U.S. DEPARTMENT OF ENERGY

Offshore Wind Energy Strategies

Regional and national strategies to accelerate and maximize the effectiveness, reliability, and sustainability of U.S. offshore wind energy deployment and operation

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Disclaimer

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Executive Summary

This report outlines strategies to accelerate and maximize the effectiveness, reliability, and sustainability of offshore wind energy deployment and operation in the United States. This report does not include commitments from any agency or entity and is meant to provide information on barriers impeding offshore wind energy deployment and effective strategies to facilitate successful industry growth.

Offshore wind has the potential to supply substantial amounts of clean energy to meet America's power needs while creating U.S. jobs and addressing the climate crisis. Further, offshore wind power plants can provide reliable and increasingly affordable renewable power near coastal energy load centers where there is a scarcity of sites for large-scale renewable energy development on land. For these reasons, many states have aggressively adopted proactive offshore wind energy policies to capture the benefits of economic growth, energy independence, and reduced greenhouse gas emissions. Based on current state policy commitments of about 39 gigawatts (GW) by 2040,[1] some coastal states are planning for 50 percent or more of their electricity to come from offshore wind in the coming decades.

In March 2021, the U.S. Department of Energy, U.S. Department of the Interior, and U.S. Department of Commerce announced a national goal to deploy 30 GW of offshore wind capacity by 2030.[2] Deploying 30 GW–or 30,000 megawatts (MW)–would mark a significant increase from the 42 MW of offshore wind energy currently operating in the United States. Reaching the 30-GW-by-2030 goal would generate enough electricity to power over 10 million American homes[3] and establish the United States as a major participant in the global offshore wind energy industry. It would also create tens of thousands of jobs in a range of occupations that would pay at or above the national average and sustain more than $12 billion a year in offshore wind project capital investments.[4] Such project investments would spur additional investments in supply chain development, port revitalization, vessel construction, wind power plant operations, and onshore assembly facilities.

Attaining the 30-GW-by-2030 deployment goal could set the country on a path towards deploying at least 110 GW of offshore wind capacity by 2050.[5] This level of deployment would

[1] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.
[2]The White House. 2021. "FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs." Last modified: March 29, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.
[3] Ibid
[4] Ibid
[5] Ibid

supply nearly 6 percent of the Nation's electricity from offshore wind power.[6] Offshore wind energy use could be even greater because of its potential to be sited where land is limited and its potential role in economywide decarbonization, such as through production of hydrogen for zero-carbon transportation fuels and industrial processes.

Offshore wind deployment has a unique set of challenges compared to land-based energy plants. For example, offshore structures and undersea electrical cables must withstand the harsh marine environment and construction and maintenance at sea requires specialized equipment and skills. Offshore wind energy is currently more expensive than more mature electricity generation technologies for a number of reasons—relatively nascent technology, the challenges of the marine environment, the cost of bringing power to shore via long submarine cables, less-established supply chains, and a more general lack of efficiencies gained with experience. Floating offshore wind technology suitable for deployment in deeper water depths, such as in the Pacific, is more commercially and technically nascent than the fixed-bottom support structures planned for deployment in waters along much of the Atlantic Coast.

The U.S. offshore wind industry has lagged Northern Europe's for a number of reasons. Electricity prices tend to be lower in the United States than in Europe, so it is more difficult for new technologies to be cost competitive in the U.S. market. Prior to states enacting mandates for offshore wind energy procurement, the United States lacked the supportive policies that drove the first decade-plus of European offshore wind energy deployment.[7] In addition, while offshore wind on the Outer Continental Shelf benefits from having a single primary Federal agency with overall permitting responsibility, many U.S. entities are involved in the processes required to site and permit power plants in Federal waters and route cables through state waters, taking significant coordination and time. Needing to navigate unprecedented and evolving processes means that some early projects missed deadlines and struggled to secure power purchase agreements.

Despite these challenges, progress is being made to increase the speed and scale of U.S. offshore wind development. Over the last year, the amount of capacity in the offshore wind pipeline has grown 24 percent to 35 GW,[8] and state-level offshore wind procurement commitments have grown to 39 GW by 2040.[9] The Department of the Interior aims to review

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[6] Lantz, Eric, Barter, Garett, Gilman, Patrick, Keyser, David, Mai, Trieu, Marquis, Melinda, Mowers, Matthew, Shields, Matt, Spitsen, Paul, and Stefek, Jeremy. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-80031. https://www.nrel.gov/docs/fy21osti/80031.pdf.

[7] European incentives for offshore wind were 16 to 20 cents/kWh, and are now being phased down. Wind Monitor. Fraunhofer Institute, Germany. "Feed-in Payment for Offshore Wind Power." Accessed date October 4, 2021. http://windmonitor.iee.fraunhofer.de/windmonitor_en/4_Offshore/6_foerderbedingungen/1_einspeiseverguetung/.

[8] As of May 2021, the National Renewable Energy Laboratory estimates the U.S. offshore wind energy pipeline to have 35,324 MW of capacity, which is the sum of current installed projects, approved projects, projects in the permitting process, existing lease areas, and unleased wind energy areas. For more information, see the Offshore Wind Market Report: 2021 Edition.

[9] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.

16 Construction and Operations Plans by 2025[10] and published seven Notices of Intent from March through September 2021 to begin the Environmental Impact Scoping process for projects on the path to meeting that target.[11] In May 2021, Vineyard Wind 1 was the first large-scale project (~800 MW)[12] to receive Federal approval for construction and operation. The project reached financial close in September 2021.

More work is left to be done in order to deploy offshore wind at the speed and scale needed to meet national climate and energy goals. U.S. offshore wind energy development will require a whole-of-government approach, as well as collaboration with a diverse range of public and private entities. The findings that underpin this report identified five policy and technology initiatives, or strategic priorities, that are seen as important potential mechanisms to realize U.S. offshore wind potential. These are:

- **Increase demand for offshore wind energy and grow the domestic supply chain at lower cost by considering expansion of Federal incentives related to offshore wind energy.** Federal incentives could also promote economic development, job creation, and community economic benefits. Technology-neutral incentives may be the most efficient way to accelerate the deployment of clean energy technologies overall. However, technology-neutral incentives will favor lower cost, land-based technologies in the near term. Targeted incentives for offshore wind could accelerate technology maturation, cost reduction, and deployment. Such near-term advancements could help the offshore wind energy industry scale up at the pace needed to contribute sufficiently to deployment and decarbonization goals.

- **Reduce offshore wind energy costs through technology innovation and adaptations that enable industry growth and provide affordable electricity throughout the country.** Reducing costs is essential to offshore wind industry growth. Expanded and accelerated research and development in site characterization and technology advancement will increase power production, reduce financial risks and uncertainties of project development, and enable domestic manufacturing. New system designs are required for U.S. operating conditions, such as deep water in the Pacific, hurricanes in the Gulf of Mexico, and ice formation in the Great Lakes. Accessing wind resources in deep-water areas (~60 percent of the U.S. offshore wind resource) will be key to reaching long-term deployment goals. The deployment of floating offshore wind platforms will lag fixed-bottom foundations as the technology is still maturing, but will be critical to development in the Pacific, Gulf of Maine and other regions with deep waters. Expanding domestic test and demonstration facilities for both components and

[10] The White House. 2021. "FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs." https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.
[11] For more information, see the BOEM's Notices Published in the Federal Register.
[12] Vineyard Wind 1: https://www.vineyardwind.com/vineyardwind-1.

full systems would enable domestic suppliers to refine and validate new products. Installation, operation, and maintenance innovations that are adapted to U.S. sites and reduce dependence on scarce equipment would make offshore wind energy more cost competitive in the United States. Integrating circular economy practices can extend the usable life of offshore wind power plants and components, thus increasing value with nominal investment.

- **Improve siting and regulatory processes by increasing transparency and predictability, auctioning new lease areas, understanding development impacts, expanding stakeholder engagement, and facilitating ocean co-use.** Responsible siting and project permitting can enable steady growth of a thriving industry, while ensuring protection of the environment and maximizing opportunities for ocean co-use. The number of lease areas will need to grow significantly over the next decade to meet state and Federal deployment goals. A regional planning approach may accelerate identification of additional wind energy sites and facilitate safe, equitable ocean co-use. The industry needs predictable and efficient regulatory reviews that are advanced by clear and efficient permitting processes. Interagency collaboration and sufficient resources for staffing, research, and monitoring are necessary to understand and mitigate offshore wind's potential impacts on the marine environment, ocean co-users, and communities. Collaborating with communities and enhancing stakeholder engagement will help enable mutually beneficial and equitable siting solutions. Developing standardized practices to minimize or offset environmental impacts, where needed, will reduce potential risks that may otherwise impede project development.

- **Invest in supply chain development, including customized offshore wind ports and vessels to establish a logistics network and attract further investment.** Investing sufficiently in manufacturing, ports, vessels, and a diverse U.S. workforce will reduce the cost of offshore wind energy, increase the pace at which projects are able to deploy, and could contribute significantly towards the energy justice goal of achieving equity in economic participation in the energy system. Building a domestic supply chain and growing the industry will require dozens of port upgrades, numerous Jones-Act-compliant vessels,[13] and new factories for component manufacturing and assembly. The availability of this infrastructure and broader certainty about the project pipeline are necessary to unlock $12 billion per year in private-sector project capital investments as well as create tens of thousands of good-paying jobs and capture the broader domestic economic gains associated with these investments. Regional collaboration in manufacturing, ports, vessels, and U.S. workforce development can result in facilities, networks, and policies that benefit all states within a region and the United States as a whole.

[13] The Merchant Marine Act of 1920, known as the Jones Act (Section 27), is a Federal statute requiring vessels that transport merchandise between two points within the U.S. territory to be built, registered, and owned in the United States, and crewed by U.S. citizens or residents. (46 U.S.C. § 55102)

- **Plan efficient and reliable grid integration to deliver offshore wind energy at scale.** Strong near-term efforts focused on grid integration are necessary to enable large-scale incorporation of offshore wind into the Nation's power grid and future energy mix without long delays or lost opportunities. In particular, facilitating collaborative, proactive, and long-term transmission planning and investing in phased grid development is vital to increase the certainty and pace of offshore wind energy development, drive cost reductions, and help identify options to optimize transmission infrastructure in a way that protects the marine environment and is compatible with existing uses of the ocean and the needs of coastal communities. Innovation, cost reductions, and domestic supply capabilities are needed in high-voltage direct current technology to enable development farther from shore. There is a lack of sufficient onshore transmission capacity to transmit power from the strongest offshore wind resources to load centers. Offshore wind energy developers, regional transmission operators (RTOs)[14] or independent system operators (ISOs)[15], and other stakeholders are already assessing the limited, existing onshore points of interconnection and seeking coordination from the Federal Government on transmission expansion. Creating incentives to plan and share transmission across multiple offshore wind projects, states, and transmission planning regions can encourage collaboration in infrastructure planning, cost allocation, and transmission system development that can benefit all states within and across regions. Renewable fuels can provide energy storage and clean fuel for applications that are difficult to electrify directly.

All of these strategic priorities require examining and integrating stakeholder feedback. Offshore wind stakeholder groups encompass a wide array of public and private participants with varying interests and obligations, including Congress, Federal agencies, Tribal Nations, state and local governments, recreational and commercial water users, coastal communities, current and potential future participants in the offshore wind industry, port authorities, transmission system operators, researchers, environmental organizations, and academic institutions. Considering and addressing the concerns of impacted stakeholders are important to understanding the complex challenges of offshore wind energy deployment and the impacts of potential strategies to grow the industry.

With a range of participants acting and collaborating on policy, investment, technology advancement, analysis, and standards development, these strategic priorities can all be achieved. Doing so would help attract investments in the U.S. supply chain that would create new job opportunities; make offshore wind energy more cost competitive with other electricity generation sources in U.S. coastal energy markets; and reduce regulatory, construction, and economic uncertainty that currently impedes industry growth.

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[14] An RTO is an independent governing body designated by the and Federal Energy Regulatory Commission that coordinates power generation and transmission within a regional market.

[15] An ISO is an independent, federally regulated entity established to coordinate regional transmission in a nondiscriminatory manner to ensure the safety and reliability of the electric system.

Offshore Wind Energy Strategies

Table of Contents

I. Report Preparation

Objective. This report outlines regional and national strategies to accelerate and maximize the effectiveness, reliability, and sustainability of U.S. offshore wind deployment and operation. The strategies described herein include work currently in progress, as well as new and expanded initiatives that would require additional resources to implement. This report does not express commitments from any agency or entity or make explicit policy recommendations. It summarizes the status of offshore wind in the United States, describes the nature of the barriers and challenges impeding further deployment, and identifies strategies to make the United States a global leader in the industry.

Methodology. This report was prepared by the U.S. Department of Energy's (DOE's) Wind Energy Technologies Office (WETO), with the understanding that carrying out the strategies presented herein will require broad involvement beyond DOE and the Federal Government. Because of the cross-agency interests inherent to offshore wind energy, these strategies were informed by a series of discussions with and/or reviews of early drafts by Federal entities, notably the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) within the U.S. Department of the Interior (DOI), the Maritime Administration of the Department of Transportation, the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce, and Federal Energy Regulatory Commission (FERC). Within DOE, WETO received input from the Loan Programs Office, Advanced Research Projects Agency – Energy (ARPA-E), and the Office of Electricity. The roles of various Federal agencies are briefly described in Appendix A1.

Report preparation included individual input from academic and research institutions, national laboratories, private companies, and state governments. For offshore wind grid integration and environmental research, WETO leveraged individual stakeholder responses to recent Requests for Information[16,17] on these topics as inputs to this report. On other technical topics, the National Renewable Energy Laboratory (NREL) sought perspectives and input from qualified individuals and did not seek group consensus. NREL hosted a series of informal discussions with qualified stakeholders to inform the challenges, opportunities, and potential actions included in the report. In this expedited outreach effort, more than 150 professionals, identified based on specific and objective criteria developed by WETO, contributed ideas and perspectives.

In preparing this report, WETO also identified more detailed actions, within the broader strategic priorities presented, for DOE itself to potentially undertake in support of U.S. offshore wind. WETO will incorporate these actions into an upcoming report on the strategic vision, progress, goals, and targets of DOE's wind energy program, including assessments of wind energy markets and manufacturing.

[16] DE-FOA-0002389: Offshore Wind Transmission System Integration Research Needs

[17] DE-FOA-0002235: Request for Information (RFI): Offshore Wind Environmental Research & Environmental Monitoring and Impact Mitigation Technology Validation Funding Opportunity

II. Offshore Wind Energy Background

Value. With continued cost reductions, offshore wind can become a critical energy source to help meet America's power needs in a low-carbon and sustainable energy future. It can generate large amounts of reliable power, because wind speeds tend to be higher, more consistent, and less turbulent over water, where there are no mountains or buildings to obstruct wind flow. Offshore wind power plants can be sited near coastal population centers with high electricity demand or load. Generating power near energy consumers helps minimize the cost of installing transmission lines and the amount of energy lost during transmission, both of which can be significant over long transmission distances. As a result, offshore wind energy is an attractive option near many populated coastal areas that have transmission constraints on land or limited land available for new utility-scale wind or solar power plants. Furthermore, many areas where offshore wind projects are planned tend to have stronger offshore winds in the afternoon and evening than in the morning.[18,19] This characteristic aligns with daily power demand cycles and can complement other variable renewables; for instance, offshore wind plants continue generating power in the evening as solar energy generation is ramping down. For these and other reasons, offshore wind can be a key contributor in certain energy markets to achieving a zero-carbon electricity grid by 2035 and net-zero emissions by 2050.[20]

Technical Context. A typical offshore wind power plant, shown in Figure 1, generates electricity from groups of wind turbines.[21,22] Each wind turbine is mounted on top of a tower that is supported by a base foundation. Offshore wind foundations are most often monopiles (tube-type), or jacket (lattice-type) structures that require driving pilings into the seabed to anchor the structure. Alternatively, a structure may be supported by "suction-bucket" anchors or a gravity base—a wide, heavy structure placed on the seafloor. Deeper waters, such as those off the West Coast and the Gulf of Maine, require floating foundations, with mooring lines connected to anchors in the seabed. A variety of large specialty construction vessels are needed to drive foundation piles, install wind turbines on top of towers, and lay the electrical cables. For example, a wind power plant using 12-megawatt (MW) turbines requires a wind turbine installation vessel that can lift 500-ton components over 500 feet high and handle wind turbine blades that are more than 300 feet long.

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[18] Mills, Andrew, Millstein, Dev, Jeong, Seongeun, Lavin, Luke, Wiser, Ryan, Bolinger, Mark. 2018. *Estimating the Value of Offshore Wind Along the United States' Eastern Coast*. Lawrence Berkeley National Laboratory. https://www.energy.gov/sites/prod/files/2018/04/f50/offshore_erl_lbnl_format_final.pdf.

[19] Optis, Mike, Rybchuk, Alex, Bodini, Nicola, Rossol, Michael, and Musial, Walter. 2020. *2020 Offshore Wind Resource Assessment for the California Pacific Outer Continental Shelf*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-77642. https://www.nrel.gov/docs/fy21osti/77642.pdf.

[20] Lantz, Eric, Barter, Garett, Gilman, Patrick, Keyser, David, Mai, Trieu, Marquis, Melinda, Mowers, Matthew, Shields, Matt, Spitsen, Paul, and Stefek, Jeremy. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-80031. https://www.nrel.gov/docs/fy21osti/80031.pdf.

[21] For additional technical context on offshore wind energy, see New York State Energy Research and Development Authority's Offshore Wind Technology 101 video.

[22] For additional technical context for floating offshore wind energy, see NREL's Overview of Floating Offshore Wind webinar recording.

Array cables carry electricity from each wind turbine to an offshore transformer substation, and a high-voltage export cable carries the electricity from the substation to land. Export cables are buried under the seafloor for protection or may be covered in rocks or concrete mats at certain sections where burial is impractical. Where the cable meets land, it may be laid in a trench, or horizontal directional drilling techniques can be used to avoid construction impacts of digging a trench on the shoreline. An onshore substation receives the electricity from the wind power plant and transmits it to the grid.

