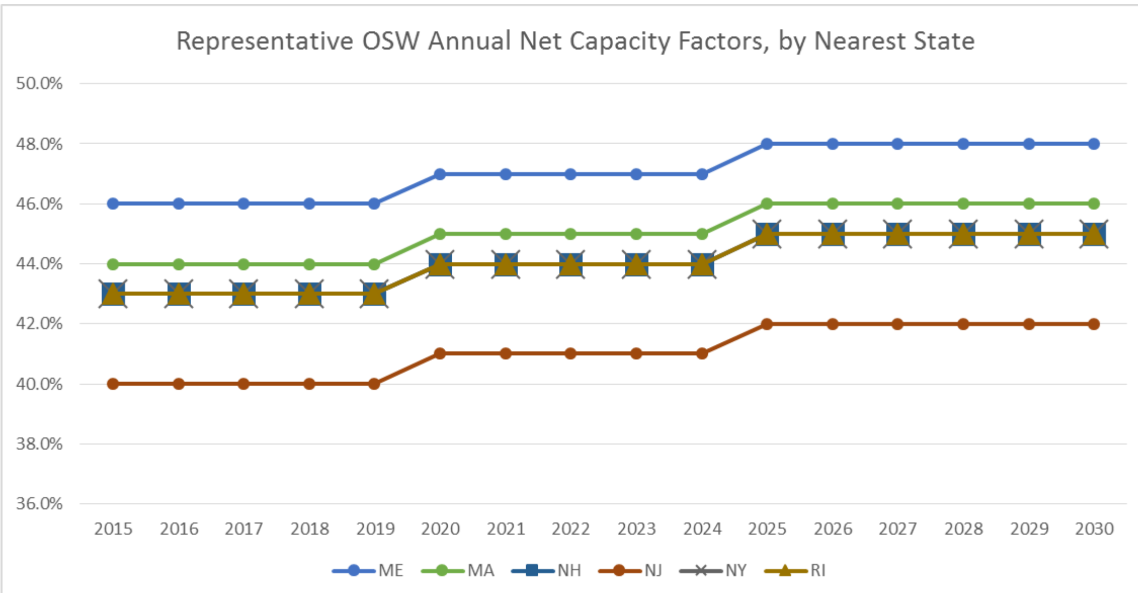

### A.1.5 Annual Energy Production

In order to estimate the approximate net annual energy production of OSW to the grid, *representative* capacity factors for areas of each state were developed for each associated state in the region and applied to all state-specific capacity (MW) metrics. These estimates, which are shown in Figure A-11, were derived by AWS Truepower by

- applying a generic 8 MW hybrid turbine power curve to modeled wind speeds
- assuming internal losses of 21%
- applying a performance advancement factor over time, similar to recent analysis for the NY Clean Energy Standard Supply Curve study (NYSERDA, Sustainable Energy Advantage, LLC, 2016b)

The annual net capacity factors in 2015 are assumed for this analysis to range from a low of 40% in New Jersey to a high of 46% in Maine with an average of 43.2%. By 2030, capacity factors are assumed to range from a low of 42% (NJ) to a high of 48% (ME) with an average of 45.2%. The increase is primarily the result of turbine performance improvements.[55]

**Figure A-11. Representative OSW Annual Net Capacity Factors by Nearest State**




## A.2 Transmission and Interconnection

The proximity of interconnection points, and their available capacity, along with the transmission capacity of key high-voltage network lines will impact the rate and scale of potential OSW deployment through 2030. Upstream transmission constraints may further limit the ability to inject OSW into some parts of the grid. This is particularly the case north of the ISO-NE north-south interface. Based on studies conducted for Maine LBW, until network upgrades (NWUs) are implemented (expected in the 2020s), the potential for OSW development off the coasts of Maine and New Hampshire will be limited (Lau & Coste, 2016). As discussed in Section 2.5, one of the advantages of OSW potential in New England is that many of the development areas are close to load centers and a number of viable points of interconnection

55 Somewhat higher expected capacity factor figures for OSW in the region have been reported from time to time, and higher capacity factors than these average assumptions, in specific locations, are certainly possible. However, when taken out of context it is not clear whether such figures reflect factors such as availability and transmission losses in a comparable manner to the figures used herein, which reflect a 21% aggregate loss factor. The pace of increase in net capacity factors is dependent on several factors. Improvements in turbine energy capture and reliability will drive capacity factor increases. However, some offsetting factors may include: higher wake losses from large arrays and from neighboring projects, and higher production losses (transmission and availability losses) as projects are built farther from shore and are harder to access when maintenance is required.

(POIs) are available and have been studied (to varying degrees). On the other hand, the absence of high voltage transmission on Long Island (whose backbone consists of a 138-kV radial system) as well as the expected difficulty, if not near impossibility, of building new facilities limits the use of New York POIs into the NYC area, with exception of up perhaps to 600 MW in Eastern Long Island (Plummer, 2016). As further discussed in Section 2.5.1, the NYC system area is a particularly constrained area, with operational/reliability constraints limiting the ability to inject large quantities of OSW supply without material upgrades.

The following assumptions were made regarding state-specific and site-specific transmission and interconnection issues:

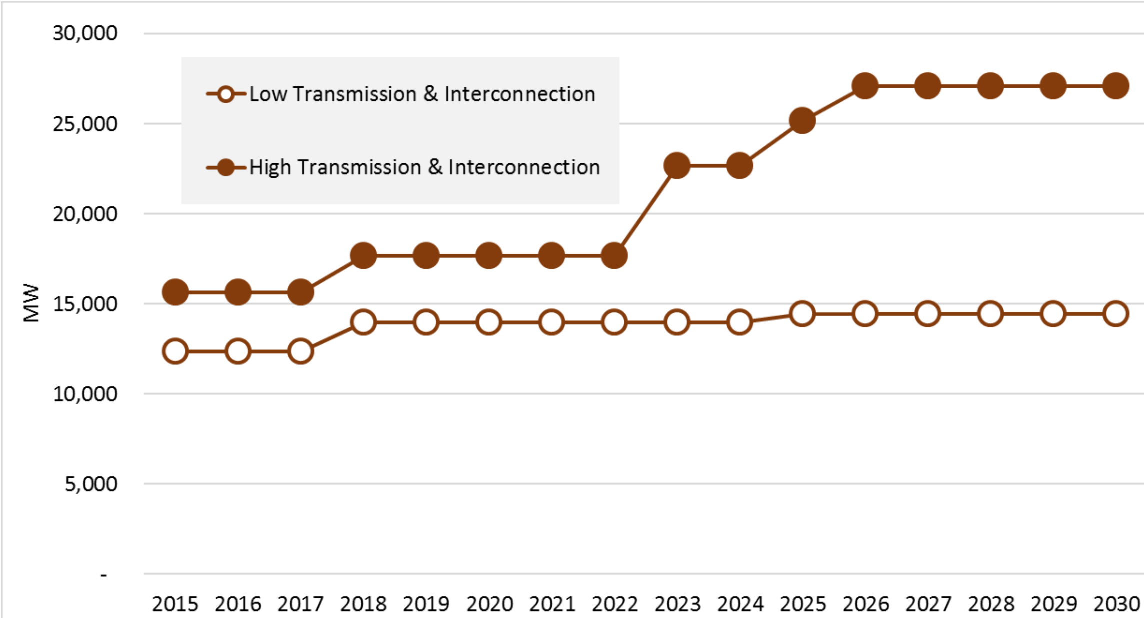
- A study commissioned by the Massachusetts Clean Energy Center identified and analyzed optimal routes and grid interconnection locations for the transmission of renewable energy from OSW planning areas located in Federal waters south of Martha's Vineyard (ESS Group, 2014). The report found that several locations along the Massachusetts and southern New England coast could serve as interconnection points, including Brayton Point Power Station in Somerset and the Canal Station in Sandwich, both located in Massachusetts. Additionally, the study stated that it is technically feasible to interconnect 500 to 1,000 MW, and in certain cases up to 2,000 MW, of OSW capacity at each potential interconnection location without significant infrastructure upgrades.
- Constraints in Maine were treated in aggregate based on the constraints limiting power movement southward across the ISO-New England N-S interface, and other internal transmission constraints further north in Maine. The project team assumed that an export constraint limiting export of OSW to no more than of 100 MW would apply prior to additional NWU to relieve these internal constraints. It was assumed that additional NWY investments could allow up to 2000 MW of additional OSW interconnection post-NWU. However, it was also assumed that potential incremental transfer capacity created by currently contemplated NWUs (as proposed in ISO-NE Economic Studies) made in the early 2020s will be made for, and consumed by, LBW, and thus specific additional NWU are assumed required to enable subsequent Maine OSW integration (Lau & Coste, 2016).
- New York interconnection sites with material additional costs for capacity resource interconnection service relative to energy resource interconnection service were assumed to require material NWU.
- All other interconnection sites were assessed on a site-specific basis.
- The Canal and Carver substations in Massachusetts are assumed to be mutually exclusive interconnection options.
- NWU discussed in the prior bullets were assumed to occur in 2023 for Massachusetts and Rhode Island, in 2025 for Connecticut and New York and in 2026 for Maine and New Hampshire.

