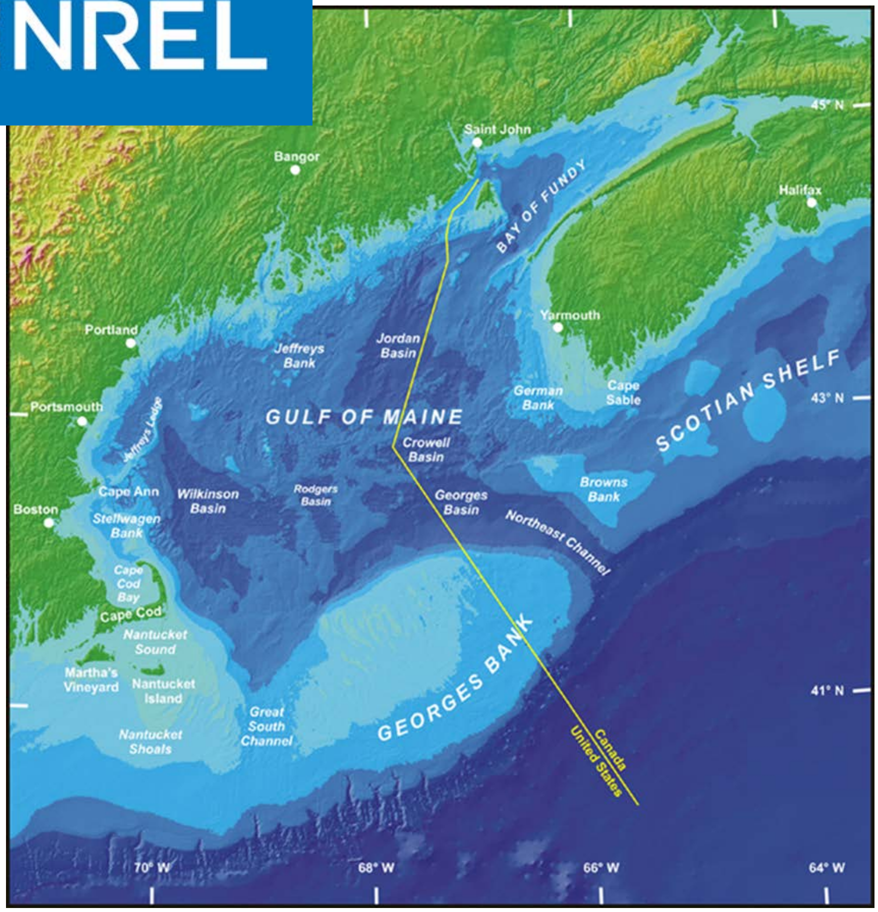

Considerations for Floating Wind Energy Development in the Gulf of Maine

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Technical Report
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15013 Denver West Parkway
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List of Acronyms

BOEM	Bureau of Ocean Energy Management
CTV	crew transfer vessel
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
ft	feet
FWG	Fisheries Working Group
GCF	gross capacity factor
GW	gigawatt
HVDC	high-voltage direct current
IEC	International Electrotechnical Commission
ISO-NE	Independent System Operator – New England
km	kilometer
kV	kilovolt
LCOE	levelized cost of energy
m	meter
m/s	meters per second
MaineDOT	Maine Department of Transportation
MassCEC	Massachusetts Clean Energy Center
MeRA	Maine Research Array
MW	megawatt
MWh	megawatt-hour
NEAV	New England Aqua Ventus
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
OETF	Ocean Energy Task Force
POI	point of interconnection
PV	photovoltaics
RFI	request for interest
SOV	service operation vessel
TLP	tension-leg platform
UMaine	University of Maine
WRF	Weather Research and Forecasting Model
WTIV	wind turbine installation vessel

Executive Summary

This report summarizes the primary considerations for developing floating offshore wind energy in the Gulf of Maine based on the current knowledge of the staff at the National Renewable Energy Laboratory (NREL) as of June 2023. This work was performed as a supplement to information solicited by the Bureau of Ocean Energy Management (BOEM) in their Call for Information and Nominations announced in April 2023 (BOEM 2023b). The purpose of this report is to provide general information to the citizens of Maine, Massachusetts, and New Hampshire, and to inform decision makers and stakeholders about the unique challenges and opportunities of developing floating offshore wind in the Gulf of Maine. This report intends to provide context to show the importance of the state-created energy markets that will be served by floating offshore wind development in the Gulf of Maine.

Some of the key findings include the following:

- **Physical Environment**
    - The bathymetry of the Gulf of Maine is too deep for commercial fixed-bottom wind energy technology that has been widely proven in Europe. However, the depth remains mostly between 100 and 300 meters throughout the Call Area, which is shallow relative to Pacific sites. This is advantageous for building technical confidence in the mooring systems that have been proven in pilot offshore wind energy projects and oil-and-gas installations at those depths and to minimize costs and anchor footprints.
    - The wind resource in the Gulf of Maine is the most energetic in the Eastern United States, ranging from 9.5 to 10.5 meters per second. Capacity factors tend to increase with distance from shore but do not provide enough additional energy to offset higher costs.
    - Diurnal and seasonal wind resource variations in the Gulf of Maine indicate winter peaks, and diurnal peaks that generally occur in the evening hours may complement daytime solar peaks.
- **Technology**
    - The State of Maine has been active in developing floating offshore wind since 2008 and has the most advanced project in the United States—New England Aqua Ventus—scheduled to deploy in 2025.
    - Mooring systems that have smaller anchor footprints are under investigation at the University of Maine and National Renewable Energy Laboratory and promise to reduce the diameter of the anchor circles by up to 50%. These new technologies can help to reduce the impact to the fishing community under some circumstances (Green et al 2023), but more engineering analysis is needed to lower the added technical risk to the developers, continue with further innovations (e.g. tension leg platforms) and ensure best engineering practices are validated.
    - The State of Maine has applied to BOEM for a research lease outside of the commercial leasing process to enable new mooring system designs to be verified on a smaller scale and to allow their impacts on the fishing industry and

ecosystems to be evaluated. BOEM has made a "determination of no competitive interest" in the Request for Competitive Interest area where the proposed research lease is located, and as of June 2023 they were completing their evaluation of the area to determine its suitability. If Maine is awarded this lease, the state intends to investigate a range of questions including mooring configuration trade-offs and coexistence of fishing and offshore wind turbines.

  - The development schedule of Maine's research array is ahead of commercial leasing in the Gulf of Maine as of June 2023 which could put Maine in a leadership position for domestic floating offshore wind energy. However, significant upfront infrastructure investment will be required to stay ahead of commercial development. The value of the research array will diminish if there are significant delays in its progress.
  - BOEM is planning for commercial lease auctions in the Gulf of Maine in late 2024 or early 2025. Commercial leasing is critically important for Massachusetts to meet its state energy decarbonization targets and the commonwealth is anticipated to begin competitive procurements for projects in the Gulf of Maine shortly after auctions occur.
  - Technology used in the commercial lease areas will not be constrained by the technology used in the Maine research lease, but it could potentially benefit from the research. Offshore wind turbines have grown globally to a 15-megawatt scale and will be coupled to a range of possible floating platform options. Semisubmersibles are the most common substructures considered by developers worldwide because they enable full assembly and commissioning at quayside with fewer port modifications.
  - One or more floating substations will likely be required for large commercial projects to convert array voltages at 66 or 123 kilovolts to higher voltage AC or DC power. The technology to develop these substations and the high-voltage dynamic cables are still under development globally.

- **Cost of Floating Offshore Wind Energy in the Gulf of Maine**
  - The cost of offshore wind energy in the Gulf of Maine has been documented in previous national studies covering Massachusetts, New Hampshire, and Maine. The studies highlighted a large, high-quality wind energy resource showing that future costs for floating wind energy could reach parity with fixed- bottom technology.
  - A new updated national cost study is forthcoming at the National Renewable Energy Laboratory and is scheduled to be published in the fall of 2023.
  - Preliminary cost analysis shows reduced sensitivities to distance from shore for floating wind projects relative to fixed bottom wind projects because much of the expensive open ocean construction activities are moved to the installation and assembly marshalling port where they are independent of the project site location. Primary cost adders for increasing project site distance in the Gulf of Maine are export cable length, anchor and mooring line installation time, increased wind turbine downtime, and higher operation and maintenance.

- **Electric Power System**
  - Projects may be located farther from shore in the Gulf of Maine, thereby necessitating the use of high-voltage direct current offshore transmission. This approach makes economic sense if the project substation is greater than 80 kilometers (50 miles) from a land-based point of interconnection.
  - Independent System Operator-New England (ISO-NE), the grid operator for the six New England states, is planning for up to 17.9 gigawatts (GW) of offshore wind from the Gulf of Maine by 2050.
  - The ISO-NE power grid electrical generation is expected to more than double by 2050 due largely to the electrification of home heating and transportation. Much of this additional generation will come from renewable energy sources such as wind and solar energy. Offshore wind from the Gulf of Maine will be a major energy contributor for Maine, Massachusetts, and New Hampshire.
  - The expanded ISO-NE grid, based on variable renewable energy sources, will require storage to achieve the necessary reliability. Peak loads will shift from the present pattern of a summer daytime peak to a winter evening peak by 2050 due to shifting energy use patterns that favor electrification of all energy sectors.
  - Transmission congestion will be a major issue for the future expanded grid but points of interconnection have been identified in Massachusetts, New Hampshire, and Maine where offshore wind power from the Gulf of Maine could be delivered. Points of interconnection are expected to be refined in the forthcoming *Atlantic Offshore Wind Transmission* study.
- **State and Federal Policy**
  - State-level efforts in Maine have pursued offshore wind energy (with a focus on floating technology) since 2008. They initially formed an intergovernmental task force in 2011 corresponding to the unsolicited Statoil (now Equinor) lease proposal. However, Maine state efforts in offshore wind energy were significantly curtailed during the LePage administration (2012−2018), before restarting with the Mills administration (2019−present) as a key part of the state's climate action goals and economic development plan.
  - Due to the evolving nature of floating technology, and sensitivities to stakeholder conflict, Maine state policy has prioritized research and demonstration opportunities while prohibiting commercial development in state waters for a ten-year period beginning in 2021. Simultaneously, Maine's Senator Mark Lawrence and a coalition of advocates have been laying the groundwork for larger projects through LD 1895, a procurement bill for 2.8 GW of offshore wind energy introduced to the Maine Legislature in January 2023.
  - Massachusetts has led the country in fixed-bottom offshore wind energy development and enacted the nation's first procurement mandate. The state is now clarifying its interests in the Gulf of Maine with its new Clean Energy Climate Plan. Of the three Gulf of Maine states, Massachusetts has the most ambitious targets for offshore wind. State modeling and energy planning under the Clean

Energy Climate Plan indicate that over 23 megawatts of offshore wind will be needed by the commonwealth by 2050 with 13 GW coming from floating offshore wind resources. Most of this floating wind capacity is expected to come from the Gulf of Maine.

  - New Hampshire has not set any offshore wind targets but has a strong interest in protecting its existing economic and environmental interests manifested in its ports, manufacturing, and transmission infrastructure.
  - Federal policy has become more coordinated with state-level policies after 2021. Due to the interconnected nature of the ecosystem, energy markets, and the stakeholders who depend upon it, a three-state regional Gulf of Maine intergovernmental task force was established in 2019, including the states of Maine, Massachusetts, and New Hampshire.
  - Federal regulatory and leasing efforts are currently focused on the state-led research lease application submitted in 2021 as well as defining larger wind energy areas by the end of 2023.

- **Stakeholder and Tribal Considerations**
  - The Gulf of Maine is distinguished by its fishing community and commercial fishermen from all three states are active in the region. Obtaining an understanding of priority commercial fishing areas will be critical to all three state's stakeholders. Efforts are being made to gain more knowledge around commercial fishing activities in federal waters including through a new reporting requirement for lobstering in federal waters. To a lesser degree, the presence of inhabited offshore islands – which both extend the jurisdiction of in-shore waters as well as sensitivities to visual impacts and stakeholder conflict – will be a consideration, especially in Maine.
  - The extended nature of offshore wind energy development in Maine, with efforts in both state and federal waters over 15 years, has challenged some stakeholders to track various processes, but recent endeavors, including the state-led road map, funding for collaborative research and outreach, the establishment of a research consortium, and expanding BOEM efforts are bringing more opportunities for the region's stakeholders to engage on the topic.
  - Consultation and engagement with tribal nations in the Gulf of Maine region has begun but will be shaped by past and present complexities with state and federal government relations. Focused workforce development efforts could create opportunities for tribal members to participate in the industry.

- **Supply Chain**
  - Floating offshore wind energy will require one or more marshalling ports where wind turbines and substructures can be assembled. Port locations have not been finalized yet, but suitable sites have been proposed at Searsport, Maine, and Salem, Massachusetts. Work to redevelop the former coal-fired power plant site in Salem into an offshore wind marshalling port to support fixed-bottom wind projects south of Cape Cod is proceeding through a public-private partnership.

Permitting is underway, engineering and design are being finalized, and significant funding has been secured. This effort may facilitate the plant's conversion into a floating wind port to serve the Gulf of Maine.

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1 Overview

The Gulf of Maine is a basin in the north Atlantic Ocean off the coast of northern New England. It is bounded by the states of Maine, New Hampshire, and Massachusetts to the west, Georges Bank and the Scotian Shelf to the south and east, and the Canadian province of Nova Scotia to the north (Figure 1). This ocean region is part of the northernmost portion of the U.S. Outer Continental Shelf that is being considered for commercial leasing of offshore wind energy.

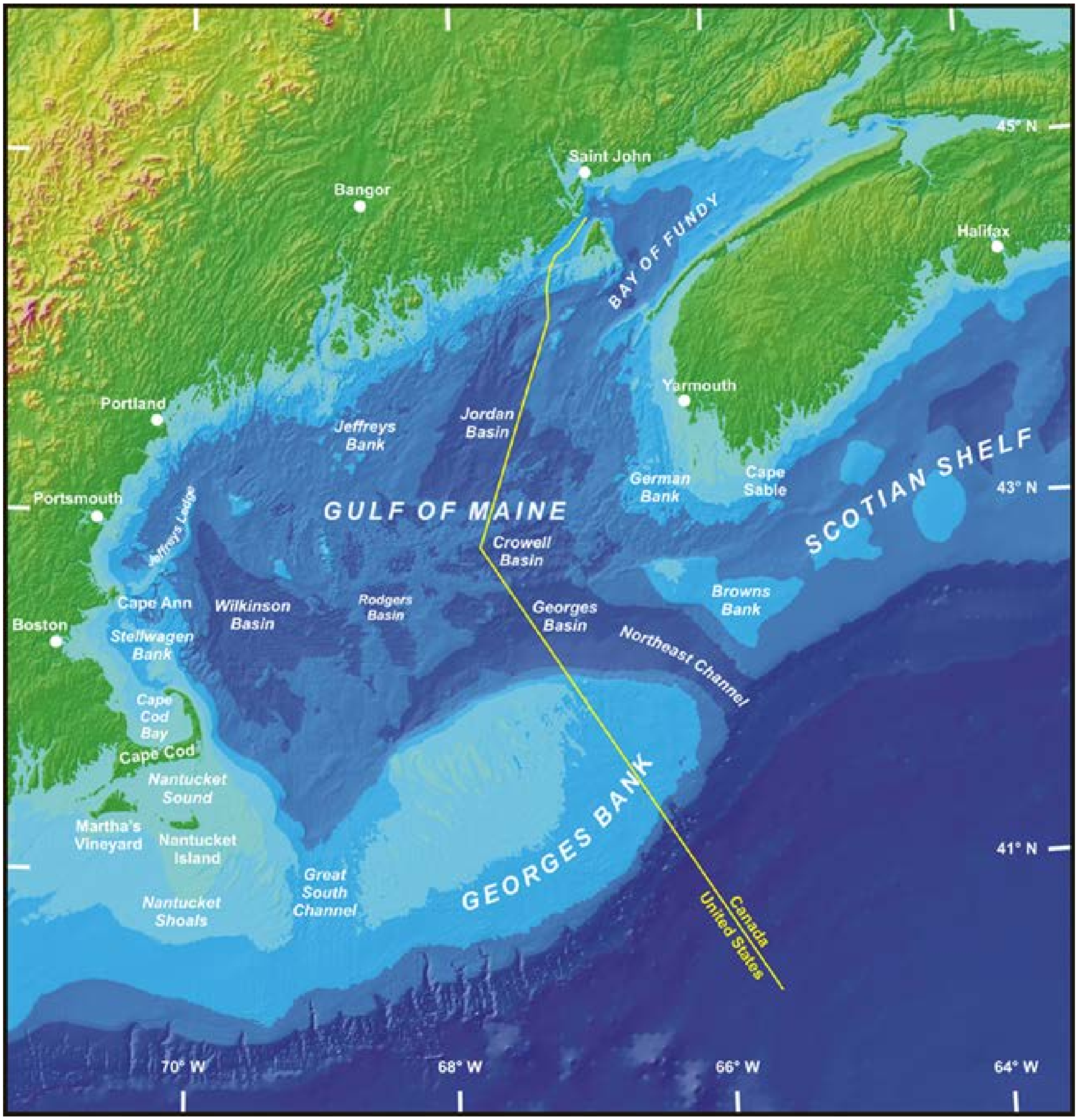

Figure 1. Ocean features of the Gulf of Maine. ***Image from the National Centers for Environmental Information 2021***

The northern New England fishing and lobster industries depend on this region to support the livelihood of the fishermen and the economies of these states. It also provides critical habitat for the wildlife that inhabit this ocean space that must be protected. The Gulf of Maine also faces exogenous threats from climate change. Long-term satellite data and ocean temperature measurements indicate that the Gulf of Maine is warming faster than 99% of the global oceans due to atmospheric emissions such as carbon dioxide from power plants, combined with the associated ocean current changes in the North Atlantic (Gulf of Maine Research Institute 2018; National Centers for Environmental Information 2021).

The United States is now taking serious steps to avert the worst impacts of climate change and has set targets to achieve zero carbon emissions nationwide by 2050. Offshore wind is expected to be a major contributor in transitioning energy use away from fossil fuels. Coastal regions in the Gulf of Maine are in proximity to large energy demand centers and land-based wind energy expansion could be constrained by conflicts with private property, other human uses, and the environment. While no energy source is without impact, offshore wind can be built at large scale and farther from most human activities, and is therefore expected to play a major role in this massive energy transition.

In October 2021, the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) released its "Offshore Wind Leasing Path Forward 2021–2025." This plan ramped up U.S. regulatory leasing activity, advancing seven new offshore wind energy development regions, including the Gulf of Maine. The first three auctions were held for six lease areas in the New York Bight, two lease areas in Carolina Long Bay, and five leases in California, respectively. The five California leases are the first commercial leases in the United States that are specifically targeted for floating offshore wind development, which will also be the technology choice for the Gulf of Maine (U.S. Department of the Interior 2021).

Although the Gulf of Maine is the last area slated for leasing in late 2024 under the near-term BOEM plan, the area is adjacent to the Independent System Operator − New England (NE) electric grid, which serves one of the most populated areas in the United States. ISO-NE is planning for at least 25 gigawatts (GW) of offshore wind energy by 2050, and a significant fraction of that is from the abundant wind resources in the Gulf of Maine, serving multiple states. The winds that blow over the Gulf of Maine are the most energetic in the U.S. Atlantic Ocean and offer a clear technical option for decarbonizing New England's energy supply. It is imperative that the development of these resources protect the natural environment of the Gulf of Maine's ecosystem, its waterfront, economy, and cultural heritage. Therefore, in advance of commercial leasing, BOEM commissioned the National Renewable Energy Laboratory (NREL), under an interagency agreement with the U.S. Department of Energy (DOE), to write this report. The purpose is to provide BOEM and the general public with an assessment of the unique aspects and challenges of the development of floating offshore wind energy in the Gulf of Maine.

1.1 Current Leasing Status

In August 2022, the U.S. Department of the Interior announced a request for interest (RFI) to determine if there was interest from commercial wind energy developers within an area in the Gulf of Maine of about 13.7 million acres, or about 21,400 square miles. On January 10, 2023, BOEM announced a series of in-person and virtual meetings to solicit feedback on the next steps for the region. After considering the information gained from public comment, the offshore wind energy industry, and experts at the National Oceanic and Atmospheric Administration's (NOAA's) National Center for Coastal and Ocean Science, the area identified in the Call for Information and Nominations released in April 2023 was reduced by about 29% to 9.8 million acres or almost 15,300 square miles. This area is shaded in green in Figure 2. It extends as far south as Cape Cod and as far from shore as 118 nautical miles (nmi) (BOEM 2023b).

The Call for Nominations will further inform BOEM about commercial offshore wind energy development interest to help narrow down the area for leasing. Commercial leasing of wind energy areas, which will occupy a fraction of this green shaded area, is planned to begin before 2025. Commercial development could serve energy supplies in northern New England beginning in the early 2030s.