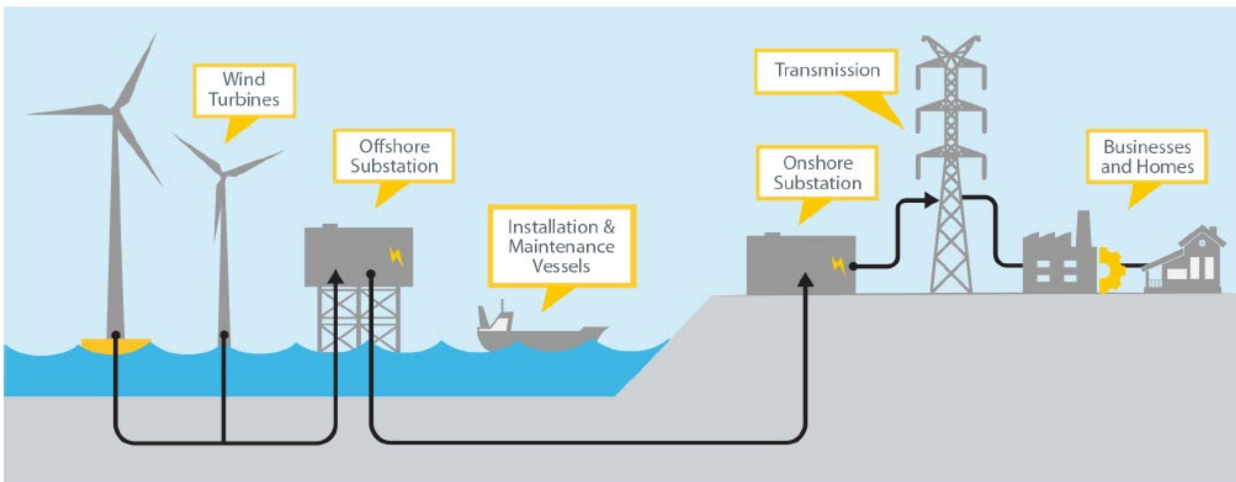

Figure 1. *Major offshore wind power plant and transmission elements*
Image created by Jennifer Breen Martinez, National Renewable Energy Laboratory

At present in the United States, the offshore wind project developer is responsible for all assets, from the wind turbines to the point of grid interconnection at the onshore substation. Presently, the costs to upgrade the substation and other affected grid components are often the developer's responsibility as well. The onshore grid must have capacity to accept the offshore wind power and dispatch it to electricity consumers. Appendix A2 describes the grid transmission planning process. The project owner, who may or may not be the developer, is responsible for operating the offshore wind power plant. The transmission owner (who may or may not be the onshore transmission developer) is responsible for physically operating the transmission facilities, in many cases under the operational authority of a regional transmission operator (RTO)[23] or independent system operator (ISO).[24]

[23] An RTO is an independent governing body designated by FERC that coordinates power generation and transmission within a regional market.
[24] An ISO is an independent, federally regulated entity established to coordinate regional transmission in a nondiscriminatory manner to ensure the safety and reliability of the electric system.

III. Offshore Wind Energy Outlook

State of the Global Industry. The global offshore wind energy industry is rapidly expanding. Offshore wind technology evolved in Northern Europe over the past 20 years and global installed capacity now exceeds 30 gigawatts (GW). At the end of 2020, the United Kingdom led the world with the most installed capacity at roughly 10.5 GW.[25] The rest of Europe had another 13 GW of offshore wind capacity installed across 11 other countries—notably Germany, Belgium, the Netherlands, and Denmark.[26] Costs have fallen significantly, such that Germany and the Netherlands have achieved several subsidy-free auctions of offshore wind energy,[27] although continued reductions are necessary for broad cost competitiveness. Since 2015, China has installed more offshore wind capacity annually than any other country, with over 7 GW installed by the end of 2020.[28] The country also has the largest pipeline of projects in the planning phase.[29] Governments from various countries and the European Union have invested in developing and demonstrating innovative technologies. Private industry continues to invest in research and development (R&D), often collaborating with other entities such as government agencies, research institutions, colleges and universities, and national laboratories.

The U.S. industry has lagged Northern Europe's, for a number of reasons. Electricity prices tend to be lower in the United States than in Europe, so it is more difficult for new technologies to be cost competitive in the U.S. market. Prior to states enacting mandates for offshore wind energy procurement, the United States lacked the supportive policies that drove the first decade-plus of European offshore wind energy deployment. In addition, many entities are involved in the processes required to site and permit power plants in Federal waters and route cables through state waters, taking significant coordination and time. Needing to navigate unprecedented and evolving processes means that early projects have missed deadlines and struggled to secure power purchase agreements.

State of the Domestic Industry and Recent Progress. As of June 2021, the United States has seven operating offshore wind turbines in two small projects totaling 42 MW of installed capacity, and 17 active commercial lease areas in Federal waters[30] with 15 commercial projects that are actively in permitting in those lease areas (see Appendix A4). As discussed in greater detail later, the Federal Government has recently committed to rapidly increase the scale of offshore wind development in the United States and progress is being made to do so. Over the

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[25] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.
[26] Ibid
[27] Jansen, M., Staffell, I., Kitzing, L. et al. *Offshore wind competitiveness in mature markets without subsidy*. Nat Energy 5, 614–622 (2020). https://doi.org/10.1038/s41560-020-0661-2.
[28] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.
[29] Ibid
[30] For leasing status, see BOEM State Activities.

last year, the offshore wind pipeline has grown 24 percent to 35 GW and state offshore wind procurement commitments have grown to 39 GW by 2040.[31] DOI aims to review 16 Construction and Operations Plans by 2025 and has published seven recent Notices of Intent to begin the Environmental Impact Scoping process for projects on the path to meeting that target.[32] Vineyard Wind 1 became the first commercial-scale U.S. project to receive Federal approval for construction and operation in May 2021,[33] and reached financial close in September 2021.[34] In response, developers have initiated offshore wind project development activities, primarily along the Eastern Seaboard.

In the Pacific, BOEM has identified potential offshore wind energy locations—known as Call Areas—in Federal waters off California and Hawaii for review and public comment to determine if they will be suitable for commercial wind energy. Planning for offshore wind leasing is also underway in Oregon. Gulf Coast states have contributed to the supply chain, including jacket structures from Louisiana and a wind turbine installation vessel under construction in Texas. The first Gulf of Mexico Intergovernmental Renewable Energy Task Meeting was held by BOEM in June 2021 to begin coordinating offshore leases areas.[35] In October 2021, BOEM announced plans to potentially hold up to seven new offshore lease sales by 2025 in the Gulf of Maine, New York Bight, Central Atlantic, and Gulf of Mexico, as well as offshore the Carolinas, California, and Oregon.[36]

Goals. In March 2021, DOE, DOI, and the U.S. Department of Commerce announced a joint agency goal to deploy 30 GW of offshore wind energy by 2030 while protecting biodiversity and promoting ocean co-use.[37] Achieving this goal would create tens of thousands of jobs in a range of occupations that would pay at or above the national average and sustain upward of $12 billion a year in project capital investments.[38] Such project investments would help spur supply chain growth, port revitalization, vessel construction, wind power plant operations, and development of onshore assembly facilities.

[31] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.
[32] For more information, see BOEM's Notices Published in the Federal Register.
[33] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.
[34] Vineyard Wind. 2021. "Vineyard Wind Becomes the First Commercial Scale Offshore Wind Farm in the US to Achieve financial Close." https://www.vineyardwind.com/press-releases/2021/9/15/vineyard-wind-1-becomes-the-first-commercial-scale-offshore-wind-farm-in-the-us-to-achieve-financial-close.
[35] For more information, see Gulf of Mexico Intergovernmental Renewable Energy Task Force.
[36] U.S. Department of the Interior. 2021. "Secretary Haaland Outlines Ambitious Offshore Wind Leasing Strategy." https://www.doi.gov/pressreleases/secretary-haaland-outlines-ambitious-offshore-wind-leasing-strategy
[37] The White House. 2021. "FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs." https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.
[38] Ibid

The Biden Administration's climate goals include decarbonizing the power sector by 2035 and reaching net-zero emissions economywide by 2050.[39] A variety of carbon-pollution-free electricity-generating sources, in combination with energy storage, will be needed to achieve these climate goals. Offshore wind can contribute to the growing renewable energy portfolio as fossil-fuel units are retired and electricity demand grows over time. Transportation, buildings, and industrial sectors will likely shift toward a cost-effective mix of electrification and clean fuels to reduce emissions, which will also increase national demand for clean electricity. Deploying 30 GW of offshore wind energy by 2030 and working toward economywide decarbonization goals could help set the country on a path to reach 110 GW of offshore wind or more by 2050.[40]

Major Barriers. Major barriers to the U.S. offshore wind energy industry must be addressed to meet these deployment goals. As an early-stage industry, offshore wind is not yet cost competitive with established energy generation sources in the United States. As of 2021, there are only 42 MW of installed offshore wind in the United States, coinciding with an immature supply chain. Offshore wind power plants can have impacts on fishing; recreation and tourism; local communities; military missions; radar; marine habitats; and species are significant concerns that need to be addressed through research to understand impacts, engagement with affected stakeholders, development of impact minimization solutions, and expanded opportunities for ocean co-use. While some impacts are not fully understood and related concerns have led to opposition for early projects, in recent years research has been conducted to understand current and potential impacts.[41,42,43] Despite notable improvements in the pace of permitting in 2021, the permitting process has historically been lengthy and uncertain, which has both slowed the pace of development and provided a challenging environment for financial investment. The limited capacity of the existing grid infrastructure is a potentially significant barrier and, unless addressed, grid integration and transmission challenges will inhibit industry growth. Particularly, innovation and cost reductions are needed in high-voltage direct current technology to enable development in deeper waters and farther from shore.

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[39] The White House. 2021. "FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies." April 22, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

[40] Lantz, Eric, Garett Barter, Patrick Gilman, David Keyser, Trieu Mai, Melinda Marquis, Matthew Mowers, Matt Shields, Paul Spitsen, Jeremy Stefek. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-80031. https://www.nrel.gov/docs/fy21osti/80031.pdf.

[41] Mills, A. D., Millstein, D., Jeong, S., Lavin, L., Wiser, R., and Bolinger, M. 2018. "Estimating the value of offshore wind along the United States' Eastern Coast." *Environmental Research Letters*, 13(9), 094013. https://doi.org/10.1088/1748-9326/aada62.

[42] Carr-Harris, A., and Lang, C. 2019. "Sustainability and tourism: the effect of the United States' first offshore wind farm on the vacation rental market." *Resource and Energy Economics*, 57, 51–67. https://www.sciencedirect.com/science/article/pii/S0928765518302902?via%3Dihub.

[43] Tegen, S., Keyser, D., Flores-Espino, F., Miles, J., Zammit, D., and Loomis, D. 2015. *Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-61315. https://www.nrel.gov/docs/fy15osti/61315.pdf.

Floating Offshore Wind. Floating offshore wind technology is needed in deep water (generally deeper than 60 meters), where deploying fixed-bottom structures becomes uneconomical or impractical. Floating offshore wind may be key to achieving long-term deployment goals as approximately 60 percent of the Nation's offshore wind technical resource potential is in deep water areas where floating platforms would be used.[44] As such, the U.S. floating offshore wind market is expected to be large and, with focused investment, the country could become a global leader in this part of the industry. Deployment of floating offshore wind platforms will lag fixed-bottom foundations as the technology matures, but floating offshore wind energy capacity could eventually exceed that of fixed-bottom offshore wind in the United States.

Regional Considerations. Most strategies and key initiatives identified in Section V of this report apply directly to all U.S. coastal regions as national interest in offshore energy increases. These strategies will be applicable with varying degrees of emphasis and urgency as each region progresses through the stages of offshore wind energy development. Certain adaptations and priorities are needed to accommodate unique regional conditions within the Atlantic, Pacific, Gulf of Mexico, and Great Lakes. Section VI summarizes each region's offshore wind development status, unique or relevant regional characteristics and factors, and expanded initiatives to address the unique challenges. Cooperative efforts in each region will likely help facilitate deployments and supply chain development to enable individual states to realize their respective offshore wind energy goals.

DOE Investments. Since 2011, DOE has supported a broad portfolio of offshore wind research, development, and demonstration projects to spur development of technologies and a domestic industry. DOE has supported a range of efforts aimed at accelerating offshore wind deployment, including environmental and siting research, stakeholder engagement, and workforce development activities. DOE is supporting research and collaborative efforts to address transmission constraints for offshore wind technologies and address grid integration challenges. Through its Loan Programs Office, DOE has the capacity to provide public financing for a range of development projects, including transmission projects and manufacturing facilities.

DOE has supported the construction of key testing facilities for turbine components, including a large-scale wind turbine blade testing facility in Massachusetts and a drivetrain testing facility in South Carolina which have been active in validating the reliability of larger components. DOE's technology demonstration program features innovative offshore wind technologies that have yet to be deployed on a commercial scale, including support for two of the Nation's first floating offshore wind demonstration projects. These demonstration projects are providing valuable technological advances and lessons in state permitting, approval, and grid interconnection processes.

[44] The technical resource potential is the amount of resource that could potentially be developed using existing technology but excludes areas that are unlikely to or cannot legally be developed. For more information, see Computing America's Offshore Wind Energy Potential.

In June 2018, DOE selected the New York State Energy Research and Development Authority to administer a $41 million National Offshore Wind R&D Consortium composed of representatives from industry, academia, government, and other stakeholders.[45] The consortium continues to grow its membership and expand its portfolio of dozens of projects that advance offshore wind plant technologies, develop innovative methods for wind resource and site characterization, and develop advanced technology solutions to address U.S.-specific installation, operation, maintenance, and supply chain needs. Also in 2018, DOE's ARPA-E started the ATLANTIS (Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control) program for floating offshore wind. The first phase of the program included 15 projects, and applied the discipline of control co-design to reduce the size of the massive and expensive floating platforms by incorporating automatic control technologies.[46,47]

[45] For more information, see DOE's National Offshore Wind R&D Consortium web page.
[46] ARPA-E. 2019. "Department of Energy Announces $26 Million for Offshore Wind Energy." https://arpa-e.energy.gov/news-and-media/press-releases/department-energy-announces-26-million-offshore-wind-energy.
[47] Additional ARPA-E projects include Ultra-Large Wind Turbine and Active Aerodynamic Load Control for Wind Turbines and Megawatt-scale Power-Electronic-Integrated Generator with Controlled Dc Output.

IV. Strategic Priorities

This report outlines five strategic priorities, each of which is supported by a number of important focus areas and actionable initiatives with potential to accelerate and maximize the effectiveness, reliability, and sustainability of U.S. offshore wind energy deployment and operation. This section expands on these priorities and discusses initiatives to achieve them. As shown in Figure 2, the strategic priorities are:

- Increase demand for offshore wind energy and grow the domestic supply chain at lower cost by considering expansion of **Federal incentives** related to offshore wind energy.
- Reduce offshore wind **energy costs** through technology innovation and adaptations that enable industry growth and provide affordable electricity throughout the country
- Improve **siting and regulatory processes** by increasing transparency and predictability, auctioning new lease areas, understanding development impacts, expanding stakeholder engagement, and facilitating ocean co-use
- Invest in **supply chain** development, including customized offshore wind ports and vessels to establish a logistics network and attract further investment
- Plan efficient and reliable **grid integration** to deliver offshore wind energy at scale.

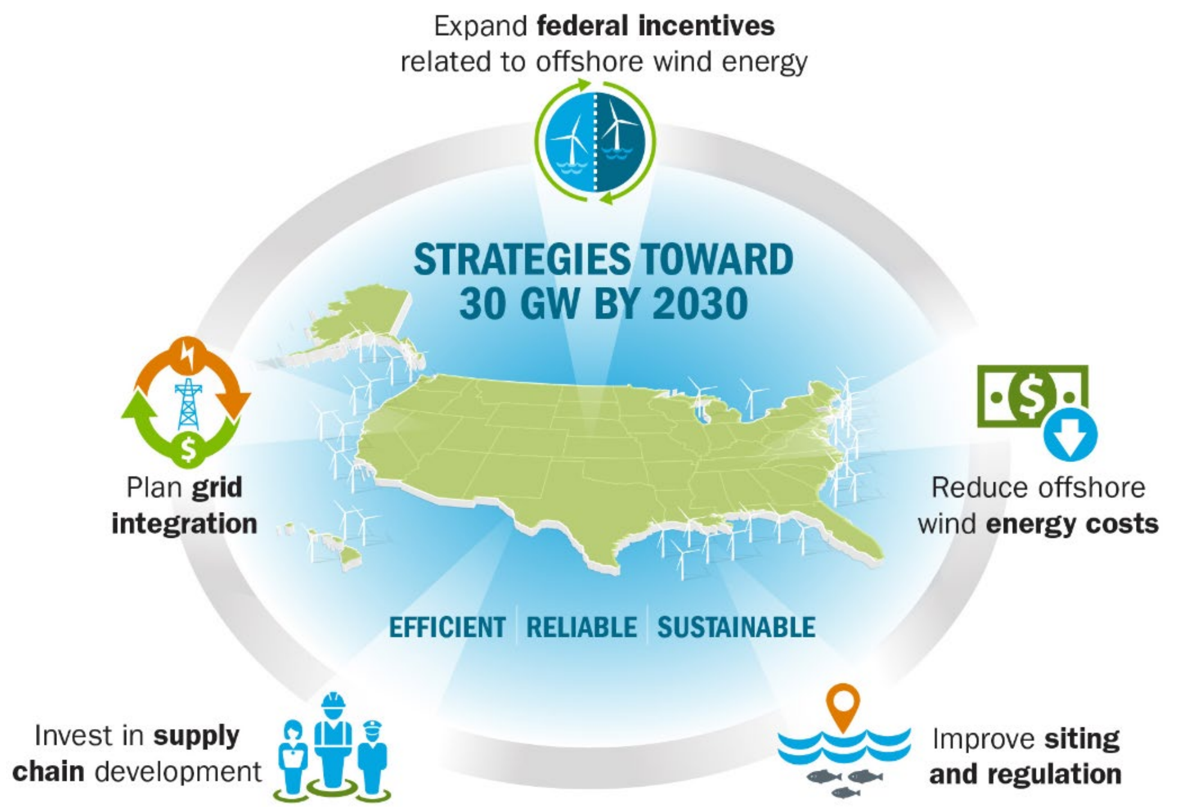

Figure 2. *Strategic priorities*
Image created by John Frenzl, National Renewable Energy Laboratory

Private investment is critical to offshore wind energy deployment, but depends on the perceived long-term certainty of the offshore wind project pipeline. Success across all five strategic priorities would help grow the pipeline and attract the hundreds of billions of dollars[48] in investment necessary to sustain the industry. That investment would result in additional technology development, grid modernization and upgrades, domestication of the supply chain, and workforce development that would further accelerate cost reductions and ultimately create a positive, self-reinforcing growth cycle.