The primary factors influencing the low- and high-case quantities include the expected minimum interconnection capabilities at onshore substations without material upstream network upgrades; higher levels of interconnection capability at onshore substations based on less conservative estimates and/or additional upstream network upgrades; and assumed current network upgrade constraints, as well as future relief of such constraints and the timing of such relief. In developing the low-case and high-case trajectories for interconnecting OSW in the region over time, the following case-specific assumptions were made:

- The low-case trajectory considered interconnection capacity is available now, without material NWU; interconnection capacity from assumed generator retirements becomes available in the given retirement year; and interconnection capacity becomes available from "at-risk" fossil fuel generation units in 2025.
- The high-case trajectory incorporated all low-case assumptions, in addition to any additional interconnection capacity that becomes available with material NWU.

Based on these assumptions, the low- and high-case trajectories depicted in Figure A-12 (MW) were developed. The initial regional interconnection capacity is about 12,300 MW in the low case and 15,700 MW in the high case. In the low case, transmission and interconnection capacity expands modestly to up to 14,500 MW in 2030. In the high-case trajectory, the expansion of T&I capacity increases modestly through 2018 plateauing at just over 17,000 MW until experiencing a sharp and then gradual expansion beginning in 2022. By 2030, T&I capacity reaches up to 27,000 MW as NWU and "at-risk" retirements provide additional T&I capacity. For more on regional transmission and interconnection opportunities and constraints, see Section 2.5.

**FigureA-12. Regional OSW Transmission and Interconnection Availability (MW)**




## A.3 Electric Market Constraints: VER Penetration Limits

Three primary market factors influence the minimum and maximum quantities of OSW penetration, including future energy demand; Variable Energy Resource (VER) penetration; and the OSW share of VER penetration, the scale of which is constrained primarily by cost considerations and policy. The fraction of potential future regional energy demand (detailed in Section 3.2) that can be met by OSW is constrained by the energy market penetration potential of VERs, the fraction of demand that can be accommodated from VERs. Several factors influence future load as well as the penetration potential of VERs and OSW specifically.

Load could be reduced through a variety of energy efficiency measures throughout the study period. Substantial quantities of anticipated energy efficiency measures are incorporated into the load forecasts presented in Section 3.2. Load could also increase as a result of the electrification of the transportation and/or residential and commercial heating sectors. The potential impact of these factors is discussed in Section 3.2 and are most likely to drive additional OSW demand if load serving the electrification of the transportation and heating sectors is sourced from renewables, as assumed in *The RGGI Opportunity 2.0* report described in Section 3.2 (Stanton, et al., 2016).

As discussed in Section 3.4, practical limits exist to how much OSW can be successfully integrated into the regional electric grid. Advances in energy storage technology and grid integration could expand these limits by making OSW or other VER production more dependable during times of need. The OSW share of market penetrating VERs is further constrained by competition with other energy resources, including solar, onshore wind, large hydro and even natural gas, contracts for and commitments to which would reduce the market demand for all VERs. The OSW market penetration analysis described in this section was used to estimate the total GWh/year of OSW that the market could integrate successfully given demand, existing procurement policies and distributed generation carve-outs, the practical penetration potential of VERs and, lastly, the assumed OSW share of VER penetration.

The following general assumptions were applied in the OSW market penetration potential analysis:

- The VER Fleet initial penetration of about 11.5 GW in 2015 (Mai, et al., 2012b).
- DG carve-outs and procurements committed to non-OSW supply by definition are assumed unavailable to OSW.
- DG carve-outs include the following in both scenarios (assumes 17.5% c.f. AC for solar) (Black, 2016):
  - Incremental NY Sun;
  - Incremental Massachusetts Solar policy-driven installations
  - Vermont's RES Tier 1
  - Connecticut's various DG Policies
  - Rhode Island's current RE Growth targets (through 2019), as well as proposed RI RE Growth expansion for ten years (through 2029) at 40 MW/year incremental, assuming all solar at 14% c.f. DC and assuming one-year lag to COD.
- Procurement commitments include the following in both scenarios:
  - Projects selected pursuant to the New England Clean Energy RFP (Geschiere & Pande, 2016)
  - Project selected pursuant to Connecticut's RFP for 2-20 MW Class I or Class III Renewables, Passive Demand Response and/or Energy Storage
  - Eversource's Cape Wind replacement commitment per the NSTAR-NU Merger settlement and
  - Generation from NYSERDA Main Tier RFPs with commercial operation dates COD through 2023.
- The OSW share of VER assumptions described below for each scenario were benchmarked using the *NREL Renewable Electricity Futures Study* (Mai, et al., 2012b).

The low- and high-case trajectories for the VER electricity market penetration analysis were derived from the following scenario-specific data components and assumptions.

**In the low case:**

- Base Case scenario regional load projections were taken from the ISO-NE CELT and NYISO Gold Book base cases
- VER penetration rate ramping up to 18.1% of total incremental uncommitted market demand by 2030. This value was derived from the regional base VER penetration by 2030 from the *NREL Renewable Electricity Futures Study Vol. 1* (Mai, et al., 2012b).
- OSW share of residual incremental VERs after DG carve-outs is assumed to comprise 25% of post-2022 VER penetration as a lower bound. This assumption is benchmarked to, and just slightly higher than, the OSW share of VER assumptions in NREL's 80% RE-ETI (low case) scenario from the *NREL Renewable Electricity Futures Study* (Mai, et al., 2012b). In this case, OSW averages 21% of Northeast regional modeled VER supply between the present and 2030.
- DG Carve-Outs include the following in addition to the programs listed above: SREC-II (MA): 946 MW (SREC-I + SREC-II = 1600 MW); and future solar policy-driven supply of an additional 1600 MW (total to 3200 MW by 2023).
- Additional VER procurement commitments committed to non-OSW supply includes low case scenarios for future Connecticut procurements pursuant to CT PA 15-107 and PA 13-303 Sections 6 and 7. It is assumed that a material amount of Connecticut procurement is large storage hydro not considered as VER.
- Incremental OSW penetration begins in 2023.

**In the high case:**

- High-case scenario regional load projections added to the figures from ISO-NE CELT/NYISO Gold Book bases an assumed incremental load created from transportation and heating electrification (see Figure 12) (Stanton, et al., 2016).
- VER penetration rate ramping up to a rate of 27.4% of total incremental uncommitted market demand by 2030; This value was derived from the national base VER penetration by 2030 from the *NREL Renewable Electricity Futures Study Vol. 1* (Mai, et al., 2012b). This figure implicitly assumes an increasing VER penetration enabled by additional energy storage deployment.
- OSW share of residual incremental VERs after DG carve-outs is assumed to comprise 70% of post-2022 VER penetration as an upper bound. This value corresponds to NREL's OSW share of VER from NREL's 80% RE-ITI (Base Case) scenario from *NREL Renewable Electricity Futures Study* (Mai, et al., 2012b), described in Section 3.4. In this case, OSW averages 50% of Northeast regional modeled VER supply between the present and 2030, peaking at 70% in 2030.
- DG Carve-Outs include the following in addition to the programs listed above: SREC-II (MA): 1163 MW (i.e. DOER emergency regulations expand SREC-II Past 1600 MW; and future solar policy-driven supply of an additional 1783 MW (total to 3600 MW by 2023).
- Additional VER procurement commitments committed to non-OSW supply includes high-case scenarios for future Connecticut procurements pursuant to CT PA 15-107 and PA 13-303 Section 6 and 7 demand. It is assumed that a material amount of Connecticut procurement is large storage hydro not considered as VER.