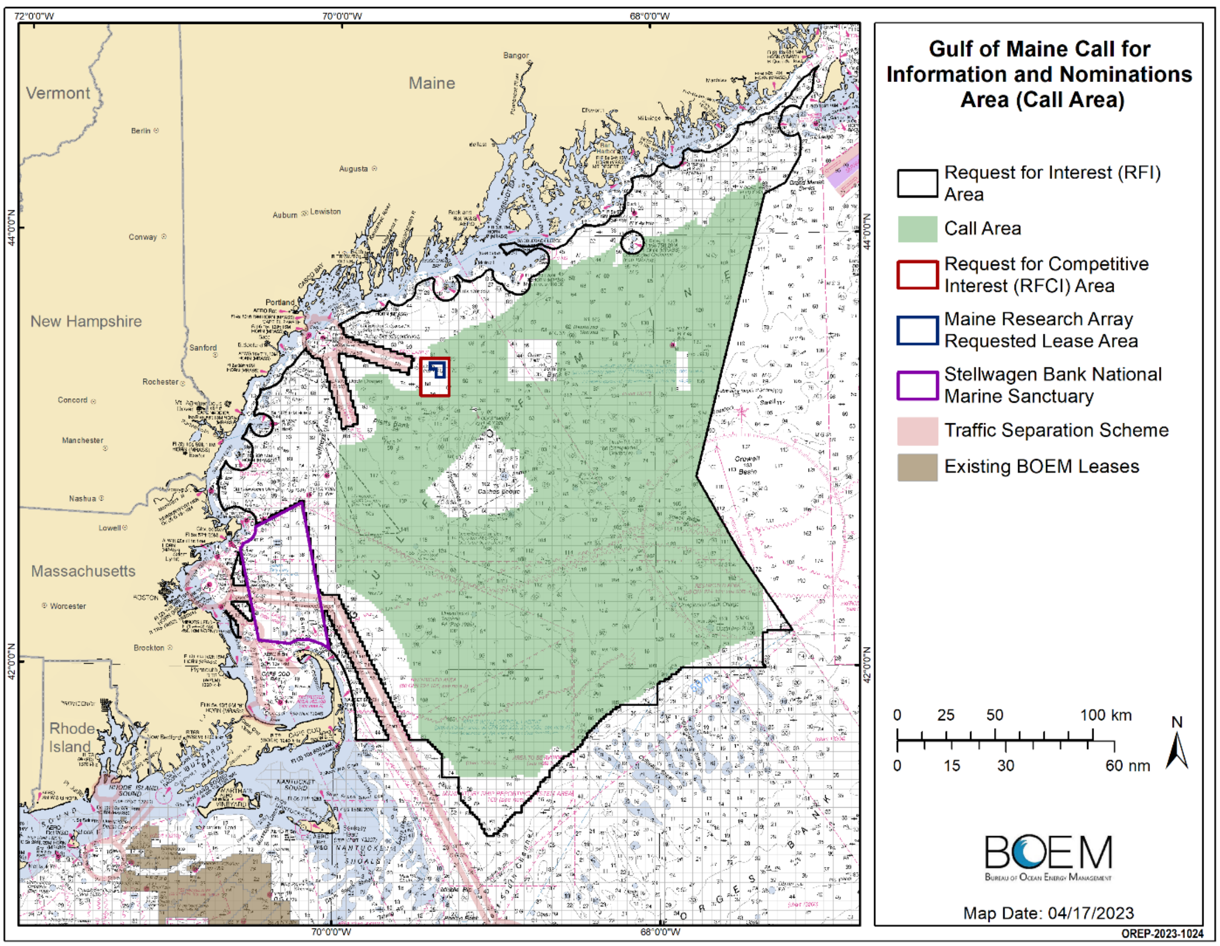

Figure 2. Map of the Call Area for the Gulf of Maine announced April 2023. ***Image from the Bureau of Ocean Energy Management (BOEM)***

In addition to commercial leasing, the State of Maine has applied for a research lease, shown in Figure 2 (L-shaped blue polygon inside the red rectangle). The state's objective for the research lease is to deploy new floating technology at a smaller scale (144 megawatts [MW]) to investigate potential conflicts and technical issues before expanding to commercial scale. This research lease application received a "Determination of No Competitive Interest" on January 19, 2023, and is now undergoing environmental review. If approved, the State of Maine can begin development of the research lease before commercial projects which would allow them to benefit from the research and experience gained, but the timing of commercial leasing does not depend on the prior development of the Maine research lease.

1.2 Scope

This report provides a broad, top-level assessment of the key challenges, risks, and opportunities that are unique to offshore wind energy development in the Gulf of Maine Call Area that was issued in April 2023. This assessment is based on NREL's knowledge base in floating wind energy technology and deployment issues and research from publicly available documents. Generally, this report does not contain significant new analysis. The topics herein include assessments of the physical environment, technology, cost, electric grid integration, state and federal policy, stakeholder issues, and supply chain.

2 Physical Environment

2.1 Bathymetry

Details of the bathymetry in the Gulf of Maine Call Area are provided in Figures 3 and 4.

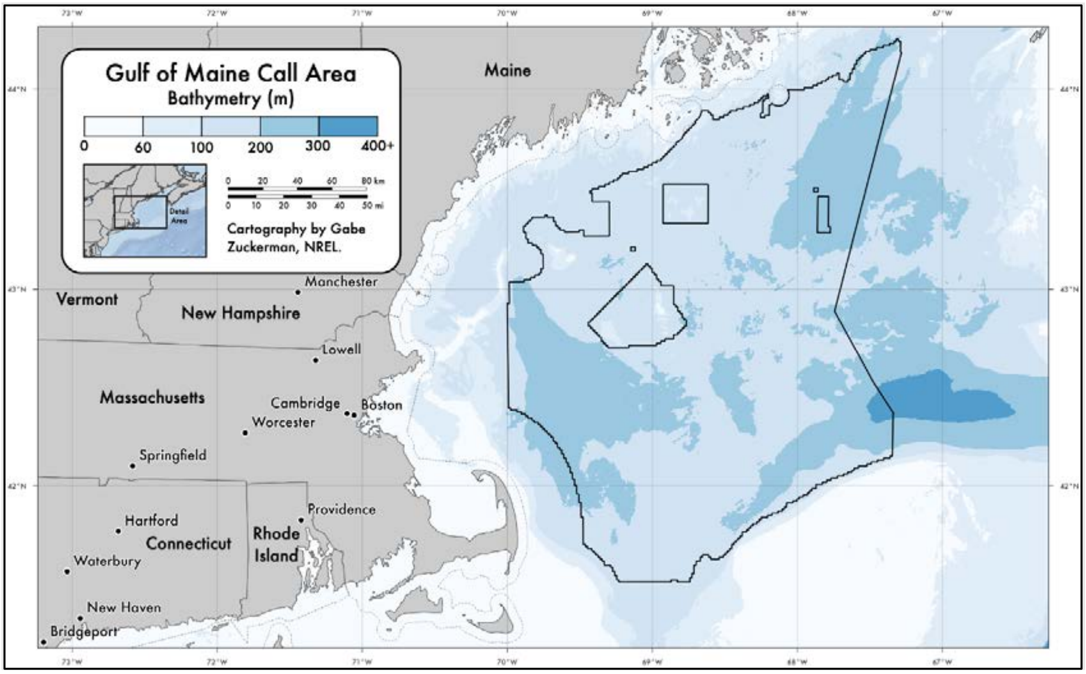

Figure 3. Map of bathymetry for the Gulf of Maine Call Area. ***Image from NREL***

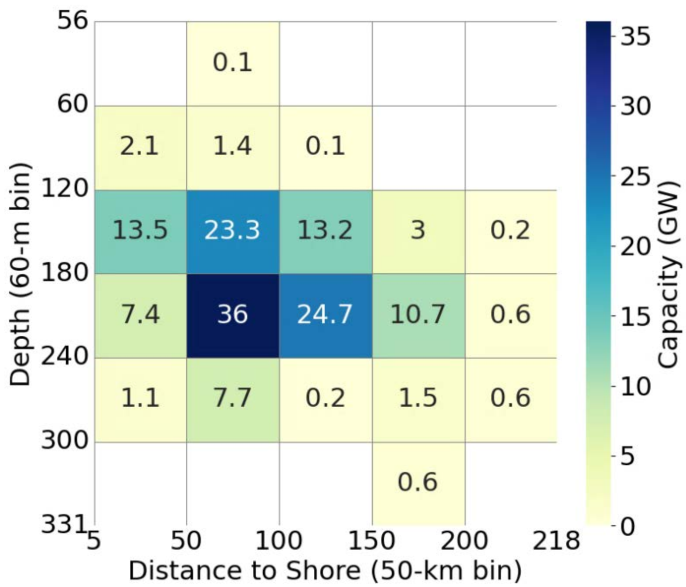

Figure 4. Approximate capacity (gigawatts [GW]) by distance to shore (kilometers [km]) and water depth in the Call Area

Figure 3 shows the water depth in bands of 100 meters (m) with a maximum depth in the Call Area of 331 m. The Gulf of Maine has a relatively flat bottom with moderate changes in depth and no obvious correlation with respect to the distance from shore. Figure 4 quantifies this bathymetry assessment. The wind resource nameplate generating capacity is calculated in depth bins of 60 m and distance to shore bins of 50 kilometers (km). Generating capacity is estimated by multiplying approximate available area in each cell by a nameplate capacity density of 4 MW/km^2, which is just under the average capacity density of the proposed fixed-bottom projects that have submitted construction and operating plans as of June 2023.[1] The chart shows the greatest capacity potential between 50 km and 150 km (27 nmi to 81 nmi) from shore, at depths between 180 m and 240 m (591 feet [ft] to 787 ft). The bins are truncated at the minimum and maximum values to enable a better assessment of the full range of each parameter. Distance to shore was measured from a point on the map to the distance to the nearest landmass, including small islands.

2.2 Resource Assessment

The wind energy resource for the Gulf of Maine was recently updated under a new study at NREL that was funded by the National Offshore Wind Research and Development Consortium. This new national resource assessment replaces previous studies (Musial et al. 2016) and is shown in Figure 5.

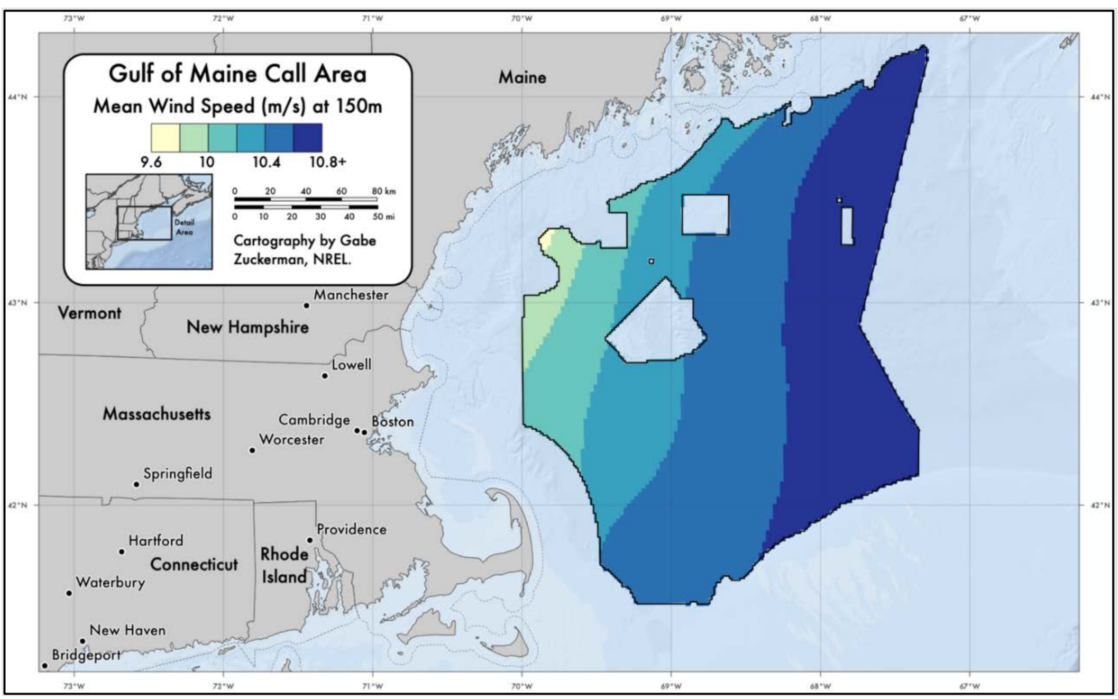

Figure 5. Average wind speeds in the Gulf of Maine Call Area are estimated at a 150-meter (m) elevation. ***Image from NREL***

[1] Note the array power density, or capacity density, is virtually independent of wind turbine size if turbine spacing is not prescribed. In the Massachusetts wind energy area, turbine spacing was fixed at 1 nautical mile, which made it difficult to achieve higher array power densities without installing larger wind turbines.

NREL produced wind resource data for offshore Gulf of Maine waters using the Weather Research and Forecasting Model (WRF) Version 4.2.1 under a separate forthcoming study funded by the National Offshore Wind Research and Development Consortium. The WRF model was initialized with the European Centre for Medium Range Weather Forecasts 5 Reanalysis (ERA-5) data set and a nested domain that refined the spatial resolution to 2 km. We ran the model using 61 vertical levels, with 12 levels in the lower 300 m. In addition, we ran the WRF model for years 2000 to 2020, and the Gulf of Maine wind resource data are available at a 5-minute resolution. Multiple WRF model setups or ensembles were used to determine the best-performing model setup and to quantify the model sensitivities. Further, we conducted detailed validation of model results against buoys, coastal radars, and offshore floating lidars (DOE 2023a).

The wind speeds shown in Figure 5 range from 9.6 meters per second (m/s) to 10.8 m/s on a gradient that increases steadily from west to east, with the strongest winds farthest from shore.

2.3 Seasonal and Daily Wind Variations

The wind resource for the Gulf of Maine was examined for seasonal and diurnal (daily) patterns over the 20-year record modeled in WRF. Figure 6 shows the average hourly diurnal wind speed patterns for four New England seasons. The four curves show a pattern of higher wind speeds in the winter and lower wind speeds in the summer, which is common in the northern hemisphere.

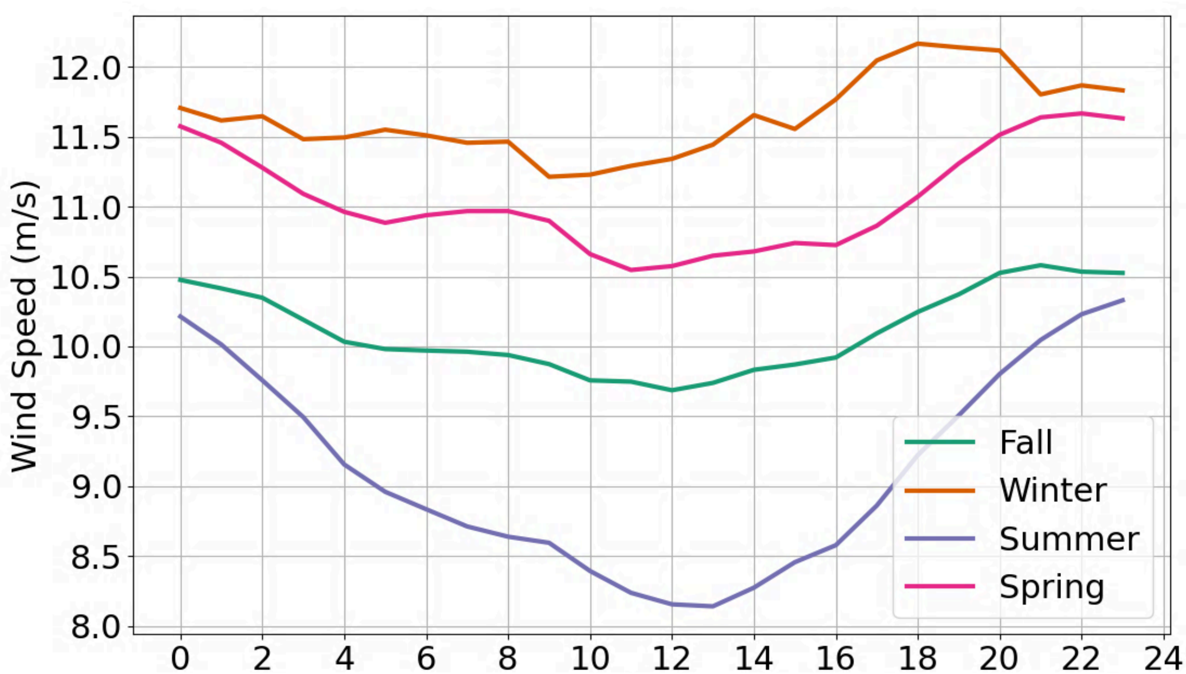

Figure 6. Seasonal and hourly average wind speeds (m/s) from 2000 to 2020 at a central location (42.813, -68.498) in the Gulf of Maine Call Area

The curves also show peak winds occurring in the evening (0 hour = midnight) with lower winds occurring midday (hour 12). These trends are very compatible with solar photovoltaics (PV), which peaks mid-day and is not generating at night. In addition, the evening peaks seen in the winter diurnal pattern are very likely complementary to the shifting energy use patterns in ISO-NE winter load peaks occurring when the wind energy is highest (DOE 2023). Note that the curves shown in Figure 6 are plotted for only a single point at the centroid of the Gulf of Maine Call Area. It is likely that there would be some variations across the region, but these data are considered representative of the trend that characterizes the Call Area. A full characterization of the resource adequacy in the Gulf of Maine is currently underway and will provide the necessary higher-fidelity estimations of capacity credit needed for accurate utility planning (NREL 2023).

2.4 Gross Capacity Factor

Gross capacity factor (GCF) is the ratio of the energy produced by a given wind turbine over the resource record divided by the maximum amount of power the turbine could make running at rated power 100% of the time. No losses are assumed in calculating GCF. Furthermore, it is a convenient way to look at the ability of a wind power plant to produce energy. The winds modeled in the resource assessment were processed through the power curve of the 15-MW Annual Technology Baseline wind turbine to determine the gross capacity factor, which is shown in Figure 7 (Gaertner et al. 2020).

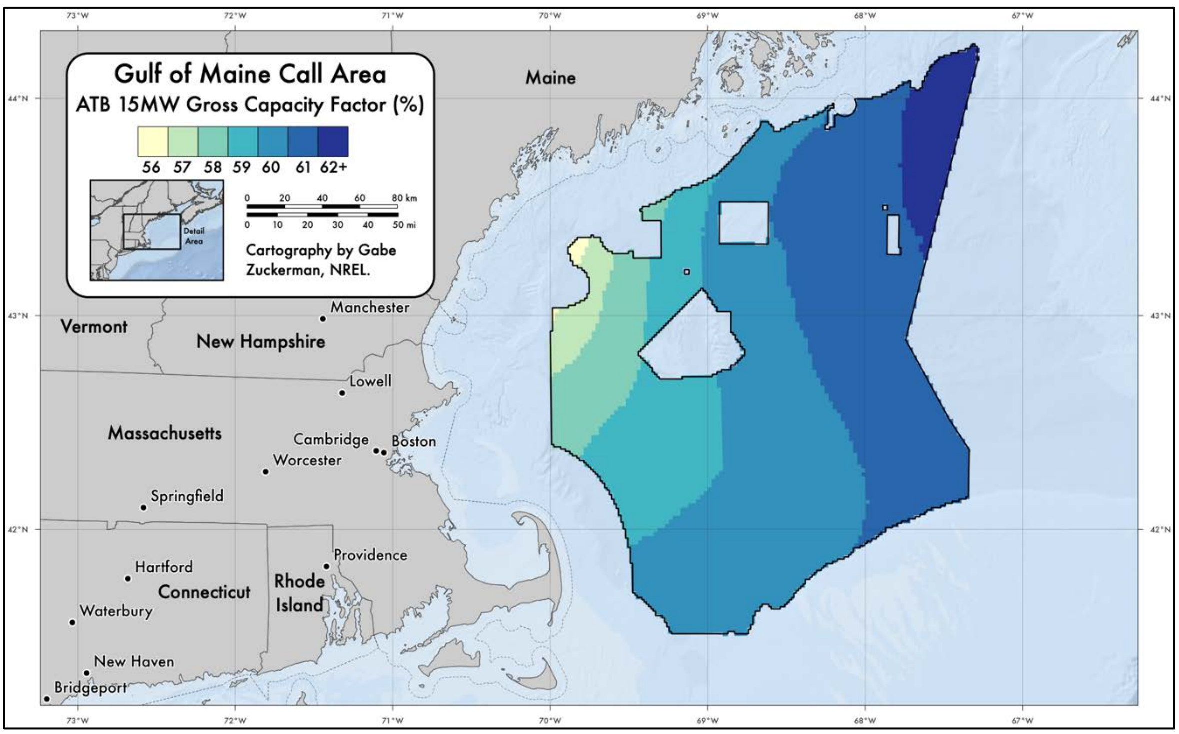

Figure 7. Gross capacity factor for the Gulf of Maine using the 15-MW NREL reference wind turbine. ***Image from NREL***

Figure 8 quantifies the GCF for both depth and distance from shore. Depth bins were set at 60 m (same as Figure 4) and distance to shore bins were set at 50 km, with a minimum distance of 5 km (2.7 nm) and a maximum distance of 218 km (118 nmi). Distance to shore is the distance to the nearest landmass, including small islands.

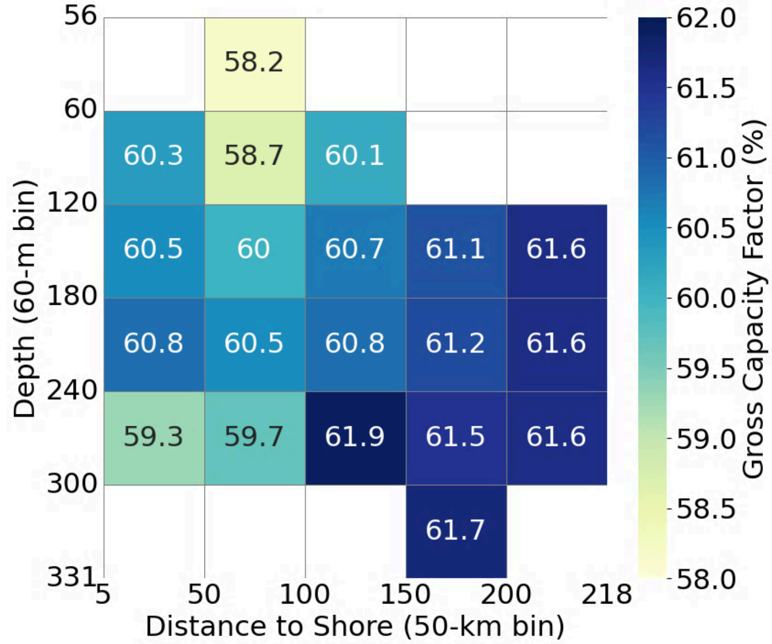

Figure 8. Mean gross capacity factor (%) for the 15-MW Annual Technology Baseline wind turbine by distance to shore and water depth in the Gulf of Maine Call Area

The gross capacity factors range from 58.1 to 61.6 in the chart, indicating that excellent power production is possible across the Call area. As the map shows, the highest GCF values are in the bins that are farthest from shore but the variation across the Call Area is only about 6%. In other words, all sites have excellent potential for wind energy production.

