Advancing Offshore Wind Energy in the United States

U.S. Department of Energy Strategic Contributions Toward 30 Gigawatts and Beyond

30 GW 2030 **110** GW 2050

U.S. DEPARTMENT OF ENERGY

Disclaimer

Executive Summary

The Strategy

The U.S. Department of Energy (DOE) has been a global leader in supporting critical wind energy research, development, demonstration, and deployment (RDD&D) for decades, helping usher in commercial wind energy production. These investments have contributed to the rise of today's wind energy sector. This offshore wind energy strategy outlines DOE's approach for accelerating the development of U.S. offshore wind to deploy 30 gigawatts (GW) by 2030 and establish a pathway to deploying 110 GW or more by 2050.[1] As a critical part of this pathway, this strategy seeks to also support the deployment of 15 GW of floating offshore wind capacity by 2035, as announced by the Biden administration in September 2022.[2]

In January 2022, DOE issued a nationwide strategy[3] that outlined broad priority areas for accelerating the sustainable development of offshore wind energy in the United States. This strategy document outlines DOE's contributions to meeting the challenges indicated in the nationwide strategy, including the need to reduce the levelized cost of energy; expand predictable leasing and permitting processes; develop the domestic supply chain; and expand transmission. DOE's efforts form a part of a broader all-of-government approach to advancing offshore wind energy and strengthening the U.S. transmission grid as part of our nation's clean energy future.

DOE's Role

For more than a decade, DOE has led a robust portfolio of RDD&D, analysis, and stakeholder engagement to advance offshore wind energy in the United States and support the transmission system upgrades that enable it. DOE supports the development of critical technologies through research, innovation, coordinated planning efforts, technical assistance programs, community engagement, demonstration projects, and federal loans for clean energy deployment, transmission buildout, and supply chain development. DOE regularly partners with numerous federal, state, local, and tribal government agencies and organizations; domestic and international private and public energy entities; and its national laboratories. DOE collaborates with U.S. agencies such as the Bureau of Ocean Energy Management to help inform siting and leasing and coordinates efforts closely with the U.S. Department of Commerce, U.S. Department of Transportation, and others to advance offshore wind energy while protecting biodiversity and ocean co-use. Through this strategy, DOE outlines a plan to bring its complement of programs and resources to bear to support offshore wind, in partnership and collaboration with the parties mentioned above, as the agency

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[1] 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.

[2] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

[3] U.S. Department of Energy (DOE). 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

seeks to steward its annual appropriations and new resources under the Bipartisan Infrastructure Law and Inflation Reduction Act.

The Vision

Together with its federal partners, DOE envisions a future in which offshore wind energy is not only a critical part of the nation's decarbonized economy and climate solution, but is developed in a way that is economic, reliable, sustainable, just, and timely (Figure H-1).