- Incremental OSW penetration begins in 2021.

The low- and high-case trajectories for OSW market penetration based on these assumptions are shown in Figure A-13 (GWh) and Figure A-14 (MW). OSW penetration potential reaches up to 6,800 GWh/year in the low case and up to 45,900 GWh/year in the high case by 2030. This translates into approximately 1,700 MW in the low case and up to 11,400 MW in the high case. These results suggest that the market could potentially be a significant constraint to regional OSW deployment, but this ultimately depends on regional demand for renewable energy, the rate and scale of non-OSW development and policy support for OSW.

**Figure A-13. OSW Electric Market Penetration (GWh/year)**

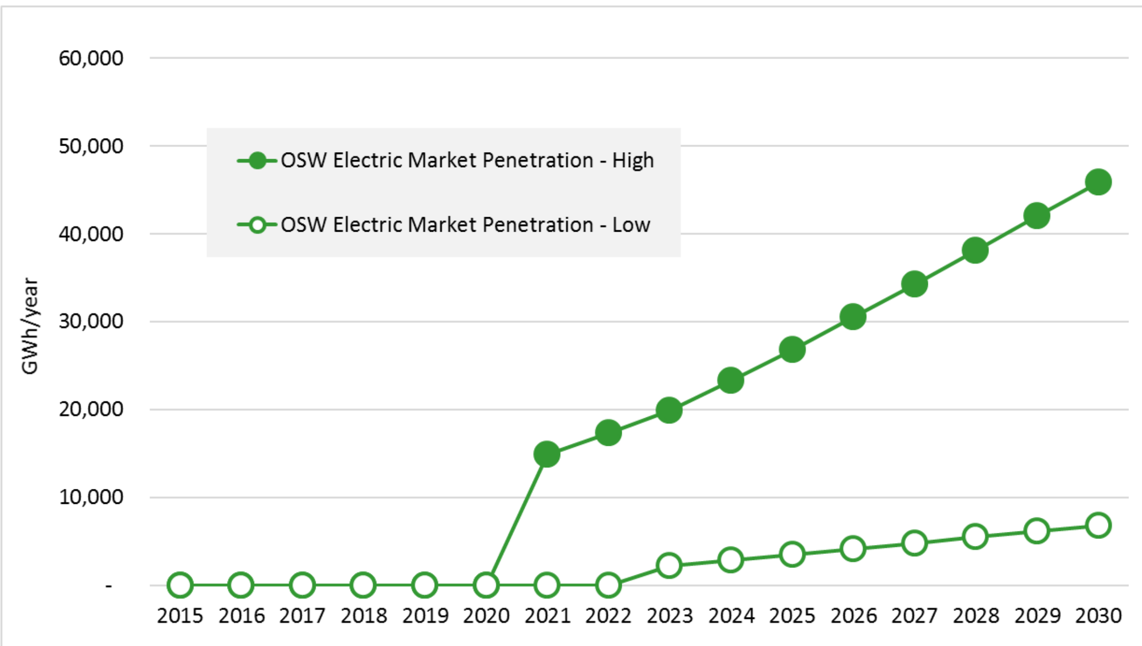
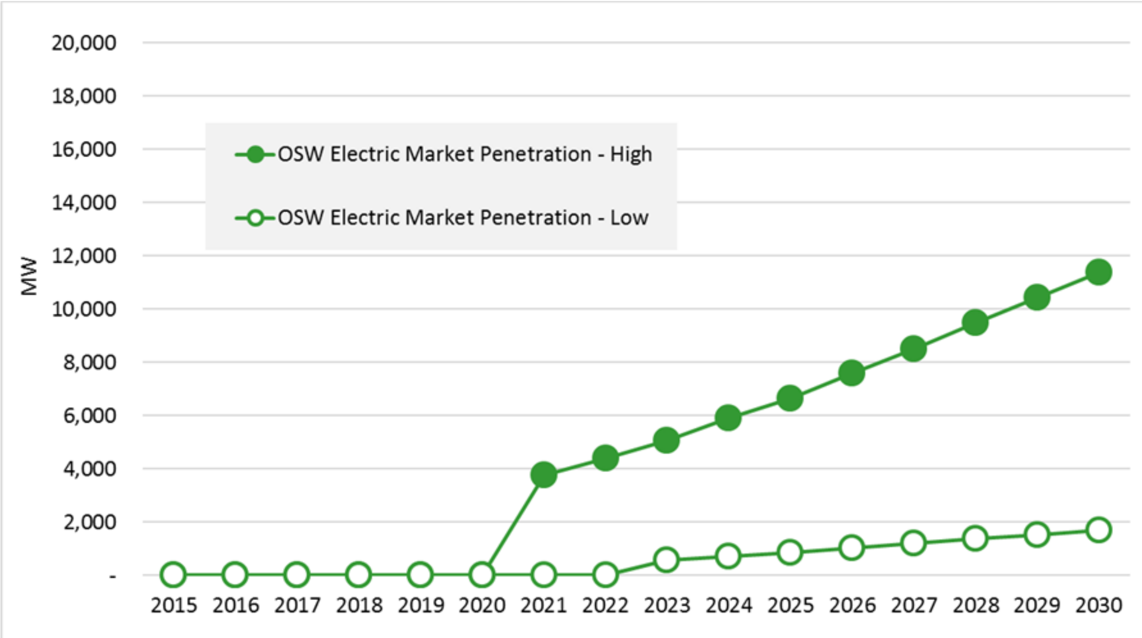


**Figure A-14. OSW Electric Market Penetration (MW)**




## A.3.1 Derivation of Offshore Wind Share of VER Penetration

To derive the OSW share of VER penetration depicted above, the following equation was employed with low- and high-case variables where applicable:

> [(Load * VER Penetration) – (Existing VER Fleet + DG Carve-Outs + Procurement Committed to non-OSW Supply)] * OSW Share of VER

Each component of this equation is illustrated below in low-case and high-case scenarios, from which the OSW market penetration trajectories were derived. The results from the low case are shown in Figure A-15 and the results from the high case are shown in Figure A-16. The cumulative share of regional energy demand met by VERs is 52,049 GWh/year in the low case and 89,622 GWh/year in the high case. Based on market constraints, OSW wind's share of total regional load by 2030 is approximately 2% in the low case and 14% in the high case.