2.5 Waves and Extreme Weather

2.5.1 Wave Climate

The mean significant wave height, or the average height of the highest third of waves, from 2002 to 2022 in the Gulf of Maine ranges from roughly 1-2 m, with generally increasing wave heights at greater distances from shore (Hersbach et al. 2020). The National Data Buoy Center operated by the National Oceanic and Atmospheric Administration (NOAA) maintains and operates long-term measurements of physical surface conditions of meteorological and ocean data across coastal regions of the United States. The National Data Buoy Center buoy 44005 (43°11.37’ N, 69°8.38’ W) located inside the Call Area recorded data for a 32-year period from December 16, 1978, through December 31, 2009, in the Gulf of Maine, east of Portsmouth, New Hampshire. The mean significant wave height during this period at this location was 1.6 m, with a standard deviation of 1.0 m (Viselli et al. 2015). Extreme significant wave heights recorded were 7.0 and 8.3 m, with return periods of 1 and 5 years, respectively. We calculated 100-year events by extrapolation from the measured data to have a significant wave height of about 10.0 m. These peak wave periods are estimated to be about 12.3, 14.1, and 16.7 seconds for a 1-, 5-, and 100-year return period, respectively (Viselli et al. 2015). A more recent analysis of extreme wave heights for a 50-year return period may exceed 15 m and are associated with the tropical cyclones that can travel northward into the Gulf of Maine and are accompanied by the extreme observed wind speeds (Barthelmie et al. 2021).

2.5.2 Extreme Climate

The Gulf of Maine is subject to both tropical cyclones (hurricanes) and extratropical cyclones (also known as Nor'easters). Storm surge, heavy winds, and large waves occur in both types of storms, but hurricanes and Nor'easters are fundamentally different. A Nor'easter is a "cold core" system that has a center colder than the surrounding air, and it forms outside of the tropics. It is associated with changes in temperature and humidity, as well as cold and warm fronts, and can have its highest winds far from the center of the storm, which does not have a well-defined eye (Berman and Nemunaitis-Monroe 2012). Nor'easters typically occur between October and April, and in association with El Nino events with some influence from the Pacific decadal oscillation (Hirsch et al. 2001). They are large storms and get their name from the winds that typically come from the northeast.

Hurricanes, or tropical cyclones, form over a tropical ocean and typically occur from June to November, with August and September being peak hurricane months (Berman and Nemunaitis-Monroe 2012). Unlike Nor'easters, the wind speeds in hurricanes are greatest near the surface and can weaken over colder water as they travel further north. For this reason, Maine typically sees lower-category hurricanes. However, as the Earth has been warming in recent years, there has been a northward trend of hurricane storm tracks (Baldini et al. 2016). In addition, an increase in the intensity of tropical cyclones in the Atlantic Ocean is expected as the sea surface continues to warm (Collins et al. 2019; Mann and Emanuel 2006). Hurricanes are less frequent in the Gulf of Maine than Nor'easters, happening roughly once every 5−10 years, whereas Nor'easters occur 20−40 times per year. As such, in the Gulf of Maine extreme waves and winds are more often associated with Nor'easters than hurricanes (Barthelmie et al. 2021). Extreme wind gusts from extratropical cyclones can exceed 70 miles per hour and hurricane wind speeds in Maine have exceeded 75 miles per hour (Emanuel n.d.). However, there is no evidence that wind gusts from either of these storm types would exceed the 156-mile-per-hour extreme gust specified by the International Electrotechnical Commission (IEC) design conditions for a floating Class 1 offshore wind turbine (Simonson 2020; IEC 2023).

3 Floating Offshore Wind Energy Technology

3.1 Global Status

The global markets for floating offshore wind energy are growing rapidly because it can be deployed in deeper waters farther from shore where there are many more siting options. In the United States, about two-thirds of the total technical offshore wind resource is in water depths greater than 60 m where floating technology is thought to be more economical than fixed-bottom technology. In Europe, 80% of the resource is in water depths where the resource is more suitable for floating wind (Musial et al. 2022). At the end of 2021, the total floating wind pipeline was over 60 GW, based on projects that have announced their planned capacity (Musial et al. 2022) with 123 MW of capacity installed. Experience from these pilot-scale projects will de-risk larger commercial-scale floating wind development, which may begin in Asia as early as 2025, with expectations that economies of commercial scale will accelerate cost reduction. Figure 9 shows the cumulative floating offshore wind capacity by country based on developer-announced commercial operation dates through 2030. Note that the figure shows an industry expectation of a worldwide commercial expansion of floating offshore wind energy to begin about 2025, with the commissioning of over 39,000 MW of announced projects by 2030. Historically, developer-announced project completion dates tend to be overly optimistic in predicting actual future deployment. Independent industry forecasts indicate deployment levels closer to 10 GW may be more realistic for 2030. Nevertheless, the general trend toward commercial growth of floating wind worldwide is more certain.

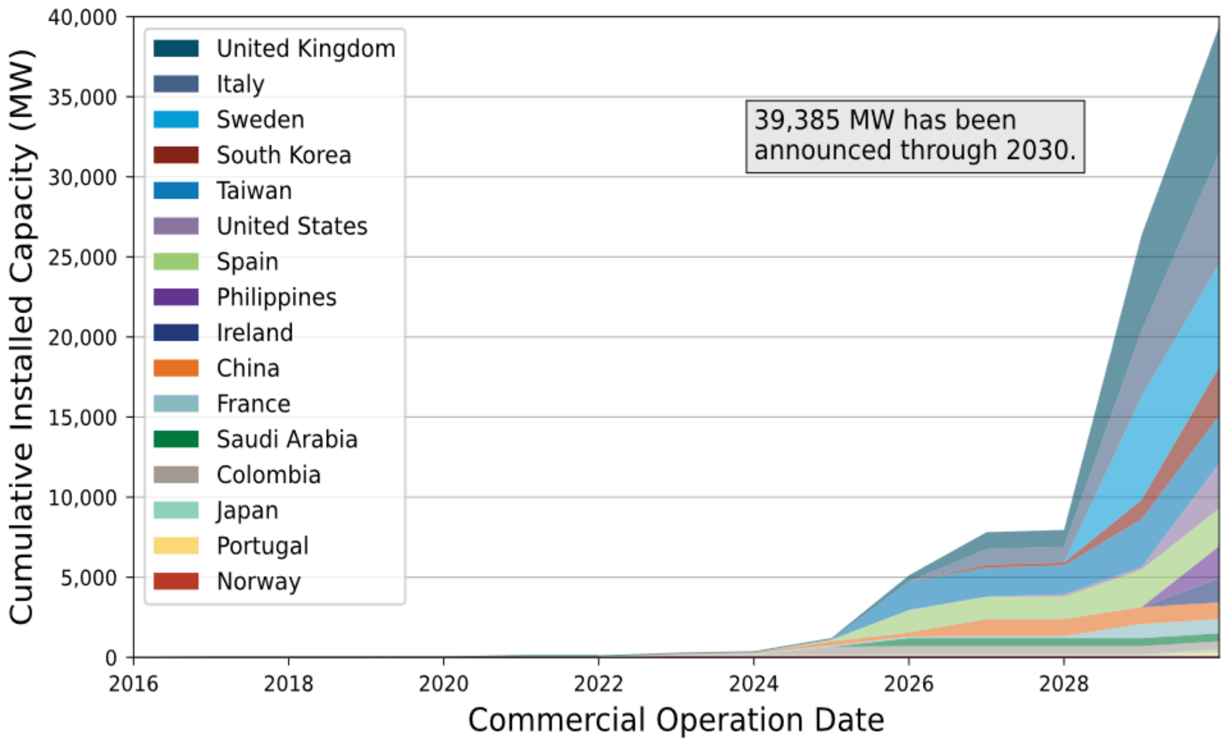

Figure 9. Cumulative floating offshore wind capacity by country based on announced commercial operation dates through 2030. ***Image by NREL***

Figure 10 illustrates three types of floating wind turbine substructures being developed. Each of these substructure types have evolved or been adapted from deep-water oil-and-gas production platforms.

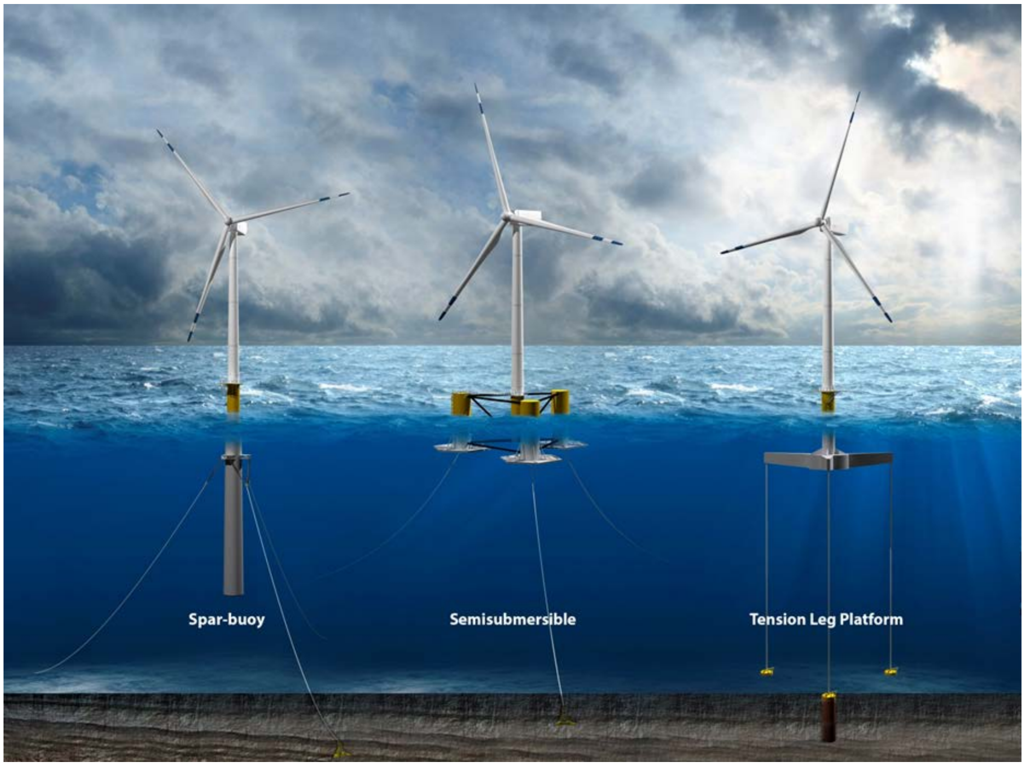

Figure 10. Substructure types for floating offshore wind systems including the spar buoy, semisubmersible, and tension-leg platform. ***Illustration by Josh Bauer, NREL***

All these concepts have advantages and disadvantages. The semisubmersible design depends primarily on buoyancy and water plane area to maintain static stability. It has the key advantage of being stable enough to support a wind turbine before connecting the mooring lines. Because of its shallow draft, the system is the easiest to deploy because it can be fully assembled at quayside and towed to its open-ocean operating site with a minimal amount of expensive labor at sea. Semisubmersibles can also be disconnected from their moorings at sea and towed to shore for maintenance at quayside to avoid expensive lift vessels that may otherwise be required for some repairs of major components. The University of Maine (UMaine) VolturnUS floating platform technology is a concrete semisubmersible (three outer columns plus a center column) that has been developed for Gulf of Maine conditions (see Section 3.2). Most semisubmersible designs use steel, including the well-established Principle Power WindFloat and the newer Ocergy platform. Several other developers are converging on simpler three-column semisubmersibles with rectangular pontoons. Generally, the focus of semisubmersible foundation developers is to create designs to maximize serial production and ease of launching from available port facilities.

Other substructure types include the spar buoy, which is stabilized by ballast and has a deeper draft (i.e., the substructure penetrates deep below the water surface), thereby avoiding surface wave action (Musial et al. 2020). A 30-MW pilot-scale floating project—the world's first commercial floating offshore wind power plant—was deployed by Equinor in October 2017 off

Peterhead, Scotland, using spar technology with a draft near 100 m. The deep draft of the spar prevents it from being a practical option for the Gulf of Maine because it cannot be assembled in any existing ports under consideration without major design modifications. Hybrid spars, which involve a suspended ballast structure that allows deployment similar to semisubmersibles, include the Stiesdal TetraSpar (steel) and the Esteyco WHEEL (concrete) which could be feasible in the Gulf of Maine.

The tension-leg platform (TLP) gets its static stability from mooring-line tension but is generally unstable until the mooring lines are attached. In addition, these substructures require high-capacity vertical load anchors that can be more expensive and require more engineering sophistication. While TLPs are more difficult to deploy, they are stable once installed and have a much smaller footprint on the seabed that does not increase with depth. The unstable deployment challenge makes it difficult to fully assemble them at quayside without adding temporary auxiliary ballast which could add cost. TLPs are less established (no existing megawatt-scale examples to date) but could apply to the Gulf of Maine if they are advanced.

In addition to these three concepts, barge-type platforms have also been developed and deployed in some global sites using various strategies to resist excess motion from wave loading. Barges can be fabricated locally and at a reasonable cost but are challenged by wave action that can create high-nacelle accelerations and higher fatigue loads if not mitigated.

Some promising hybrid variations of the classic archetypes combine the physical principles of operation with practical constraints to reduce costs. Examples of some of these practical design constraints include limiting wind turbine nacelle accelerations, reducing labor at sea, and accommodating the existing marine infrastructure in system designs including the emerging supply chain (Barter et al. 2020).

3.2 University of Maine Floating Offshore Wind Energy Technology

Maine's interest in floating offshore wind energy technology was sparked by spiking oil prices, energy security concerns, opportunities for economic benefits, growing concerns about climate change, and recognition that current fixed-bottom technology would not be suitable in the Gulf of Maine due to its deeper water. Since 2008, UMaine has been developing specific floating platform designs with similar characteristics that are targeted for the single-turbine New England Aqua Venus project and the Maine Research Array. UMaine's initiative led to state legislative action, and state financial support that was bolstered by DOE funding. This enabled the university to take a leadership role and embark on a novel quest to develop floating offshore wind energy technology, with the prospect of being the first to deploy a full-scale floating wind turbine in the United States.

The New England Aqua Ventus (NEAV) project is an 11-MW pilot-scale project that officially began in 2012 after UMaine was awarded over $50 million in funding under a cooperative agreement as part of the DOE Offshore Wind Advanced Technology Program (USDOE undated). Under this program, a novel concrete semisubmersible floating foundation design was developed known as the VolturnUS, which uses proven industrialized concrete construction methods. The VolturnUS concept was built at one-eighth scale and tested in the sheltered waters of Penobscot Bay in 2013 to demonstrate its feasibility. Relative to steel semisubmersibles, the

VolturnUS design has greater weight and size, but the use of concrete may better suit local production abilities and lower embodied emissions.

In 2014, the Maine Public Utilities Commission approved a term sheet between Central Maine Power Co. and the NEAV project, under which Central Maine Power would buy electricity generated by the project for 20 years. In January 2018, the Maine Public Utilities Commission reevaluated the terms, and in June 2019, legislation was passed directing the Maine Public Utilities Commission to approve the contract, resulting in a power purchase agreement that was awarded in November 2019 (Shumkov 2019).

The NEAV demonstration project is planned to be deployed in state waters off the southern coast of Monhegan Island in about 2025. The project received a significant boost in August 2020 when it was announced that Diamond Offshore Wind, a subsidiary of the Mitsubishi Corporation, and RWE Renewables, would invest a combined $100 million in the project, although in July 2023, RWE announced that it was selling its shares to Diamond Offshore Wind (RWE 2023). The NEAV demonstration project is the most advanced full-scale floating wind turbine project in the United States and is likely to be the first of its kind installed in U.S. waters. It promises to help the industry evaluate the challenges and impacts of nascent floating wind energy technology, and to help develop best practices and enable coexistence with other ocean users. Moreover, it is slated to be the flagship for the next generation of floating offshore wind technology that will be deployed at the Maine Research Array (MeRA).

3.3 Maine's Offshore Wind Strategy

The first effort to deploy floating wind turbines in the Gulf of Maine came in October 2011 when the Norwegian oil company, Statoil North America Inc. (now called Equinor) submitted an unsolicited lease application to BOEM for a commercial lease to deploy five 5-MW wind turbines in federal waters (BOEM 2011). BOEM reviewed the lease application and determined that Statoil was legally, technically, and financially qualified to hold a commercial lease on the Outer Continental Shelf, but the proposal was not supported by the LePage administration and Statoil eventually withdrew the application.

Maine's strategy for floating offshore wind was later articulated by UMaine during the early stages of the DOE Advanced Technology Demonstration program for Aqua Ventus and has been largely adopted in principle statewide (UMaine 2013). Maine's floating offshore wind energy pathway began with the one-eighth-scale demonstration of the VolturnUS, which successfully demonstrated the concrete semisubmersible platform technology that has been integrated into the design of the full-scale 11-MW single turbine demonstration planned for deployment in state waters near Monhegan Island (NEAV) in 2025. Similarly, the NEAV project is intended to inform the larger Maine research array that will in turn answer key questions about the integrity of the technology and the compatibility with other ocean users prior to gigawatt-scale commercial leases and the generation of bulk floating offshore wind power for northern New England. This progression in project scale was envisioned and proposed to enable transparency and lower risk for Maine's key stakeholders and the commercial leaseholders.

3.4 Maine Research Array

In October 2021, the State of Maine proposed a research lease to BOEM for 9,900 acres in federal waters approximately 40 nmi east of Portland, Maine. The state-proposed research lease is the L-shaped orange polygon inside the BOEM-defined black rectangle in Figure 11. BOEM has some flexibility to move the research lease within this black box. The objective is to deploy new floating technology at a subcommercial scale (up to 144 MW)[2] to investigate potential conflicts and technical issues before expanding to gigawatt commercial-scale projects. As part of this effort, BOEM published a "Determination of No Competitive Interest" on March 20, 2023. The status as of June 2023 is that BOEM is moving forward with the research application process. The next steps include initiating an environmental review of potential impacts from leasing activities associated with the proposed research lease, siting the lease within the area identified in the Request for Competitive Interest, and negotiating lease terms. This process is expected to be completed by the end of 2023.

MeRA could potentially address the five objectives of the 2023 Maine Offshore Wind Roadmap including 1) building the offshore wind supply chain to support economic growth, 2) harnessing renewable energy to fight climate change, 3) advancing Maine-based innovation to compete globally, 4) supporting the coexistence of Maine's seafood industries and coastal communities, and 5) protecting Maine's environment, wildlife, and fisheries ecosystems.

In 2021, the Maine State Legislature directed the development of the Maine Offshore Wind Research Consortium, requiring significant representation of the commercial fishing industry on its advisory board and establishing a fund to support the consortium's activities. The consortium held its first meeting on February 14, 2023. Through the consortium and related efforts, the MeRA will allow Maine to investigate best practices for mitigating conflicts with other ocean users and lowering technical risks at a smaller scale before full-scale commercial development commences.

Maine's approach is to build a pathway to commercialization through prototype development with the NEAV 11-MW demonstration project, and then through the 144-MW research array before embarking on a full utility-scale project. This is a conservative approach that is intended to allow stakeholders to observe the technology in operation and ask questions before development begins, but this approach is not tied to commercial leasing so it will have the most value if MeRA can be deployed first.

[2] Although a 144-MW wind power plant is small compared to today's utility-scale projects, this array has the potential to provide electricity for over 600,000 Maine households based on the 2021 average energy use reported by the Energy Information Administration, assuming a net capacity factor of 45% (Energy Information Administration 2023).

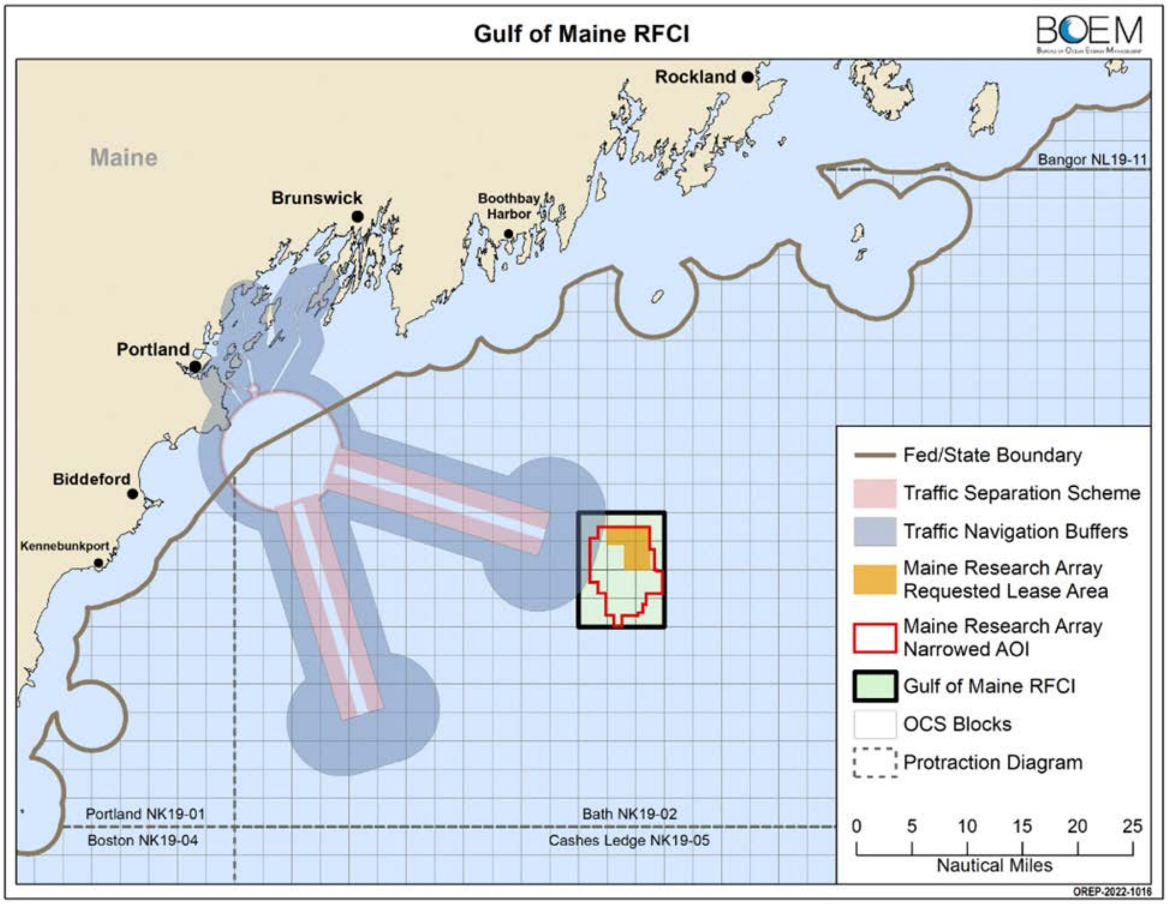

Figure 11. Map of Maine Research Array proposed lease area. ***Image from BOEM***

Counter perspectives are that the research array is unnecessary because the feasibility of floating offshore wind energy has already been demonstrated globally, project costs will be higher for the smaller array, and the urgency to address climate change on a larger scale should take precedence. Further, the offshore wind energy industry has matured to the point where incremental technology changes such as larger wind turbines no longer trigger the need for pilot-scale demonstration because the core technology is still bankable.