IV1. Consider Expansion of Federal Incentives

Increase demand for offshore wind energy and grow the domestic supply chain at lower cost by considering expansion of Federal incentives related to offshore wind energy. Federal incentives could also promote economic development, job creation, and community economic benefits. Technology-neutral incentives may be the most efficient way to accelerate the deployment of clean energy technologies overall. However, technology-neutral incentives will favor lower cost, land-based technologies in the near term. Targeted incentives for offshore wind could accelerate technology maturation, cost reduction, and deployment. Such near-term advancements could help the offshore wind energy industry scale up at the pace needed to contribute sufficiently to deployment and decarbonization goals.

To achieve the national 30-GW-by-2030 deployment goal, it will likely be necessary to continue and expand incentives at the state and Federal levels. Potential Federal incentives could include, for example, extended tax credits or new tax credits for offshore wind supply chain, port, and vessel investments. Ambitious state targets—totaling 39 GW by 2040 (Appendix A5)—have been the primary driver for offshore wind development to date, but until offshore wind energy is more broadly competitive with other sources of electricity, its deployment may be constrained to these states in the absence of the market demand created by specific national policy support.

The existing 30 percent investment tax credit for offshore wind is important for reducing the costs of near-term projects; however, it is set to expire in 2025,[49] meaning it will not support offshore wind projects that are expected to begin construction in 2026 or later. Additionally, the immature U.S. supply chain, lack of suitable port infrastructure, and lack of specialized offshore wind installation vessels could limit rapid offshore wind deployment. Manufacturing incentives could help boost the domestic offshore wind supply chain. Federal and state

[48] Lantz, Eric, Garett Barter, Patrick Gilman, David Keyser, Trieu Mai, Melinda Marquis, Matthew Mowers, Matt Shields, Paul Spitsen, Jeremy Stefek. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-80031. https://www.nrel.gov/docs/fy21osti/80031.pdf.

[49] DSIRE, N.C. Clean Energy Technology Center. 2021. "Business Energy Investment Tax Credit (ITC)." https://programs.dsireusa.org/system/program/detail/658.

incentives could include detailed procurement requirements to enhance economic development such as diverse supplier requirements (e.g., small and disadvantaged business set-asides) and incentives for local sourcing, job creation, or community ownership.

One type of Federal incentive related to offshore wind that could be considered is extended or expanded tax incentives.

Tax Credits. Tax credits reduce project costs, thereby lowering the electricity prices that offshore wind energy projects are able to negotiate with utilities, resulting in lower electricity rates for the public. This approach can mitigate any cost impact from offshore wind power procurement mandates and could accelerate the timeframe within which offshore wind energy becomes competitive in coastal electricity markets, as costs come down relative to other forms of electricity generation. The Consolidated Appropriations Act of 2021 created a 30 percent investment tax credit for offshore wind energy projects beginning construction between January 2017 and December 2025.[50,51] Current Internal Revenue Service guidance allows such projects 10 calendar years to enter into service after the calendar year during which construction of the project began, so offshore wind projects with a commercial operation date[52] in 2035 or earlier are likely to qualify depending on when they start construction.[53] However, given the early state of floating offshore wind technology development, extending the investment tax credit or expanding the definition of "start of construction" is likely necessary to drive significant floating offshore wind energy development. Extending the tax credit for all offshore wind deployment can help realize consistent industry growth and maximize economic benefits. Additionally, similar to the 48C Manufacturing Tax Credits in the American Recovery and Reinvestment Act of 2009,[54] incentives for other parts of the sector could stimulate investment in offshore wind energy installation vessels, port equipment, and manufacturing facilities. Manufacturing tax credits could come in multiple forms that could be deployed separately or together. Investment tax credits would reduce the costs of supply chain development and could accelerate the development of new factories or retooling existing ones; volume-based manufacturing tax credits (paid based on the volume of components produced in the United States) would make U.S. component production more competitive relative to imports and could increase the domestic content of offshore wind facilities. Further, making tax credits refundable could benefit more businesses and further encourage investment and growth.[55] Establishing tax credits before large-scale commercial deployment starts would enable simultaneous construction of multiple projects, allow U.S. manufacturers to establish a role in domestic and global markets, and maximize near-term economic benefits.

[50] See Consolidated Appropriations Act of 2021 (Pub. L. No. 116-260, div. EE, tit. I, §204).
[51] For more information, see The Energy Credit or Energy Investment Tax Credit (ITC).
[52] The commercial operation date is the date a project has demonstrated operation and certified commission to meet project completion as required by the power off-taker.
[53] Internal Revenue Service Notice 2021-05: https://www.irs.gov/pub/irs-drop/n-21-05.pdf.
[54] U.S. Department of Energy. 2013. FACT SHEET: 48C MANUFACTURING TAX CREDITS. https://www.energy.gov/downloads/fact-sheet-48c-manufacturing-tax-credits.
[55] Refundability would immediately pass the full value of the credit to the developer, regardless of their tax liability, allowing them to avoid costs associated with depreciation or the need for a tax-equity partner.

Table 1. Tax Credit Initiatives

Initiatives	Specific Actions To Implement	Outcome
Consider extending investment tax credits	Support floating offshore wind energy projects that may begin construction later than 2025	Economic deployment of floating offshore wind energy technology
Consider establishing a tax credit for offshore wind manufacturing facilities	Make manufacturing equipment, port-based equipment, and offshore wind vessels eligible	Growth of a cost-competitive domestic supply chain

IV2. Reduce Offshore Wind Energy Costs

Reducing costs is essential to offshore wind industry growth. Expanded and accelerated research and development in site characterization and technology advancement will increase power production, reduce financial risks and uncertainties of project development, and enable domestic manufacturing. New system designs are required for U.S. operating conditions, such as deep water in the Pacific, hurricanes in the Gulf of Mexico, and ice formation in the Great Lakes. Accessing wind resources in deep-water areas (~60 percent of the U.S. offshore wind resource) will be key to reaching long-term deployment goals. Deployment of floating offshore wind platforms will lag fixed-bottom foundations as the technology matures, but will be critical to development in the Pacific, Gulf of Maine and other regions with deep waters. Expanding domestic test and demonstration facilities for both components and full systems would enable domestic suppliers to refine and validate new products. Installation, operation, and maintenance innovations that are adapted to U.S. sites and reduce dependence on scarce equipment would make offshore wind energy more cost competitive in the United States. Integrating circular economy practices can extend the usable life of offshore wind power plants and components, thus increasing value with nominal investment.

Continued cost reductions can accelerate and maximize the competitive potential of offshore wind energy in all U.S. coastal regions. As an increasing amount of offshore wind energy has been deployed globally, the reported costs of new projects have dropped by 28–51 percent since 2014.[56] The factors contributing to these cost reductions include larger-capacity wind turbines, larger-scale projects (gigawatt scale), component and process improvements, competitive procurement regimes, more favorable financing terms, dedicated infrastructure, and overall experience in the supply chain. In Europe and Asia, fixed-bottom offshore wind energy has become an economically feasible electricity generation source in some locations.[57] Domestic infrastructure

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[56] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.

[57] Jansen, M., Staffell, I., Kitzing, L. et al. "Offshore wind competitiveness in mature markets without subsidy." *Nat Energy* 5, 614–622 (2020). https://doi.org/10.1038/s41560-020-0661-2.

investments (discussed under the Supply Chain strategic priority), technology advancements, dedicated incentives (discussed in the Federal Incentives strategic priority), large-scale deployment, and other activities are needed to support continued cost reductions in the United States. An improved economic offering from offshore wind energy yields ratepayer benefits and enables it to become a cornerstone of a sustainable, least-cost, and reliable power system. For offshore wind to play a central role in all U.S. coastal regions, deeper waters need to be accessed through floating offshore wind energy technologies. Currently entering its commercial deployment phase, floating offshore wind features costs that are as much as 50 percent higher than fixed-bottom technologies. Yet the technology has the potential to achieve significant cost reductions and unlock untapped resources, particularly along the U.S. Pacific Coast.

DOE's research goal is to reduce the levelized cost of energy (LCOE)[58] for both fixed-bottom and floating offshore wind energy by 40–55 percent by 2030 from today's levels (Table 2). This goal serves as a benchmark for evaluating the impact of Federal R&D activities over time. Figure 3 shows the detailed factors that will likely drive cost reductions.

Table 2. DOE's Levelized Cost of Energy Goals[59]

	2020 (reported) (cents per kilowatt-hour [¢/kWh])	2030 Goal (¢/kWh)
Fixed-bottom	8.6	5.2
Floating	13.5	6.1

Offshore wind energy deployment is determined by project LCOE and expected revenue, which both vary from one location to another because of differences in project siting characteristics (e.g., wind speeds, water depth, distance to shore) and local power system pricing (e.g., alternative generation options, transmission constraints, and policy). Therefore, the economically feasible LCOE of a project can vary from one location to another. In market regions that tend to have higher power prices (e.g., because of constrained land-based energy siting options or transmission constraints), the economic offering from offshore wind can be particularly attractive.

As with all sources of energy, offshore wind energy has costs and benefits that are not captured in LCOE. For example, switching from fossil-fuel generation to offshore wind energy reduces carbon dioxide, nitrogen oxides, and sulfur dioxide emissions and therefore provides public health and climate benefits. In 2020, the health and climate benefits of land-based wind energy generation averaged $76 per megawatt-hour (MWh) across the United States—with climate

[58] LCOE is the average cost of electricity generated over the lifetime of the power plant, considering capital expenditures, operating expenditures, annual energy production, and years in service.
[59] Stehly, Tyler, Duffy, Patrick and Beiter, Philipp. 2021. 2020 Cost of Wind Energy Review. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-81209. https://www.nrel.gov/docs/fy22osti/81209.pdf

benefits contributing on average $46/MWh and health benefits contributing $32/MWh.[60] The environmental impact of waste generated at the end of a power plant's life is a cost not typically accounted for in LCOE. The ability to reuse and recycle wind power plant components and their materials could significantly reduce this cost.

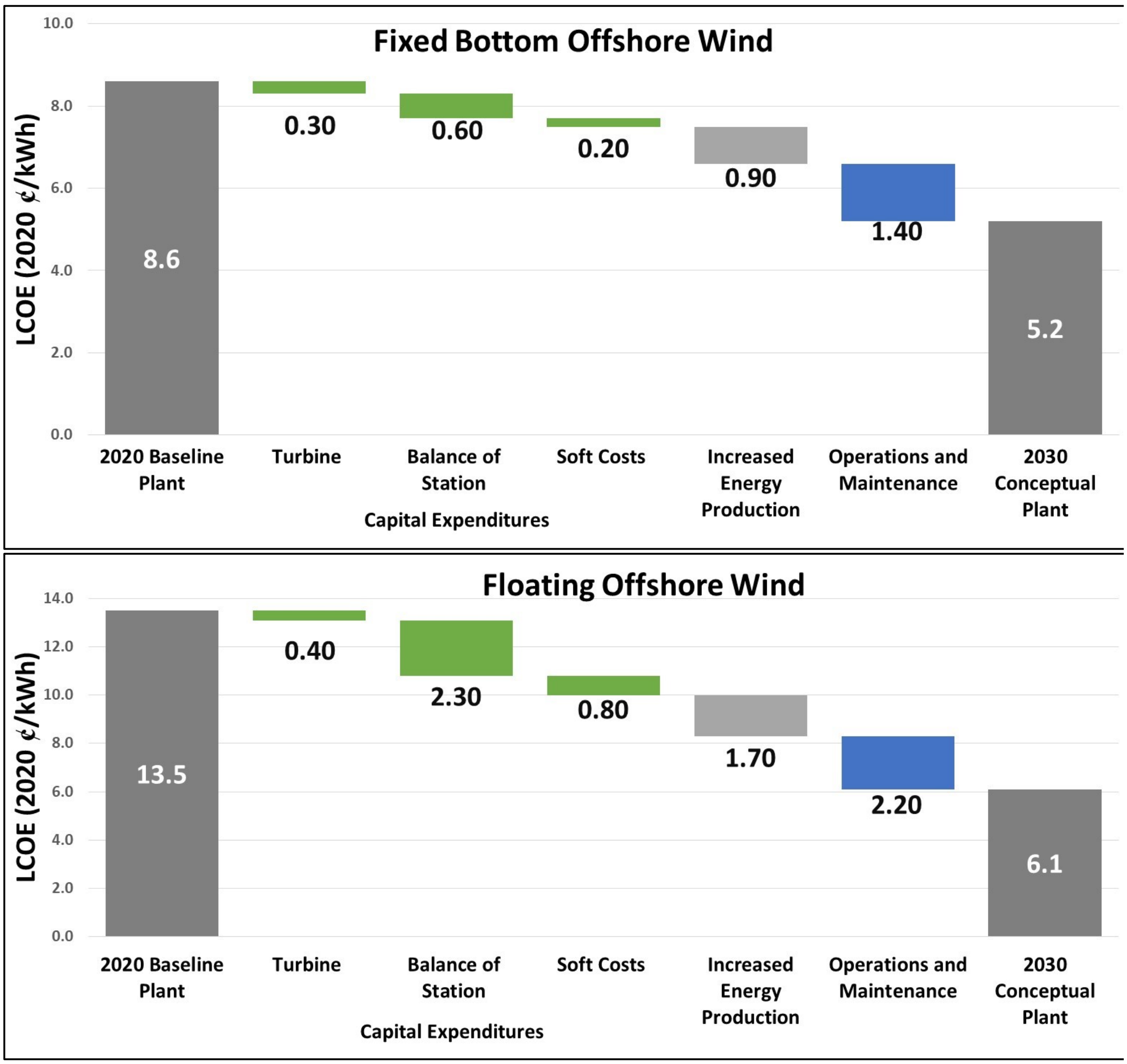

Figure 3. Levelized cost of energy cost reduction targets and contributing factors

Offshore wind energy cost reductions are achievable with investments in the following areas:[61]

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[60] Wiser, Ryan, Bolinger, Mark, Hoen, Ben, Millstein, Dev, Rand, Joe, Barbose, Galen, Dargouth, Naïm, Gorman, Will, Jeong, Seongeun, Mills, Andrew, and Paulos, Ben. 2021. *Land-Based Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere/wind/articles/land-based-wind-market-report-2021-edition-released.
[61] For more information, see the 2020 Cost of Wind Energy Review.

- Efficiencies gained through larger project sizes, bigger wind turbines, improved cables, and optimized foundation designs (especially impactful for floating systems)
- Lower financing costs made possible by decreased project risks as a result of industry experience and a robust, predictable project pipeline
- Increasing energy production with larger wind turbines that access more consistent winds, enhanced control strategies, reduced energy losses throughout the system, and higher availability as a result of improved maintenance
- Decreasing operation and maintenance costs by minimizing the need for at-sea personnel and reducing wind turbine downtime. This can be achieved through advancements such as designs that are easier to maintain, the use of remote monitoring and automation, and maintenance decision-making tools to optimize the timing and method of maintenance actions.

In addition to the research needs mentioned above that apply to both fixed-bottom and floating, floating offshore wind especially needs:

- Industrialization to develop floating structure designs and the supporting manufacturing infrastructure for mass production, unlocking significant economies of scale
- Full-system innovations including platforms, anchors, moorings, turbines, and controls[62] to improve designs and reduce system costs.

Technical advancements are needed to lower offshore wind costs, facilitate domestic manufacturing, and open new regional markets. The North- and Mid-Atlantic markets of the United States are developing first, and it is expected that initially, existing technology and logistical solutions can be leveraged from European supply chains. To reduce costs, create new and lasting U.S. jobs, and optimize the energy production of U.S. wind power plants, supply chains and technology innovation must be tailored to U.S. markets. This is particularly true for locations where new technology must adapt to the unique offshore conditions of the region. For example, floating offshore wind technology will be necessary for most projects developed in the Pacific because of the deeper waters.

Floating offshore wind technology could also open up many other regions to offshore wind energy development, including the Gulf of Maine and the Great Lakes. This expanded development potential could contribute significantly to the Nation's full transition to clean energy. However, floating foundations introduce additional technology challenges and cost drivers, including anchoring and mooring systems, floating platform design, and the need for integrated platform and wind turbine controls. An expanded R&D effort to lower the cost, as

[62] Wind turbine controls operate the electrical and mechanical systems of a wind turbine, using a network of sensors connected to a central processing system. The sensors collect data about the conditions surrounding the turbine such as temperature, wind speed, and voltage on the electric grid. The central processing system receives the data, identifies what action should be taken based on predefined settings or algorithms, and sends signals to the turbine's mechanical and electrical systems to respond accordingly—such as changing the speed of the rotor or the power coming from the inverter.

well as advance the commercial and technical readiness, of floating offshore wind energy is needed to unlock wind energy resources in regions with deep water. Experience gained from R&D and early projects could help establish the United States as a global manufacturing leader of this emerging technology solution. Technical advancements in floating offshore wind energy—as well as increasing wind turbine capacity and plant size—could reduce the LCOE by nearly 55 percent by 2030, as shown in Figure 3.

Near-term initiatives to lower costs and open new regional markets fall under four key focus areas: wind resource and site characterization; technology innovation; installation, operation and maintenance; and circular economy.

Wind Resource and Site Characterization. Developers must conduct a full assessment of the project site before designing a wind power plant. Currently, this site characterization includes evaluating the energy potential of the wind resource, the wave and current conditions, and the atmospheric and seabed properties that shape the plant design. Additional ecological and co-use data are needed to inform project siting and design. For the purposes of this report, these are covered in the Siting and Regulatory Processes section.

The offshore environment introduces atmospheric phenomena that are not prevalent for land-based wind, such as highly stable flow, low-level jets (fast streams of wind low in the atmosphere), and high vertical shear (a large difference in wind speed at different altitudes). Additionally, it is difficult to get accurate and sustained measurements and observations offshore because of the remote locations and harsh environment. Thus, atmospheric science offshore has greater uncertainty than on land, particularly at the height of wind turbines. The lack of sufficient measurements limits the accuracy of models and analysis used to ensure the reliability and cost effectiveness of offshore wind energy projects. Uncertainty in site assessments adds to project risk and increases costs associated with large engineering safety margins and less-favorable financing terms. Uncertainty in power output adds grid adequacy risk and transmission system operational risk, both of which impact cost and reliability. Through its Atmosphere to Electrons (A2e) and Wind Forecasting Improvement Project (WFIP 3) programs, DOE, in partnership with NOAA, is pioneering advancements in the understanding of atmospheric flow, wind farm layout, and the relationship of meteorological and ocean conditions to wind farm design in order to reduce uncertainty and optimize energy production.