**Figure A-15. OSW and VER Electric Market Penetration: Low Case (GWh/year)**

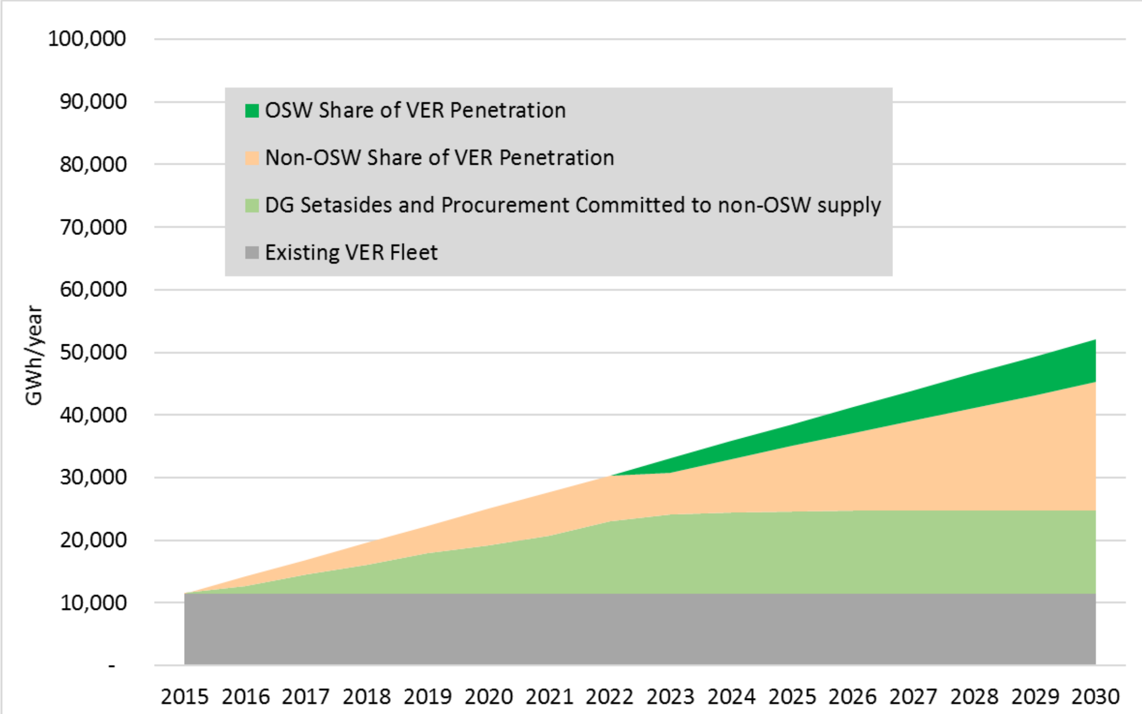
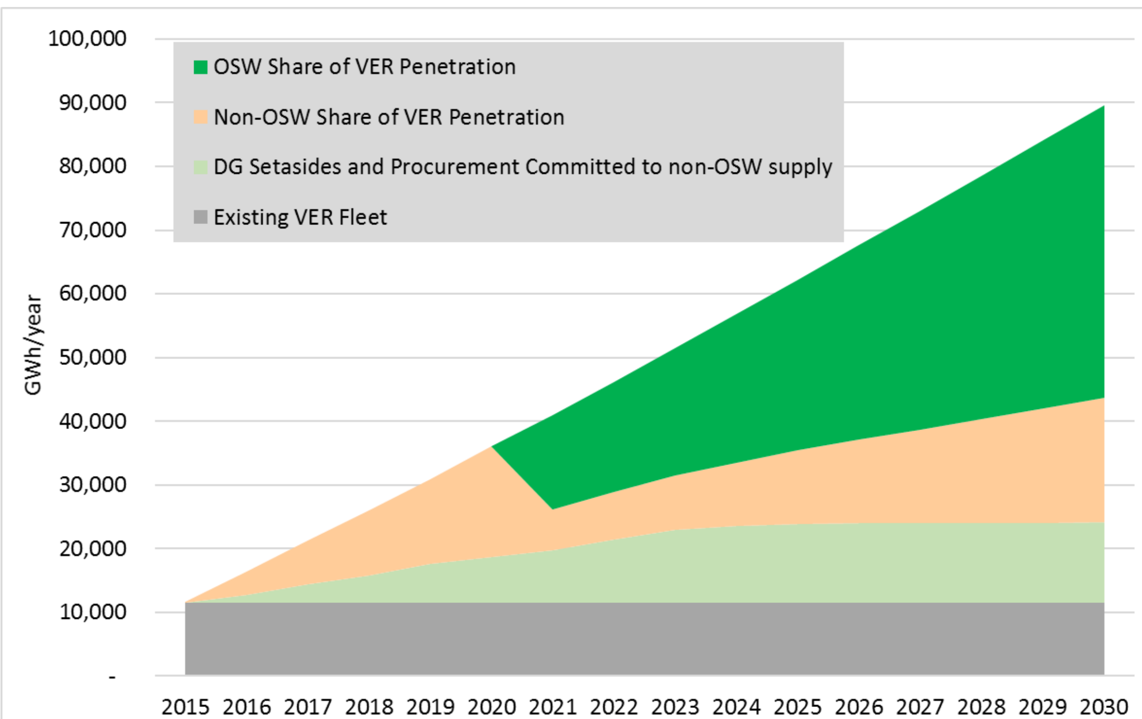



**Figure A-16 OSW and VER Electric Market Penetration: High Case (GWh/year)**



## A.4 Electric Market Opportunities

Another indicator of the potential scale of regional OSW deployment is the market opportunities created by retiring generation. Without such market opportunities, OSW development potential would be limited to incremental regional energy demand. With retirements of baseload and cycling resources, however, comes the need for new capacity, a need which OSW can contribute to meeting.

The market gap between the capacity of resources deployed and integrated into the bulk power system and those required to meet regional energy demand is a function of planned retirements and "at-risk" retirements.[56] OSW can contribute to replacing the sources of energy generation. Within this gap, however, the practical limits on OSW's integration into the bulk power system, discussed in the prior Section, still apply and are ultimately more constraining. To integrate OSW successfully at scale, peaking plants and/or utility-scale energy storage will be needed to complement VERs to fulfill capacity and reserve requirements.

As illustrated in Section 3.2, regional energy forecasts are relatively flat across the region. The current fleet of generation units meets the region's load. The market gap is a function of the 5,940 MW of regional planned retirements identified in Table 11 and the additional 17,491 MW of aging capacity at risk for retirement throughout the study period. The process used for identifying "at-risk" units is described in Section 3.3.

The following assumptions were applied to establish the low- and high-case trajectories for the market gap, the result of which is displayed in Figure A-17

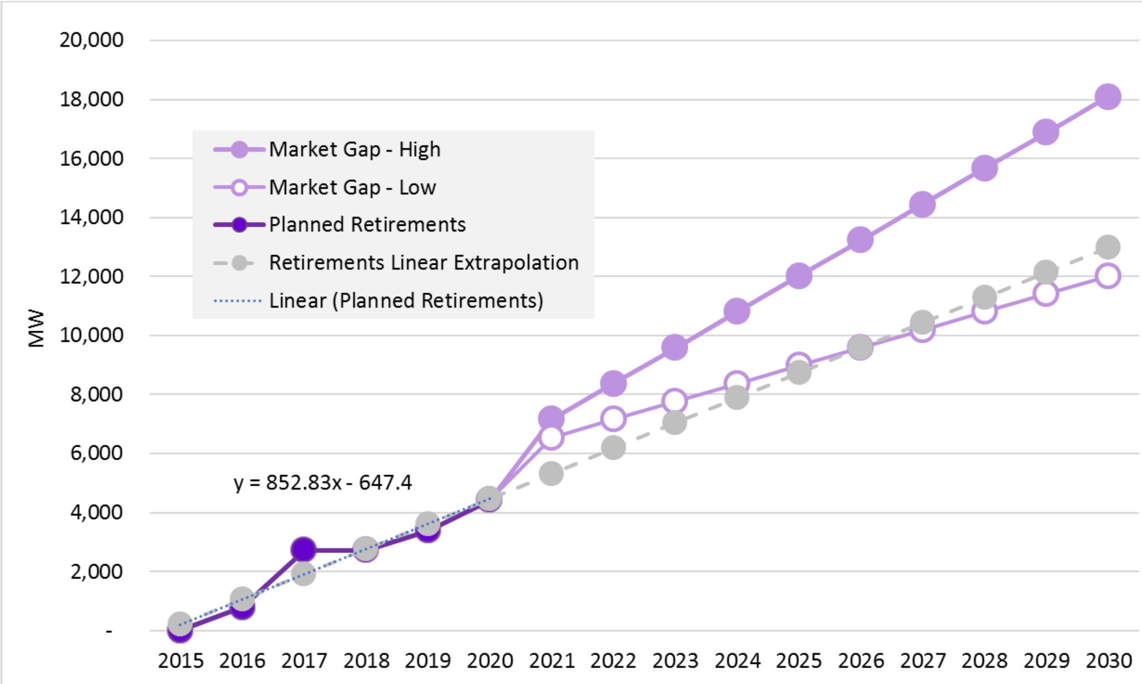
- In the low case, 4% of at-risk capacity retires annually beginning in 2021.
- In the high case, 8% of at-risk capacity retires annually beginning in 2021.

These low and high trajectories bracket a linear extrapolation of the near-term "identified retirements" trend as shown in Figure A-18, which identifies a market gap of 13 GW by 2030. Based on these assumptions, the market gap reaches 12 GW in the low case and up to 18.1 GW in the high case.

---

56 This space in the supply, however, is not an absolute constraint, as additional renewables could displace additional fossil resources that are not considered "at risk" as a result of economics and/or policy.