But floating offshore wind energy is still at a nascent stage and some of the regional questions about its impact on the Gulf of Maine may best be answered by conducting controlled, transparent, and collaborative research at a smaller scale (and higher cost), which may have greater long-term benefits. For example, when the 30-MW Block Island Wind Farm in Rhode Island was deployed in 2016, the industry's confidence in fixed-bottom offshore wind increased, helping drive the present surge in commercial offshore wind energy development in the United States. So, if the 11-MW NEAV is successfully deployed and becomes the first U.S. floating offshore wind turbine, investor and public confidence and acceptance will likely rise. The best estimates for development timelines indicate that demonstration of both the 11-MW NEAV and MeRA would likely begin before larger commercial development in the Gulf of Maine because the MeRA leasing schedule is more than 1 year ahead of the commercial lease schedule at this time. This head start could potentially enable MeRA to inform commercial development, lower project risk, and develop strategies to facilitate coexistence with stakeholders.

There is additional vulnerability to Maine's commercialization plan due to limitations in procuring large offshore wind turbines in small quantities. Based on private conversations with industry developers, the cost and availability of a single turbine from original equipment manufacturers with relevance to the future floating market (e.g.,11-MW scale) will be challenging. Therefore, there may be a dependency between the NEAV project and the MeRA array to lower costs, yet these two projects represent the best opportunity for Maine to establish an early foothold in this industry. Beyond these two pilot projects, larger commercial projects will compete for procurements and offtake agreements over the multi-state region. These agreements will likely be negotiated with states that have procurement policy incentives, but closer to current market rates.

In May 2022, Pine Tree Offshore Wind filed for a power purchase agreement of more than a billion dollars with Maine Public Utilities to develop a wind plant on the Maine research lease. Pine Tree Offshore Wind is a partnership between Diamond Offshore Wind and RWE Renewables that is committed to advancing the VolturnUS concrete foundation technology that will be demonstrated at full scale in NEAV (Maine Public Utilities Commission 2022; Turkel 2022). It is not clear how Diamond Offshore Wind's acquisition of the RWE shares in the NEAV and MeRA projects will affect this partnership going forward.

Commercial offshore wind leasing in the Gulf of Maine is likely to follow NEAV and MeRA by no more than a couple of years. Under BOEM's commercial leasing, competitive auctions will be held for multiple lease areas that may be over eight times larger than the 9,900-acre research array. Exclusive site control and development rights will be granted to the lease auction winners. These future lease holders may benefit from the experience gained in MeRA but will not be obligated to use any of the technology. Future regulations could also potentially adopt some of this knowledge as best practices, particularly regarding coexistence; however, BOEM and the Bureau of Safety and Environmental Enforcement have no obligation to do so.

Therefore, the research lease would have high value to the state of Maine, not just to inform stakeholders, but to anchor key supply chain activities and infrastructure to support the $50+ billion[3] emerging floating offshore wind energy market in the Gulf of Maine and to potentially provide these industrial capabilities on a national scale. However, the value of MeRA to both Maine and the wider floating offshore wind community would diminish as U.S. and global commercial floating wind development catches up, because the primary value of MeRA is to gain knowledge and experience in advance.

3.5 Technologies To Reduce Social and Environmental Impacts

Federal waters of the Call Area overlap with existing fishing grounds, as the Gulf of Maine is used extensively for commercial and recreational fishing. Floating wind plants often have larger footprints on the seabed and in the water column due to their mooring systems, which can extend horizontally a large distance from the wind turbines. This spread of the mooring lines, along with intra-array power cables that run between the turbines, is required to stay within a lease area, which is a challenge for developers trying to maximize the energy capture within that space. The

[3] The $50-billion market is a conservative estimate of the total revenue that 17.9 GW of wind energy deployment would generate (17.9 GW is the estimated deployment based on 2050 planning targets from ISO-NE).

spread of the mooring and anchor systems can also affect fishing activities, particularly due to the uncertainty of their location below the surface. BOEM, the state of Maine, and the technology developers are working on strategies to minimize the impacts to the commercial fishers and other stakeholders. Typically, water depth has the largest impact on the anchor circle diameter for a given wind turbine's mooring system. However, in the Gulf of Maine, the water depths are relatively constant (ranging between 100 and 300 m) compared to other regions. So the type of mooring system has a much larger influence on the anchor circle diameter than water depth.

Mooring systems can be configured in a variety of ways (Figure 12), with anchor spacing distances that vary from 1 km down to only the width of the platform (with vertical mooring lines attached to anchors directly below the platform).

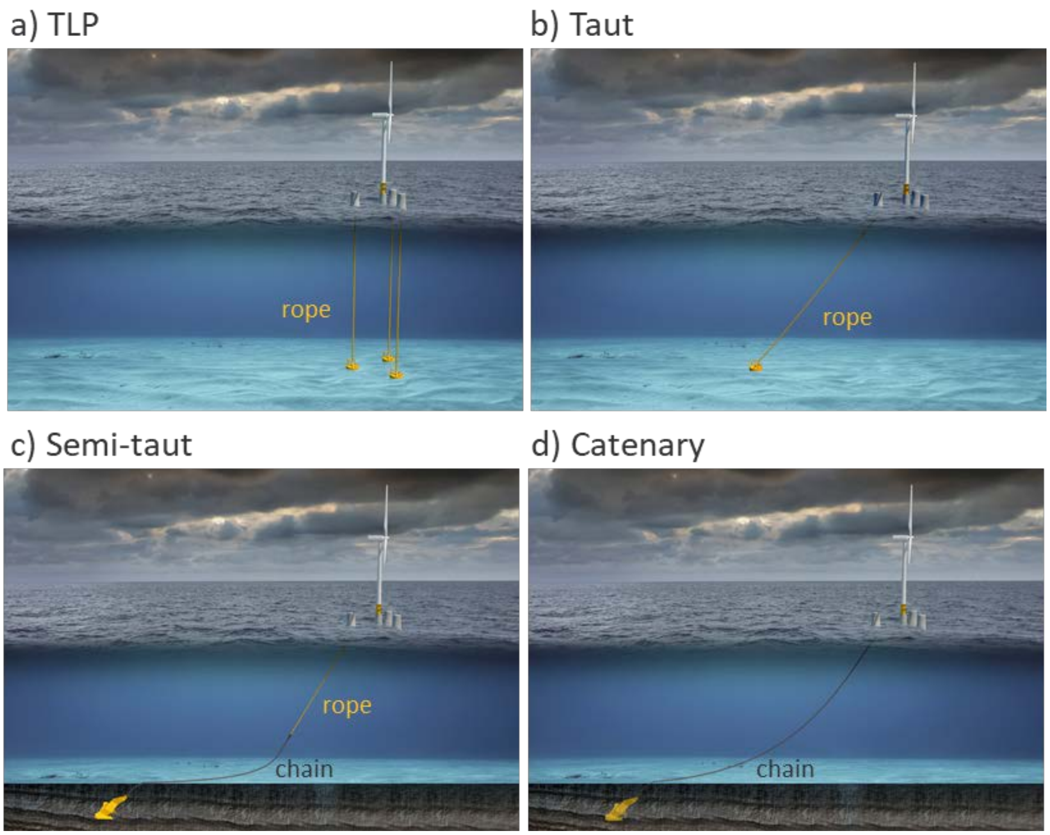

Figure 12. Four typical mooring line configurations. ***Illustration by Joshua Bauer, NREL***

Catenary mooring (Figure 12d) lines are the simplest and most conventional approach but have the largest anchor circle and therefore occupy the largest space on the seabed. They comprise a long length of heavy chain and have a relatively slack profile to accommodate the motions of the floating platform. The long length and heavy weight of chain along the seabed is needed to prevent vertical loads on the anchors, allowing the use of low-cost, drag-embedment anchors. Catenary chain mooring line configurations will be effective in the water depths in the Gulf of Maine (e.g., 200 m) but in deeper waters (e.g., Pacific Ocean) the longer lines will suffer from excessive weight, and in shallow waters (e.g., 60- to 90-m depth), the risk of high tensions and snap loads increases.

Semitaut mooring lines (Figure 12c) typically feature a length of synthetic fiber rope (such as polyester or nylon) for the portion of the mooring line that does not touch the seabed, combined with a catenary chain section for the portion that contacts the seabed. The use of fiber rope adds elasticity to the mooring line, allowing a smaller anchor footprint with less chain along the seabed. The elasticity of the fiber rope acts as a spring that helps reduce tension peaks in shallow water, and its light weight makes this configuration suitable for deeper waters.

Taut mooring lines (Figure 12b) use synthetic fiber rope almost entirely and keep a taut, nearly straight profile from the anchor to the floating platform. No chain is needed because the mooring line does not contact the seabed. In this configuration, anchors experience significant vertical loads, requiring vertical capacity such as suction piles. All taut mooring system compliance comes from rope elasticity, so the rope material type, diameter, and length must be designed to meet the required station-keeping stiffness. For example, deep water requires stiffer ropes, such as polyester, whereas shallow water applications require more compliant materials, like nylon.

Vertical mooring lines are used in tension leg platforms (TLP) (Figure 12a). They require high-capacity vertical load anchors and may use synthetic rope as tendons. TLPs would have the smallest footprint on the seabed which is desired, but the wind industry has not yet deployed a TLP at commercial scale. The primary drawback is that they are difficult to deploy because they are hydrodynamically unstable with a turbine installed unless the mooring lines are connected, increasing the complexity and cost of deployment at a conventional port facility. Hybrid designs that integrate temporary auxiliary buoyance systems during assembly and tow-out may create feasible solutions that enable TLP designs.

To reduce mooring system footprints and reduce challenges with fishing coexistence, UMaine has focused heavily on taut and semitaut mooring configurations for its VolturnUS platform design. Based on an NREL analysis of the UMaine semitaut configurations, these mooring systems can reduce the diameter of the mooring system footprint by around 50% relative to catenary configurations with negligible change to the overall system cost. Discussions with commercial fisheries participants and organizations indicate that the footprint reduction provides a modest increase in the perceived accessibility and acceptability of a floating wind farm in the Gulf of Maine, though many questions and concerns around these interactions remain that may potentially be the subject of research at NEAV and MeRA (Green et al. 2023).

The maximum height of offshore wind turbines may be more than 200 m off the water surface to the top of the rotor which can potentially be seen from long distances in good weather. To mitigate viewshed concerns, the BOEM Call Area eliminated most areas of 20 nmi or less. This approach will avoid most visual concerns from the mainland, although some offshore island communities could have greater visibility of the projects if the lease areas are near the western edge of the Call Area. BOEM's Call Area also avoids many of the most heavily trafficked fishing grounds. In addition, Maine has placed a prohibition on commercial offshore wind energy in state waters (0 to 3 nmi from any state land).[4]

[4] The prohibition excludes demonstration projects in state waters such as NEAV.

4 Offshore Wind Energy Cost in the Gulf of Maine

The levelized cost of energy (LCOE) is one of the primary metrics that determines the viability of a particular resource, but the value of offshore wind energy is often measured in other ways as well, including economic growth and stability, energy security, social justice, and compatibility with other stakeholders and the natural environment. The federal government has recently taken steps to make floating offshore wind energy one of its priorities in the future U.S. energy strategy. On September 15, 2022, DOE announced the Floating Offshore Wind Shot,™ which targets cost reductions to $45 per megawatt-hour (MWh) by 2035. In addition, the administration announced it will advance leasing in deeper waters to enable the deployment of 15 GW of floating wind energy capacity by 2035 (DOE 2022). These actions include the Gulf of Maine, which has a floating wind resource potential estimated to be 150.4 GW in the Call Area.

4.1 Status of Current Assessments

The cost of offshore wind energy in the Gulf of Maine has been documented in several previous studies. In 2016, NREL published the first national assessment of offshore wind cost of energy that included Massachusetts, New Hampshire, and Maine, highlighting the large resource in the Gulf of Maine and showing costs for floating wind energy that were comparable to fixed-bottom sites (Beiter et al. 2016). A follow-on study in 2017 looked at the "economic potential" of offshore wind nationally by comparing the LCOE to the levelized avoided cost of energy[5]. The levelized avoided cost of energy can be considered a proxy for the prevailing cost of electricity in a particular region. The 2017 study found that Maine had over 65 GW of economic potential for the reference year of 2027, the highest of any state in the country, due to its relatively high energy prices and potential for low-cost technology (Beiter et al. 2017).

One of the major challenges in developing cost models for floating wind energy is that there is not yet a commercial-scale market baseline for LCOE. Therefore, commercial costs for gigawatt-scale wind farms must be assessed with cost models that extrapolate costs from a limited number of pilot-scale projects (10 to 50 MW). Specifically, the cost differential between a small-scale, first-of-its-kind project like the 11-MW NEAV and a utility-scale project using mature technology was investigated in two other NREL reports in 2018 and 2020, respectively (Musial 2018; Musial et al. 2020). These reports were conducted for UMaine and the DOE as part of the Advanced Technology Demonstration project to highlight the benefits of project upscaling. The reports focused on providing updated estimates for decision makers that seek to understand the range of costs associated with the commercial scaling of the 11-MW NEAV project to gigawatt-scale commercial wind in the Gulf of Maine.

The 2020 study used NEAV substructure costs and technology assumptions provided by UMaine, and NREL's wind turbine and balance-of-system assumptions. The NREL models estimated that LCOE could decline to $74/MWh by 2027 and $57/MWh by 2032. Lower costs in the 2020 study were attributed to technological and commercial improvements applicable to the

[5] Levelized avoided cost of energy is a metric used to approximate the electric system value of a generation technology operating in a given location over its expected lifetime and is commonly expressed in dollars/megawatt-hour. It is defined as the revenue that an offshore wind generator can earn (reflecting its marginal economic value) without considering subsidies.

wind turbine design, effects of larger 15-MW-class turbines on the balance of station, financing terms commensurate with fixed-bottom projects, and lower costs for the floating platform, array, and export cables. Gigawatt-scale plant costs modeled using the NEAV assumptions were found to be approximately five times lower than the pilot-scale demonstration project cost that was estimated at $300/MWh. This difference in costs illustrates the huge advantage a gigawatt-scale[6] project has over a small 11-MW project, as well as the rapidly advancing technology and market conditions that are enabling offshore wind energy deployment to compete globally. These lower $/kilowatt costs for the large-scale array also assume that the market and supply chain have matured sufficiently to achieve the economies of scale of the learning curve. This assumption may be overly optimistic for the 2032 timeframe because the pace of industry maturity has been slower than anticipated and this cost reduction depends heavily on the industrial floating supply chains being built in northern New England. Through land-based wind energy experience, we have learned that industrialization and mass production can be the most important lever to drive the floating offshore wind costs down to those estimated by Musial et al. (2020) and the $45/MWh targets by 2035 set by the DOE Floating Offshore Wind Shot (Wiser et al. 2022; Musial et al. 2020; USDOE 2022). In addition, the first movers in the development of ports, infrastructure, and the manufacturing of Tier 1 and 2 components may have an advantage in securing jobs and economic benefits from early commercial procurements even before the full cost reductions are realized.

As of April 3, 2023, the 2020 Musial et al. cost study provides the best cost information for offshore wind energy in the Gulf of Maine, however a national offshore wind cost study is underway and will be published by NREL and BOEM in late 2023. This study is expected to provide more accurate cost updates.

4.2 Distance From Shore Cost Impacts

The Gulf of Maine is relatively wide relative to other areas in the United States where offshore wind is being considered. In most areas, the continental shelf drops off rapidly, but the Gulf of Maine has a relatively flat bottom. The distance to shore of the Call Area boundaries range from 5 to 218 km (3 to 117 nmi). Therefore, the siting of projects farther from shore may be less constrained technologically, although it is known that projects sited farther from shore will cost more and may have greater environmental impacts due to increase vessel traffic. Although projects sited closer to shore will cost less, they may overlap more with other ocean use activities such as commercial fishing. This section provides a qualitative assessment of these trade-offs (Table 1).

[6] Note that the 2020 study examined a 600-MW plant size and project sizes are now averaging closer to 1,000 MW (i.e., 1 GW). The costs advantage for a 1,000-MW plant size was found to be about 2%.

Table 1. Cost Factors With Increasing Distances to Shore

Negative Factors With Greater Distance to Shore	Positive Factors With Greater Distance to Shore
• Operational expenditures	• Higher energy yield potential
• Export cable cost	• Possible multigigawatt plant aggregations
• Installation costs of wind turbines, cables, anchors, moorings, and substations	• Fewer conflicts with commercial fishing
• Emissions from ships	
• Exposure to whales	
• Turbine downtime	
• Electrical losses	
• Safety risk to crews	

4.2.1 Negative Cost and Performance Factors

Negative cost and performance factors include:

- **Operational expenditures.** Wind plant maintenance will be performed by shore-based crews that need to transit the distance from the operations and maintenance port to the wind plant, which is generally done with crew transfer vessels (CTVs) for projects located closer to shore or with service operation vessels (SOVs) if the project is far from shore. SOVs avoid the transit back to shore daily and can help offset the increasing cost of maintenance with distance from shore. The cost of maintaining these wind plants is directly related to the time and effort to reach the project. Weather windows and transit times can be disproportionately affected by siting at farther distances.
- **Export cable cost.** Export cable costs are directly related to their length and make up a large portion of the capital expenditures. Export cables cost about $2 million per mile, but developers are reporting that actual costs may be even higher.
- **Installation costs for the wind turbine, cables, anchors, moorings, and substation.** For floating offshore wind systems, the turbine and substructure are assumed to be assembled and commissioned in a port at quayside. This procedure provides a significant advantage for floating wind over fixed-bottom systems; however, there is still a significant cost in towing the assembled units to their station at sea and connecting them to the mooring and anchor system. In addition, anchor and mooring installation will use high-cost vessels and labor, and capital costs will increase with the distance to shore.
- **Emissions from ships.** Most ships that are used to install and service offshore floating wind plants still run on fossil fuels. Therefore, longer transit times and distances will result in greater emissions.
- **Exposure to whales.** Whale migrations are known to intersect with possible transit routes used for future offshore wind plants. Increased vessel traffic will occur with offshore wind energy projects at greater distances from shore, which could increase the probability of a whale being struck by a vessel enroute. Mitigation strategies have been proposed to limit vessel speeds that will increase costs for installation and maintenance even further. As of March 2023, there are no current or proposed static speed restrictions within the Call Area, though a 2022 proposed rule from the National Marine Fisheries

Service included the potential to establish a dynamic speed restriction framework that could temporarily slow vessel traffic in areas where sightings are more intermittent, including the Gulf of Maine.

- **Wind turbine downtime.** Increasing distances required for crews to access wind turbines means that faulted or disabled turbines will take longer to return to service. Downtime is lost energy that cannot be recovered and will ultimately raise costs.
- **Electrical losses.** The export cables from the project to shore will absorb some of the energy generated in resistive losses. The longer the cable, the more losses will be incurred. One mitigating factor is that for longer distances, developers will likely shift to high-voltage direct current (HVDC) systems, which will have lower losses per mile than high voltage AC systems.
- **Safety risk to crews.** Wind power plants located farther from shore will expose workers to longer durations and more hours spent at sea. Longer distances also increase weather uncertainty, which can increase the probability that crews will encounter severe weather events. This increased exposure will translate to a higher risk of injury.

4.2.2 Positive Cost and Performance Factors

Positive cost and performance factors include:

- **Higher energy yield potential.** Wind resource assessments conducted at NREL indicate a significant wind speed gradient with distance from shore that results in a GCF that ranges from 58% on the western edge (close to shore) to 62% on the eastern edge of the Call Area. This higher productivity would offset some of the additional cost and losses.
- **Possible multigigawatt plant aggregations.** Some additional economies of scale may be possible by aggregating multiple gigawatts of offshore wind farther from shore. This aggregation could provide more opportunities for shared infrastructure to reduce costs, but these scenarios were beyond the scope of this study.
- **Lower conflicts with commercial fishing.** Commercial fishing activity is greater in regions closer to shore, therefore placing floating wind plants farther from shore could reduce potential conflicts to some degree. However, there is a potential for these two industries to coexist in the same space as well, but these opportunities have not been thoroughly studied.

Another factor that gives the Gulf of Maine an advantage over most other regions on the U.S. Outer Continental Shelf is the region's relatively flat bottom. As distance from shore increases, the water depth does not change significantly in most areas, which tempers the increase in cost with depth seen in most other regions. In most other regions, water depth would be considered a negative cost factor with distance from shore.

5 Electric Grid

5.1 State and Regional Carbon-Reduction Scenarios

Floating offshore wind in the Gulf of Maine has been identified as one of the primary renewable energy sources that can substantially reduce carbon emissions from the electric, heating, and transportation sectors in the New England region. The nation, along with five of the six New England states, have set ambitious targets to increase clean energy resources and reduce greenhouse gas emissions by 2050. Adjacent to the Gulf of Maine, Massachusetts has made statutory commitments to achieving net-zero greenhouse gas emissions by 2050 while Maine's current commitment is to reduce those emissions 80% below 1990 levels by 2050, and to achieve carbon neutrality by 2045 (State of Maine 2023a; DOE 2023b; White House 2021).

New England is overly reliant on natural gas to generate electricity and heat buildings, which is causing electricity rates to increase across the region and is contributing to energy security concerns across the region (State of Maine 2023a). Maine is the most heating-oil-dependent state in the nation, spending more than $4 billion a year to import these fossil fuels. Over the next few decades, the nation will see a dramatic shift away from the use of hydrocarbons and toward expanded grid electrification using renewable energy sources. This shift will entail electric cars, electrifying home heating with heat pumps, and the generation of green fuels such as hydrogen to power an array of industrial and transportation uses. In addition, this renewable energy transition may see a tripling of the amount of electricity generation, transmission and consumption within the national electric grid (Denholm 2022).

ISO-NE manages the generation and transmission of electricity throughout the six New England states. As offshore wind and other renewable energy sources are integrated onto the ISO-NE grid, there are many challenges with respect to the expansion of transmission and generating facilities while maintaining grid stability. This section summarizes several studies and reports by states and ISO-NE to help understand the regional planning strategies and some of the major challenges in the renewable energy transition.