In partnership with BOEM, DOE has deployed two highly instrumented buoys in key potential wind areas in both the Atlantic and Pacific Oceans to provide unprecedented, publicly available data sets of the offshore wind resource and environment. The buoys also inform lease planning and serve as platforms for validating new instruments. DOE is also working with Woods Hole Oceanographic Institution to collect high-quality offshore wind resource data off the coasts of Massachusetts and Rhode Island. Researchers will use all the data to improve atmosphere-ocean simulation tools and reduce uncertainty in offshore wind resource assessment and forecasting. While these projects provide useful data, the current geographic and time coverage of offshore measurements is insufficient to provide needed certainty. NOAA and other agencies also have offshore observation networks that could be expanded and integrated into a larger ocean-observing network.

Europe has a number of offshore meteorological towers gathering long-term measurements of wind speed and turbulence at wind turbine hub heights. Remote-sensing instruments, such as satellites, and temporary deployments of floating platforms, such as buoys, are primarily used in U.S. waters. Fixed meteorological towers can also be deployed and used to populate data sets, improve remote-sensing accuracy, and validate predictive models.

Making the necessary investments in offshore observation infrastructure and measurements will enable data collection to inform offshore wind energy planning, as well as broader applications in weather forecasting and climate impact studies. Weather forecasts of winds at turbine hub height are needed to efficiently integrate wind-generated power into the electric grid, and these observational data sets will be instrumental in improving existing climate and weather forecast models.[63] Further, new protocols are needed to facilitate data sharing among project developers, Federal agencies, utilities, RTOs/ISOs, and researchers and to create uniform methods for instrumentation, data capture, and analysis. Improved measurements and large resource data sets enable efforts in next-generation wind plant optimization, high-fidelity modeling, and advanced controls; and these advanced capabilities could help maintain transmission system reliability and reduce offshore wind LCOE significantly.

Table 3. Wind Resource and Site Characterization Initiatives

Initiatives	Specific Actions To Implement	Outcome
Invest in expanding national-scale programs supporting offshore measurements	Deploy offshore observation infrastructure (e.g., meteorological towers) and publish wind, wave, and geotechnical data	Better prediction of energy production, better understanding of design conditions, and lower project risk
Advance scientific and technical understanding of offshore wind physics and correlation to energy production	Collect measurements and improve models to show effects of climate, downwind turbine wakes, and extreme storms	Accurate modeling tools that reduce uncertainty, improve engineering and safety, and help maximize power generation
Improve hub-height wind speed forecasts	Improve physics characterizations within operational weather forecast models	Better prediction of wind and energy production, enabling better integration into the grid

Technology Innovation. Research, development, demonstration, and deployment of new-and-improved components and systems are needed to achieve efficiencies in manufacturing and installation, improve the performance of offshore wind turbine systems, and increase the

[63] NOAA Research has partnered with WETO on an offshore wind resource characterization and forecasting project (WFIP3) in which Woods Hole Oceanographic Institution will conduct a year-long offshore wind field campaign in 2023–2024 to collect high-quality data and improve NOAA's weather forecast models. See DOE's funding announcement.

potential for domestic supply chain growth. The burgeoning U.S. offshore wind energy industry can be accelerated by supporting and implementing emerging technologies that address key challenges, including those arising from the unprecedented scale of planned deployments and unique site conditions in U.S. waters. Floating wind turbine platforms will enable access to about 60 percent of the U.S. offshore wind resource and introduce new challenges such as mooring, anchoring, and platform motions that affect turbine operation and electrical cables. Other examples of emerging technologies that DOE is actively supporting to address these key challenges include improved material and manufacturing processes to lower cost and reduce weight; advanced wind turbine and array controls to optimize electricity production; and advanced simulations and hybrid testing that couples physical testing with computational models to accelerate development prior to more expensive large-scale physical testing.

DOE supports such R&D activities directly, through its National Laboratories, and through external collaborations via other research entities, such as the National Offshore Wind R&D Consortium. A variety of projects are in progress to reduce cost and risk, increase wind power plant value, and adapt offshore wind energy systems to regional conditions such as deep water, hurricanes, or surface ice loading. Several DOE-funded projects have developed widely used engineering modeling and analysis tools that are seen as seminal design tools to reduce costs and design the next generation of offshore wind technologies, including optimized turbines and foundations. NREL, through an international collaboration funded by WETO, developed a 15-MW offshore wind reference turbine—an open-access design of a complete wind turbine system that researchers use to evaluate the performance and cost of proposed system modifications. In addition to WETO efforts, ARPA-E's ATLANTIS program in floating offshore wind applies the discipline of control co-design to reduce the size of the massive and expensive floating platforms by incorporating automatic control technologies.

However, expanded public and private investment is needed to accelerate innovative component and system designs and meet deployment goals cost effectively. With concerted effort, cost-effective offshore wind technologies could be developed for all U.S. regions by 2035. As the country gains leadership in developing advanced offshore wind energy technology, such as lightweight systems and floating platforms, the United States can eventually expand its influence by exporting goods, services, and solutions to growing offshore wind markets overseas in this multibillion-dollar global industry.

Additional technology innovations are discussed in the Siting and Regulatory Processes section and Grid Integration section (including efforts to integrate hydrogen production with offshore wind plants).

Table 4. Technology Innovation Initiatives

Initiatives	Specific Actions To Implement	Outcome
Expand and accelerate R&D to lower system cost and de-risk offshore wind technology	Collaborative public/private research on larger plants, larger wind turbines, performance optimization, reliability, life extension and reuse, designs to mitigate cumulative impacts, hurricane resiliency, ice loading, and efficient electrical collector systems that support the grid	Engineering adaptations to accelerate U.S. manufacturing, reduce costs, maintain grid reliability, and address technology barriers; broad participation of the U.S. industry, universities, and national laboratories to support near- and long-term technology innovation
Expand R&D in floating offshore wind energy technology to accelerate floating market development	Optimize floating platforms for weight, manufacturability, and integration with wind turbines; optimize designs of mooring, anchoring, and electrical cables	Technologies that can be cost-effectively produced domestically to open new ocean areas for offshore wind energy and establish the United States as a global leader in floating offshore wind technology
Upgrade U.S. test and validation capabilities to address reliability of new, larger wind turbines	• Increase the capacity of prototype, test, and demonstration capabilities to accommodate continued wind turbine growth at existing U.S. facilities, such as blade testing and drivetrain test facilities. • Develop advanced simulation and hybrid testing techniques to maximize development prior to more expensive large-scale physical testing. • Evaluate need and use case for floating lab and field research test sites to address topics such as physics validation, conflicting use mitigations, and component demonstration.	• Higher reliability on first generations of larger wind turbines, resulting in lower operation and maintenance costs and market risk. • Ability to test and develop large components domestically, in support of a U.S. supply chain.

Installation, Operation, and Maintenance. Working at sea to install, operate, and maintain equipment and structures is more challenging and costly than work performed on land or in a port facility. Wind turbine sizes are increasing and require very large, specialized wind turbine installation vessels (WTIVs) that are expensive to build, operate, and charter. As a result, offshore wind component designs and supporting infrastructure need to evolve to reduce the specialized requirements for WTIVs, address the logistical challenges of handling increasingly larger components, and maximize worker safety. Novel wind turbine support structures and installation methods can be developed that leverage existing supply chain capabilities and reduce the requirements on WTIVs, which are discussed more thoroughly in the Supply Chain section. For example, the DOE research portfolio includes proposed designs of innovative float-out systems that could enable tower and wind turbine assembly at the port and avoid bottlenecks caused by WTIV shortages—especially with the likelihood of concurrent project installations. Rough seas and strong winds can shorten time windows for installation or maintenance work at sea—especially in the Pacific, which tends to have higher waves than in other regions.

Marine operations and logistics can be adapted to minimize labor in the open sea, with solutions such as portside component assembly or the use of drones and unmanned inspection vehicles. DOE and other research institutions currently support advanced work in this area, including incorporation of new sensors and artificial intelligence into defect detection, diagnosis, and maintenance planning, but the opportunity for further advancement is significant.

Table 5. Installation, Operation, and Maintenance Initiatives

Initiatives	Specific Actions To Implement	Outcome
Continue R&D on improved installation methods and technologies	Develop lightweight components and process alternatives that reduce WTIV requirements (e.g., portside wind turbine assembly)	Reduced cost and duration of wind turbine installations
Expand R&D on advanced operation and maintenance technologies and processes	Develop or refine technologies, such as remote and autonomous condition monitoring and repair capabilities	Improved wind power plant reliability and worker safety, as well as reduced offshore labor requirements

Circular Economy.[64] Producing wind power plant components requires reliable access to critical and imported materials like rare-earth elements. Sustainable expansion of the domestic wind energy industry can be greatly enhanced with methods that help eliminate waste and reduce material usage. These methods include redesigning, reusing, refurbishing, recycling, and repairing parts. In addition to supporting sustainable development, circular economy methods help reduce or eliminate impacts on communities and the environment caused by waste and carbon emissions. In future decades, older offshore wind power plants may be repowered or upgraded to extend their useful life while recycling obsolete components. Extending the life of a wind power plant is one of the most effective ways to reduce LCOE, as upgrade costs tend to be much lower than the capital costs of constructing a new wind power plant. Incentives, including those related to finances and taxes, can be evaluated to focus industry participants on long-term sustainable practices. As a budding industry in the United States, offshore wind energy has an opportunity to adopt sustainable practices early on and establish a circular economy within the industry.

Some initial DOE research activities are ongoing in this area, such as reducing critical materials in wind turbine generators, extending wind turbine life, and using recyclable blade materials. DOE's Advanced Manufacturing Office and WETO are working to develop a material properties database for wind energy that will include information about potential supply chain vulnerabilities stemming from wind turbine components that contain critical materials. This information will act as a roadmap for future technology innovation by identifying which circular

[64] Using, reusing, recycling, and remanufacturing wind turbine materials will reduce waste and create a "circular economy." A circular economy for energy materials also means that technology should be engineered from the start to require fewer materials, resources, and energy while lasting longer and having components that can easily be broken down for use in subsequent applications. For more information on this topic, see No Time To Waste: A Circular Economy Strategy for Wind Energy.

economy efforts are likely to have the highest impacts on strengthening the supply chain and increasing the circularity of wind materials. DOE is working with General Electric to demonstrate a high-efficiency ultra-light low-temperature superconducting generator that eliminates the need for foreign-sourced rare earth materials.

Table 6. Circular Economy Initiatives

Initiatives	Specific Actions To Implement	Outcome
Develop processes and technologies for repair and other methods of life extension, recycling, and reuse	Collaborate with manufacturers and potential secondary users to advance system designs, processes, and enabling technologies	Offshore wind components and systems with reduced waste, reusable materials (specifically including critical materials), extended life, and lower full life cycle costs
Assess potential techniques to accelerate industrywide sustainable practices	Conduct analysis to understand impacts of incentives and mandates on the effectiveness and pace of reducing critical materials, as well as increasing recycling, and material recovery	Recommendations for accelerated employment of sustainable practices throughout wind turbine industry

IV3. Improve Siting and Regulatory Processes

Responsible siting and project permitting can enable steady growth of a thriving industry while ensuring protection of the environment and maximizing opportunities for ocean co-use. The number of lease areas will need to grow significantly over the next decade to meet state and federal deployment goals. A regional planning approach may accelerate identification of additional wind energy sites and facilitate safe, equitable ocean co-use. The industry needs predictable and efficient regulatory reviews that are advanced by clear and efficient permitting processes. Interagency collaboration and sufficient resources for staffing, research, and monitoring are necessary to understand and mitigate offshore wind's potential impacts on the marine environment, ocean co-users, and communities. Collaborating with communities and enhancing stakeholder engagement will help enable mutually beneficial and equitable siting solutions. Developing standardized practices to minimize or offset environmental impacts, where needed, will reduce potential risks that may otherwise impede project development.

Siting and regulating offshore wind energy projects is complex and requires time-intensive processes involving Federal, state, and local government agencies with legal and regulatory authority over projects and affected protected resources. The siting and development of offshore wind power plants also involves and affects a diverse set of stakeholders and Tribal Nations, all of whom have diverse equities, perspectives, and interests. The roles and equities of various Federal agencies are briefly described in Appendix A1.

An offshore wind energy developer must obtain authorization from a state and/or the Federal Government, depending on project location, before they can begin to plan and build a project. In Federal waters, which extend from approximately 3 nautical miles from shore out to 200 nautical miles in most U.S. waters,[65] site access is granted through a Federal leasing process led by BOEM. Additional lease areas are needed to continuously grow the U.S. project pipeline and realize offshore wind energy's full potential for economic growth, job creation, and clean energy benefits. Clear siting policy goals and Federal wind energy lease sale timelines would provide more planning certainty for project developers and reduce risks for financial investors.

Efforts to improve processes for offshore wind project siting fall within the following four key focus areas: regulatory certainty, environmental considerations, ocean co-use and community engagement, and lease areas. Several other focus areas are also closely related to effective site determination, including wind resource and site characterization (previously described in the Reduce Offshore Wind Energy Costs section) and transmission (in the Plan Grid Integration section).

[65] For more information, see BOEM's Outer Continental Shelf web page.

Regulatory Certainty. Over the last two decades, the United States has needed to develop a new regulatory regime tailored to the new offshore wind energy industry. Authority, regulations, and processes to site and permit power plants in Federal waters and route cables through state waters needed to be established and refined over time as the industry evolved. A key advance was the development of a process to identify offshore wind energy areas (WEAs) that are screened for conflicts and prioritized for leasing. Nonetheless, applying regulatory processes to a new industry in a marine environment that implicates multiple agencies with varying jurisdictions and mission priorities has been challenging. Agencies have made significant progress in developing more transparent regulatory procedures, strengthening and sustaining interagency coordination, obtaining needed resources, and improving certainty and reducing risk for project developers and investors. More work on all of these fronts is needed, and is underway. In turn, advances in these areas will provide greater confidence for the supply chain and other entities with a stake in offshore wind energy development. Additional scientific data and information related to the regulatory environmental review process also can improve efficiency and environmental outcomes. BOEM, in particular, has made significant progress to advance the regulatory review of proposed offshore wind energy projects to create greater process certainty. Further, as directed in Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad,* BOEM is advancing efficiencies and identifying opportunities to further engage ocean users, including standardizing the review process, encouraging engagement with ocean users before projects are designed, and coordinating with other Federal agencies.[66]

Table 7. Regulatory Certainty Initiatives

Initiatives	Specific Actions To Implement	Outcome
Improve efficiency and transparency of the renewable energy regulatory regime	Refine procedures and address inconsistencies; ensure Federal agencies have sufficient resources to perform expanding responsibilities including specialized staff and scientific support. Explore the opportunities to standardize the offshore wind permitting and review processes.	Enhanced review and oversight capabilities; accelerated processes; and reduced risk for project developers and investors
Develop a Federal interagency road map to increase coordination between agencies	Promote efficient, effective, and transparent review of renewable energy proposals; clarify jurisdictional authorities and stages where each agency is engaged; and identify overlaps or gaps	Clear and consistent regulatory processes for a safe and environmentally conscientious offshore wind energy industry
Adopt standards	Develop and adopt consensus standards governing safety management system requirements and technical design guidelines for the U.S. industry.	Reduced risk and greater transparency of requirements for industry and regulators

Environmental Considerations. Given the early stage of U.S. offshore wind energy development, there are gaps in our understanding of the environmental impacts of this

[66] See Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, Sec. 207, *Renewable Energy on Public Lands and in Offshore Waters* (86 FR 7619 (January 27, 2021)).

development on wildlife and ecosystems. Much can be learned from research that has been conducted around the world regarding the anticipated type and scale of impact, as well as the effectiveness of methods to monitor and minimize those impacts; however, given the newness of development in the United States, additional research is needed. Extensive research has been performed at the first two projects[67] constructed in U.S. waters,[68] and there is ongoing research studying marine life and fisheries, as well geospatial tools to inform siting decisions. Federal and state agencies have fostered broad environmental portfolios that include international collaboration and information sharing, environmental monitoring technology development, baseline data collection, and support of research to understand and minimize impacts to wildlife. Still, there is a need to evaluate the impacts of each individual project on wildlife and ecosystems and the cumulative impacts of all projects across ecosystems, with a near-term need to investigate impacts on the first generation of projects built in the Atlantic. In addition, research is needed to help inform the siting of WEAs for potential leases in new regions, such as the Pacific Coast. To fill these gaps, coordinated data collection occurring before, during, and after construction, as well as during operations and decommissioning, is needed. From there, data from across projects can be integrated with existing survey efforts, such as regular surveys conducted to assess bird and marine mammal distributions and densities. These findings can inform the siting of future WEAs and projects, including associated cabling infrastructure, as well as the understanding of project-level and cumulative impacts of projects. They can also inform whether there is a need to limit adverse effects to marine wildlife and habitats from individual projects or cumulatively, and inform the design of mitigation solutions.

Table 8. Environmental Initiatives

Initiatives	Specific Actions To Implement	Outcome
Collect baseline environmental data	Continue to track regional and temporal changes to habitats, species distribution, and abundance; expand data collection efforts in new offshore wind regions	Environmental data are available to inform project siting and evaluate potential impacts of offshore wind energy deployments in new and existing regions of development
Research environmental impacts	Continue coordination across stakeholders on wind power plant monitoring, data sharing, and impact analysis before, during, and after construction; continue developing solutions to avoid, model, mitigate, and minimize impacts	Understanding of environmental impacts and use of impact minimization techniques where needed, such as reducing marine wildlife exposure to noise
Disseminate information	Report impacts of offshore wind energy on marine ecosystems, climate change, and air pollution; continue data sharing and scientific collaboration	Well-informed communities, developers, regulators, decision-makers, and researchers

[67] The Block Island Wind Farm and the Coastal Virginia Offshore Wind pilot project.
[68] BOEM's Realtime Opportunity for Development Environmental Observations (RODEO) study was designed to make direct, real-time measurements of the nature, intensity, and duration of potential environmental stressors during the construction and initial operations of selected offshore wind energy facilities. For more information, see BOEM's RODEO web page.