**Figure A-17. Market Gap Due to Planned and At-Risk Retirements (MW)**

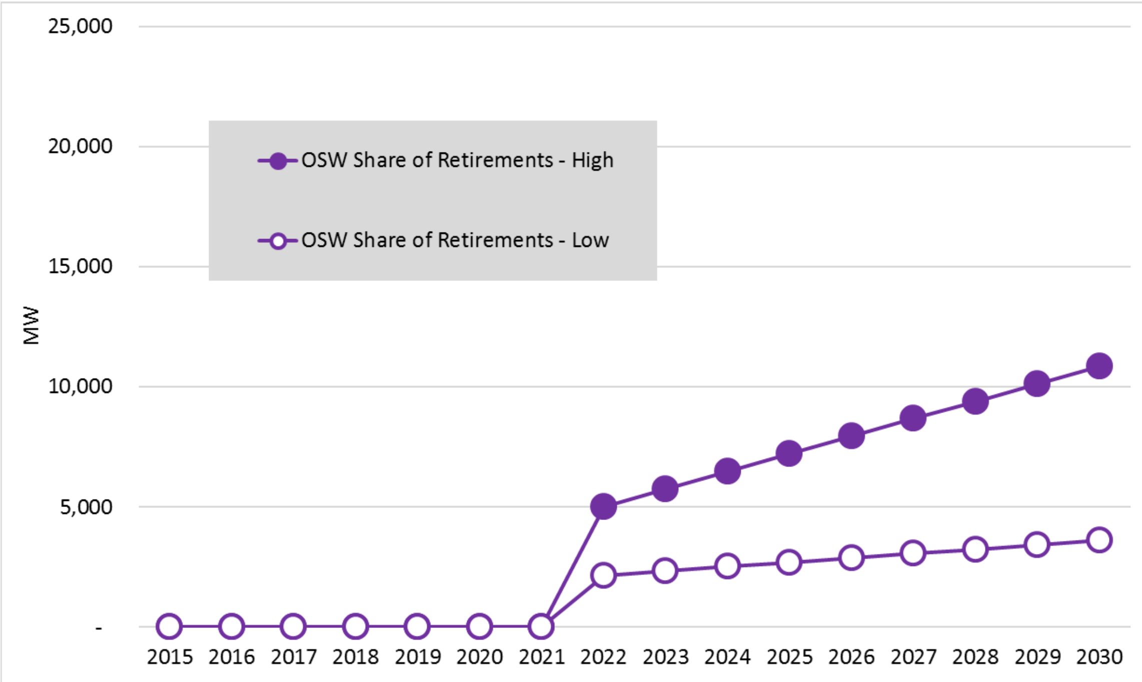



An assumed OSW share of the market gap analysis was applied to project the total potential for OSW to fill the market gap, with results depicted in Figure 44. The following additional assumptions were used for the OSW share of filling the market gap:

- OSW can begin filling the market gap in 2022.
- In the low case, OSW is assumed to replace only 30% of baseload/cycling retirements based on peak coincidence and capacity factors, among other considerations described in Section 3.3.
- In the high case, OSW is assumed capable of replacing an upper bound of 60% of baseload/cycling retirements based on peak coincidence and capacity factors, among other considerations described in Section 3.3.

Based on these assumptions, by 2030 the OSW share of retirements reaches 3.6 GW (14,530 GWh/year) in the low case and 10.8 GW (43,750 GWh/year) in the high case. In considering planned and at-risk retirements, the market gap is not a constraining factor to significant OSW deployment.

**Figure A-18. OSW Share of Retirements (MW)**




# A.6 Regional State Policies and Plans

## A.6.1 Regional RPS Demand for Offshore Wind

The combined demand for Class I resources driven by the RPS programs in New York and New England are described in Chapter 4. Going forward, the future growth in RPS targets will contribute to the potential market for OSW in the region. As discussed in Chapter 5, the portion of incremental and proposed RPS demand creates a floor for the scale of the OSW market.

The assessment of what share of that future market might be served by OSW is based on the following assumptions and inputs.

- OSW is not assumed to displace renewable developed to meet RPS demand prior to the time at which OSW can enter the market. This, RPS demand predating OSW's entry into the market at scale is not available to OSW. The existing eligible renewable generating fleet meets demand for RPS Class I resources through the present target levels. The first year that OSW is assumed available to meet incremental RPS targets is 2022; only incremental demand thereafter is considered.

- The incremental needs for Class I resources are based on RPS programs in NY (the Clean Energy Standard), Rhode Island, Massachusetts, New Hampshire and Connecticut. Class I RPS targets in Maine stop increasing after 2017, and there are no current discussions to expand these targets, so Maine provides no opportunity for incremental OSW demand. The low scenario reflects targets in the current statute. The high scenario reflects current statutory targets plus the following potential target increases actively or potentially under consideration:
    - Massachusetts: 2% annual increase in target starting in 2017 (based on currently proposed legislation).
    - Rhode Island: 1.5% annual increase starting in 2020 (based on legislation adopted in 2016).
    - Connecticut: Assume future legislation to increase to 30% by 2030 (increased expected to be investigated in the 2016 Comprehensive Energy Plan proceeding, and consistent with legislation proposed during the 1017 session).
- The RPS demand is driven by load forecasts produced by NYISO (NYISO, 2015)and ISO-NE (ISO New England, 2015), as discussed in Section 3.2. The Gold Book and CELT reports contain forecasts in a base case, low electricity load case, and a high electricity load case. The low load forecasts are used in the low case, while the high load forecasts are used in the high RPS demand case. In addition, for this analysis, the high electricity load case also includes additional load driven by the deployment of electric vehicles and heat pumps (Stanton, et al., 2016).
- The portion of the incremental RPS demand served by other resources through set-asides for distributed generation and procurements for long-term renewable energy are by definition unavailable to OSW according to the assumptions presented above.
- The OSW share of residual incremental RPS demand after 2022 is assumed to be 25% in the Low OSW Penetration Scenario and 50% in the High OSW Penetration Scenario.

Figure A-19 presents the range of potential demand for OSW driven by the RPS programs in the study region through 2030. Based on the assumptions described above, OSW's potential share of future incremental demand from RPS programs could range from approximately 5,000 to nearly 19,000 GWh per year by 2030.

**Figure A-19. RPS Demand for OSW (GWh/year)**

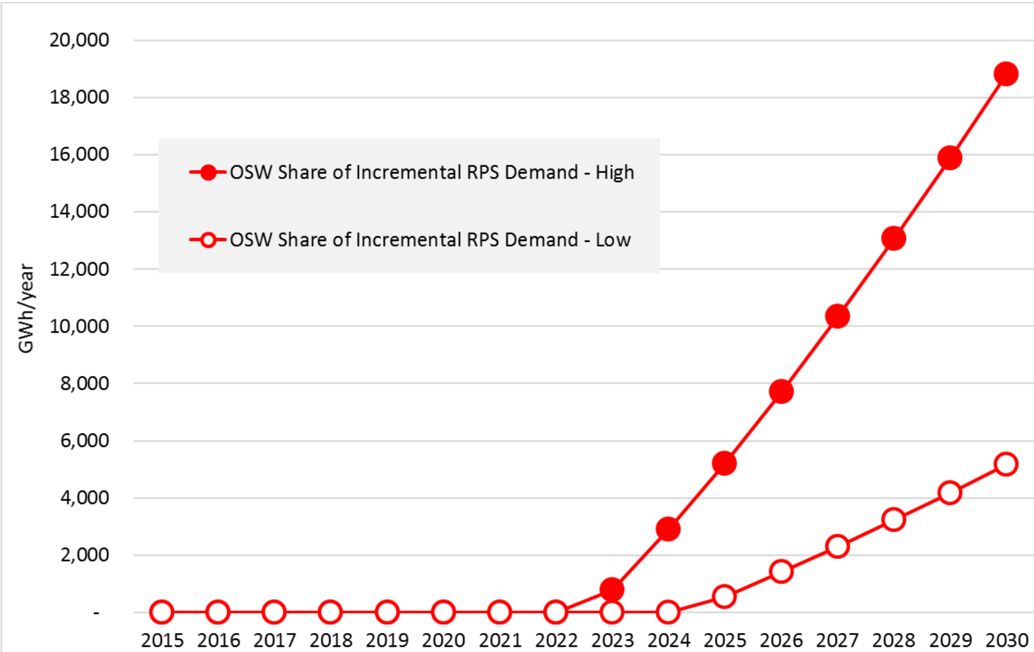



Figure A-20 presents the range of potential demand for OSW generating capacity driven by the RPS programs in the study region through 2030. Based on the assumptions described above, OSW's potential share of future incremental demand from RPS programs could range from 1,300 to 4,700 MW by 2030.