The *2050 Transmission Study* (ISO-NE 2022a) and *Future Grid Reliability Study* (ISO-NE 2022b) provide a general overview of the issues that need to be addressed when planning the future electric grid in New England. The region's planning strategies are similar to those underway in other parts of the country, but the tactics vary by the quantity and quality of the available renewable energy resources, which are primarily centered around the use of wind, solar, and energy storage technologies. As such, the key strategies must include managing a large influx of new renewable-energy-generating sources and coordinating the grid's transmission system to maintain reliability with these sources. The transition to variable power sources requires a large amount of storage added to the system (generally modeled as batteries), which the present grid does not have. Some consideration is also given to dispatchable electricity imports from Canada.

Grid planning must consider peak and minimum load conditions, identifying needed transmission upgrades to prevent overloading, and examining vulnerabilities to avoid cascading outages, grid destabilization, and blackouts (ISO-NE 2022b). The estimated values of the primary generating resource capacities that were considered in the 2050 transmission study are provided in Table 2.[7][8][9][10]

Figures 13, 14, and 15 show the energy generation planning scenarios for ISO-NE the Gulf of Maine including Maine, Massachusetts, and New Hampshire, respectively. The figures illustrate the quantities of low-carbon generation expected by the year 2050 by state and the generation data are shown in megawatts. Offshore wind energy is broken down by floating offshore wind and fixed offshore wind. Because all of the Gulf of Maine Call Area would require floating offshore wind technology, it can reasonably be assumed that all floating offshore wind energy generation modeled by ISO-NE in these three states will come from the Gulf of Maine Call Area.[11]

Figure 16 shows the floating offshore wind generation quantities by state for the ISO-NE planning years of 2035, 2040, and 2050. These figures show the potentially large shift by New England states toward offshore wind in the Gulf of Maine, comprising about 44%, 24%, and 8% of the future energy supply for Maine, Massachusetts, and New Hampshire, respectively. In 2050, these planning numbers total 17.9 GW of floating offshore wind energy, which represents a significant energy supply and a market that is roughly $50 billion based on gross revenue.

Table 2. ISO-New England Generation Scenarios for 2035, 2040, and 2050 Planning

State	Resource Type	2035 (MW)	2040 (MW)	2050 (MW)
Maine	**Floating Offshore Wind**	**902**	**3,015**	**6,933**
	Land-Based Wind	2,433	2,433	2,433
	Ground-Mounted PV	3,432	3,432	3,432
	Natural Gas	1,550	1,550	1,550
	Nuclear	0	0	0
	Hydropower	667	667	667
	Biomass	342	342	342
	Storage	400	400	400
	Total	**9,726**	**11,839**	**15,757**
Massachusetts	**Floating Offshore Wind**	**302**	**2,667**	**9,791**
	Fixed-Bottom Wind	5,845	6,656	6,681
	Land-Based Wind	44	44	44

[7] The coal, diesel, oil, and solid waste resources are assumed to be retired by 2035 in this study.
[8] The generation portfolio of nuclear, hydroelectric, and biomass generating units are retained but are assumed to remain at the same value from the existing fleet out to 2050.
[9] The availability of these resources is adjusted based on the historical outputs from the 2019 weather year data.
[10] The 2,433 MW of onshore wind in Maine includes the request for proposal of 1,200 MW in Aroostook County and northern Maine.
[11] Massachusetts has modeled floating wind capacity requirements at about 13 GW, which exceed the ISO-NE planning capacity. The state is interested in possible floating wind areas to the south of Cape Cod.

State	Resource Type	2035 (MW)	2040 (MW)	2050 (MW)
	Ground-Mounted PV	1,219	4,406	16,200
	Natural Gas	6,009	6,009	6,009
	Nuclear	0	0	0
	Hydropower	307	307	307
	Biomass	18	18	18
	Storage	2,270	2,270	2,270
	Total	**16,104**	**22,377**	**41,320**
New Hampshire	**Floating Offshore Wind**	**41**	**714**	**1,177**
	Land-Based Wind	207	207	207
	Ground-Mounted PV	3,348	5,088	8,714
	Natural Gas	1,383	2,083	2,083
	Nuclear	1,309	1,309	1,309
	Hydropower	573	573	573
	Biomass	246	246	246
	Storage	14	55	496
	Total	**7,121**	**10,275**	**14,805**

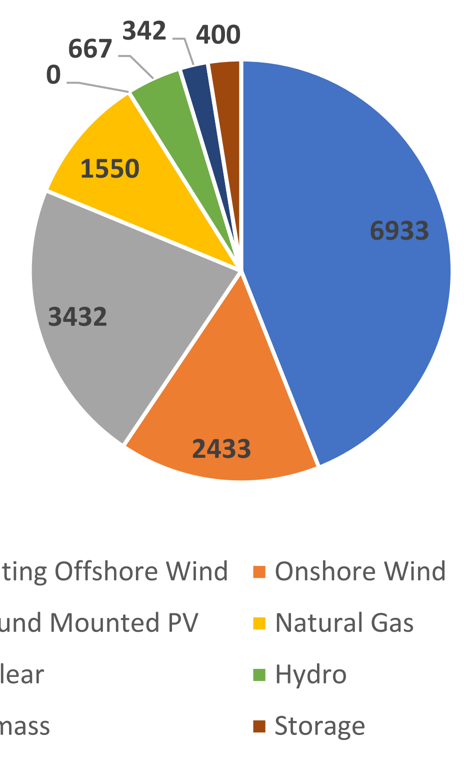

Figure 13. Maine generation mix scenario (in MW) for 2050

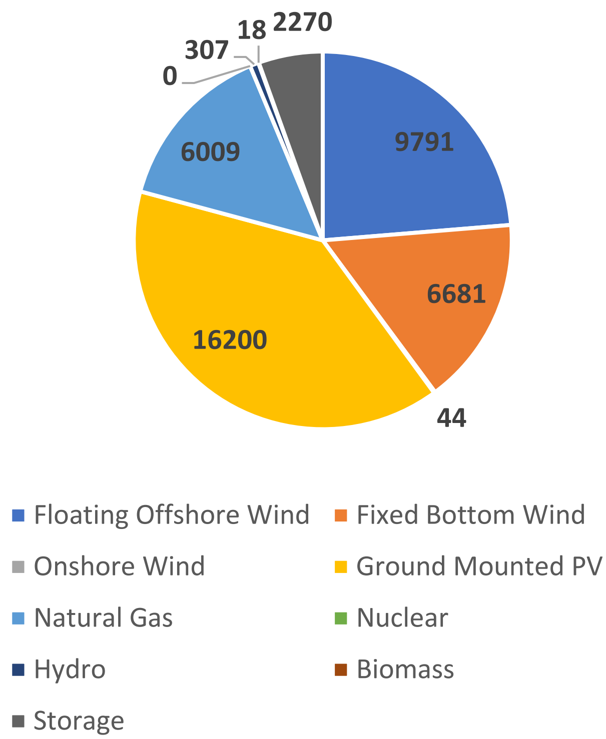

Figure 14. Massachusetts generation mix scenario (in MW) for 2050

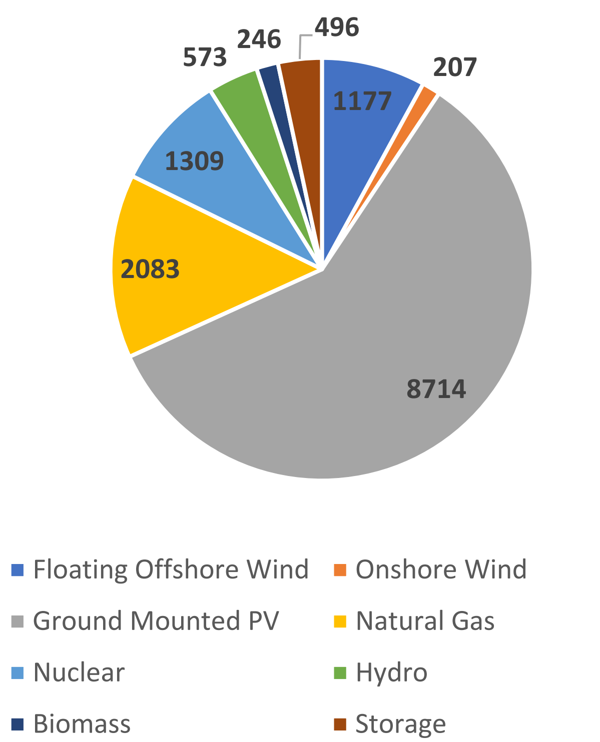

Figure 15. New Hampshire generation mix scenario (in MW) for 2050

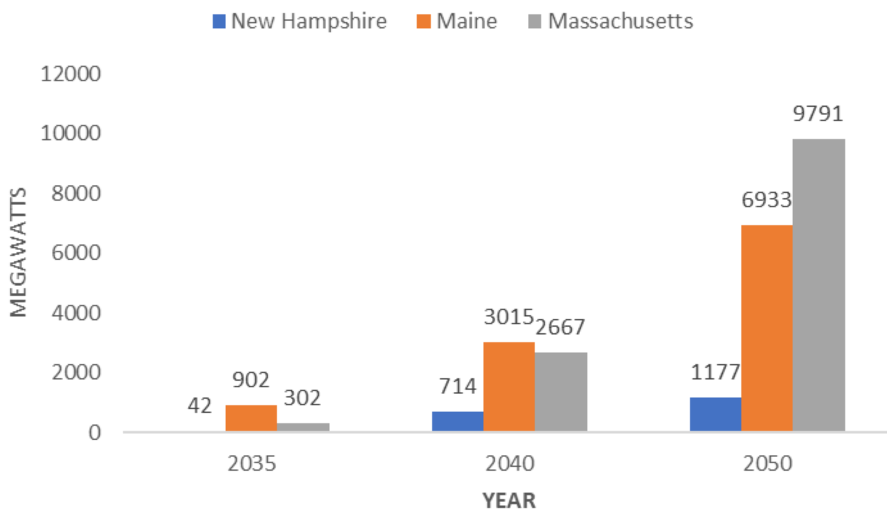

Figure 16. Breakdown of offshore wind energy from the Gulf of Maine by state for ISO-NE planning years 2035, 2040, and 2050

ISO-NE's *2050 Transmission Study* reviewed the hourly load profile data for the years 2035, 2040, and 2050, and calculated the characteristics of peak loads as the energy use profiles shift under the high-electrification, deep-decarbonization scenarios. Figure 17 provides a comparison of the expected peak loads and shows a shift from the present summer daytime peak load that is largely driven by air conditioning of buildings on hot summer days to a much larger winter peak. The shift to a winter peak load is driven by the electrification of energy use that has been traditionally met through the burning of fossil fuels, including heating homes and charging automobiles.

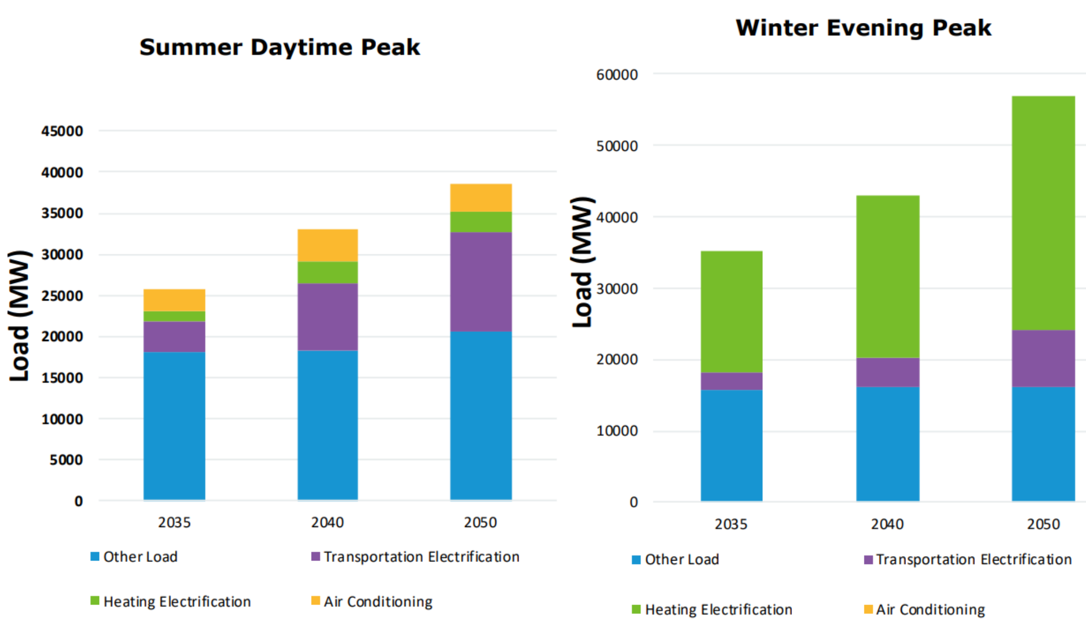

Figure 17. Comparison of summer and winter peak loads for ISO-NE planning years 2035, 2040, and 2050

Another key observation from the study is that to meet the winter peak a large amount of battery storage will be required to back up the offshore wind plants, even though the resources show a significant diurnal offshore wind resource peak coinciding with peak loads (e.g., around 6 p.m.).

5.2 Transmission Issues

5.2.1 Points of Interconnection

The second revision of the ISO-NE *2050 Transmission Study* provides details on the expected points of interconnection (POI) as the grid expands over the next few decades. Figures 18, 19, and 20 isolate some of the POI being considered for offshore wind plants in the Gulf of Maine for the planning years of 2035, 2040, and 2050. The wind plants will be interconnected to 345-kilovolt (kV) or 115-kV substations based on their proximity to shore or load centers. For the ISO-NE study, the maximum size of a single offshore wind plant was assumed to be 1.2 GW and the wind plants were limited to 2.4 GW on the same bus. Note that the POI presented are preliminary and are subject to change upon further analysis. Note that the red stars in these figures indicate the POI locations for the new wind additions while the green stars indicate the locations of those that currently exist or already planned.

Currently, a larger study, the *Atlantic Offshore Wind Transmission Study*, funded by DOE and being conducted by NREL and the Pacific Northwest Laboratory is underway and will refine the assumptions and requirements regarding these POI (NREL 2023).

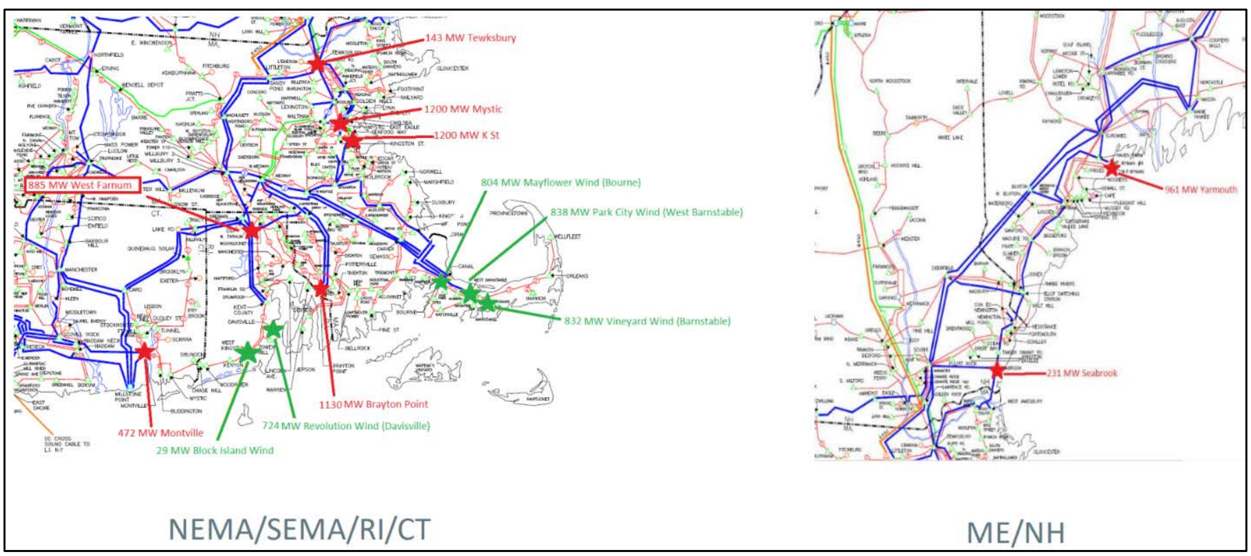

Figure 18. 2035 points of interconnection and estimated capacities. ***Image from ISO-NE (2022a)***

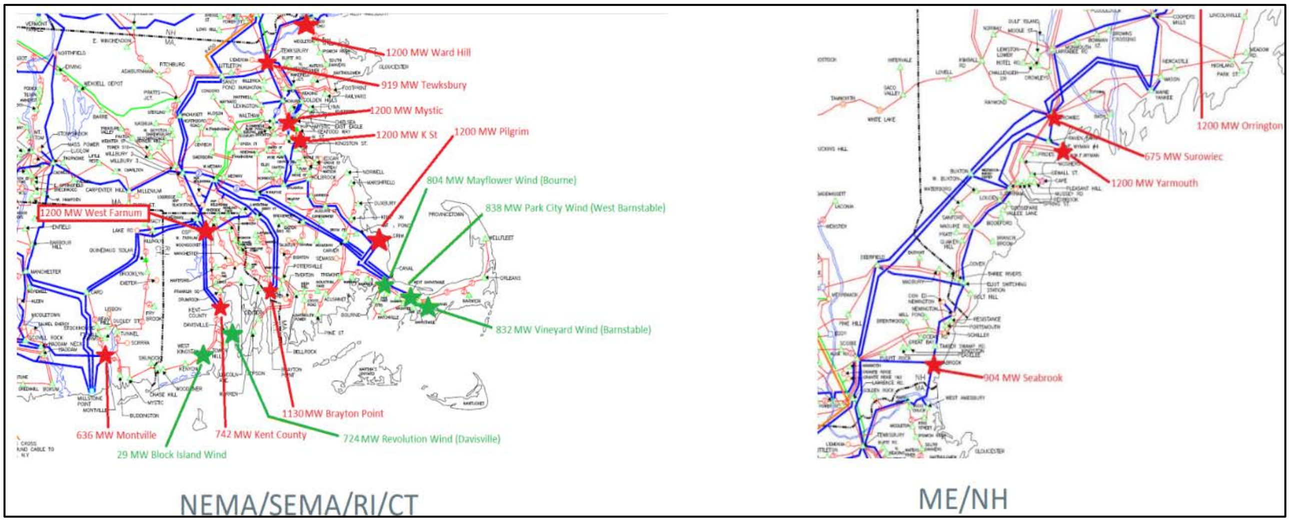

Figure 19. 2040 points of interconnection and estimated capacities. ***Image from ISO-NE (2022a)***

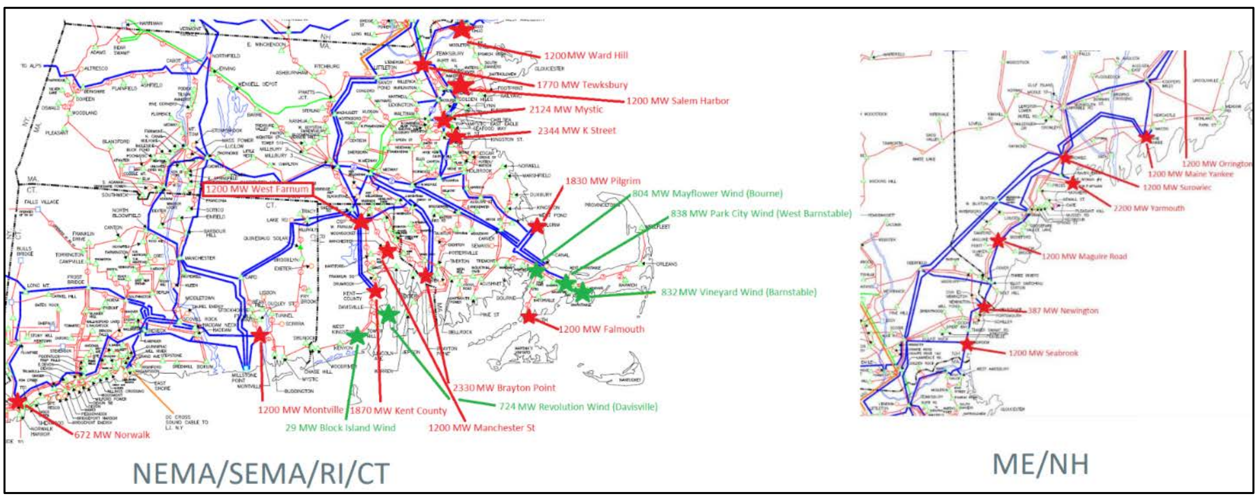

Figure 20. 2050 points of interconnection and estimated capacities. ***Image from ISO-NE (2022a)***

As electric generation on the ISO-NE grid shifts toward renewable energy over the coming decades, the study found that approximately 45% of the pool transmission facilities lines could be overloaded by 2050, indicating that transmission line congestion will become a major infrastructure issue. ISO-NE is currently developing a solution package to upgrade some of their onshore transmission lines and transformers to tackle these 2050 winter peak challenges as well as expand transmission capacity to accommodate the increased electric grid size (ISO-NE 2022c).

Transmission

Building off its 2020 vision statement on a regional electric grid,[12] the New England region is seeking to facilitate a proactive planning process for offshore wind transmission projects. In January 2023, Maine, Connecticut, Rhode Island, and Massachusetts, with the support of New Hampshire and Vermont, submitted a concept paper for a Joint State Innovational Partnership for Offshore Wind to DOE's Grid Resilience and Innovation Partnership program in January 2023. The proposed partnership will organize states, transmission providers, wind energy developers, and ISO-NE to plan, identify, and select a portfolio of transmission projects (including HVDC transmission lines and shoreside infrastructure) that facilitate the development of offshore wind energy. The regional approach is intended to support policy integration into the transmission planning process, produce lower-cost projects, and address winter energy security and reliability issues (New England Energy Vision 2023). The vision seeks to facilitate the initial deployment of offshore HVDC systems in the near term while enabling upscaling of the system to accommodate a first-in-the-nation networked or "meshed" multiterminal high-voltage direct current system as that technology becomes available (DOE 2023b).

Some other key takeaways from the ISO-NE study were:

- Approximately 50% of the pool transmission facility line miles (predominantly 115 kV) and 60% of the pool transmission facility transformers (mostly 345/115 kV) in New England could be overloaded in 2050 during the 2050 Winter Peak Scenario.

- The regions of transmission line overload observed during the 2050 summer daytime and winter evening peak are not the same (75 miles of new overload observed in Maine for the 2050 summer peak that are not observed during the winter peak). Therefore, two different strategies are needed to relieve congestion across two seasons.