Ocean Co-Use and Community Engagement Offshore wind energy should be designed to coexist with other users of state and Federal water to the greatest extent possible, benefit coastal communities, and ensure environmental justice. Offshore wind energy project siting and design require considerable research and planning in close, respectful cooperation with coastal communities, Tribal Nations, and those engaged in activities such as fishing; tourism and recreation; wildlife viewing; maritime operations; weather and marine forecasting; and navigation. BOEM's WEA identification initiates early site screening and the Agency's leasing processes work to minimize potential impacts; however, as commercial-scale projects are developed, it will be important to monitor and research their potential impacts, as well as integrate those findings into future siting processes and mitigating impacts.[69] Further research should be conducted on more robust mechanisms to identify areas for development to take advantage of the latest science and modeling capabilities.

In recent years, Federal and state agencies, and others have conducted initial research to understand current and potential socioeconomic impacts of offshore wind energy facilities on coastal communities and co-users of state and Federal waters.[70,71,72] Such research is critical to siting projects well and maximizing benefits for coastal communities. Research is also needed in this focus area to identify practical and equitable solutions to optimize co-use and minimize negative impacts as commercial-scale projects are developed across a range of locations. Further, research should be coordinated with coastal communities, Tribal governments, and ocean users. Successfully engaging with these stakeholders in the energy planning process and addressing their concerns can result in mutually beneficial solutions and increased community interest and support for offshore wind energy.

Learning from Tribal Nations and incorporating their viewpoints and recommendations into the analytical and decision-making process is also of critical importance. Consideration of the effects that offshore wind development might have on Tribal historic properties (including submerged) is required by Section 106 of the National Historic Preservation Act.[73] Consultation with Tribal Nations also includes formal government-to-government consultation and Tribal participation during environmental reviews conducted under the National Environmental Protection Act (NEPA), as well as ongoing informal dialogue, collaboration, and engagement. BOEM Tribal Liaison Representatives seek to establish meaningful engagement that is built on a

[69] Gill, Andrew, Degraer, Steven, Lipsky, Andrew, Mavraki, Ninon, Methratta, Elizabeth, Brabant, Robin. 2020. *Setting the Context for Offshore Wind development effects on fish and Fisheries*. Oceanography. December 2020. http://dx.doi.org/10.5670/oceanog.2020.411.

[70] Mills, A. D., Millstein, D., Jeong, S., Lavin, L., Wiser, R., and Bolinger, M. 2018. "Estimating the value of offshore wind along the United States' Eastern Coast." *Environmental Research Letters*, 13(9), 094013. https://doi.org/10.1088/1748-9326/aada62.

[71] Carr-Harris, A., and Lang, C. 2019. "Sustainability and tourism: the effect of the United States' first offshore wind farm on the vacation rental market." *Resource and Energy Economics*, 57, 51–67. http://dx.doi.org/10.1016/j.reseneeco.2019.04.003.

[72] S., Keyser, D., Flores-Espino, F., Miles, J., Zammit, D., and Loomis, D.. "Offshore Wind Jobs and Economic Development Impacts in the United States: Four Regional Scenarios." United States: N. p., 2015. https://doi.org/10.2172/1171787.

[73] For more information, see BOEM's Historic Preservation Activities of the Office of Renewable Energy Programs web page.

foundation of trust, respect, and shared responsibility, leading to more effective collaboration, and ultimately, more informed decision making.[74]

In addition to coordinating with nongovernmental stakeholders, interagency cooperation is needed to address potential conflicts with government agencies' missions, such as national security; impacts on radar systems used for aviation, security, and weather forecasting purposes; and marine surveys used to assess fish populations. In partnership with Department of Defense, the Federal Aviation Administration, the Department of Homeland Security, NOAA, and BOEM, DOE leads the interagency Wind Turbine Radar Interference Mitigation working group, which is pioneering solutions to wind turbine interference with radar systems.

Table 9. Co-Use and Community Engagement Initiatives

Initiatives	Specific Actions To Implement	Outcome
Expand efforts to exchange information and collaborate with ocean users and coastal communities	Improve information sharing, increase outreach, and strengthen stakeholder engagement; especially in local communities	Early engagement and continuous inclusion of communities involved in ocean and coastal activities
Optimize potential for co-use	Improve and validate tools and strategies for spatial planning, BOEM's area identification, and maximizing ocean co-use	Avoided, minimized, and mitigated negative impacts and increased benefits to existing ocean users
Ensure equity, environmental justice, and community benefits	Expand socioeconomic impacts research to study various energy development models, including community ownership, for maximizing community benefits	Verified models resulting in greater community benefits, especially in historically underserved communities
Continue and expand Federal mitigation programs for impacts of wind power plants interagency missions	Continue to develop and implement tools and other solutions to mitigate impacts of wind turbines on national security activities, radar systems, and marine surveys	Minimized impacts on access, environmental surveys, radar performance, and other activities

Lease Areas. To further grow the offshore wind energy industry, realize its climate and economic benefits, and allow future development with floating technology, BOEM will need to identify new offshore WEAs to offer for sale. The Agency is working to rapidly and responsibly site and designate new WEAs in Federal waters, which would lead to future lease auctions that can expand deployment. Appendix A3 shows a high-level view of the processes for acquiring an offshore wind commercial lease on the Outer Continental Shelf. Further, BOEM conducts studies and engages with stakeholders to help realize the potential of these new areas. These efforts include expanding development to new areas such as the Pacific, Gulf of Maine, and Gulf of Mexico, and considering regional approaches to identifying WEAs in some locations. Opening new areas for offshore wind energy development requires engaging Federal agencies—notably BOEM, the U.S. Department of Defense, U.S Coast Guard, and NOAA—along

[74] For more information, see BOEM's Tribal Engagement web page.

with state governments, Tribal Nations, and public stakeholder groups to identify potential WEAs and resolve potential co-use conflicts. Examples of successful collaboration include the BOEM-led Offshore Wind Permitting Subgroup,[75] BOEM's Intergovernmental Renewable Energy Task Forces,[76] and other stakeholder-or issue-specific engagement efforts.[77] Additional research and site characterization related to potential future WEAs, focused ecological, socio-economic, and co-use topics, could help establish the value of given areas in terms of energy production and revenue, and support assessment of the impacts, costs, and benefits of projects deployed within them.

Table 10. Lease Areas Initiatives

Initiatives	Specific Actions To Implement	Outcome
Create a national leasing schedule and strategy	Develop a national-scale, interagency, strategic leasing and development plan and ensure adequate agency resources to evaluate and plan new areas. Consider a regional approach to establishing WEAs	Early cooperative planning with local communities and longer-term certainty for project developers and supply chain participants

[75] The Offshore Wind Permitting Subgroup was established in 2016. This BOEM-led group of Federal agencies meets monthly to discuss coordination and share knowledge about offshore wind energy planning and activities. The subgroup has over 150 participants, representing approximately 20 Federal agencies.

[76] BOEM has established approximately 15 state-specific and regional intergovernmental task forces, in partnership with 20 coastal states.

[77] Recent examples include BOEM-hosted Tribal ocean summits, maritime industry knowledge exchanges, and fisheries-specific coordination meetings.

IV4. Invest in Supply Chain

Investing sufficiently in manufacturing, ports, vessels, and a diverse U.S. workforce will reduce the cost of offshore wind energy, increase the pace at which projects are able to deploy, and could contribute significantly towards the energy justice goal of achieving equity in economic participation in the energy system. Building a domestic supply chain and growing the industry will require dozens of port upgrades, numerous Jones-Act-compliant vessels, and new factories for component manufacturing and assembly. The availability of this infrastructure and broader certainty about the project pipeline are necessary to unlock $12 billion per year in private-sector project capital investments as well as create tens of thousands of good-paying jobs and capture the broader domestic economic gains associated with these investments. Regional collaboration in manufacturing, ports, vessels, and U.S. workforce development can result in facilities, networks, and policies that benefit all states within a region and the United States as a whole.

A robust domestic supply chain and workforce are needed to realize the 40–55 percent cost reductions previously discussed and can spur significant national and regional economic growth. Developing the supply chain and logistics network will increase the skilled labor force and revitalize heavy industry and maritime infrastructure. This type of industrial development has been demonstrated in Northern Europe, where numerous manufacturing facilities have been adapted or built to produce the wide range of products required in offshore wind power plant construction.

Analysis of the 30-GW-by-2030 OSW deployment goal highlights the potential for similar economic growth in the United States, spurring project capital investment of more than $12 billion per year through 2030 and supporting more than 77,000 direct and indirect U.S. jobs. Meeting 2030 deployment targets will require momentous supply chain growth, including significant investments in port upgrades. New, expanded, or adapted U.S. manufacturing facilities will be needed for wind power plant components, including tower top assemblies (nacelles), blades, towers, foundations, and subsea cables. Constructing 4–6 specialized wind turbine installation vessels in U.S. shipyards, representing an investment between $250 million and $500 million each,[78] would support logistics and drive industry confidence. Supply chain development can be structured to revitalize declining manufacturing sectors, aid in transitioning businesses from the oil and gas industry to offshore wind, enhance diversity in the workforce, and build modern sustainable infrastructure that contributes to an equitable clean energy future. To support investment decisions that would enable the creation of a domestic supply chain, businesses need assurance of a robust project pipeline and long-term demand for wind power plant materials, components, and services. While this section describes efforts to

[78] The White House. 2021. FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.

directly impact supply chain and workforce development, work described in other strategic priorities that improve the overall outlook for the industry will also likely have positive impacts to private investments in the supply chain.

Supply chain growth and workforce development can contribute significantly to energy justice, with the goal of achieving equity in social and economic participation in the energy system by involving affected stakeholders in a meaningful way to develop a clean energy industry.

Many businesses, agencies, and individuals will be closely tied to the supply chain and infrastructure needs of the industry, including port authorities, shipyards, offshore service providers, manufacturers, suppliers, local communities, displaced workers, technical schools, and training facilities. It is important to ensure that supply chain and workforce development:

- Fosters creation of well-paying jobs, job training, and a diverse workforce
- Coordinates investments and leverages funds where possible to provide and maximize multiple benefits
- Avoids potential burdens to disadvantaged communities
- Adequately accounts for the disproportionate, disparate, and cumulative impacts pollution and climate change have on low-income communities and communities of color
- Does not exclude qualified entities from participating in and benefiting from the wide range of offshore-wind-energy-related social and economic activities.

Key initiatives advancing the potential for supply chain development and economic growth, as stimulated by offshore wind energy development, fall within three focus areas: workforce development, domestic manufacturing, and ports and vessels.

Workforce Development. Outreach, education, training, and adapting skills from other industries are required to meet the labor needs for offshore wind energy projects and grid upgrades. Accredited training programs and certification standards are also needed to ensure the safety and proficiency of offshore wind workers during construction, operation, and maintenance. Analyzing long-term job requirements will inform targeted investment in training initiatives. DOE is supporting the development of an Offshore Wind Workforce Roadmap, which will outline anticipated training needs and existing programming, and identify potential future gaps. Through NREL, DOE is also standing up an Offshore Wind Workforce Development Network to spur a coordinated approach to fill those gaps. Offshore wind energy construction and operation jobs are currently limited, but demand for these skills will increase as the industry grows. Displaced workers from oil and gas and other industries will be able to transition into the offshore wind energy workforce and meet qualifications by earning training certifications. Further, developing career pathways that promote diversity and include historically disadvantaged Americans will help address energy justice priorities. In July 2021, the Southeastern Massachusetts Building Trades Council and Vineyard Wind signed a project labor agreement that supports local union jobs and boosts recruitment and training opportunities for underserved communities.[79] Although several state agencies, developers, and industry organizations have initiated workforce training activities, expanded offshore wind deployment goals have created opportunities for additional programs focused on meeting the industry's labor needs.

Table 11. Workforce Development Initiatives

Initiatives	Specific Actions To Implement	Outcome
Expand training programs to address industry requirements and skills gaps	Anticipate offshore wind energy development patterns and develop certification and training requirements, programs, and facilities according to expected needs	A robust and capable workforce meeting industry's needs and timetables for engagement
Establish career pathways that promote diversity and facilitate workers from other industries to transition into a career in offshore wind	Collaborate with unions and workforce programs to implement effective practices for diverse recruitment	New, well-paying job opportunities for people from disadvantaged communities and declining industries

Domestic Manufacturing. Realizing national, regional, and local economic potential for offshore wind energy requires growth of a domestic supply chain for wind power plant components ranging from onshore electrical interconnection hardware to offshore wind turbines. Cost-competitive domestic product lines and fabrication facilities will continue to reduce U.S. offshore wind costs and create export potential for U.S. companies. Competition among states has led to project agreements that incentivize the use of local content from the given state, but do not incentivize domestic content from other states over international imports. States could collaborate with Federal agencies to establish a cooperative supply chain framework for offshore wind energy. Further, regional and national coordination could lead to increased procurements of American-made goods and services for U.S. projects. DOE, the National Offshore Wind R&D Consortium, the state of Maryland, NREL, and the Business Network for Offshore Wind are developing a supply chain roadmap that will present the collective benefits of a domestic supply chain and facilitate the acceleration of the offshore wind industry in the United States.

Commitment to growing the industry will lower risks for suppliers and attract market investments. Because of the very large size of components, some new factories require major investment and must be built close to the operational sites, or near a waterway to accommodate transportation over water. Manufacturing facility tax credits, such as reauthorizing and expanding 48C Advanced Manufacturing Tax Credits, can stimulate

[79] Vineyard Wind. 2021. "Building Trades Union and Vineyard Wind Sign Historic Project Labor Agreement." https://www.vineyardwind.com/press-releases/2021/7/16/building-trades-union-and-vineyard-wind-sign-historic-project-labor-agreement.

investment in offshore wind energy manufacturing facilities. This concept is discussed more thoroughly in the Federal Incentives section. It is expected that offshore wind project developers will initially procure major wind power plant components from overseas, increasing the barriers for American fabricators to win subsequent orders. Greater domestic economic benefits are likely if Federal incentives supporting U.S. manufacturing are established early and doing so may reduce the opportunity for overseas manufacturers to establish a first-mover advantage.[80] These incentives could further be structured to encourage investment in disadvantaged communities.

Table 12. Domestic Manufacturing Initiatives

Initiatives	Specific Actions To Implement	Outcome
Consider incentivizing supply chain infrastructure and capabilities	Authorize clean energy manufacturing tax credits and loans for adapting or constructing manufacturing facilities	A competitive domestic supply chain that includes design, manufacturing, transportation, and construction
Expand R&D to develop solutions optimized for the domestic supply chain	Shift technology options toward cost-effective application of domestic capabilities and materials (e.g., structural concrete)	Lower costs, streamlined manufacturing, and U.S. job creation

Ports and Vessels. While some project-specific staging ports are already being developed, further expansion of port facilities is needed to meet the expected growth of the offshore wind energy industry and the demanding requirements of handling, transporting, erecting, and servicing offshore wind power plants. The size of system components[81] presents unique requirements for capacities and capabilities of port facilities and vessels. Floating turbine deployment, such as for the West Coast, will change the port requirements. For example, one promising installation method is to assemble and test the full turbine in port and then tow the platform with the turbine to the wind plant site. This requires waterways that have no vertical obstructions (such as bridges) between the port and open ocean and requires the port to have deep berths to accommodate heavy floating platforms. Existing infrastructure grant financing programs, such as the Department of Transportation Rebuilding American Infrastructure with Sustainability and Equity grants[82] and Maritime Administration Port Infrastructure Development and Small Shipyard Grants,[83] could be leveraged to upgrade ports. States could collaborate to establish a cooperative supply chain framework that includes coordinated development at our Nation's ports to handle components and equipment for offshore wind energy construction and operations.

The Merchant Marine Act of 1920, known as the Jones Act (Section 27), is a Federal statute requiring vessels that transport merchandise between two points within the U.S. territory to be

[80] First-mover advantage is a competitive advantage from being the first or early entrant into a market.
[81] For example, current blade lengths are over 105 meters and 15-MW generators can exceed 400 tons.
[82] The U.S. Department of Transportation Discretionary Grant program is intended to invest in road, rail, transit, and port projects that promote safety, environmental sustainability, quality of life, economic competitiveness, good repair, innovation, and partnership.
[83] For more information, see the U.S. Maritime Administration's Small Shipyard Grants.

built, registered, and owned in the United States, and crewed by U.S. citizens or residents.[84] The Passenger Vessel Services Act of 1886 applies to the Outer Continental Shelf and requires vessels transporting passengers between places in the United States to be wholly owned by U.S. citizens. [85]

Offshore wind vessel supply, particularly of WTIVs, is a major challenge to realizing the 30 GW by 2030 target. Jones-Act-compliance obligations create both further constraints and opportunities for offshore wind energy project developers and the domestic maritime industry. As of August 2021, one Jones Act-compliant WTIV is being constructed in the United States and plans for a second were announced to support the domestic offshore wind energy industry;[86] however, more WTIVs are likely required to meet deployment goals. Additionally, Jones-Act-compliant feeder vessels may be used to transport large components from ports to wind power plants for installation by either Jones-Act or non-Jones-Act installation vessels that remain on-site. Financial incentives could support U.S. vessel construction, such as through modifications to the Maritime Administration's Federal Ship Financing Program, Capital Construction Fund Program, Construction Reserve Fund Program, or the DOE Loan Programs Office's authorities. There are several challenges to constructing new vessels domestically, some of which may be mitigated with public financing. Most notably, uncertainty regarding long-term utilization rates could preclude offshore wind vessels from third-party investment. Tax credits, grants, or loans could help to reduce the price of domestic vessel construction and enable them to compete with foreign-flagged vessels.

Table 13. Ports and Vessels Initiatives

Initiatives	Specific Actions To Implement	Outcome
Invest in port infrastructure customized for offshore wind energy	Evaluate and leverage financing programs for offshore-wind-customized ports	Ports equipped to support offshore wind energy deployments before projects enter the construction phase
Incentivize vessel construction, upgrades, and repurposing	Evaluate and leverage financing programs for constructing U.S.-flagged vessels to support deployment	Sufficient vessels available so that multiple offshore wind energy projects can be installed simultaneously

[84] For more information, see the U.S. Customs and Border Protection's (CBP's) The Jones Act.
[85] For more information, see CBP's The Passenger Vessel Services Act.
[86] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.