**Figure A-20. RPS Demand for OSW (MW)**

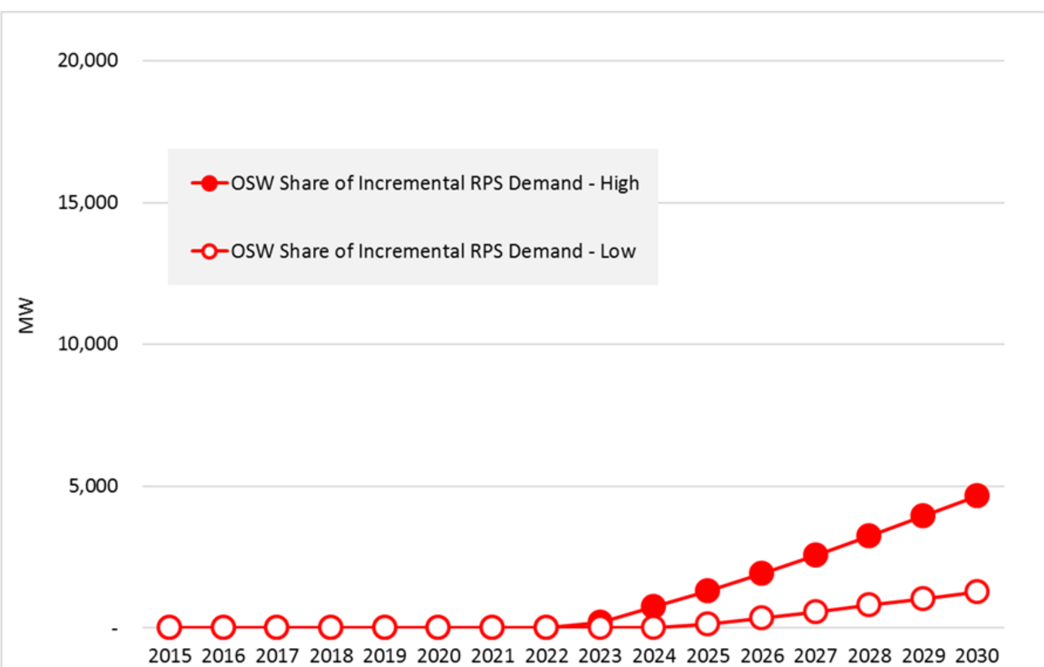


**Figure A-21. Incremental RPS Demand for OSW - Low (GWh/year)**

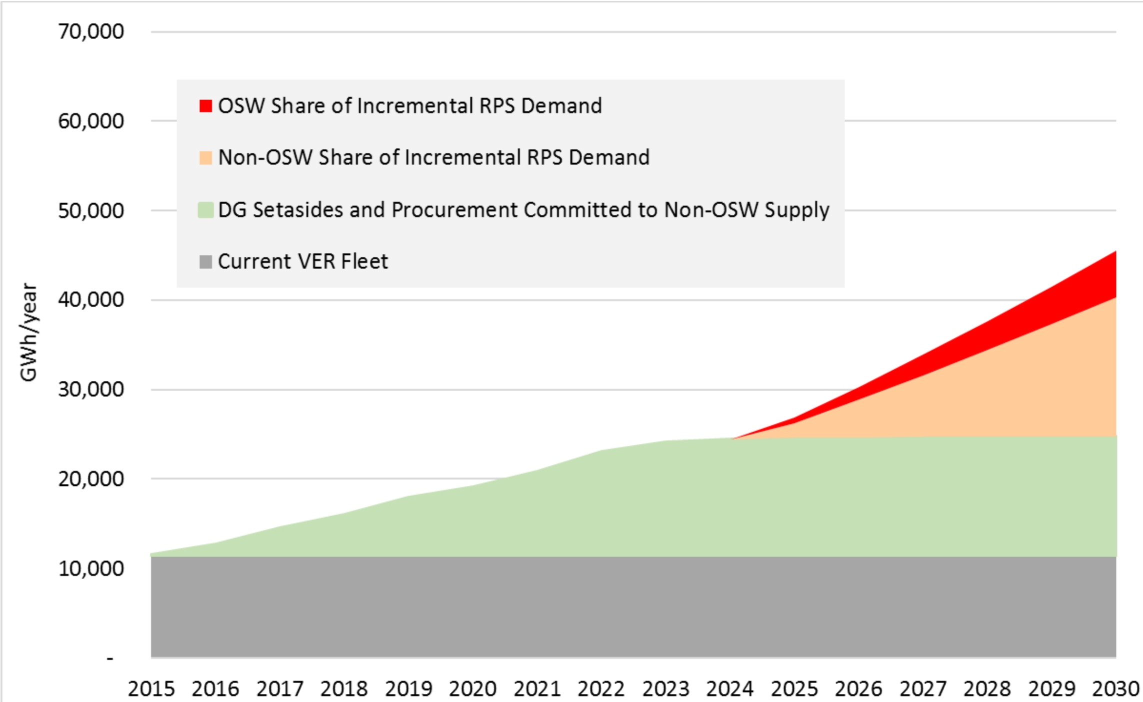



**Figure A-22. Incremental RPS Demand for OSW - High (GWh/year)**

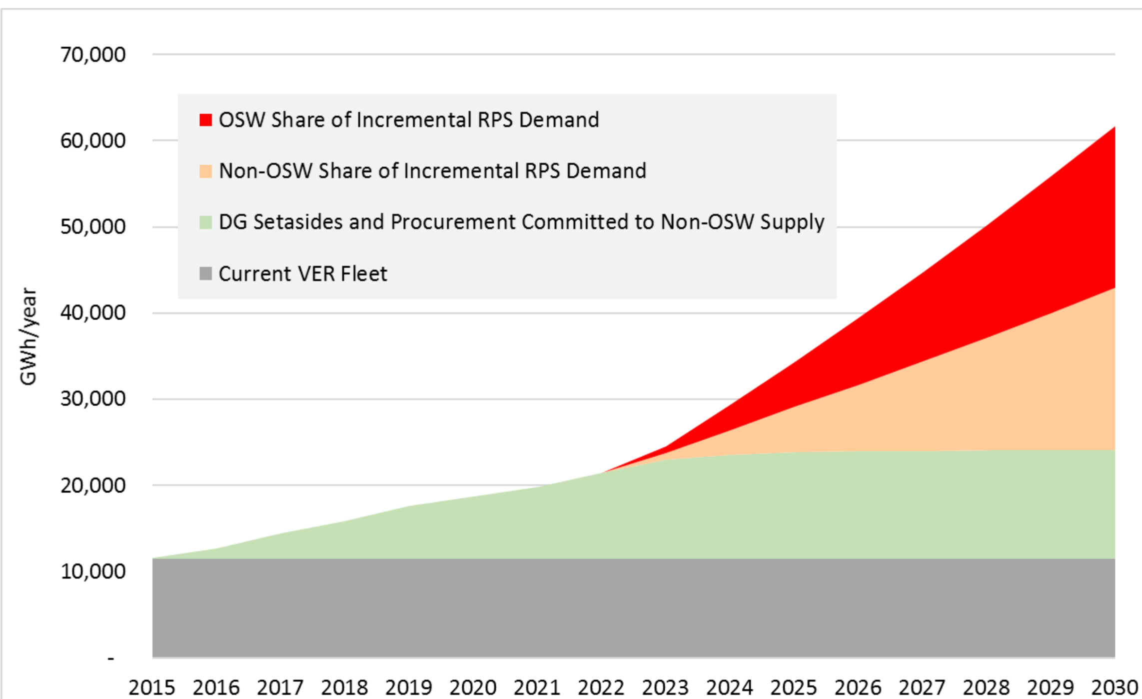


Figure A-21 (low case) and Figure A-22 (high case) present total incremental RPS demand through 2030 according to the relative shares of energy production from OSW, DG set-asides and procurement, and other eligible renewable energy generators given the assumptions listed above.

### A.6.2 GHG Policy-Driven Demand

As discussed in Chapter 4, state and regional GHG policies represent a material driver for additional carbon-free generation to meet the region's energy needs. Relative to the other factors examined in the characterization of the regional market for OSW, GHG policies create a likely cap on the potential OSW market. Overall, GHG targets are assumed to subsume and surpass the influence that RPS targets have on the potential OSW market.

The characterization of the way GHG reduction policies shape the share of that future market might be served by OSW includes the following assumptions and inputs.