- The northern New England states may have excess generation and can take advantage of Canadian imports better compared to the southern New England states. Further analysis will likely find solutions that could impact the optimum location of the POI for projects in the Gulf of Maine (e.g., possibly moving interconnect locations further inland).

[12] For more information, see *New England States' Vision for a Clean, Affordable, and Reliable 21st Century Regional Electric Grid* at https://nescoe.com/resource-center/vision-stmt-oct2020/.

6 State and Federal Policy

This section outlines the state and federal energy use and offshore wind energy policies for the Gulf of Maine states. These policies directly or indirectly impact the offshore wind industry across Maine, New Hampshire, and Massachusetts. Each state can also benefit from a range of new federal policies that aim to promote clean energy (including floating offshore wind) as well as stimulate U.S. economic growth and job creation. These policies are rapidly changing, and they are looking forward as far as 2050. In many cases, the state policies complement the federal policies and targets that aim to reach net-zero carbon emissions from the region's energy supply. These policies are also designed to steer the energy use patterns, which now show a high regional dependence on fossil fuels, toward clean energy sources.

6.1 State of Maine

Maine has a population of just over 1.3 million and has the lowest population density of the three states. Yet, it has the largest land area and longest coastline, and has been working on floating offshore wind energy the longest. For Maine, offshore wind from the Gulf of Maine could potentially make up to 50% of the state's future energy supply.

6.1.1 Maine Energy Use

Maine has long been distinguished by its unique energy needs, particularly with heating. As the most rural state in the contiguous United States, the natural gas infrastructure fails to reach many of the residents, contributing to its distinction as the state most dependent on heating oil in the nation. Maine has taken action to mitigate this dependency and now leads the region in installed land-based wind capacity and recently expanded its policies to incentivize solar energy development, underscoring the need to electrify the energy supply. Currently, Maine ranks among the lowest in the country for per-capita consumption of electricity at roughly 360 kilowatt-hours/month, which is likely to increase as state policy and innovative programs have led Maine to have the highest per-capita installation of air-source heat pumps in the nation, despite its cold temperatures.

Power system analysis has shown that the development of floating offshore wind energy will be key to reversing Maine's dependence on fossil fuels and realizing decarbonization scenarios in both Maine and New England. Building off the transmission study led by ISO-NE and described in Section 5, the State of Maine commissioned DNV to perform an assessment to inform its road map effort and policymaking (DNV 2022b). The study found that it was "highly implausible" that Maine could meet its renewable energy targets with land-based renewable energy alone, though a 1-GW land-based wind project and transmission line in northern Maine, the largest land-based wind energy project in the eastern United States, was able to win regulatory approvals in early 2023 (Turkel 2023b; DNV 2022b; U.S. Energy Information Administration [EIA] 2021).

6.1.2 Offshore Wind Energy Policy in Maine

Maine's efforts with offshore wind energy began in 2008 when Governor John Baldacci established the Maine Ocean Energy Task Force (OETF) on the heels of a global energy crisis and amidst an economic recession. The effort was intended to explore the potential to harness

Maine's indigenous ocean energy resources while simultaneously reducing the state's reliance on imported fossil fuels for home heating and transportation. To support the development of nascent ocean energy technologies in the Gulf of Maine's deep waters, particularly floating offshore wind, OETF supported the state to identify demonstration areas as part of an effort to establish a "fair, efficient, and predictable process for the temporary, relatively short-term testing of emerging offshore wind and wave technologies in pre-selected state waters" (State of Maine 2009). In December 2009, the state announced its selection of three demonstration areas, assigning the site off Monhegan Island as the Maine Offshore Wind Energy Research Center and for the exclusive use of UMaine. The state also released the OETF's final report, which detailed a series of recommendations that included a goal of installing 5 GW of offshore wind energy by 2030. This target is being reconsidered now to reflect current state objectives, but no official state targets have been set.

In 2010, the Maine State Legislature passed LD 1810, forwarding many of the OETF's recommendations, including the development of a procurement process that would eventually lead to an unsolicited lease request from Statoil North America for a project in federal waters, the establishment of the BOEM Maine Renewable Energy Task Force, and a draft power purchase agreement for the project. However, the transition to Governor Paul LePage's administration (2011−2019) reversed the course on the state's offshore wind activities, as Governor LePage eventually signed legislation to reopen the procurement process, leading Statoil to withdraw its lease request in 2013. In 2017, the administration supported legislation to ban offshore wind energy development in state waters, including at the Monhegan demonstration area, though the bill did not emerge from committee.

The transition to Governor Janet Mills' administration (2019−present) showed a marked shift for offshore wind, as part of its significant focus on climate action and clean energy development. In early 2019, Governor Mills set goals to reduce greenhouse gas emissions by 45% by 2030 and at least 80% by 2050 and achieve carbon neutrality by 2045. The administration also set a goal to derive 80% of Maine's electricity from renewable sources by 2030 and 100% by 2050. To facilitate these efforts, the administration launched the Maine Offshore Wind Initiative, a coordinated effort led by state government, and convened the Maine Climate Council to develop a 4-year action plan that was delivered in December 2020. In February 2023, Governor Mills announced intentions to submit a bill to the Maine Legislature that would accelerate progress on clean energy targets and reach 100% clean energy by 2040, a decade earlier than previously intended (Billings 2023).

Maine's approach to offshore wind is codified primarily in the Maine Wind Energy Act in the state's Public Utilities statute (Title 35-A, Part 3, Chapter 34). Over the past decade, the act has evolved to include language on a moratorium on development in state waters (S.3405 2021) and the establishment of the Maine Offshore Wind Research Consortium (S.3406 2021). The designation and permitting of state demonstration areas are addressed in the Conservation (Title 12, Part 2, Chapter 220) and Waters and Navigation (Title 28, Chapter 3) sections of the statute, respectively.

In June 2021, Governor Mills enacted a bill that required the Maine Public Utilities Commission to purchase power for up to 144 MW from MERA. Two weeks later, in response to growing objections from Maine fishermen, Governor Mills signed a law prohibiting commercial offshore wind energy development in state waters. According to the Mills administration, 75% of Maine's commercial lobster harvesting takes place within state waters (State of Maine 2021b). Concerns and priorities of Maine fishermen regarding offshore wind are included in Section 7.1. The offshore wind industry supported this legislation to give some legal protection to the Maine fishermen as there were no plans to develop commercial offshore wind in state waters. The same legislation also directed the creation of the Maine Offshore Wind Research Consortium, an effort to develop and implement a strategy to better understand the local and regional effects of floating offshore wind in the Gulf of Maine that is inclusive of the fishing industry's research interests.

In January 2023, LD 1895 was introduced at the Maine State Legislature to require the competitive procurement of 1 GW of offshore wind by 2030 and 2.8 GW by 2035 (Maine State Legislature 2023; Turkel 2023a). The bill also included provisions on stakeholder engagement, economic and community benefits, diversity, equity, and inclusion, as well as research and monitoring. The bill is currently under negotiation and continued development in the Legislature, with consideration being given to the interconnected nature of Maine's economy and the Gulf of Maine ecosystem. Action on the bill is expected before the legislative sessions end in late June 2023.

6.1.3 Maine Offshore Wind Road Map

The Governor of Maine's Energy Office released the *Maine Offshore Wind Roadmap* on February 24, 2023, a stakeholder-driven comprehensive plan offering detailed strategies for Maine to realize economic, energy, and climate benefits from offshore wind energy, in conjunction with communities, fisheries, and wildlife in the Gulf of Maine (Durakovic 2023; State of Maine 2023a). Funded by a $2.1-million grant from the U.S. Department of Commerce's Economic Development Administration in 2020, the road map effort enabled the state to commission extensive new analysis around the potential for offshore wind energy, as well as to launch a focused effort to re-engage stakeholders for the first time since 2010. The road map was guided by the input of an advisory committee and four expert working groups: Energy Markets and Strategy; Supply Chain, Workforce Development, Ports, and Marine Transportation; Fisheries; and Environment and Wildlife; nearly 80 stakeholder-focused public meetings; and hundreds of public comments. The final road map, working groups' recommendations, technical documents, and road map proceedings are hosted on the Maine Offshore Wind Initiative's website.[13]

6.2 Commonwealth of Massachusetts

Massachusetts is the most densely populated of the three states with almost 7 million residents in 2021. Massachusetts has also set the most ambitious clean energy goals with one of the largest offshore wind resources in the United States. As such, the Gulf of Maine represents only a portion of the state's total offshore wind resources, yet it is likely that Massachusetts will ultimately use the largest quantity of resources from the Gulf of Maine. Although, compared to Maine and New Hampshire, a smaller fraction of Massachusetts's total energy will come from the Gulf of Maine.

[13] For more information, see the Maine Offshore Wind Initiative's website: https://www.maineoffshorewind.org/.

6.2.1 Massachusetts Energy Use

In 2021, over 50% of Massachusetts households used natural gas for home heating with about 25% using fuel oil, and about 17% of households heated with electricity. The liquefied natural-gas terminal in Everett, Massachusetts, accounted for about 99% of the nation's total natural gas imports in 2021. In 2020, Massachusetts was among the lowest consumers of electricity on an economywide basis, although it is heavily reliant on out-of-state imports. However, the commonwealth uses less electricity per capita than all but four other states including Maine. In 2021, solar energy accounted for 20% of Massachusetts' total in-state electricity net generation (EIA 2023).

6.2.2 Offshore Wind Policy in Massachusetts

The Commonwealth of Massachusetts has played a leading role in the development of offshore wind energy for the country. A series of legislation has committed the commonwealth to procure offshore wind energy, including *An Act Relative to Energy Diversity* that was signed into law in August 2016, resulting in a state commitment to procure 1.6 GW of offshore wind. This legislation was the first in the United States to provide a mandate for offshore wind that was later followed by seven other states. *An Act to Advance Clean Energy* was signed into law in 2018, resulting in an additional commitment of 1.6 GW of offshore wind. Lastly, *An Act Driving Clean Energy and Offshore Wind* was signed into law in 2022, resulting in an additional commitment of 2.4 GW, bringing the total Massachusetts commitment to 5.6 GW.

Alongside these efforts, the commonwealth continues to work with BOEM, other states and federal agencies, local communities, and many stakeholders on leasing and commercial wind energy development south of Martha's Vineyard and Nantucket. In 2019, Massachusetts indicated its formal support of the formation of an intergovernmental renewable energy task force for offshore wind energy leasing in the Gulf of Maine and is collaborating with BOEM and the states of Maine and New Hampshire to advance these commercial leasing efforts. As of 2022, Massachusetts has procured 3.2 GW of offshore wind. On May 2, 2023, the Massachusetts Department of Energy Resources and the electric distribution companies jointly filed a draft Request for Proposals with the Department of Public Utilities. If approved, the draft RFP will seek new applications to procure up to 3,600 MW of new offshore wind generation, which represents 25 percent of the state's annual electricity demand. This would be the largest procurement for offshore wind energy generation ever in New England (Mass.gov 2023).

6.2.3 Massachusetts Decarbonization Road Map and Clean Energy Climate Plans

To inform its ambitious target of net-zero emissions by 2050, the commonwealth released the *Massachusetts 2050 Decarbonization Roadmap* in late 2020 (Ismay et al. 2020) that examined eight integrated, regional, cross-sector-energy-system net-zero-compliant pathways and a Massachusetts-specific analysis for the buildings, transportation, nonenergy, and land sectors as well as economic and health impacts. Among its findings, the report concluded that offshore wind energy will be the backbone of decarbonized electricity generation in Massachusetts, along with solar PV. According to the findings, if offshore wind deployment was constrained, imported energy sources including hydropower would increase and new nuclear generation could be cost-effective in the Northeast. In December 2022, the Massachusetts Department of Energy

Resources released its *Clean Energy and Climate Plan for 2050*, which establishes sector-specific greenhouse-gas emission limits for transportation, residential heating and cooling, commercial and industrial heating and cooling, electric power, industrial processes, and natural-gas distribution and services that collectively reduce economywide emissions to achieve slightly more than the 85% emissions reduction required by law. Building off the decarbonization road map, additional modeling and greenhouse-gas emissions accounting was completed to set sector-specific limits. The *Clean Energy and Climate Plan for 2050* affirms that offshore wind energy would serve as a key piece of the state's decarbonization plan, requiring 23 GW of generation to be deployed between 2020 and 2050. The plan identifies working with BOEM and other entities to identify new offshore wind lease areas in federal waters in the Gulf of Maine as a priority.

6.3 State of New Hampshire

New Hampshire has the shortest coastline facing the Gulf of Maine but has a strong presence and long history on the waterfront. Its population is roughly the same as Maine but with a much smaller land area. New Hampshire has collaborated with the other states to participate in the joint task force and for grid and transmission planning but appears to be positioned to reap a smaller fraction of offshore wind energy than the other states based on ISO-NE planning targets and less aggressive state policy to date. New Hampshire's stated priorities for offshore wind in the Gulf of Maine are to preserve their existing economic and environmental interests, which include opportunities to use their ports, manufacturing, and transmission/interconnection facilities.

6.3.1 New Hampshire Energy Use

Over 40% of New Hampshire households use fuel oil as their primary heating fuel; a lower fraction than Maine households but well above the national average. In 2021, New Hampshire generated over half of its electricity from the Seabrook nuclear power plant, which is one of the last remaining nuclear plants in New England. Also in 2021, 16% of New Hampshire's electricity generation came from renewable resources, including small-scale solar installations. Most of the state's renewable generation comes from hydroelectric power, biomass, and land-based wind. New Hampshire has the two coal-fired power plants that provide electricity on high-demand days. New Hampshire's residential sector is the largest energy consumer (EIA 2023).

6.3.2 Offshore Wind Energy Policy in New Hampshire

New Hampshire's ambitions for offshore wind began to gain traction in 2019 when Governor Chris Sununu called for BOEM to establish the multistate, tribal, and federal task force to ensure coordination and consultation on offshore wind planning and leasing and then issued Executive Order 2019-06, which established advisory boards for the task force and directed state agencies to begin collaborating on an offshore wind energy assessment. In the 4 years since these first actions, New Hampshire has established the following:

- **House Bill 1245**. In 2020, the New Hampshire Legislature passed House Bill 1245 to establish the Commission to Study Offshore Wind and Port Development, which assembled a range of relevant stakeholders who have been meeting since 2020 to consider the environmental and economic benefits and challenges related to offshore wind energy development alongside the outset of the Gulf of Maine Task Force process.

- **Executive Order 2021-03**. In 2021, Governor Sununu issued Executive Order 2021-03, amending and restating Executive Order 2019-06 to extend the timeline needed to prepare the analysis on scenarios for greenhouse-gas-emissions reductions and the need to develop New Hampshire infrastructure due to the Covid-19 pandemic. In 2022, the *Report on Greenhouse Gas Emissions, and Infrastructure and Supply Chain Opportunities as it Relates to the Deployment of Offshore Wind in the Gulf of Maine* (New Hampshire Departments of Energy, Environmental Services, and Business and Economic Affairs 2022) was released, outlining emissions reductions scenarios with offshore wind and an overview of existing port facilities, transmission infrastructure, and supply chain operations.
- **Senate Bill 440**. On the heels of a failed 2021 procurement bill, Senate Bill 440 was enacted in 2022, directing the state's Department of Energy to develop a series of recommendations by June 2024 on factors for the public utilities commission to consider when evaluating future offshore wind power purchase contracts, actions needed to support mitigation and consistency recommendations, and how utilities can use renewable energy credits for offshore wind energy contracts.
- **Senate Bill 268**. Enacted in 2022, Senate Bill 268 requires the public utilities commission to ensure that impact and use studies are completed before approving any offshore wind power purchase agreements, outlines how mitigation funds should be administered, and identifies how the state can declare economic interests and a role in decision-making related to development in federal waters.
- **Senate Bill 152**. Passed in 2023, Senate Bill 152 seeks to enhance workforce development opportunities by creating a committee to explore the issue and consider a potential workforce training center in the port community of Portsmouth and ways to invest in other new and existing seacoast area training programs.

6.3.2.1 Additional Supporting Measures

New Hampshire's offshore wind energy ambitions have also been underscored by its creation of the Office of Offshore Wind Industry Development within the state's Department of Energy in 2021, as well as its 10-year state energy strategy, most recently updated in 2022, which outlines past and upcoming efforts to evaluate the potential for offshore wind and recommends that the state "should reduce unnecessary regulatory barriers that would hinder responsible wind development in the waters in the Gulf of Maine" (New Hampshire Departments of Energy, Environmental Services, and Business and Economic Affairs 2022). In addition, the state is anticipated to publish an impact analysis in June 2023 that considers the economic, energy, and environmental implications of offshore wind development. Various events have also highlighted the potential for offshore wind in the region, most recently including the New Hampshire Offshore Wind Summit, which was co-sponsored by the state and business interests in September 2022, and the Environmental Business Council of New England's Fourth Annual Offshore Wind Conference in October 2022.

6.4 State Collaborations: Maine, New Hampshire, and Massachusetts

Maine, New Hampshire, and Massachusetts have a long history of collaborating on energy issues, as they are linked by common interests ranging from the grid operator (ISO-NE) to participation in a carbon cap-and-trade program (the Regional Greenhouse Gas Initiative). With offshore wind energy, the states are actively seeking to understand each other's decarbonization scenarios, engage with and minimize impacts to fisheries stakeholders, and pursue opportunities for investment in regional infrastructure, supply chain, workforce, and environmental research. These goals are in addition to the efforts on transmission described in Section 5.

6.4.1 Gulf of Maine Intergovernmental Renewable Energy Task Force

BOEM's Gulf of Maine Task Force serves as the foundation of collaborative efforts on offshore wind energy in the region. Formed after a request from New Hampshire Governor Christopher Sununu in January 2019, the regional task force includes participation from Maine, Massachusetts, New Hampshire, and federally recognized tribes. It reflects the high likelihood that development in the Gulf of Maine will affect activities in multiple states, as well as its shared ecosystem and stakeholders (BOEM 2023b). The formation of this regional intergovernmental task force enabled the advancement of leasing in the Gulf of Maine including the MERA.

6.5 Supporting Federal Policy

A combination of state and federal policies may help floating offshore wind energy technology in the Gulf of Maine successfully achieve competitive commercial status and secure the associated local economic and health benefits. In 2021, the administration set a goal of 30 GW of offshore wind energy by 2030, with a long-range target of 110 GW or more by 2050. Full decarbonization scenarios under investigation suggest that the 2050 target may be conservative (Denholm et al. 2022).

On August 7, 2022, the Senate passed the Inflation Reduction Act of 2022, which contains multiple provisions related to offshore wind energy (Congressional Research Service 2022). For example, the act contains a provision related to interregional and offshore wind electricity transmission planning, modeling, and analysis and would appropriate $100 million for convening stakeholders and conducting analysis related to interregional transmission development and offshore wind energy transmission development.

Key initiatives provided by the Biden administration may also help New England states to reach federal clean-energy goals. For example, on September 15, 2022, DOE announced the Floating Offshore Wind Shot, which targets cost reductions of 70% down to $45/MWh. As part of this initiative, the administration announced that it will also advance lease areas in deep waters of the United States through the U.S. Department of the Interior to deploy 15 GW of floating offshore wind capacity by 2035 (DOE 2022).

There are also other provisions related to transmission that could have implications for the Gulf of Maine's renewable energy transition. Section 13702 of the Inflation Reduction Act provides a new clean electricity investment tax credit for the domestic production of wind energy components and related goods, such as specialized offshore wind energy installation vessels.

6.6 Canadian Considerations

Canada could potentially play a significant role in developing offshore wind energy in the Gulf of Maine. It is too early to identify major contributors, but the development of Nova Scotia ports and supply chains could support offshore wind development activities in the region. Unlike European supply chains, the proximity of Canada could allow for additional Jones-Act-compliant construction, operations, and maintenance solutions to be implemented. In addition, there is already an early-stage proposal to consider an offshore transmission backbone from Halifax to Boston proposed by the New England Maritimes Offshore Energy Corridor that could serve projects in the Gulf of Maine (Power Advisory and DNV 2023).

7 Stakeholder and Tribal Considerations

Maine-based Gulf of Maine offshore wind energy stakeholders are distinguished by the economic and cultural significance of the region's commercial fishing industry and tribal communities, as well as the capacity constraints faced by its many small coastal communities including its islands.

7.1 Commercial Fishermen

The Gulf of Maine provides a rich habitat or a passageway for more than 652 species of fish, providing the foundation for robust commercial fishing activity in the region. The type of species landed[14] has varied significantly over the past century as ecological conditions, fisheries stocks, and regulations have changed, but the American lobster (*Homarus americanus*) has become the dominant species landed in the region, both by weight and dollar value. Lobster is currently the most valuable species of fish caught in the United States, with 80% of it being landed in Maine. Nearly three-quarters of the dollar value of commercial fish landings in Maine come from lobster.

Gulf-of-Maine commercial fisheries possess significant cultural, economic, and political strengths, yet a number of factors shape their engagement in offshore wind energy. First, much of the fishing activity in the Gulf of Maine is dispersed due to the region's long coastline and remote peninsulas and islands, as well as the requirement of Maine's 4,800 lobster licenseholders to own and operate their own boats. Further, fisheries activities are co-managed by a multitude of bodies ranging from lobster management zone councils for Maine's in-shore lobster fishery, to the Atlantic States Marine Fisheries Council for its federal lobster fishery, and the New England Fisheries Management Council for other species, requiring engagement with multiple forums to exchange information.

This diversity of management has also led to significant differences in how data are collected on commercial fishing in the Gulf of Maine, which, in some cases, has been problematic for ocean planning processes and decision-making around offshore wind energy. This data inconsistency has particularly been the case for lobstering in both state and federal waters, as until recently, very little spatial and temporal data were required to be collected. However, a 2022 rule from the Atlantic States Marine Fisheries Commission requires electronic tracking on all federally permitted lobster vessels by the end of 2023 (Atlantic States Marine Fisheries Commission 2022). This rule, combined with other investments in data collection for lobster and other commercial fishing activities,[15] will begin to close important ocean-use knowledge gaps, though

[14] In its latest *Fisheries Economics of the United States* report, the National Oceanic and Atmospheric Administration (NOAA) Fisheries identified the following as key commercial species in New England: American lobster, Atlantic herring, Atlantic mackerel, bluefin tuna, cod, haddock, flounder, goosefish, quahog clam, sea scallop, and squid (NOAA Fisheries 2020).