IV5. Plan Grid Integration

Strong near-term efforts focused on grid integration are necessary to enable large-scale incorporation of offshore wind into the Nation's power grid and future energy mix without long delays or lost opportunities. In particular, facilitating collaborative, proactive, and long-term transmission planning and investing in phased grid development is vital to increase the certainty and pace of offshore wind energy development, drive cost reductions, and help identify options to optimize transmission infrastructure in a way that protects the marine environment and is compatible with existing uses of the ocean and the needs of coastal communities. Innovation, cost reductions, and domestic supply capabilities are needed in high-voltage direct current technology to enable development farther from shore. There is a lack of sufficient onshore transmission capacity to transmit power from the strongest offshore wind resources to load centers. Offshore wind energy developers, RTOs or ISOs, and other stakeholders are already assessing the limited, existing onshore points of interconnection and seeking coordination from the Federal Government on transmission expansion. Creating incentives to plan and share transmission across multiple offshore wind projects, states, and transmission planning regions can encourage collaboration in infrastructure planning, cost allocation, and transmission system development that can benefit all states within and across regions. Renewable fuels can provide energy storage and clean fuel for applications that are difficult to electrify directly.

Grid integration is essential for offshore-wind-generated power to be brought onshore and transmitted over the electricity grid to reach consumers in a reliable, secure, and resilient manner. Efficiently integrating offshore wind energy requires coordinated grid infrastructure planning, innovations to assess and maintain grid reliability, and market compensation for offshore-wind-provided grid reliability services that adjust power output to grid system needs. A timely interconnection process is needed for individual offshore wind energy projects, and streamlined, well-defined, and transparent permitting procedures are needed to accelerate grid infrastructure development. Decarbonizing the power sector introduces new challenges to managing the grid. Transmission system operators have extensive experience controlling traditional large-scale fossil-fueled generators that have rotating inertia and fault current that help make smooth adjustments and protect the grid system. Inverter-based resources[87] like wind and solar lack these characteristics and introduce the challenge of variable weather-dependent generation. Innovative power storage and generation using clean fuels can help alleviate system challenges. Offshore wind grid integration requires careful consideration and planning by RTOs/ISOs, utilities, and state energy departments—all within the context of regulations and requirements from FERC, the North American Electric Reliability Corporation (NERC), and state regulators. Because of the complexity associated with the transmission planning process, further details on this process are provided in Appendix A2.

[87] An electricity source that either partly or completely interfaces with the grid through power electronics.

Key initiatives for ensuring efficient and reliable grid integration fall within four focus areas: transmission, grid reliability, market design, and renewable fuels.

Transmission. Grid interconnections are essential to offshore wind energy growth. Maximizing offshore wind energy will require new offshore and onshore transmission facilities, as well as major system upgrades necessary to reliably and efficiently deliver offshore wind energy to load. As of June 2021, RTOs/ISOs such as ISO New England, New York ISO, and PJM Interconnection are conducting independent transmission studies that include offshore wind. Accommodating 30 GW or more of offshore wind energy will require significant transmission upgrades or new transmission onshore and shared offshore transmission solutions, and will necessitate development of nascent technologies for an offshore high-voltage direct current network.[88] In November 2020, New Jersey formally requested the use of a State Agreement Approach[89] with PJM to proactively and competitively plan transmission for all of the state's 7.5 GW of offshore wind energy deployment by 2035. In California, the California Independent System Operator (CAISO) is conducting early transmission studies that include offshore wind. In June 2021, FERC and the National Association of Regulatory Utility Commissioners announced a task force of Federal and state entities to identify and realize benefits that transmission can provide while ensuring efficient and fair cost allocation.[90] In July 2021, FERC issued an Advance Notice of Proposed Rulemaking seeking comment on possible regional transmission planning and cost allocation and generator interconnection reforms, including reforms "to plan for the transmission needs of anticipated future generation to meet a changing resource mix, including generation that is not yet in the interconnection queue."[91] In November 2021, WETO launched a study of interconnection and transmission options to support offshore wind development on the U.S. East Coast through 2030 and 2050.[92]

Acquiring rights-of-way, permitting, and other regulatory processes to build new transmission takes roughly as long as building an offshore wind power plant (5–7 years after the lease sale); however, the transmission process is often started later due to the existing interconnection processes, creating the potential for delays. Therefore, there is an immediate need to plan ahead for sufficient onshore and offshore transmission capacity to handle the anticipated offshore wind energy generation. Analysis of potentially supportive public policies may indicate effective methods to facilitate offshore wind interconnection. There are various potential configurations for offshore transmission, including individual plant connections, a transmission backbone connecting multiple projects offshore, and meshed networks where several offshore wind power plants are connected by multiple shared transmission lines. DOE is supporting

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[88] For more information, see DOE's Atlantic Offshore Wind Transmission Literature Review and Gaps Analysis.
[89] New Jersey Board of Public Utilities. 2021. "PJM State Agreement Approach." https://www.nj.gov/bpu/about/divisions/ferc/saa.html.
[90] FERC. 2021. "FERC, NARUC to Establish Joint Federal-State Task Force on Electric Transmission" June 17, 2021. https://www.ferc.gov/news-events/news/ferc-naruc-establish-joint-federal-state-task-force-electric-transmission.
[91] "Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection." 86 FR 40266, 40274 (July 27, 2021).
[92] For more information, see DOE's announcement: Atlantic Offshore Wind Transmission Study Will Inform Options to Support National Goals.

ongoing analysis for each of these configurations, as well as a cost and benefit evaluation of a high-voltage direct current network which would require the use of nascent technologies.[93] In the United States, there are currently few incentives to plan strategically across state or regional boundaries and consider long-term transmission system costs, efficiency, and reliability. Without coordinated planning, early offshore wind energy developers may create physical and financial barriers to future development by using up the limited available sites for cable routing and interconnection. Planning transmission capacity and interconnection for prospective build-out beyond currently awarded offshore wind energy projects would attract future development and enable industry growth, as revealed by prior efforts, such as after Texas implemented the Competitive Renewable Energy Zones.[94]

Table 14. Transmission Initiatives

Initiatives	Specific Actions To Implement	Outcome
Evaluate transmission configurations	Consider offshore meshed systems or backbones that connect multiple projects; evaluate the economics, adequacy, and operating reliability of transmission options	Sufficient number of cable routes, landing points, and points of interconnection for future projects; potential to mitigate impacts on coastal communities and habitats and reduce overall costs
Comprehensively plan staged development of integrated transmission infrastructure and reduce transmission congestion	Convene collaboration among FERC, DOE, RTOs/ISOs, utilities, BOEM, states, industry, and other participants to plan long-term grid upgrades inclusive of prospective future offshore wind projects, and to refine cost allocation[95] to incentivize long-term coordinated transmission planning across multiple projects	Forward-looking and economically sound transmission capacity expansion that enables timely and reliable integration of offshore wind energy

Grid Reliability. As renewable energy generation increases and fossil-fueled generators are retired, new challenges must be overcome to maintain the reliability and stability of the transmission system. For example, planned U.S. offshore wind plants have very high generation capacities, and injecting large amounts of energy into certain areas of the grid causes challenges. DOE has been conducting research to advance controls that allow wind power plants to react to existing grid needs and develop tools that assess reliability. With WETO support, NREL, CAISO, Avangrid, and General Electric successfully demonstrated the capability of large utility-scale wind plants to provide essential reliability services to the electricity grid in 2019.[96] Enhancing the ability to control power output will enable offshore wind systems to react to existing and emerging grid needs. For example, offshore wind power could be used to

[93] For more information, see NREL's Atlantic Offshore Wind Transmission Study web page.
[94] U.S. Energy Information Administration. 2014. "Fewer wind curtailments and negative power prices seen in Texas after major grid expansion." https://www.eia.gov/todayinenergy/detail.php?id=16831&src=email.
[95] Cost allocation is a FERC-approved transparent process to assign costs of shared transmission projects across multiple beneficiaries.
[96] U.S. DOE. June 2020. "EERE Success Story—Beyond Power, Wind Plants Can Provide a Full Suite of Essential Reliability Services to the Grid." https://www.energy.gov/eere/success-stories/articles/eere-success-story-beyond-power-wind-plants-can-provide-full-suite.

restart the grid after a blackout if equipped with grid forming capabilities.[97] Developing systems that combine offshore wind energy generation with energy storage will help balance consumer electricity demand with supply and support reliable grid operation. Offshore wind power output is variable and directly related to the weather; improved offshore wind power forecasts are critical for efficient integration of wind power into the grid. More information can be found in the Wind Resource and Site Characterization section of this report.

Energy stored in batteries, generators using clean fuels, and other means can be used at times when electricity demand exceeds weather-dependent generation, which may occur in daily and seasonal cycles. Improving offshore wind transmission technologies, such as subsea cables and high-voltage direct current technologies, can increase system performance and lower costs to consumers. Offshore wind generation and transmission must also be resilient to extreme events, including cyber and physical security threats. Updated models and tools that account for sources of variability, uncertainty, and component reliability are needed to plan more resilient systems and enable transmission system operators to run the grid more efficiently. Transmission system operators equipped with these tools will be able to monitor and assess grid needs and take timely actions that further improve system reliability, including control of offshore wind power supplied to the grid. Transmission infrastructure upgrades will safeguard overall system reliability while supporting well-paying jobs in the United States.

Table 15. Grid Reliability Initiatives

Initiatives	Specific Actions To Implement	Outcome
Enhance offshore wind energy controls to respond to grid requirements	Develop control systems that allow offshore wind power plants to react to existing and emerging grid needs including grid forming and provide a broad set of grid services	Offshore wind power plants contribute to grid reliability and resilience
Combine offshore wind with energy storage	Develop hardware, controls, and models for offshore wind energy storage systems	Flexibility in meeting consumer demand and increased utilization of offshore wind power
Advance offshore wind power system technologies	Improve hardware and develop operating tools for the offshore substation and transmission system	Improved reliability within the offshore wind plant and when delivering power to the grid
Secure offshore wind energy from cyber and physical threats	Promote best practices for offshore wind cyber and physical security resilience design early in project development	Improved resilience of the offshore wind power plant to cyber and physical threats

Market Design. More certainty in expected revenue estimates will help attract competitive offshore wind development in energy markets and incentivize deployment of technologies that support grid reliability services. Electricity market participants and government agencies could review market rules to ensure offshore wind generators, as well as other resources, are paid for

[97] For grid forming definition, see Reliability Guideline: Improvements to Interconnection requirements for BPS-Connected Inverter-Based Resources.

their contribution toward meeting system capacity, energy, and grid service requirements. Offshore wind systems tend to have high capacity factors, meaning the amount of power generated throughout the year is a high portion of the maximum possible power the equipment could generate under ideal conditions and weather. Furthermore, many offshore wind plants will be sited near high population load centers, such that energy and grid services from offshore wind can be readily delivered to where they are needed and less likely to be curtailed. These advantages are beneficial to the grid system and should be properly valued. ISO-New England is currently investigating market design for the future grid that will incorporate offshore wind power and other clean energy generation.[98] FERC has held several technical conferences to consider electricity market design changes in the RTOs/ISOs in an environment where state policies increasingly affect resource decisions.[99] DOE efforts have begun identifying major challenges and research priorities around wholesale market design for a modern grid.[100] Federal and state agencies, including DOE, BOEM, and FERC could convene with RTOs/ISOs and utilities to design and implement market structures in anticipation of significant increases in renewable power generation.

Table 16. Market Design Initiatives

Initiatives	Specific Actions To Implement	Outcome
Develop market rules for the future grid	Improve the pricing of clean energy attributes and establish an industry task force to explore the need for new grid service products and how market rules could enable offshore wind market participation and proper compensation for its unique value contributions.	Offshore wind generators compensated for services contributing to grid reliability, locational value, and policy goals

Renewable Fuels.[101] Offshore wind power can be used to produce clean renewable fuels, such as hydrogen or hydrogen-derived fuels. These fuels can be used for energy storage, in backup power systems, or in support of industries that cannot easily transition to electricity. Both grid-connected and off-grid offshore wind power plants could be used to produce such fuels. Conversion plants could be built on land and powered by offshore wind energy, or conversion equipment could be located offshore at the wind power plant with the renewable fuel transported to shore in an undersea pipe or by marine vessels. Conversion technologies complement offshore wind because conversion can make use of inexpensive electricity during times when offshore wind power production exceeds electricity demand. This minimizes the potential curtailment or underutilization of offshore wind energy generation. In a hybrid energy system that includes both power generation and storage, renewable fuel could be converted back to electricity, when needed, through fuel cells or low-emissions combustion. Such long-

[98] For more information, see New England's Future Grid Initiative.
[99] Notice of Technical Conference, Docket No. AD21-10 (February 18, 2021); Notice of Technical Conference, Docket No. AD21-10 (April 22, 2021); Notice of Technical Conference, Docket No. AD21-10 (July 14, 2021).
[100] For more information, see *Research Priorities and Opportunities in United States Competitive Wholesale Electricity Markets.*
[101] Renewable fuels are produced using energy from renewable sources.

term, high-capacity energy storage solutions can alleviate variability and uncertainty in renewable energy production.

Renewable fuels will be needed to reach net-zero carbon emissions and a 100 percent clean energy economy. These fuels can be used in transportation (including marine vessels), heating, and industrial processes that are difficult to electrify directly and have traditionally relied on fossil fuels. There is even potential to use existing infrastructure, such as natural-gas pipelines and liquid natural-gas terminals, for renewable fuels delivery. DOE's H2@Scale[102] initiative is researching the vast impact hydrogen can have in different applications. Coordinated near-term plans for research, technology innovation, small-scale systems demonstration, and infrastructure deployment between WETO and DOE's Hydrogen and Fuel Cell Technologies Office could facilitate efficient advancement of offshore-wind-powered renewable fuel production systems. Low-carbon fuel standards that increase over time could create a market for renewable fuels and other clean energy solutions. To reduce the carbon footprint of hydrogen production and enable at-scale hydrogen use, in June 2021 DOE announced the Hydrogen Shot,[103] aiming to reduce the cost of clean hydrogen by 80% to $1/kilogram in one decade.

Table 17. Renewable Fuels Initiatives

Initiatives	Specific Actions To Implement	Outcome
Evaluate policy to support renewable fuels use and production	Evaluate low-carbon fuel standards and consider financial incentives	Clear and predictable demand for fuels produced by offshore wind energy
Optimize offshore wind renewable fuel production systems	Conduct R&D for hydrogen production systems in marine environments and to optimize offshore wind plants dedicated to hydrogen production	Cost-effective renewable fuels produced using offshore wind power

[102] For more information, see DOE's H2@Scale web page.
[103] For more information, see DOE's Hydrogen Shot web page.

V. Regional Considerations

Nearly 80 percent of the U.S. population is located in the 30 states that border an ocean or a Great Lake. These states can be grouped into the following regions:

- Atlantic (North, Mid-, and South)
- Pacific (including Hawaii and Alaska)
- Gulf of Mexico
- Great Lakes

To date, there has been a strong focus within the offshore wind energy industry on the North and Mid-Atlantic regions of the country (see Appendix A4), but the majority of strategies and key initiatives identified in this report apply directly to all coastal regions, as national interest in offshore wind energy increases. These strategies will be applicable with varying degrees of emphasis and urgency as each region progresses through the stages of offshore wind energy development—from state energy goals and initial project proposals to fully operating offshore wind power plants. Certain adaptations and priorities are needed to accommodate unique regional conditions.

Collaborative strategic planning by states, industry, interested organizations, and Federal partners can result in regionally specific offshore wind energy development roadmaps. Offshore development in each region must be respectful of indigenous values during regional planning and during project reviews. Collaborative regional initiatives would increase the likelihood of achieving national deployment targets. Cooperative efforts could include increased coordination among neighboring states on mutual needs for training, supply chain, ports and vessels, and electrical transmission, as well as engagement of local communities, tribes, and impacted ocean co-users. These steps will likely help limit deployment delays and supply chain bottlenecks that could impact the ability of individual states to realize their respective offshore wind energy goals.

To supplement the strategic priorities identified in Section V, a non-exhaustive list of near-term initiatives that could accelerate and maximize offshore wind energy deployment in each U.S. coastal region is provided here. These initiatives include brief summaries of each region's development status and unique or high-profile characteristics.

Atlantic Coast. Initial, large-scale U.S. offshore wind energy development is occurring along the Atlantic Seaboard, which has a strong wind resource, large population centers, and high energy prices. Other than in the Gulf of Maine, relatively shallow water depths extend far out onto the Outer Continental Shelf in the Atlantic. These depths are suited for fixed-bottom structures with little or no visibility of wind turbines from land. Siting other types of utility-scale renewable energy generation in this region is often constrained by resource limitations or land availability near population centers. The Block Island Wind Farm (30 MW) and Coastal Virginia Offshore Wind pilot (12 MW) projects have demonstrated the feasibility of constructing and operating offshore wind power plants in the U.S. Atlantic. In May 2021, Vineyard Wind 1 became the first commercial-scale project to receive Federal approval for construction and operation.

Progress in offshore wind development has been significant in recent years, driven primarily by state-level offshore wind procurement commitments. As of June 2021:

- Eight Atlantic states have solicited a total of more than 15 GW of offshore wind generation capacity and committed to a total of 39 GW of offshore wind energy by 2040.
- There are 17 active commercial lease areas in Federal waters in varying stages of development.[104]
- There is a deep-water floating demonstration project under development for the Gulf of Maine.

Floating offshore wind technology may become necessary to meet growing state commitments—particularly if such commitments are enacted in regions with deeper waters. Key areas of concern around delivering power to cities include limitations in cable routing options as a result of geographic constraints, potential points of grid interconnection, and transmission capacity on land.

In addition to the strategic priorities in Section V, which are common to all regions, near-term initiatives with potential to accelerate and maximize offshore wind energy deployment in the Atlantic region include:

- Accelerating and fostering collaboration, including transmission studies among regional RTOs/ISOs, to inform the costs and benefits of proactive and coordinated interconnection and transmission planning and upgrades
- Conducting research and analysis to better understand and design for hurricane risks in the Mid- and South Atlantic regions
- Continuing and expanding the use of the first offshore wind power plants in the United States to conduct on-site monitoring and research to better understand environmental impacts, effects on communities and ocean co-users, and wind power plant performance.