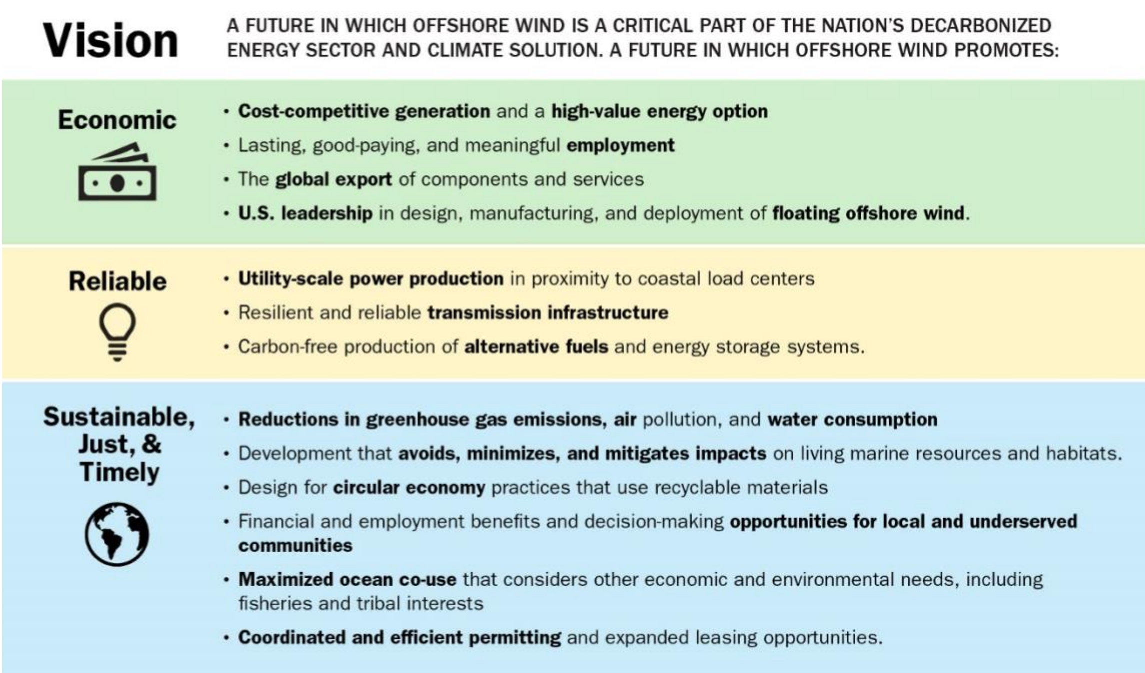


Figure H-1. All-of-government offshore wind energy vision

The Opportunity

Offshore wind is a growing source of reliable and clean energy around the world, with over 50 GW installed across more than 250 projects, as of mid-2022. The United States (U.S.) has just begun to tap the vast resource potential along its coasts with seven turbines (42 megawatts [MW]) installed off Rhode Island and Virginia as of 2022, but has a project pipeline of 40 GW planned.[4] In addition to the federal offshore wind target of 30 GW by 2030 and 15 GW of floating offshore wind by 2035, individual U.S. states policies aim to procure at least 39 GW by 2040.[5]

[4] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.
[5] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.

With over 4,200 GW of technical resource potential, offshore wind could meet today's U.S. electricity demands by more than three times.[6] [7] A single offshore wind power plant can deliver a significant amount of energy to coastal load areas, which tend to suffer from transmission congestion and limited siting options for large-scale, land-based renewable energy generation. The potential scale of offshore wind energy's deployment and its access to the nation's highest and most reliable wind speeds makes this generation source a crucial infrastructure investment, and one that can help revitalize coastal communities, including ports and manufacturing facilities. Achieving the administration's goal of 30 GW by 2030 would translate to more than 77,300 employed workers in jobs induced by offshore wind activity, capital investments in offshore wind energy projects of more than $12 billion per year, and 5−10 new manufacturing plants (for producing wind turbine nacelles, blades, towers, foundations, and subsea cables).[8] Infrastructure investments also include marshaling ports, fabrication ports, and large installation vessels for a total of approximately $11 billion needed by 2030 to support the manufacture, transport, and installation of major offshore wind energy components.[9]

National Offshore Wind Energy Priority Needs

This strategy builds on the 2022 *Offshore Wind Energy Strategies* report[10] published by DOE, in coordination with other federal agencies, that outlines the following regional and national challenges and strategies to accelerate offshore wind energy deployment in the United States (Figure H-2):

- **Reducing offshore wind energy costs**. The average cost of offshore wind energy generation in the United States is above that of many other generation sources. Additionally, at the time of publication, offshore wind projects are facing challenges associated with rising costs due to inflation and rising cost of capital. Reducing the generation cost is a need for both fixed-bottom and floating offshore wind systems, though reducing that cost is a particular area of emphasis for floating offshore. Floating offshore wind systems are at an earlier commercial and technological stage with costs that tend to be above those of fixed-bottom offshore wind systems.
- **Supporting optimized siting and regulation**. The extent of lease areas available for offshore wind energy development will need to grow considerably in the coming decades to meet longer-term state and federal deployment goals. Future offshore wind leasing also requires increased certainty in timing and processes, and careful consideration of ocean co-use, environmental sustainability, benefits to underserved communities, and energy justice.