[15] Other relevant data collection efforts include the Responsible Offshore Development Alliance's Fisheries Knowledge Trust (https://rodafisheries.org/portfolio/fisheries-knowledge-trust/) and a related University of Maine project funded by the Northeast Sea Grant Consortium (https://seagrant.umaine.edu/research/projects/r-22-24-nesgr-beard-can-proprietary-commercial-lobstering-data-be-used-to-inform-offshore-wind-development/).

likely not soon enough to fully inform near-term ocean-use decisions, including BOEM's Gulf of Maine offshore wind leasing process.

Data limitations have also proven problematic as the commercial fishing industry grapples with regulations being considered to protect the North Atlantic right whale. As initially proposed, these regulations require fishermen to shift and/or reduce their effort and make costly adjustments to their gear, despite significant uncertainty about the origins of entanglements and mortalities. In June 2023, a federal appellate court invalidated the biological opinion used to justify the impending regulations, keeping the rules in place but requiring a new assessment to take place before any additional modifications to fishing can be required (Laclaire 2023).

The sensitivity around these regulations has also contributed to stakeholder questions about the interactions between the right whale and offshore wind energy projects, including potential impacts to whales or their habitat during both the construction process and during the operations. Gulf of Maine fishermen are particularly interested in interactions with floating turbine mooring lines and the potential risk for secondary entanglement (Green et al. 2023). Notably, findings from NOAA indicate that it has not found any evidence that preconstruction offshore wind surveys caused recently documented whale mortalities (NOAA Fisheries 2023). Nonetheless, right-whale-related issues compound with concerns around offshore wind energy development and a host of other unrelated challenges such as the opioid crisis, decreasing access to working waterfronts, and increasing energy and bait prices to create a state of extreme financial and emotional stress for many Gulf of Maine fishery participants.

Engaging in the offshore wind energy development process has been challenging for many commercial fishermen in the region, as the industry is not only potentially disruptive to the way in which they fish, but also to their traditional role in decision-making through co-management. Tensions with Maine fishermen mounted in 2021 in response to issues with NEAV cable preparations (Turkel 2021; Charpentier 2021) and the administration's increasing focus on offshore wind (Bever 2021), contributing to Governor Mills' move to prohibit project development in state waters that same year. Capacity to track and engage in the development process has also been identified as a challenge due to the distributed nature of the fishing industry and the sheer number of issues it faces, as well as the need to come up to speed on floating technology, which is new for many of the fishermen and fisheries entities that have been tracking offshore wind in southern New England. To address these challenges, the state agencies in each of the region's states, trade organizations,[16] and other nongovernmental organizations[17] are increasingly dedicating financial resources and staff capacity to the issue. The topic is routinely covered by key trade publications such as *Landings* and *National Fisherman*, as well as through sessions at the widely attended Maine Fishermen's Forum each March.

[16] These include, but are not limited to, Atlantic Offshore Lobstermen's Association, Cape Cod Commercial Fishermen's Alliance, Downeast Lobstermen's Association, Maine Coast Fishermen's Association, Maine Lobstering Union – Local 207, Maine Lobstermen's Association, Massachusetts Fishermen's Partnership, Massachusetts Lobstermen's Association, and Northeast Seafood Coalition

[17] These include, but are not limited to, Gulf of Maine Research Institute, Sea Grant programs in Maine, Massachusetts, and New Hampshire, The Nature Conservancy, and Island Institute.

In 2022, the National Offshore Wind Research and Development Consortium awarded a project to NREL on co-design of floating offshore wind with the fishing industry that will include a case study in the Gulf of Maine. The goal of the study is to provide forward-looking technology solutions by developing and applying an engineering co-design process that is iterative and collaborative with focal fisheries, leading to actual co-designed floating array solutions (National Offshore Wind Research and Development Consortium 2023).

7.1.1 Fisheries Compensation

Since 2021, the three states have also been collaborating on an approach to fisheries compensation. In November 2021, Maine, New Hampshire, and Massachusetts, in conjunction with six other Atlantic states, submitted a letter to BOEM that encouraged a standardized approach to fisheries compensation that was followed by BOEM's release of its Draft Fisheries Mitigation Framework in June 2022. In December 2022, the states (which have since grown to a total of 11), with the support of the Special Initiative for Offshore Wind and the Consensus Building Institute, released an RFI for a regional fisheries compensatory mitigation fund administrator. RFI responses were due in early February 2023 (Special Initiative on Offshore Wind 2022).

7.1.2 Fisheries Working Group–Maine Offshore Wind Road Map

Building off its engagement with the fishing industry during the development of the research array application in early 2021 (State of Maine 2021a), the state created a fisheries working group (FWG) later that year to inform its road map process. The FWG—which represented the state's most extensive effort to engage the industry in the offshore wind energy development process to date—included a diverse set of experienced stakeholders from commercial, recreational, and aquaculture sectors. Over the 18-month initiative, the group developed recommendations that spanned the life cycle of an offshore wind project, focusing on strategies to avoid, minimize, and mitigate impacts. All efforts were reflected throughout the final road map, particularly in Objective D: Support Maine's Vital and Thriving Seafood Industries and Coastal Communities (State of Maine 2023a). Many of the issues considered by the FWG were also reflected in the fisheries interviews and secondary research that DNV performed for its socio-economic impact analysis during the same time period and summarized in Figure 20 (DNV 2022a).

Key finding	Derived from	
	Interviews	Secondary research
Members of the fishing industry are worried about losing harvesting areas.	✓	✓
Multidirectional communication that occurs as early in the planning process as possible is a best practice to avoid conflict and minimize negative impacts to commercial fisheries.	✓	✓
Navigation routes might increase in length.	✓	✓
There will be multiplier effects for any lost maritime jobs.	✓	✓
Co-location might be feasible if safety concerns are addressed.	✓	✓
Previous experiences with regulations around the protection of right whales are affecting fishery response to OSW.	✓	
Fishermen found it difficult to provide ideas for mitigation measures that adequately addressed their concerns.	✓	

Figure 21. Summary of key findings from DNV's fisheries interviews and secondary research.
Image from DNV (2022a)

In addition to being included as an appendix in the *Maine Offshore Wind Roadmap*, the FWG submitted its recommendations as part of its October 2022 comments in response to BOEM's Gulf of Maine RFI. The State of Maine also referenced these recommendations in its comments to BOEM's RFI. Key recommendations included a proposed exclusion area that included Lobster Management Area 1 to protect what the FWG considered the most significant commercial fishing area on the Eastern Seaboard as well as significant habitat areas (Maine Offshore Wind Roadmap Fisheries Working Group 2022). As part of the release of its draft Call Area in January 2023, BOEM noted its considerations of these recommendations (Figure 22). In a June 12, 2023 letter to BOEM, Maine's Congressional delegation and Governor Mills echoed the FWG's request to remove Lobster Management Area 1 from consideration for leasing, as well as areas currently closed to fishing due to the potential presence of the North Atlantic right whale (Office of Senator Susan Collins 2023).

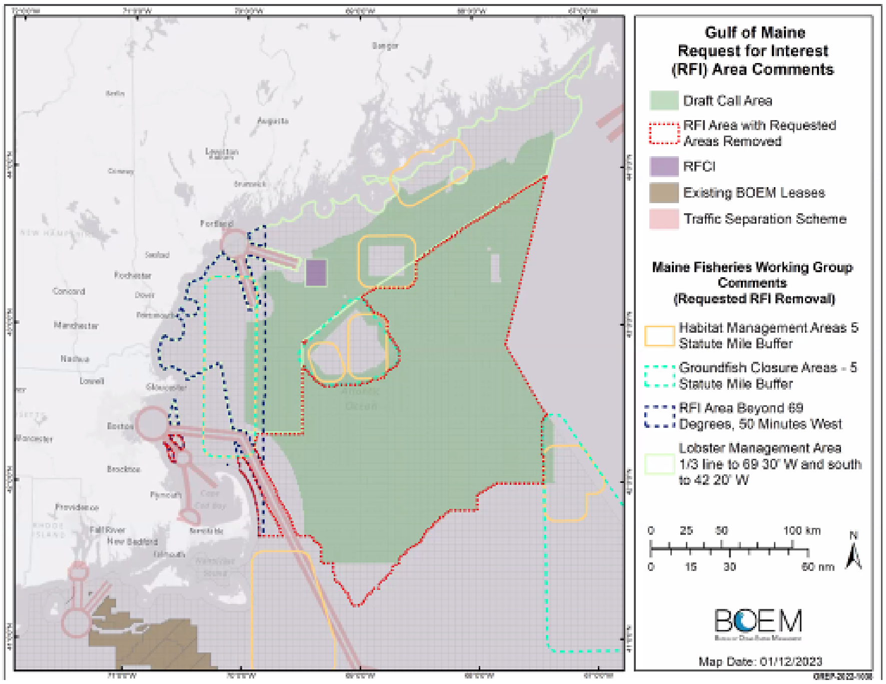

Figure 22. Gulf of Maine request for interest area comments. ***Map from BOEM***

The FWG also highlighted the need for a socio-economic impact analysis to better understand and prepare for the potential impacts of offshore wind on land-based fishing communities. This need was later emphasized in DNV's 2022 socio-economic impact report, as the study recommended that additional analysis should be done as more specific information became available through the leasing process (DNV 2022a). This research is being considered by the newly established Maine Offshore Wind Research Consortium and was the focus of a March 2023 state-led proposal in response to DOE's call for community-focused social science longitudinal studies in offshore wind that is expected to complement forthcoming analysis from BOEM on the socio-economic impact of activities at sea. If funded, work on the state's proposed project is anticipated to begin in January 2024 (Watson 2023). In the meantime, and with the Maine road map process coming to an end, the Maine Department of Marine Resources continues to facilitate an ad hoc advisory group of self-selecting fishery participants who will be asked for input on policy matters related to offshore wind and fisheries going forward (Mendelson 2023).

7.1.3 Massachusetts Fisheries Working Group

For more than a decade, fisheries stakeholders in Massachusetts have also been advising on the offshore wind energy development process through the Massachusetts Fisheries Working Group on Offshore Wind Energy (Commonwealth of Massachusetts 2023b). Established in 2011, the working group is facilitated by the Massachusetts Executive Office of Energy and Environmental Affairs through its Office of Coastal Zone Management and is supported by the Massachusetts Clean Energy Center and the Division of Marine Fisheries. One important role for the working group is to supplement the efforts of the BOEM Intergovernmental Renewable Energy Task Force by creating a forum for discussion with key fisheries stakeholders. According to the commonwealth, "input from the working groups has directly resulted in accommodations to avoid important marine habitat, fishing grounds, and marine commerce routes in the designation of the wind energy lease areas" (Commonwealth of Massachusetts 2023). The working group comprises voluntary members from commercial and recreational fisheries, research organizations, and state and federal agencies. The efforts of the Massachusetts Fisheries Working Group also intersect with the work of the Massachusetts Habitat Working Group, a related effort to engage key environment and wildlife stakeholders alongside the BOEM process.

7.2 Other Ocean Users

Additional ocean users in the Gulf of Maine include:

- **Recreational fishing**. Recreational saltwater fishing occurs throughout the Gulf of Maine, though it primarily originates from ports in the southern part of the region out of southern Maine, New Hampshire, and Massachusetts. In Maine, most of the recreational fishing activity is based in the southern part of the state's coast, with some activity extending up to its midcoast (Boothbay Harbor). The Maine Department of Marine Resources maintains a list of the saltwater fleet that is available for hire including charter boats (six or fewer passengers) and head boats (seven or more passengers) and their respective home ports. In March 2023, there were 124 vessels included on the list (Maine Department of Marine Resources 2023). While the exact number of outfits operating in the Call Area is unknown, it is likely to be a smaller fraction of this total, with few venturing that far offshore. However, surveys led by the Maine Department of Marine Resources in 2023 identified a concentration of fishing activity for highly migratory species in the northwest corner of the Draft Call Area, with the area around Platts Bank and the northern end of Wilkinson Basin being most utilized (Davis and Kneebone 2023).

- **Commercial shipping**. The Gulf of Maine hosts extensive commercial shipping activity originating from and departing to all parts of the world. Commercial shipping vessel traffic involving Maine's ports was recently characterized in Section 5.9 of the State of Maine's 2021 research lease application to BOEM.

    - The *MSIB 23-001 Ports Access Route Study: Approaches to Maine, New Hampshire, and Massachusetts* was published by the U.S. Coast Guard in March 2023 after extensive data collection and public outreach (U.S. Coast Guard 2023). The study found that anticipated changes, including offshore wind energy development, may result in the introduction of larger vessel classes, greater traffic densities, and displacement of some traditional transit routes within the study area. As a result, the report recommended a series of proposed routing measures, as well as those that are specific to offshore wind that include addressing specific concerns about proposed wind energy areas, consistent wind turbine layouts and cable routes, safe mooring and navigation systems, and mitigation of marine vessel radar system impacts. Specific to MeRA, the U.S. Coast Guard outlined concerns related to the project in its May 2023 presentation to the Gulf of Maine task force, including increased vessel traffic, potential navigation hazards, and heighted safety concerns (Aulner 2023). Moving forward, the U.S. Coast Guard is expected to initiate a federal rulemaking process to establish unobstructed shipping fairways.

- **Offshore cruising and tourism**. Cruise ships, yachts, whale-watching boats, and seabird tours all operate within the Gulf of Maine (UMaine and James W. Sewall Company 2012), though most of this activity takes place closer to shore than within the Call Area.

- **Ocean research**. The Gulf of Maine is one of the more highly instrumented bodies of water of its size, hosting research performed by state and federal agencies, academia, nonprofits, and the private sector. Fisheries stakeholders have voiced concerns about the potential for offshore wind energy development to impact stock assessments and other fisheries-related sampling efforts that inform regulatory decisions, whereas industry stakeholders anticipate that offshore wind predevelopment work and the efforts of MeRA will significantly increase the amount of data available to regulators.

- **Wildlife and fisheries stakeholders**. While a summary of the Gulf of Maine's broader ecosystem considerations for offshore wind energy development was outside the scope of this report, there is a broad range of stakeholders focused on the health and well-being of the fish and wildlife species that live in or transit the region. Many of these stakeholders—ranging from state agency staff to research institutes and nonprofits—have been engaging in BOEM and state processes, underscoring the need to address data gaps and pursue regional collaborations, and developing new research on the topic (State of Maine 2022; Stepanuk et al. 2022). All three states have established working groups focused on this topic to inform state reports such as the recent Maine road map and BOEM engagement.

7.3 Tribal Considerations

The Gulf of Maine region is home to many indigenous peoples, including those belonging to the Wampanoag and Passamaquoddy tribes, the Penobscot Nation, the Aroostook Band of Micmac, and the Houlton Band of Maliseet. Past, present, and future connections to the land and sea, and those broader ecosystems are of great cultural and spiritual importance to these peoples. Participation and influence in decision-making processes that will potentially impact these resources are also a priority, though complicated by a history of being marginalized and harmed by such processes and by limited capacity and timelines that can make it difficult to meaningfully engage.

Research has identified three key areas of concern that have emerged in narratives on indigenous peoples and offshore wind energy development in New England: 1) religious, cultural, and spiritual value, 2) land and identity, and 3) process and procedures (Bacchiocchi et al. 2022). Specifically, concerns may include impacts to submerged lands and burial grounds, sunrise ceremonies, access to land and sea for traditional uses, and the need for consultation in decision-making processes. As a result of the Maine Indian Claims Settlement Act of 1980, tribes in that state do not currently have full access to federal laws and benefits. BOEM implements tribal consultation policies on offshore wind in the region through both formal government-to-government consultation and informal dialogue, collaboration, and engagement. The three states have also sought to involve tribal representatives, including in Maine's recent road map, yet point out the need for continued engagement and focused efforts to address unique barriers to participation.

Offshore wind energy may also bring workforce and related economic development opportunities for Native people in the Gulf of Maine region, particularly if proponents invest in initiatives that recognize and seek to overcome barriers to access and create more equitable opportunities. Increasingly, procurement initiatives are supporting or incentivizing such efforts, including recent proposed legislation in Maine and the Commonwealth of Massachusetts' fourth offshore wind energy solicitation. Some tribes, developers, and other organizations such as Cape and Islands Self-Reliance and Vineyard Power are engaging in related efforts in southern New England, providing cost-free protected species observer trainings and certifications, as well as larger scholarships to pursue four-year college degrees and other certifications to prepare for a wide range of positions in the offshore wind workforce.

7.4 Other Stakeholders

Maine's long coastline is home to more than 150 communities, 75% of which have populations of 3,500 or less and 25% of which have populations less than 750 (Island Institute 2020). Natural resource industries play an important role in the coastal economy with more than double the number of workers employed in the sector than the national average and more than four times the New England average (Island Institute 2018). While the potential positive and negative impacts of offshore wind energy development are of significance to many municipal leaders, limited capacity constrains their ability to closely track and engage in the process, though the state's road map process and the Offshore Wind Ports Advisory Committee[18] has sought to engage both inland and coastal community members. Coastal town leaders have expressed concerns about the potential for the offshore wind industry to disrupt local economies through impacts to commercial fishing, as well as to exacerbate the pandemic-spurred real-estate shifts that have led to an affordability crisis and dwindling public access to working waterfronts (DNV 2022a).

Communities in the southern part of the Gulf of Maine typically have much larger populations than those on the coast of Maine, but share many of the same interests, particularly around port development (e.g., Portsmouth, New Hampshire, and Salem, Massachusetts) and potential fisheries impacts (e.g., Gloucester, Massachusetts, and Rye, New Hampshire). Many of these communities are supported to engage in offshore wind development discussions by regional planning agencies including the Metropolitan Area Planning Council (Massachusetts) and the Rockingham Planning Commission (New Hampshire) and entities such as NOAA's Sea Grant. The Commission on Clean Energy Infrastructure Siting and Permitting, an effort announced by the Commonwealth of Massachusetts in April 2023, may also create opportunities for municipalities to engage in decision-making around offshore wind infrastructure (Commonwealth of Massachusetts 2023).

The Gulf of Maine is also distinguished by the presence of year-round island communities. While New Hampshire's Isles of Shoals are largely uninhabited and Massachusetts' island communities sit just outside of the Gulf of Maine Call Area, the Maine coastline is home to thousands of small islands, including 15 year-round, unbridged island communities within 20

[18] For more information on the Maine Offshore Wind Ports Advisory Committee, see: https://www.maine.gov/mdot/ofps/oswpag/.

miles of the mainland.[19] The presence of these communities extends the state's geographic jurisdiction and facilitates an extensive in-shore (state waters) commercial fishery. With a sizable dependence on fisheries—up to 43% of residents in some island communities holding lobster licenses (Island Institute 2018)—and potentially more pronounced visual impacts due to closer proximity to offshore wind projects, Maine island communities represent a unique stakeholder group in the Gulf of Maine. The extensive experience of the Monhegan Island community with the NEAV project provides insight into island stakeholder priorities, engagement lessons learned, and approaches to community benefit agreements (Klain et al. 2015; Monhegan Energy Task Force 2017).

Community benefit agreements, as a mechanism to address any local impacts and/or enhance the value of offshore wind development, is a topic of broad interest in the region, going back to BOEM's use of them as a non-monetary factor and credit its 2014 final sale notice in Massachusetts (Walker and Jacobson 2023). The State of Maine also notes its interest in and the need for additional local capacity to engage in the topic its recent road map. As BOEM considers the potential use of multiple-factor bidding and non-monetary credits in the Gulf of Maine, stakeholders in the region could benefit from opportunities to learn about these topics.

[19] For more information on Maine's year-round island communities, see: https://www.islandinstitute.org/community-profiles/.

8 Supply Chain

8.1 Floating Offshore Wind Energy Ports

The necessary port infrastructure for offshore wind energy development in the United States has not yet been built and the requirements in most cases exceed the capabilities of the existing ports. Because offshore wind turbines are extremely large, among the largest rotating machines ever built, most of the fabrication, assembly, installation, and maintenance must be performed at a coastal facility. There are different types of offshore wind ports and their capabilities can be classified according to their purpose. The following is a list of the general port types ranked in descending order of the complexity and development costs:

- Turbine assembly and installation (marshalling ports)
- Operations and maintenance
- Substructure fabrication
- Manufacturing supply chain.

Along the U.S. North Atlantic coast there are currently seven offshore wind marshalling ports being developed for fixed-bottom offshore wind, but the related development has unique infrastructure requirements that will involve special purpose port facilities. The wind turbine and substructure assembly and installation ports are the most important. For floating systems, the substructure and wind turbine are assembled and commissioned at port and towed out to the site for installation, whereas fixed-bottom systems are assembled at sea with large installation vessels.

Marshalling ports are the biggest challenge and highest cost because they have the most stringent requirements for crane capacities and heights, lay down or quayside space, port depth, wharf length, and overhead air draft limits to allow assembled wind turbines and substructures to be towed out to site. Operation and maintenance ports have similar requirements as the wind turbine assembly (marshalling) ports but do not require as much upland area. The substructure fabrication ports do not have the same constraints for high-capacity overhead lifting and air draft but should be close to or part of the assembly port, with the ability to maneuver the substructures, which are the heaviest components. Manufacturing and supply chain port facilities for other Tier 1 components, such as wind turbine towers and nacelles, should be located nearby with reasonable distances for shipping.

With the formation of the Intergovernmental Renewable Energy Task Force for the Gulf of Maine and the commencement in late 2019 of planning efforts for potential offshore wind energy development, Massachusetts initiated a project to expand a 2017 offshore wind ports and infrastructure assessment to the North Shore region of Massachusetts (from Revere to Salisbury). In April 2022, the Massachusetts Clean Energy Center (MassCEC) released the *Massachusetts Offshore Wind Ports and Infrastructure Assessment: North Shore* which includes:

- A summary of the workings and general requirements of operations and maintenance ports
- A screening level assessment of port facilities that are 20 acres or greater that could have a potential reuse as a marshalling, manufacturing or service/repair port

- An assessment of the existing conditions and engineering requirements for the primary site at Salem, Massachusetts that was identified from the screening level assessment.

Special consideration was given to properties with the potential to service offshore wind plant developments in the Gulf of Maine (where floating foundations are anticipated), as well as to the south of Cape Cod (where fixed-bottom turbine foundations are being used). The following were considered in the evaluation of the North Shore sites:

- The need for floating foundations for offshore wind turbines in the Gulf of Maine
- The continued technological advancements in offshore wind turbines, which continue to increase in capacity and size, with the largest commercially available turbines currently in the 10- to 15-MW range but planning for possible 20-MW maximum capacity in the future
- The manufacturing of Tier 1 offshore wind components such as wind turbine blades, as well as other potential manufacturing activities such as secondary steel, coating applications, and so on.