Pacific Coast. In general, waters off the Pacific Coast are much deeper than off the Atlantic Coast. Therefore, floating wind technology is the only viable option for large-scale offshore wind energy development in this region. In particular, offshore California and Oregon have areas with very high wind speeds, though some of the best wind resources are not located near major population centers or existing high-capacity transmission corridors. Electricity prices in California, Alaska, and Hawaii are among the highest in the Nation. Large amounts of potentially lower-cost renewable energy resources are available in Pacific Coast states. Many

[104] For leasing status, see BOEM's State Activities web page.

areas where offshore wind energy projects are planned tend to have stronger offshore winds in the afternoon and evening.[105] This characteristic aligns with daily power demand cycles and can complement other variable renewables; for instance, offshore wind plants continue generating power in the evening when electricity demand is peaking and solar energy generation is ramping down.

Extensive use of ocean areas off central California and Hawaii for U.S. military testing and training have caused concerns regarding potential mission interference from large offshore wind power plants. Cooperative dialogue led the Federal Government and California to announce an agreement on May 25, 2021, to advance planning for WEAs off the northern and central coasts of California, with a possible lease sale auction targeted for mid-2022.[106] In September 2021, the California Legislature approved legislation requiring the California Energy Commission to prepare a strategic plan for developing offshore wind resources and establish deployment targets for 2030 and 2045.[107] Wind energy Call Areas off Hawaii are also under review by BOEM to determine their suitability for commercial wind energy. Native Hawaiians have expressed the need to consider offshore development impacts to places and natural resources with cultural and spiritual importance, highlighting the need to engage local and indigenous communities early in potential project processes.[108] Planning for offshore wind energy leasing is also underway in Oregon.

Given the lack of data on or examples of floating offshore wind energy projects in the Pacific Coast region, there are significant stakeholder concerns about potential environmental and fisheries impacts, as well as possible limitations in suitable port and fabrication infrastructure.

In addition to the strategic priorities in Section V, which are common to all regions, near-term initiatives with a focus on accelerating deployment in the Pacific region include:

- Accelerating R&D and investment in floating offshore wind technology
- Accelerating development of port and fabrication infrastructure
- Facilitating continued Federal cooperation to resolve military use concerns related to potential WEAs
- Accelerating analysis and planning to address specific onshore transmission capacity constraints related to the long distances between population centers and the highest wind speeds
- Expanding on existing baseline environmental, meteorological, and oceanographic data collection crucial to the responsible deployment of floating offshore wind systems,

[105] Optis, Mike, Rybchuk, Alex, Bodini, Nicola, Rossol, Michael, and Musial, Walter. 2020. *2020 Offshore Wind Resource Assessment for the California Pacific Outer Continental Shelf*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-77642. https://www.nrel.gov/docs/fy21osti/77642.pdf.
[106] U.S. Department of the Interior. 2021. "Biden-Harris Administration Advances Offshore Wind in the Pacific." https://www.doi.gov/pressreleases/biden-harris-administration-advances-offshore-wind-pacific.
[107] For more information, see California Legislature's Assembly Bill No. 525 Chapter 231
[108] For more information, see BOEM's Tribal Engagement web page.

including conducting studies on species and potential impacts, characterizing the wind resource and sea states, evaluating seafloor conditions, and assessing regional oceanic phenomena such as upwelling
- Establishing the economic value of offshore wind in each state relative to other energy sources, particularly with respect to integrating offshore wind with other renewables, such as solar and land-based wind, and considering the industry's potential impact on overall economic growth through jobs and infrastructure development
- Developing mooring and inter-array cabling, as well as floating sub-stations, suitable for the deep waters of the region.

Gulf of Mexico. With its relatively shallow waters, low average wave heights, and mild climate, the Gulf of Mexico presents many positive attributes for offshore wind energy development. The existing logistics and fabrication infrastructure for both offshore oil and gas and land-based wind along the Gulf Coast offers a great opportunity to contribute towards a regional and national offshore wind supply chain. The first Gulf of Mexico Intergovernmental Renewable Energy Task Meeting was held in June 2021[109] to begin coordinating offshore WEAs. However, unique conditions in the Gulf of Mexico introduce engineering and cost challenges, such as frequency and severity of hurricanes, low average wind speeds, and relatively weak soil strength (necessitating deeper foundations). Demonstrating cost competitiveness in this region may prove difficult considering its relatively low electricity prices and abundant natural gas resources. Given the energy intensive infrastructure in the region, there is a need to consider and mitigate the cumulative impacts of development.

In addition to the strategic priorities in Section V, which are common to all regions, near-term initiatives to employ Gulf Coast industries and accelerate offshore wind energy deployment in the Gulf of Mexico include:

- Leveraging the significant logistics and fabrication infrastructure of the Gulf Coast to supply major components and vessels for offshore wind power plants nationwide
- Supporting the transition of labor and other supply chain assets from the oil and gas and land-based wind industries to the offshore wind industry on a regional and national basis through training and investment
- Conducting research and analysis to better understand and design for major hurricanes including assessing current offshore wind turbine designs and performance in other global regions prone to extreme tropical storms, such as Taiwan
- Expanding R&D on low-wind-speed turbines optimized for performance in the wind resources of the Gulf of Mexico
- Reducing costs of jacket-type foundations and other alternative substructure designs used by the oil and gas industry that are suited to the Gulf of Mexico's low soil strength and breaking wave loads.

[109] For more information, see Gulf of Mexico Intergovernmental Renewable Energy Task Force.

Great Lakes. In general, this region has a strong wind resource, smaller average wave heights, less extreme weather, and less need for corrosion mitigation than the open ocean. In the Great Lakes, major population centers and energy markets are located on or near lake shores, along with major transmission corridors and potential interconnection points. Electricity rates are low relative to much of the country, with significant amounts of renewable energy provided by land-based wind power plants in the Midwest. Individual states will have jurisdiction over offshore wind energy projects in their respective state waters. From 2008 to 2013, DOE funded the Great Lakes Wind Collaborative, a multisector collaborative facilitated by the Great Lakes Commission to address regional challenges to offshore wind energy development.[110] A demonstration project off Ohio in Lake Erie has been in the design and planning phase for several years, and New York State is conducting a Great Lakes offshore wind feasibility study.

The Great Lakes region has a strong maritime tradition and extensive port and manufacturing infrastructure that could be adapted for offshore wind energy. However, large wind turbine installation vessels capable of lifting contemporary offshore wind turbines of 12 MW or larger are too wide to navigate through the locks of the St. Lawrence Seaway to reach the Great Lakes from the Atlantic Ocean. This creates a unique installation challenge that may limit deployable wind turbine size and realization of certain economies of scale in the region. Monopile foundations may not be feasible because of bedrock under the lakebed. Shallow foundations may be practical in Lake Erie, and floating offshore wind technology is needed in the other lakes, which are deeper. Further, prior work has indicated that ice buildup and movement are major design considerations for structures and wind turbine systems installed in the region.

In addition to the strategic priorities in Section V, which are common to all regions, near-term initiatives to accelerate and maximize offshore wind deployment within the Great Lakes include:

- Assessing the potential of Great Lakes ports and other maritime infrastructure, including vessels, to handle and install larger offshore wind turbines and structures, including ocean-access constraints and potential synergies with Canadian assets
- Renewing collaboration of interested regional entities with individual states and Federal agencies to determine energy market potential, development benefits and concerns, and realistic timelines for the region
- Developing economical methods to mitigate the impacts of surface ice and equipment icing on structural loads and energy production
- Assisting regional companies currently in the land-based wind supply chain to expand into the national offshore wind energy supply chain, based on their capabilities.

[110] For more information, see Great Lakes Wind Collaborative: Project Archive.

VI. Additional Consortia

Collaborations are needed to accelerate and maximize the effectiveness, reliability, and sustainability of U.S. offshore wind energy deployment and operation. As discussed in this report, further work and collaboration are needed across all strategic priorities—for R&D, testing and demonstration, data sharing, strategy development, infrastructure buildout, and overall planning.

Collaboration can take many forms including consortia, task forces, centers of excellence, and partnerships. Numerous federally funded entities are already established that can be used to coordinate on many topics of interest. For example:

- The National Offshore Wind Research and Development Consortium was established with funding by DOE and the New York State Energy Research and Development Authority to support R&D activities that reduce cost and risk of offshore wind energy development projects throughout the United States. Members include representatives from six states and industry from across the country.
- The Ocean Energy Safety Institute is co-funded by DOE and BSEE to improve the safety and environmentally sustainable development and operation of offshore energy production, including oil and gas, hydrokinetic energy, and offshore wind energy.
- DOE's Grid Modernization Laboratory Consortium leverages national laboratories to collaborate on the goal of modernizing the nation's grid.
- The National Oceanographic Partnership Program can facilitate interagency co-funding of offshore wind energy research. For example, in January 2021, DOE issued a Funding Opportunity Announcement for environmental research in permitting in conjunction with the National Oceanographic Partnership Program and with funding from BOEM.
- BOEM's Regional Task Forces are non-decisional, intergovernmental groups that facilitate coordination among Federal, state, local, and Tribal governments regarding the wind energy leasing process. Members share information about existing activities and marine conditions and provide updates on regional offshore wind goals.

Additionally, many non-federally funded collaboration entities are operating or being established in the offshore wind energy space across a variety of technical areas. Such collaboration entities, in combination with existing federally funded consortia and task forces, offer a significant opportunity to expand collaboration toward accelerating and maximizing offshore wind energy deployment. Coordination and communication between organizations are important to promote valuable complementary projects and avoid duplicate efforts.

Similarly, establishing any new consortia requires careful consideration and coordination. Any new organization is most valuable if it offers unique capabilities to address relevant industry needs with minimal overlap to existing collaborations. Such capabilities may include expertise, data access, testing facilities, demonstration sites, regional ties, or industry influence. Each consortium should have a well-defined purpose or technical scope to be relevant without duplicating work. Members should contribute capabilities and expertise with a credible path for ensuring results are used by the intended recipients. Members should be willing to dedicate time and energy toward the consortia's mission. The organization's desired life span should be determined upfront—whether to exist indefinitely or until certain goals are accomplished. The relationship between funding organizations and other consortia members or contributors, as well as how decision-making authority is shared, should be carefully considered.

VII. Conclusion

The Biden Administration's goals of a carbon-free electricity system by 2035 and a net-zero emissions economy by 2050 are unlikely to be met without development of offshore wind energy in the United States. Achieving these goals, including 30 GW of offshore wind by 2030, will require major commitments by the Federal Government and partners to reduce risks and barriers to successful deployment of offshore wind energy. Despite risks and barriers, the future of offshore wind energy is promising, as eight Atlantic states have announced targets totaling 39 GW of offshore wind by 2040.

In summary, addressing the five strategic priorities (outlined in this report and below) will help increase offshore wind market penetration, address transmission challenges, and ensure a robust domestic supply chain, create tens of thousands of good-paying jobs and capture the broader domestic economic gains associated with these investments.

- **Increase demand for offshore wind energy and grow the domestic supply chain at lower cost by considering expansion of Federal incentives related to offshore wind energy.** Federal incentives could also promote economic development, job creation, and community economic benefits. Technology-neutral incentives may be the most efficient way to accelerate the deployment of clean energy technologies overall. However, technology-neutral incentives will favor lower cost, land-based technologies in the near term. Targeted incentives for offshore wind could accelerate technology maturation, cost reduction, and deployment. Such near-term advancements could help the offshore wind energy industry scale up at the pace needed to contribute sufficiently to deployment and decarbonization goals.

- **Reduce offshore wind energy costs through technology innovation and adaptations that enable industry growth and provide affordable electricity throughout the country.** Reducing costs is essential to offshore wind industry growth. Expanded and accelerated research and development in site characterization and technology advancement will increase power production, reduce financial risks and uncertainties of project development, and enable domestic manufacturing. New system designs are required for U.S. operating conditions, such as deep water in the Pacific, hurricanes in the Gulf of Mexico, and ice formation in the Great Lakes. Accessing wind resources in deep-water areas (~60 percent of the U.S. offshore wind resource) will be key to reaching long-term deployment goals. Deployment of floating offshore wind platforms will lag fixed-bottom foundations as the technology matures, but will be critical to development in the Pacific, Gulf of Maine and other regions with deep waters. Expanding domestic test and demonstration facilities for both components and full systems would enable domestic suppliers to refine and validate new products. Installation, operation, and maintenance innovations that are adapted to U.S. sites and reduce dependence on scarce equipment would make offshore wind energy more cost competitive in the United States. Integrating circular economy practices can extend the usable life of offshore wind power plants and components, thus increasing value with nominal investment.

- **Improve siting and regulatory processes by increasing transparency and predictability, auctioning new lease areas, understanding development impacts, expanding stakeholder engagement, and facilitating ocean co-use.** Responsible siting and project permitting can enable steady growth of a thriving industry, while ensuring protection of the environment and maximizing opportunities for ocean co-use. The number of lease areas will need to grow significantly over the next decade to meet state and Federal deployment goals. A regional planning approach may accelerate identification of additional wind energy sites and facilitate safe, equitable ocean co-use. The industry needs predictable and efficient regulatory reviews that are advanced by clear and efficient permitting processes. Interagency collaboration and sufficient resources for staffing, research, and monitoring are necessary to understand and mitigate offshore wind's potential impacts on the marine environment, ocean co-users, and communities. Collaborating with communities and enhancing stakeholder engagement will help enable mutually beneficial and equitable siting solutions. Developing standardized practices to minimize or offset environmental impacts, where needed, will reduce potential risks that may otherwise impede project development.

- **Invest in supply chain development, including customized offshore wind ports and vessels to establish a logistics network and attract further investment.** Investing sufficiently in manufacturing, ports, vessels, and a diverse U.S. workforce will reduce the cost of offshore wind energy, increase the pace at which projects are able to deploy, and could contribute significantly towards the energy justice goal of achieving equity in economic participation in the energy system. Building a domestic supply chain and growing the industry will require dozens of port upgrades, numerous Jones-Act-compliant vessels, and new factories for component manufacturing and assembly. The availability of this infrastructure and broader certainty about the project pipeline are necessary to unlock $12 billion per year in private-sector project capital investments as well as create tens of thousands of good-paying jobs and capture the broader domestic economic gains associated with these investments. Regional collaboration in manufacturing, ports, vessels, and U.S. workforce development can result in facilities, networks, and policies that benefit all states within a region and the United States as a whole.

- **Plan efficient and reliable grid integration to deliver offshore wind energy at scale.** Strong near-term efforts focused on grid integration are necessary to enable large-scale incorporation of offshore wind into the Nation's power grid and future energy mix without long delays or lost opportunities. In particular, facilitating collaborative, proactive, and long-term transmission planning and investing in phased grid development is vital to increase the certainty and pace of offshore wind energy development, drive cost reductions, and help identify options to optimize transmission infrastructure in a way that protects the marine environment and is compatible with existing uses of the ocean and the needs of coastal communities. Innovation, cost reductions, and domestic supply capabilities are needed in high-voltage direct current technology to enable development farther from shore. There is a lack of sufficient onshore transmission capacity to transmit power from the strongest offshore wind resources to load centers. Offshore wind energy developers, RTOs or ISOs, and other stakeholders are already assessing the limited, existing onshore points of interconnection and seeking coordination from the Federal Government on transmission expansion. Creating incentives to plan and share transmission across multiple offshore wind projects, states, and transmission planning regions can encourage collaboration in infrastructure planning, cost allocation, and transmission system development that can benefit all states within and across regions. Renewable fuels can provide energy storage and clean fuel for applications that are difficult to electrify directly.

With a range of participants acting and collaborating on policy, investment, technology advancement, analysis, and standards development, these strategic priorities can all be achieved. Doing so would help attract investments in the U.S. supply chain that would create new job opportunities; make offshore wind energy more cost competitive with other electricity generation sources in U.S. coastal energy markets; and reduce regulatory, construction, and economic uncertainty that currently impedes industry growth.

VIII. Appendices

A1. Key Federal Agency Roles in Offshore Wind Energy Development

Many Federal agencies have roles and responsibilities regarding U.S. offshore wind including:

U.S. Department of Energy

- The Wind Energy Technologies Office (WETO) within the Office of Energy Efficiency and Renewable Energy plans and executes a diversified portfolio of research and development to advance technologies for offshore, land-based, and distributed wind energy, as well as integration with the electric grid. WETO also supports research to understand and resolve wind-related siting and environmental challenges.
- The Advanced Research Projects Agency-Energy (ARPA-E) advances high-potential, high-impact energy technologies that are too early for private-sector investment.
- The Loan Programs Office finances large-scale energy infrastructure projects in the United States.
- The Office of Electricity works closely with private and public sectors to ensure that the Nation's energy delivery system is secure, resilient, and reliable through the advancement of grid research, promotion of energy resiliency, and development of grid operating technologies.

U.S. Department of the Interior

- The Bureau of Ocean Energy Management (BOEM) is responsible for energy and mineral resource development in the outer continental shelf. This includes issuing leases, easements, and rights of way on the Outer Continental Shelf for the purpose of renewable energy production, transmission, and support. BOEM is the lead agency for National Environmental Protection Act (NEPA) analyses and associated consultations pertaining to various leasing actions.
- The Bureau of Safety and Environmental Enforcement (BSEE) is tasked with developing workplace safety, environmental compliance, and enforcement strategies for offshore wind energy projects.
- The Office of Natural Resources Revenue manages and ensures full payment of revenues owed for the development of the Nation's energy and natural resources on the Outer Continental Shelf and onshore Federal and Indian lands.
- The U.S. Fish and Wildlife Service is responsible for stewardship of species affected by offshore wind energy projects protected under the Migratory Bird Treaty Act, Endangered Species Act, and other statutes.
- The National Park Service is responsible for stewardship of the Nation's Federal parks and engages in consultation with offshore wind projects on impacts to recreational uses and historical and archaeological resources.

U.S. Department of Commerce

- The National Oceanic and Atmospheric Administration (NOAA)'s National Marine Fisheries Service (NMFS, also known as NOAA Fisheries) is responsible for the stewardship and management of fisheries, protected species, and their habitats under the Magnuson-Stevens Act, the Endangered Species Act, the Marine Mammal Protection Act, and other statutes. NMFS is also the lead agency responsible for implementing scientific surveys and research in U.S. Federal waters in support of mandates related to the stewardship of fisheries, wildlife conservation, habitat protection, and ecosystem-based management. The Agency is a key contributor to and user of NEPA analyses as both an adopting and coordinating agency with expertise and subject matter jurisdiction. It is also the primary Federal agency engaged with fishing industry constituents and recreational ocean users and stakeholders.
- Several other offices within NOAA have roles in offshore development including:
    - NOAA's Office of Oceanic and Atmospheric Research (NOAA Research)
    - NOAA's National Weather Service
    - NOAA's National Ocean Service
    - NOAA's Office for Coastal Management
    - NOAA's National Centers for Coastal Ocean Science
    - NOAA's Integrated Ocean Observing System
    - NOAA's Office of National Marine Sanctuaries.