- Synapse Energy Economics recently conducted a study of the quantity of VER's required to achieve regional GHG reduction targets of 40% by 2040. This study projected the quantities of VERs (GWh/year from wind and solar) in each state in the study region (Stanton, et al., 2016). These quantities represented the starting point for the GHG-driven analysis.
- The portion of the incremental VERs needed to GHG reduction targets served by other resources through set-asides for distributed generation and procurements for long-term renewable energy are by definition unavailable to OSW according to the assumptions presented in earlier.
- In order to bound a reasonable range, the OSW share of residual incremental demand for VERs was assumed to ramp up from 2022 to 2030 reaching 25% in the Low OSW Penetration Scenario and 50% in the High OSW Penetration Scenario.

Figure A-23 presents the range of potential demand for OSW driven by GHG targets in the study region through 2030. Based on the assumptions described above, OSW's potential share of future incremental demand for VERs to meet GHG targets could range from over 15,000 to over 30,000 GWh per year by 2030.

Figure A-24 presents the range of potential demand for OSW driven by GHG targets in the study region through 2030. Based on the assumptions described above, OSW's potential share of future capacity to provide incremental demand for VERs to meet GHG targets could range from 3,800 to 7,700 MW by 2030.

**Figure A-23. GHG Policy-Driven Demand for OSW (GWh/year)**

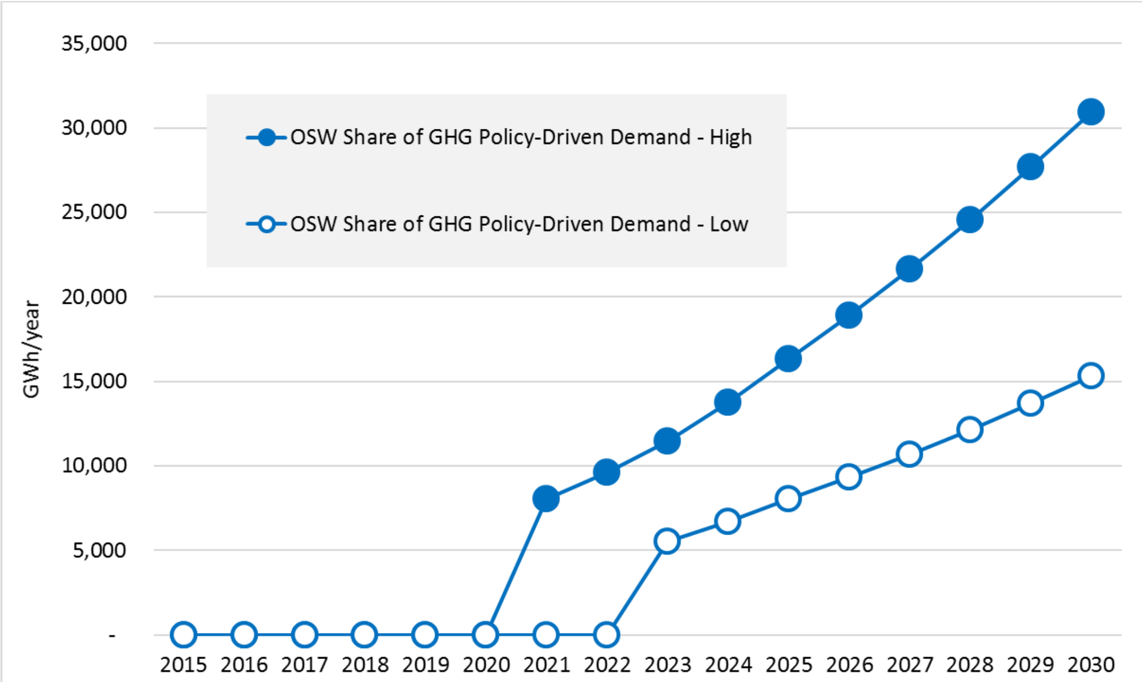



**Figure A-24. GHG Policy-Driven Demand for OSW (MW)**

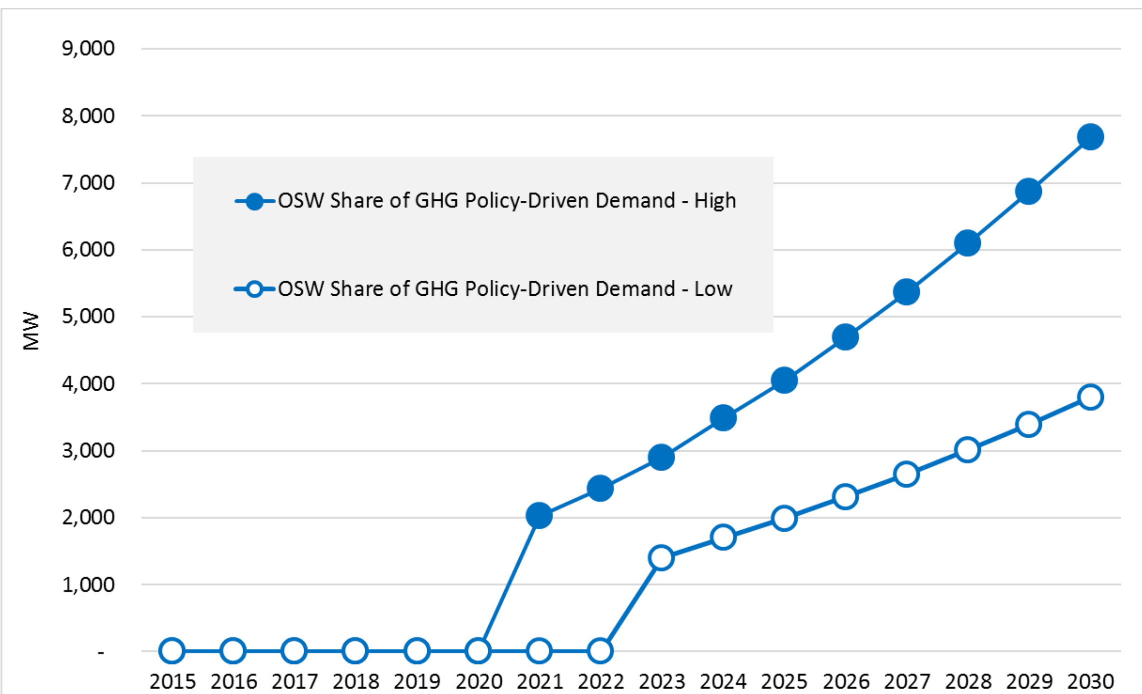


Figure A-25 (low case) and Figure A-26 (high case) present total incremental electricity production from VERs to meet GHG targets through 2030 according to the relative shares of energy production from OSW, DG set-asides and procurement, and other eligible renewable energy generators given the assumptions listed above.