The primary site in Salem, Massachusetts, is at the location of a former coal-/oil-fired power plant, a portion of which was redeveloped in 2017 into a modern gas-fired power-generating facility. The remaining 42 acres is now the site of the Salem Wind Port where a public-private partnership is developing the facility into a world-class, purpose-built offshore wind marshalling terminal.

Maine has been a technology leader in the development of floating offshore wind, whereas other states to the south have been leading fixed-bottom offshore wind. Experience has demonstrated that the port can be the focal point for development and a magnet for the development of future supply chains and associated jobs. Port development has been one of the major objectives for the State of Maine in proactively pursuing this technology. The capability to assemble a full-scale floating wind turbine does not exist in the emerging fixed-bottom ports of the Atlantic, so even for the NEAV single-turbine project, a port facility with the necessary lifting and water draft capabilities must be developed either in Maine or elsewhere. As MeRA advances, these facilities would be needed at a slightly larger scale. To support commercial leasing the scale of the required port facilities must grow proportionately, and for full-scale offshore wind energy development in the Gulf of Maine, multiple ports may be required.

Maine began investigating a suitable site for a floating offshore wind marshalling port a few years ago and the Maine Department of Transportation (MaineDOT) commissioned Moffat and Nichol to investigate the coast of Maine and assess suitable locations (MaineDOT 2021). Although the report does not offer a final conclusion, it illuminates many key issues to help narrow down the possible locations for multi-port scenarios. Following the Maine DOT study, the State of Maine formed an Offshore Wind Port Advisory Group to advise state government officials about the development of an offshore wind energy port that will allow Maine to realize the environmental and economic benefits of floating offshore wind while considering the state's and local community values, and minimizing adverse impacts. The port advisory group is expected to complete its review in 2023. Although no decision has yet been made to develop an offshore wind port for the Gulf of Maine or how costs will be allocated, there are two primary locations that are being evaluated: the Port of Searsport, Maine, and the Port of Salem, Massachusetts. These locations are described as follows.

8.1.1 Port of Searsport/Mack Point

Figure 23 shows a map of the Port of Searsport located at the top of Penobscot Bay just east of Belfast, Maine. One of the key areas of interest is the Mack Point Terminal, which is an existing industrial port used for fuel storage among other things. Across the channel is Sears Island, a 940-acre island roughly two-thirds of which is held in conservation, with the remaining third owned by the State of Maine and available for port development.

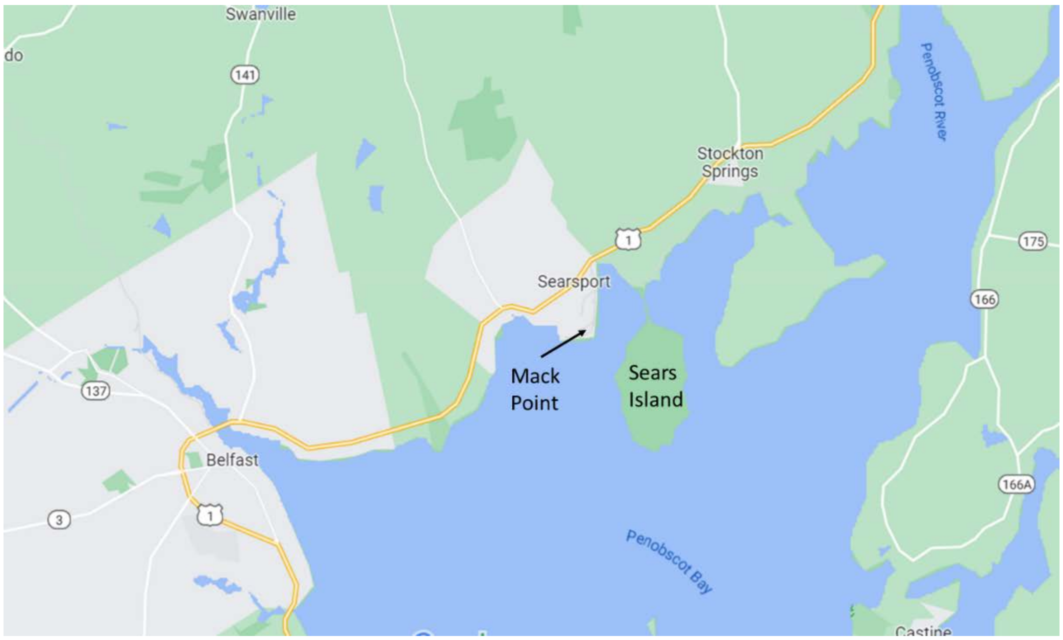

Figure 23. Location of proposed floating offshore wind port at Mack Point Terminal

According to the MaineDOT study, the site at Mack Point Terminal was made available for study by the Maine Port Authority and Sprague Energy. The area currently operates as a liquid and dry bulk cargo terminal. Sprague Energy has identified approximately 85 acres for potential offshore wind energy port development, as shown in Figure 24. This area has approximately 2,060 ft of undeveloped water frontage. Vessel access to the site is via Penobscot Bay and the maintained federal navigation channel. Additionally, there is an active rail line that runs at the eastern and southern extent of the property. To make the Mack Point site feasible, new construction would be required to create a quay approximately 795 ft to the south of the existing shoreline to achieve the required water depth. In addition, dredging would be required to remove about 10 ft of soil above the top of bedrock and glacial till to achieve the required water depth at the berth. However, these specifications are very preliminary and subject to significant revision as more detailed assessments are made.

Figure 24. Aerial view of the proposed 85-acre Mack Point Terminal development area

A portion of Sears Island is zoned as a transportation/marine development parcel and owned by the MaineDOT. The area comprises approximately 330 acres of undeveloped land with approximately 9,000 linear feet of undeveloped water frontage. Vessel access to the site is via Penobscot Bay and the maintained federal navigation channel. Similar to the Mack Point site, new construction would be necessary to establish a quay with a berthing face on the west side of Sears Island site approximately 795 ft, 200 ft, and 970 ft from the existing shore at the northern, central, and southern extents of the site, respectively. At the Sears Island site, no dredging would be needed. As part of the study, MaineDOT acknowledged that if port development and investment were to occur on the transportation parcel, improvements could also be made to the conservation area to improve the experience for visitors to the island. These potential improvements include an education center building, interactive/interpretive landscape zones, outdoor classrooms, a waterfront and boating access area, an education center/waterfront access parking area, a trailhead parking area, and cell tower road improvements.

Although Mack Point would be the preferred site, it may not have a large enough capacity to handle commercial development at the scale expected for the Gulf of Maine. With only about 200 MW of floating wind turbines installed globally, there are no commercial floating ports that exist yet. Therefore, the state should consider a phased approach that begins with the NEAV and MeRA pilot projects but allows expansion to the commercial scale.

VHB Environmental performed an initial environmental and permitting review of the Mack Point and Sears Island facilities. Each site was reviewed to identify known and potential resource concerns, including wetlands, dredging, fill areas, eel grass, sensitive species, and navigational constraints. The permitting review identifies the federal, state, and local permits that are likely to be required to move forward with development at either site.

It is anticipated that, as the industry grows in Maine and the region, additional waterfront facilities will be required. These facilities can serve in support roles comprising (but not limited to) raw materials supply, component manufacturing, and operations and maintenance. There are multiple properties in the Port of Searsport that may be able to fulfill these functions.

8.1.2 Salem Offshore Wind Terminal

Another offshore wind energy port site that is currently being redeveloped into a purpose-built marshalling facility is the Salem Offshore Wind Terminal that sits on 42 acres of waterfront property in the port area of Salem Harbor, south of Cape Ann in Massachusetts. The Salem Wind Port is a private-public partnership between MassCEC, the City of Salem, and Crowley Wind Services. The port is being developed currently and will operate as Massachusetts' second major offshore wind port for fixed-bottom wind energy. The first tenant to use the port will be Avangrid Renewables, LLC. Avangrid is a leading renewable energy company in the United States and will be the first leaseholder once the construction is complete. Avangrid will use the new facility as a marshalling port for offshore wind components for their lease areas south of Cape Cod. MassCEC will own the site and Crowley will operate the port under a ground lease. MassCEC will also convey a portion of the site to the City of Salem (Salem Offshore Wind Terminal 2023).

The property was the site of a 750-MW coal- and oil-fired power plant that encompassed the original 65-acre parcel. The coal plant was demolished in 2014 and the site has undergone environmental remediation. Currently, the site hosts a new natural-gas-fired power plant on 23 acres and the remaining 42 acres are being developed into the Salem Offshore Wind Terminal (see Figure 24).

Figure 25. Artist rendition of the Port of Salem, Massachusetts. ***Image from Salem Offshore Wind Terminal (2023)***

The new terminal will comprise heavy-lift deployment and logistics services for fixed-bottom offshore wind operations. In addition, the site will contain the following elements:

- Two laydown yards, providing space for nacelles, blades, and towers
- A transition yard to connect the two laydown yards and provide additional storage
- A preassembly and load area for preassembly, staging, and loadout activities adjacent to the bulkhead and wharf
- A wharf and bulkhead; area improvements will provide adequate landside and waterside structures for loading and unloading of vessels
- Several berths for vessels to accommodate berthing and moorage of wind turbine installation vessels (WTIVs) for loadout operations as well as heavy transportation vessels for inbound deliveries
- On-site equipment, such as transport vehicles and high-capacity cranes, to assist with moving the wind turbine blades and nacelles.

The terminal is scheduled to open in 2025 for fixed-bottom projects. Assessments are underway to determine what improvements may be necessary for the terminal to serve as a marshalling and assembly port for these projects. The long-term plan for Massachusetts is to use the Salem Wind Port as a floating offshore wind marshalling port for the Gulf of Maine but the cost and timing of converting it are not publicly available. To date, more than $100 million has been secured for this development, permitting is underway, and lease commitments have been made.

8.1.3 Long-Term Port Capacity

The scale of development for the Gulf of Maine is likely to require multiple ports in the region to enable the full transition to a net-zero carbon energy supply by 2050. The cost allocation and benefits of these port facilities are not fully understood but the long-term investment outlook is very good for offshore wind energy and could additionally benefit other industries with port needs. Each of these floating ports can help revitalize waterfront communities, provide high-paying jobs, and remediate social, economic, and health burdens that may have disadvantaged some communities in the past. Some issues that should be addressed in future port development for the Gulf of Maine are socio-economic and infrastructure costs to the state and local community for the facility as well as how long-term energy prices might be impacted.

8.2 Gulf of Maine Supply Chain Base

The Gulf of Maine is in a strategically advantageous location for the states to build a strong floating offshore wind supply chain, from the ports to subcomponent manufacturing. State incentives along with financial and legislative support can build opportunities for local companies, encourage international partnerships, and secure the economic opportunities of being at the forefront of the emerging global floating offshore wind industry. However, as a nascent industry that is tied to the more advanced fixed-bottom offshore wind industry that is experiencing exponential growth in wind turbine size, the lack of certainty in the future specifications of Tier 1 and 2 floating wind components may cause some hesitation for investors seeking initial supply chain opportunities.

The *Supply Chain Road Map for Offshore Wind Energy in the United States* indicates that to reach the national target of 30 GW by 2030 and maintain a constant deployment after the beginning of the 2030s, new manufacturing facilities must be built. In a completely domestic supply chain scenario developed by Shields et al. (2023), the states in the Gulf of Maine would need to build four additional manufacturing facilities—potentially a blade factory in Massachusetts, a tower factory in Maine, a flange factory in New Hampshire, and a mooring rope factory in Maine (Shields et al. 2023).

8.2.1 Maine Supply Chain

Maine currently has a leadership role in the floating offshore wind energy industry due to its 15-year history of technology development and the state's focus on floating wind. Maine's leadership is fragile, however, as multibillion-dollar offshore wind supply chains emerge for the fixed-bottom offshore wind industry to the south. But the nascent floating industry could become larger than the developing fixed-bottom industry, with two-thirds of the U.S. offshore wind energy development potential in deeper waters suited for floating technology, and as a result, the Gulf of Maine could emerge early as the floating wind center of development. Due to Maine's proximity to this abundant high-quality resource, its head start with NEAV and MeRA, and its ability to leverage its marine industries, Maine can compete nationally; but timing is critical to ensure that these projects do not lose their leadership positions by being overtaken by the commercial floating industry.

Maine is somewhat disadvantaged as a small state and lacks some of the manufacturing infrastructure to produce large-scale Tier 1 components such as nacelles, blades, towers, and substructures that are being built in neighboring states. The *Summary of Maine Manufacturing Assets for Offshore Wind* indicates that the manufacturing development in Maine should aim for Tier 3 and 4 components to support the out-of-state domestic and foreign Tier 1 manufacturers (State of Maine 2023b). A review of the sectors where Maine could play a key role in the offshore wind energy supply chain based on their current capabilities include the following:

- **Construction and engineering substructures** could be sourced in state and fabrication may need to be close to the marshalling port for cost competitiveness.
- **Moorings and anchors** can be made at several Maine manufacturing facilities including cordage for offshore applications, pull lines, commercial marine tow lines, safety and rescue lines, crane and heavy-lift lines, rope access, and safety supplies to workers.
- **Secondary steel components** such as railings, barriers, platforms, J-tubes, boat interface steelwork, brackets, plating, handrails, flooring, and ladders can be made in state.

There are numerous Maine companies that are unaware of the potential capabilities of entering into the floating offshore wind energy industry. It may be necessary to educate, organize, and encourage steel, cable, and other small parts manufacturers in the state to give them a sense of tolerance, scales, and techniques required for offshore wind energy component manufacturing (State of Maine 2023b).

The Gulf of Maine will likely see the development of alternate technologies for the floating wind industry in the 2030s, including concrete semisubmersibles like the VolturnUS patented floating platform design. The VolturnUS technology is industrialized through precast bridge construction techniques that can be made anywhere in the world using locally sourced material and labor. It has no complex features like active ballast systems, heave plates, or hanging masses, and the rectangular bottom beam sections are easier to construct than cylindrical sections. Given the characteristics of this local patented technology, Maine and other states in the Gulf of Maine could benefit from its industrialization and massive production in the 2030s. More specifically, the massive production of this technology could create pronounced opportunities for local concrete product manufacturers.

8.2.2 Massachusetts Supply Chain

Massachusetts is a much larger state than Maine and has the advantage of already engaging with the commercial fixed-bottom offshore wind energy supply chain. Literally, hundreds of offshore wind companies and suppliers have already set up positions in Massachusetts specifically to serve the industry (MassCEC 2023). Massachusetts is actively supporting companies and business development activities across the entire scope of offshore wind project development, including:

- Primary suppliers: manufacturing and fabrication services and wind original equipment manufacturing
- Tier 2 suppliers, marine facilities, transport, logistics, and safety
- Project construction and installation scope
- Development and professional services
- Operations and maintenance
- Equipment, supplies, materials, and associated services.

MassCEC has programs in place to support port infrastructure, supply chain, and workforce development, including:

- The Offshore Wind Ports and Infrastructure Development Program, which recently awarded $180 million to seven priority ports in Massachusetts
- Offshore wind tax credits to facilitate economic development
- Forums and events to educate suppliers and connect them with the established offshore wind industry
- An offshore wind supplier assistance program
- A robust offshore wind workforce development program that has invested more than $8 million to 20 different organizations and institutions for offshore wind workforce introduction courses, health/safety, technical training, industry and trades partnerships, undergraduate and graduate programs, and Access to Opportunity.[20]

8.3 Vessel Requirements

The offshore wind vessels for floating wind in the Gulf of Maine will be a market characterized by the different installation techniques employed in floating offshore wind farms. American Clean Power estimates that each offshore wind energy project takes 2 to 3 years for its offshore installation, and that at least 25 vessels per project across all project stages (American Clean Power 2021). The vessel needs of fixed-bottom projects in the United States are understood more accurately due to the published construction and operation plans from many different projects.

[20] Access to Opportunity is a program aimed at measuring and improving secondary students' access to high school coursework and enrollment in colleges focused on the most disadvantaged students.

However, there are no published plans or similar records for floating projects. The average number of vessels needed for the installation phases was estimated based on an industry cross section comprising four fixed-bottom projects in the United States—Vineyard Wind 1 (2020), New England Wind (Epsilon 2022), Atlantic Shores South (2021), and Kitty Hawk Wind North (2022)—which are shown in Table 3. We can approximate the primary differences in vessel needs between fixed-bottom and floating projects and use that data to gain insights for a floating offshore wind energy project.

Table 3. Average Vessel Needs per Installation Phase Across Four Fixed-Bottom Offshore Wind Energy Projects (Vineyard Wind 1, New England Wind, Atlantic Shores South, and Kitty Hawk Wind North)

Installation Phase	Vessel Category	Average Number of Vessels Needed per Phase – U.S. Fixed-Bottom Projects
Array Cable	Anchor Handling Tug Supply	1
	Cable Support Vessel	2
	Cable Lay Vessel	1
	Crew Transfer Vessel	1
	Rock Dumping or Scour Protection Vessel	1
	Safety Vessel	1
	Survey Vessel	1
Export Cable	Anchor Handling Tug Supply	1
	Cable Support Vessel	2
	Cable Lay Vessel	2
	Crew Transfer Vessel	1
	Dredging Vessel	1
	Rock Dumping or Scour Protection Vessel	1
	Safety Vessel	1
	Survey Vessel	1
Foundation	Anchor Handling Tug Supply	1
	Barge	3–6
	Crew Transfer Vessel	2–4
	Heavy Lift Foundation Vessel	1–2
	Rock Dumping or Scour Protection Vessel	1
	Safety Vessel	1
	Support Vessel	1
	Tugboat	4–5
Offshore Substation	Barge	2
	Crew Transfer Vessel	2
	Heavy-Lift Foundation Vessel	2
	Tugboat	3–4
Scour Protection	Dredging Vessel	1
	Rock Dumping or Scour Protection Vessel	1
Wind Turbines	Barge	1–2
	Crew Transfer Vessel	2
	Feeder Barge or Vessel	2–5
	Tugboat	2–6
	Wind Turbine Installation Vessel	1–2
Commissioning	Crew Transfer Vessel	1–3
	Service Operation Vessel	1

One of the key value-adders for floating offshore wind energy is that the installation of floating wind turbines requires smaller vessels that generally require a lower capital investment. The installation of fixed-bottom wind turbines requires much larger, expensive vessels such as WTIVs and heavy-lift foundation vessels that carry out the foundation pile driving on the lease area, lift the tower, install it on the foundation, and attach the nacelle and blades to the tower. However, in floating wind, the wind turbine and floating substructure are assembled at port and towed out to the site, where anchor-handling tug supply vessels hook up the mooring lines to the floating foundation. In comparison with a fixed-bottom offshore wind project, a floating wind project would not need the most expensive ships, which include:

- Heavy-lift foundation vessels
- WTIVs
- Rock dumping/scour protection vessels (anchors are below the seabed surface so scouring is not an issue)
- Feeder barges.

Floating offshore wind projects would generally need:

- A larger fleet of small vessels including tugboats and anchor-handling tug supply vessels, all of which are available within the United States
- Service operation vessels and crew transfer vessels for maintenance
- A vessel spread that is prepared to operate at deeper waters and more challenging water conditions.

A critical constraint of the offshore wind vessel market in the United States is the Jones Act, also known as the Merchant Marine Act of 1920. The Jones Act requires that goods transported between two U.S. points must be carried on vessels that are built, owned, and crewed by U.S. citizens or permanent residents (U.S.-flagged vessels) (Papavizas 2022). To comply with the Jones Act, the U.S. offshore wind energy industry is working to develop domestic vessel manufacturing facilities. Some companies have already begun to invest in building vessels in the United States while others are partnering with U.S. shipyards to retrofit existing vessels or construct new ones. In the short term, the U.S. vessel market will have shortages of U.S.-flagged WTIVs and developers will solve this shortage by combining U.S.-flagged feeder barges with foreign-flagged WTIVs. As offshore wind turbines start being commissioned on the East Coast, the vessel demand will go from construction vessels like WTIVs to operation and maintenance vessels like CTVs and SOVs. A moderate-sized shipyard in Maine could probably produce one to two CTVs per year (State of Maine 2023b). Given the fact that CTVs are needed during the construction and operation and maintenance stages, the CTV market could be a great business opportunity for the Gulf of Maine.

9 Recommendations and Next Steps

The offshore wind energy commercial leasing of the Gulf of Maine is progressing rapidly, and it is essential that the major steps forward are taken in a coordinated and transparent manner to ensure all stakeholders are included in the process and their issues properly acknowledged. Regardless of the timelines, all interests may not be satisfied completely but substantial efforts are being made and need to continue to ensure best practices are used to avoid or mitigate conflicts.

Critical decision-making regarding site suitability needs to be informed by the most advanced economic and engineering tools available so that siting decisions can consider development costs, energy pricing, technical risk, and cumulative impacts in addition to avoiding stakeholder conflicts.

Supporting analysis should continue to develop more accurate cost models to estimate the impact of siting trade-offs for projects in the Gulf of Maine. Some of the trade-offs that lack proper understanding include the benefits of large-scale projects (5 GW) farther from shore (and other geospatial cost trade-offs), aggregation of grid and transmission to reduce cable landings, the economics of offshore backbones, impacts to wind turbine upscaling, and supply chain industrialization strategies.

Engineering to develop technology solutions to minimize anchor spread and minimize the footprints of individual wind turbines on the seabed and in the water column should continue.

Studies to evaluate the coexistence of marine life inside a floating wind plant before, during, and after construction, including the behavior of lobsters, groundfish, and marine mammals, should be prioritized for NEAV and MeRA so results can be made public to benefit future projects.

Maine has a unique opportunity to establish national leadership in the development of floating offshore wind energy and to launch the commercial U.S. floating wind industry regionally using their stated phased approach, whereby NEAV and MeRA could inform commercial leasing without impeding it. However, the speedy development of the critical infrastructure, such as a suitable port, may be the determining factor. Maine should prioritize port development as part of its overall strategy.

The Maine Offshore Wind Research Consortium is poised to conduct critical research that addresses some of the primary stakeholder concerns about the possible interference of offshore wind energy with other existing ocean activities, tribal practices, and its readiness to serve the commercial energy industry. This research consortium, working in sync with NEAV and MeRA, has the potential to leverage and extract a much more productive stream of useful information than the commercial projects that will follow or than previous research programs conducted on the other U.S. pilot projects at Block Island and Coastal Virginia. We recommend this consortium be fully supported to maximize Maine's investment and reduce risk to the future floating wind industry.

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