U.S. Department of Defense

- The U.S. Army Corp of Engineers is the lead Federal agency for NEPA analyses for offshore wind energy projects that occur in state waters and in the Great Lakes, and issues permits under the Clean Water Act and Rivers and Harbors Act for projects on the Outer Continental Shelf.
- The Department is responsible for evaluating impacts to military training, testing, and operations through the Military Aviation and Installation Assurance Siting Clearinghouse.

U.S. Department of Homeland Security

- The U.S. Coast Guard is responsible for evaluating impacts of offshore wind energy projects on the Marine Transportation System, safety of navigation, the traditional uses of the particular waterway, and other missions.
- The U.S. Customs and Border Protection (CBP) evaluates impacts to its maritime border protection missions and issues rulings determining whether offshore wind projects are in compliance with the Jones Act and Passenger Vessel Services Act.

Federal Energy Regulatory Commission (FERC)

- FERC regulates the interstate transmission of electricity and establishes regional transmission planning, interregional transmission coordination, and cost allocation requirements, which may impact offshore wind energy transmission. It also regulates generator interconnection for FERC-jurisdictional transmission providers. In addition, FERC regulates RTO/ISO capacity, energy, and ancillary services markets, which affect offshore wind energy providers' compensation.

U.S. Department of Transportation

- The Maritime Administration (MARAD) promotes the use of waterborne transportation and its integration with other segments of the transportation system, and the viability of the U.S. merchant marine. MARAD works in many areas involving ships and shipping, shipbuilding, port development and operations, vessel construction and operations, national security, the environment, mariner education and training, and safety.
- The Federal Aviation Administration reviews projects for hazards to air navigation and, within the first 12 miles from the shoreline, has jurisdiction over how wind turbines should be marked and lit to maintain safe airspace. They also advise BOEM on lighting and marking for projects farther offshore.

A2. Background of Transmission Planning Along the Atlantic Seaboard

Transmission planning is complex, yet critical, to offshore wind energy. New electricity generators primarily connect to the grid through the generator interconnection process, which includes multiple studies and agreements conducted over 2 to 3 years. Transmission projects are also identified as part of local and regional transmission planning. Such planning includes maintaining reliability according to NERC transmission planning criteria, improving market efficiency, or implementing upgrades driven by Federal, state, or local public policy.

Transmission providers (most of which are public utilities) plan for new transmission facilities. They have FERC open-access transmission tariffs that detail their transmission planning processes and how shared transmission costs are allocated between beneficiaries. FERC broadly defines principles that regional transmission planning processes must meet, and transmission providers have flexibility to use structures that best meet their regionally specific needs as long as they comply with those principles.

Regional Transmission Planning. Some transmission owners are within a regional RTO/ISO market structure, such as ISO-New England (ISO-NE), New York ISO (NYISO), and PJM. The RTOs/ISOs provide a regional transmission planning process with cost allocation methods filed with FERC. The transmission planning processes rely on stakeholder input, including from states and public policymakers. Other areas, like parts of North Carolina and South Carolina, are not in an RTO/ISO, but still have regional transmission planning processes with cost allocation methods filed with FERC. The Atlantic regional FERC transmission entities are shown in Figure A.1. Transmission planning regions also conduct reliability assessments on a regular basis. These are reported to their individual NERC Regional Reliability Entities, which also conduct reliability assessments across broader regions.

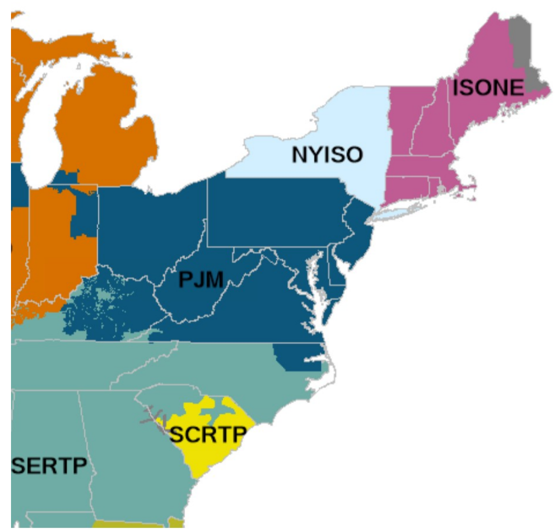

Figure A.1. Transmission planning regions

Interregional Transmission Coordination Among Coastal States. In compliance with FERC Order No. 1000, each of the regions engages in interregional transmission coordination (which does not include long-term interregional planning of prospective projects) with their neighboring regions. An agreement between ISO-NE, NYISO, and PJM includes committees and stakeholder advisory processes to consider projects that may impact multiple regions. The objective is to meet needs more efficiently or cost effectively than separate regional solutions. Similar interregional transmission coordination processes and cost allocation methods exist between the PJM and Southeastern Regional Transmission Planning (SERTP) regions and between the SERTP and South Carolina Regional Transmission Planning regions (SCRTP).

A3. Bureau of Ocean Energy Management's Permitting Process[111]

Figure A.2. Bureau of Ocean Energy Management's Regulatory Roadmap

[111] For more information, see BOEM's Regulatory Framework and Guidelines.

A4. Offshore Wind Energy Activity in U.S. Waters

All 35,324 MW that make up the U.S. offshore wind energy pipeline as of May 2021 are itemized as an individual project or project opportunity in Table A.2, and in the maps shown in Figure A.3, corresponding to the eastern Atlantic Coast (and Great Lakes), California Coast, and Hawaii. Note that the first column in Table A.2 corresponds to the numbers on the maps. Table A.1 contains the definitions for the categories used in the Status column of Table A.2.

Table A.1. U.S. Offshore Wind Energy Pipeline Categories[112]

Status	Description
Operating	The project is fully operational with all wind turbines generating power to the grid.
Under Construction	All permitting processes are completed. Wind turbines, substructures, and cables are being installed. Onshore grid upgrades are underway.
Financial Close	Begins when sponsor announces a financial investment decision and has signed contracts for major construction work packages.
Approved	BOEM and other Federal agencies have reviewed and approved a project's COP. The project has received all necessary state permits and has completed an interconnection agreement to inject power into the grid.
Permitting	The developer has site control and has initiated permitting processes to construct the project and sell its power.
Site Control	The developer has acquired the rights to a lease area. Depending on market demand, developers may or may not incrementally build out projects to use a given lease area's entire size/potential.
Unleased Wind Energy Areas	The rights to lease areas have yet to be auctioned to developers.

[112] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.

Table A.2. U.S. Offshore Wind Pipeline[113]

#	Lease/ WEA /Call Area Location	Project Name	Developer	Status	Lease Area	Foundation Type	Permit Status	Offtake Agreement	Approved Interconnect Location	Estimated Commercial Operation Date	Size (MW)
1	ME	New England Aqua Ventus I	Univ. of Maine /RWE/Mitsubishi	Permitting	State Lease	Floating	State Approved	Yes	TBD	2023	12
2	MA	Bay State Wind	Ørsted/Eversource	Site Control	OCS-A 0500	Fixed Bottom	COP	TBD	Yes	TBD	2,277
3	MA	Park City Wind	Avangrid/Copenhagen Infrastructure Partners	Permitting	OCS-A 0501	Fixed Bottom	COP	Yes	TBD	2025	804
4	MA	Vineyard Wind 1 + (Residual)	Avangrid/Copenhagen Infrastructure Partners	Approved	OCS-A 0501	Fixed Bottom	Approved	Yes	Yes	2023	800 (421)
5	MA	Beacon Wind	Equinor/BP	Permitting	OCS-A 0520	Fixed Bottom	SAP	Yes	TBD	2026	1,230
6	MA	Mayflower Wind + (Residual)	Energias de Portugal Renováeis/Shell	Permitting	OCS-A 0521	Fixed Bottom	COP	Yes	TBD	2025	804 (747)
7	MA	Shell/Atkins/Ocergy Floating Demonstration	Shell/Atkins/Ocergy	Permitting	OCS-A 0521	Floating	TBD	Yes	TBD	2025	10
8	MA	Liberty Wind	Avangrid/Copenhagen Infrastructure Partners	Site Control	OCS-A 0522	Fixed Bottom	SAP	TBD	TBD	TBD	1,607
9	MA	Sunrise Wind	Ørsted/Eversource	Permitting	OCS-A 0487/0500	Fixed Bottom	COP	Yes	TBD	2024	880
10	RI	Revolution Wind	Ørsted/Eversource	Permitting	OCS-A 0486	Fixed Bottom	COP	Yes	TBD	2023	704
11	RI	South Fork	Ørsted/Eversource	Permitting	OCS-A 0517	Fixed Bottom	COP	Yes	Yes	2023	130
12	RI	Block Island Wind Farm	Ørsted/Eversource	Operating	State Lease	Fixed Bottom	State Approved	Yes	Yes	2016	30
13	NY	Fairways North WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	1,071
14	NY	Fairways South WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	289
15	NY	Hudson North WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	523
16	NY	Central Bight WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	1,028
17	NY	Hudson South WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	6,890
18	NY	Empire Wind	Equinor/BP	Permitting	OCS-A 0512	Fixed Bottom	COP	Yes	TBD	2024	816
19	NY	Empire Wind II	Equinor/BP	Permitting	OCS-A 0512	Fixed Bottom	COP	Yes	TBD	2028	1,260
20	NJ	Atlantic Shores Offshore Wind	EDF/Shell	Site Control	OCS-A 0499	Fixed Bottom	COP	Yes	TBD	TBD	2,500
21	NJ	Ocean Wind + Residual	Ørsted/PSEG	Permitting	OCS-A 0498	Fixed Bottom	COP	Yes	TBD	2024	1,100

[113] Musial, Walt, Beiter, Philipp, Spitsen, Paul, Duffy, Patrick, Marquis, Melinda, Cooperman, Aubryn, Hammond, Robert, Shields, Matt. 2021. *Offshore Wind Market Report: 2021 Edition*. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://energy.gov/eere/wind/articles/offshore-wind-market-report-2021-edition-released.

22	DE	Garden State Offshore Energy	Ørsted/PSEG	Site Control	OCS-A 0482	Fixed Bottom	SAP	TBD	TBD	TBD	1,050
23	DE	Skipjack	Ørsted	Permitting	OCS-A 0519	Fixed Bottom	COP	Yes	TBD	2026	120
24	MD	MarWin + Residual	US Wind	Permitting	OCS-A 0490	Fixed Bottom	COP	Yes	Yes	2023	966
25	VA	Coastal Virginia Offshore Wind - Commercial	Dominion Energy	Permitting	OCS-A 0483	Fixed Bottom	COP	Utility Owned	Yes	2024	2,640
26	VA	Coastal Virginia Offshore Wind - Pilot	Dominion Energy	Operating	OCS-A 0497	Fixed Bottom	State Approved	Utility Owned	Yes	2021	12
27	NC	Kitty Hawk	Avangrid	Permitting	OCS-A 0508	Fixed Bottom	COP	TBD	TBD	2024	1,485
28	NC	Wilmington West WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	627
29	NC	Wilmington East WEA	N/A	WEA	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	1,623
30	SC	Grand Strand Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A
31	SC	Winyah Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A
32	SC	Cape Romain Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A
33	SC	Charleston Call Area	N/A	Call Area	N/A	Fixed Bottom	N/A	N/A	N/A	N/A	N/A
34	OH	Ice Breaker	LEEDCo/Fred Olsen	Permitting	State Lease	Fixed Bottom	State Approved	Yes	TBD	2023	21
35	CA	Humboldt Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A
36	CA	Morro Bay Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A
37	CA	Diablo Canyon Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A
38	HI	Oahu North Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A
39	HI	Oahu South Call Area	N/A	Call Area	N/A	Floating	N/A	N/A	N/A	N/A	N/A
											35,324

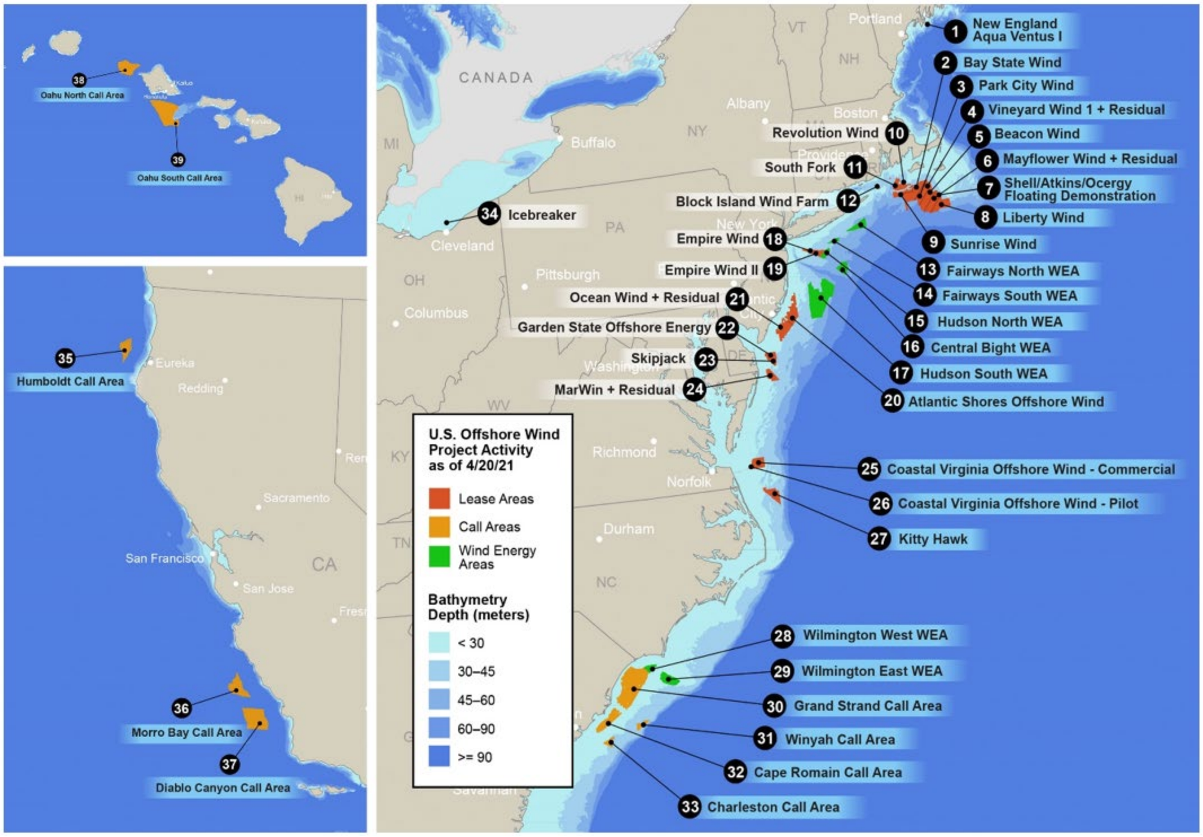

Figure A.3. Locations of U.S. offshore wind pipeline activity and Call Areas as of May 31, 2021
Map created by John Frenzl, National Renewable Energy Laboratory

A5. State Offshore Wind Commitments

The U.S. offshore wind energy market continues to be driven by state-level offshore wind procurement activities and policies (Table A.3). In aggregate, these activities call for deploying at least 39,298 MW of offshore wind capacity by 2040.

Table A.3. U.S. Offshore Wind State Procurement Policies and Activity as of May 31, 2021

State	Total Capacity Commitment (MW)	Target Year	Amount Procured (MW)	Contract Type	Year Enacted	Authority
Massachusetts	5,600	2035	1,604	PPA	2016 2018 2021	An Act to Promote Energy Diversity An Act to Advance Clean Energy An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy
Rhode Island[114]	430	-	430	PPA	-	-
New Jersey	7,500	2035	1,100	OREC	2010 2018 2019	Offshore Wind Economic Development Act Executive Order 8/Assembly Bill 3723 Executive Order 92
Maryland	1,568	2030	368	OREC	2013 2019	Maryland Offshore Wind Energy Act Clean Energy Jobs Act
New York	9,000	2035	6,816	OREC	2018 2019	Case 18-E0071 Climate Leadership & Community Protection Act
Connecticut	2,000	2030	1,104	PPA	2017	Public Act 17-144 House Bill 7156
Virginia	5,200	2034	12	Utility-Owned	2020	Virginia Clean Energy Economy Act
North Carolina	8,000	2040	0	TBD	2021	Executive Order 218
Total	**39,298**		**11,434**			

Note: PPA = power purchase agreement; OREC = offshore renewable energy certificates

[114] Note, Governor Raimondo signed Executive Order 20-01 that targeted Rhode Island being powered by 100% clean electricity by 2030; however, the Executive Order did not identify a specific offshore wind target.

A6. Acronyms

A2e	Atmosphere to Electrons (program within Wind Energy Technologies Office)
ARPA-E	Advanced Research Projects Agency-Energy
ATLANTIS	Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control
BOEM	Bureau of Ocean Energy Management
BSEE	(U.S. Department of Interior's) Bureau of Safety and Environmental Enforcement
CAISO	California Independent System Operator
CBP	(U.S. Department of Homeland Security's) Customs and Border Protection
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
FERC	Federal Energy Regulatory Commission
GW	gigawatt(s)
ISO	independent system operator
ISO-NE	Independent System Operator—New England
ITC	Investment Tax Credit
LCOE	levelized cost of energy
MARAD	(U.S. Department of Transportation's) Maritime Administration
MW	megawatt(s)
MWh	megawatt-hour(s)
NEPA	National Environmental Policy Act
NERC	North American Electric Reliability Corporation
NMFS	(NOAA's) National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NYISO	New York Independent System Operator
R&D	research and development
RFI	Request for Information
RODEO	(BOEM's) Realtime Opportunity for Development Environmental Observations
RTO	regional transmission operator
SERTP	Southeastern Regional Transmission Planning
SCRTP	South Carolina Regional Transmission Planning
WTIV	wind turbine installation vessel
WEA	wind energy area
WETO	(U.S. Department of Energy's) Wind Energy Technologies Office
WFIP	Wind Forecasting Improvement Project