**Figure A-25. OSW Share of Incremental GHG Policy-Driven Demand: Low Case (GWh/year)**

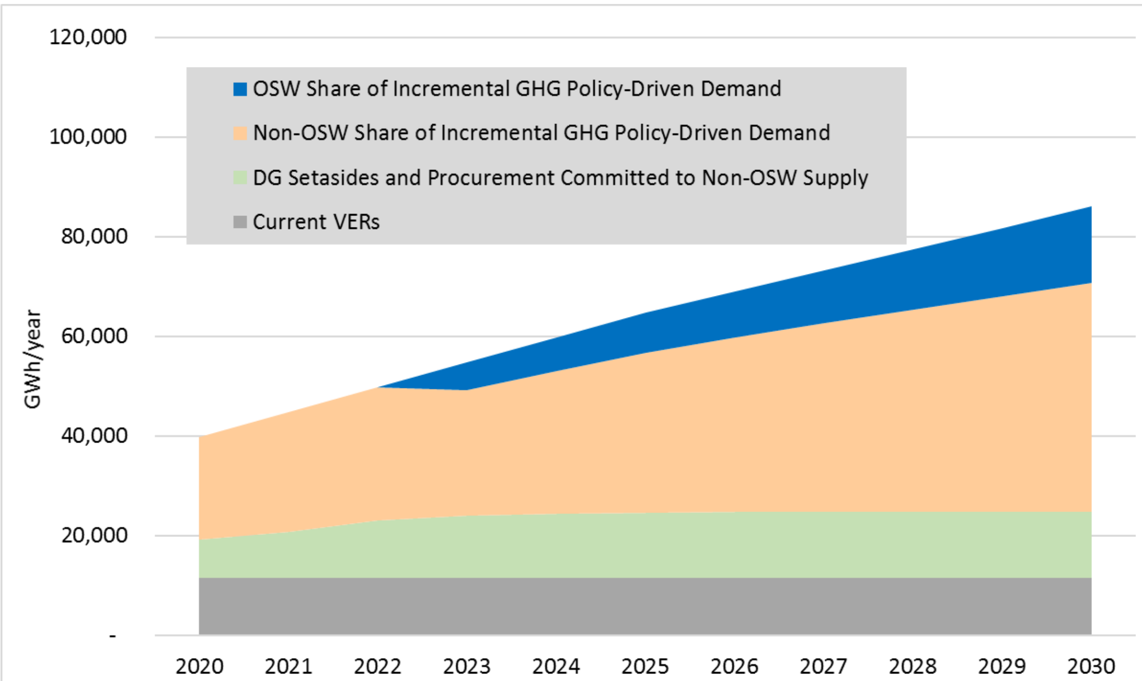
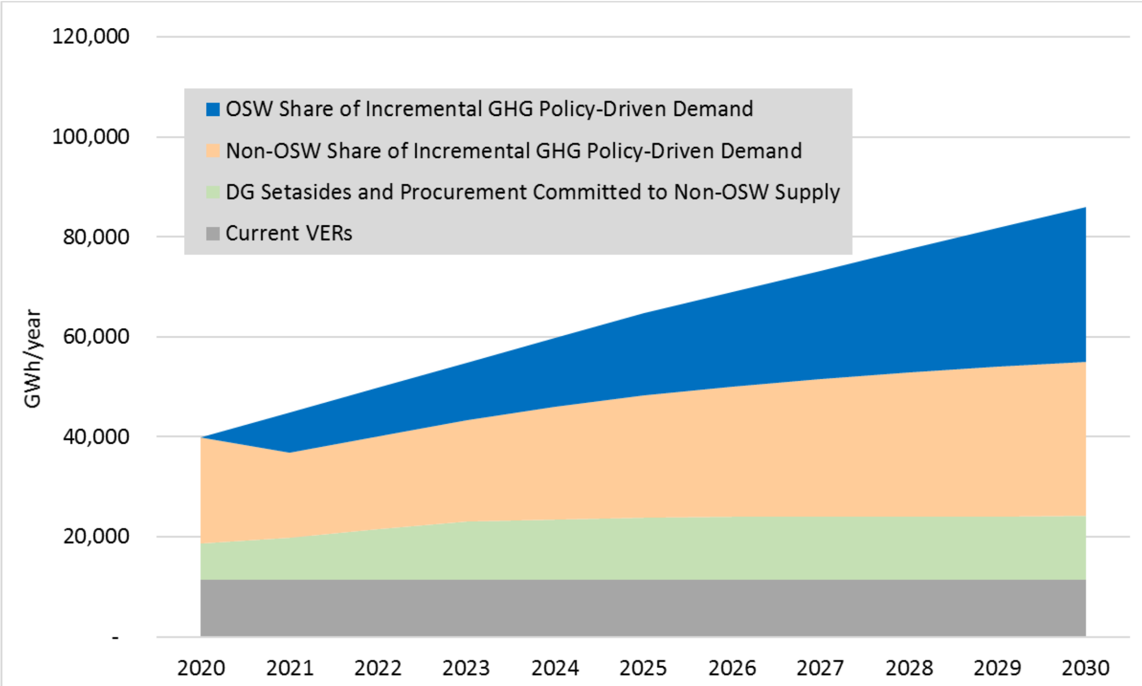


**Figure A-26. OSW Share of Incremental GHG Policy-Driven Demand: High Case (GWh/year)**

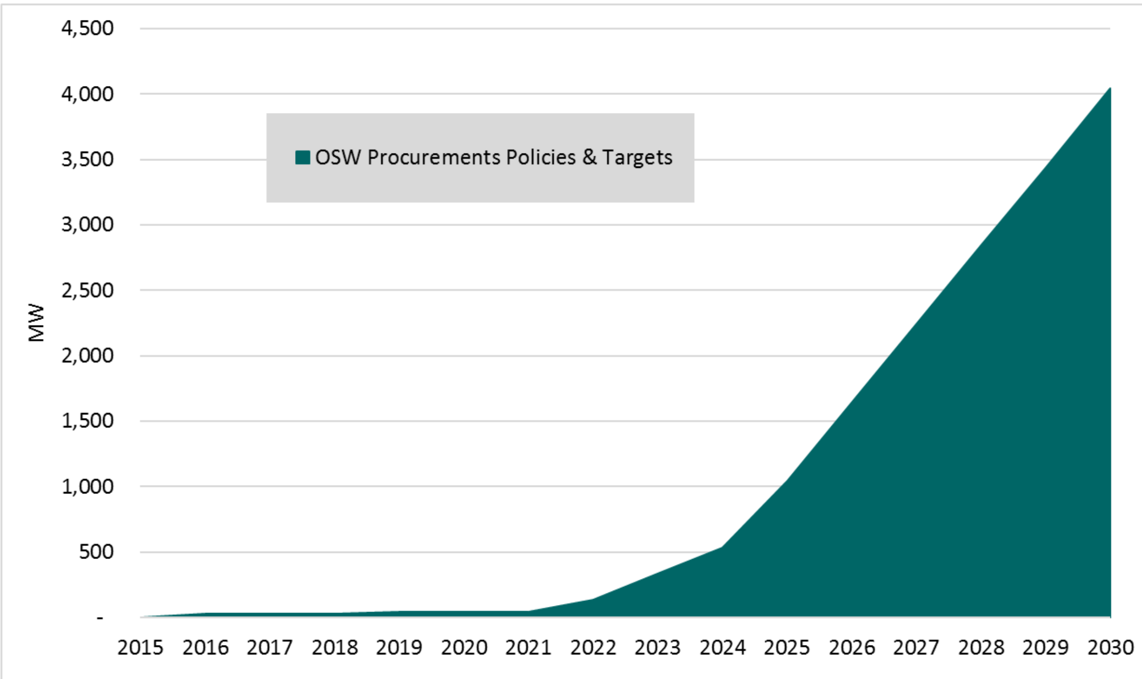



## A.6.3 Offshore Wind Goals, Plans, Procurement Targets, Contracting Policies

Chapter 4 includes descriptions of various goals, targets, and plans for procurement beyond those reflected in Section 5.3 and this Appendix. These various policies are indicative of the increasing level of commitment to GHG reductions, renewable energy expansion, and OSW deployment. However, they vary widely in their form and application, ranging from pilot programs to statutory procurement goals to aggressive, aspirational and non-binding targets. Their timings vary widely. Most are in the early stages of consideration. In addition, to serving as useful benchmarks against which to view the Regional OSW Deployment trajectories, the low case for regional planned procurement policies and targets by individual states in the study region was utilized as the basis for the Low-OSW Deployment trajectory itself. The low case, which is illustrated in Figure A-27, shows that based on operational projects and existing OSW procurement policies and targets, total regional OSW capacity reaches 4,030 MW by 2030. In the high case, total regional OSW capacity reaches 4,042 MW by 2030. The OSW procurement policies and targets were additive to the currently operational Block Island Wind Farm (30 MW) in the high and low case, and to the Aqua Ventus project (12 MW) solely in the high case. The procurement policies and targets included, as well as their respective trajectories, did not differ between cases. The following procurement policies and targets were included:

- 1,600 MW of OSW in MA by 2030 pursuant to Section 83C of An Act to Promote Energy Diversity, which was adopted into law in 2016 (Massachusetts General Court, 2016)
- 2,400 MW of OSW in New York pursuant to the Governor's State of the State Address announcing the state's commitment to achieving 2.4 GW of OSW by 2030 (Cuomo A. M., 2017c).[57]

**Figure A-27. OSW Procurement Policies and Targets - Low Case**




57 See Table 14.

For more information about this report, please contact NYSERDA


**New York State Energy Research and Development Authority**

17 Columbia Circle
Albany, NY 12203-6399

**toll free:** 866-NYSERDA
**local:** 518-862-1090
**fax:** 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

# Northeast Offshore Wind Regional Market Characterization

## A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind


New York State Energy Research and Development Authority
Massachusetts Clean Energy Center
Massachusetts Department of Energy Resources
Rhode Island Office of Energy Resources
Clean Energy States Alliance


Report 17-21 October 2017