[6] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.
[7] U.S. Energy Information Administration. 2022. *Annual Energy Outlook 2022.* https://www.eia.gov/outlooks/aeo/narrative/pdf/AEO2022_Narrative.pdf
[8] Lantz, E., G. Barter, P. Gilman, D. Keyser, T. Mai, et al. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030.* https://www.nrel.gov/docs/fy21osti/80031.pdf.
[9] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.
[10] DOE. 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

- **Investing in supply chain development**. The nation is readying for its first commercial-scale offshore wind energy projects, yet the domestic supply chain is not yet mature enough to manufacture all key components needed to reach the Biden Administration goals, as well as serve global markets.
- **Planning the grid integration of offshore wind energy**. Most U.S. coastal areas lack adequate transmission capacity to bring gigawatt-scale production from offshore wind turbines to coastal load centers. Therefore, there is a need to deploy offshore and onshore transmission networks to deliver offshore wind power and improve reliability and resilience and to enable dynamic cable solutions for floating offshore wind energy.

The 2022 Offshore Wind Energy Strategies report also identifies expanded federal incentives related to offshore wind energy as a challenge area.[11] Since the publication of that report, the Inflation Reduction Act of 2022 was passed,[12] which extends tax credits for clean energy and manufacturing. These tax credits have the potential to support both offshore wind market growth, as well as the development of a domestic supply chain[13] and may help address some of the challenges associated with rising project costs.

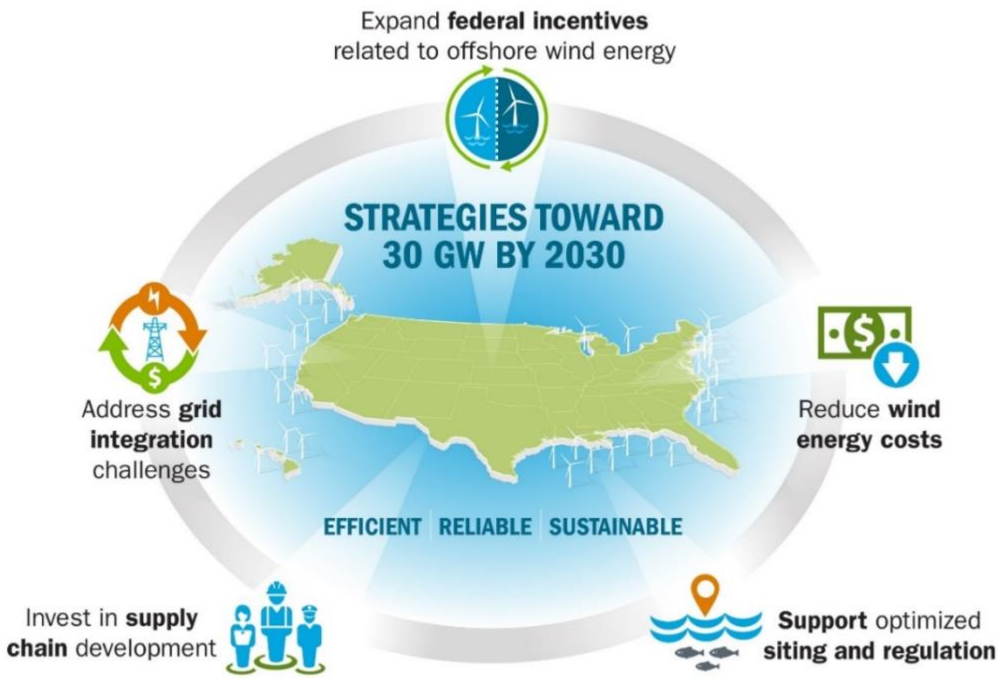


Figure H-2. Key needs for meeting 30 GW by 2030. Image modified from "Offshore Wind Energy Strategies." *DOE (2022)*[14]

[11] DOE. 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.
[12] Inflation Reduction Act of 2022. H.R.5376. 117th Congress. 2022. https://www.congress.gov/bill/117th-congress/house-bill/5376/text.
[13] The White House, "Building A Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action," January 2023, https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

Offshore Wind Technology Types

Offshore wind turbines are the largest rotating structures ever built and are highly complex systems. These systems can be broadly categorized into fixed-bottom and floating offshore wind systems. Deployment of offshore wind energy across all major U.S. coastal areas requires using both fixed-bottom and floating substructures because of varying water depths. Fixed-bottom substructures are secured in the seabed by monopiles, "jacketed" lattice-type frames, or gravity or suction bucket anchors and are typically deployed in water depths of 60 meters (m) or less. Floating wind turbines are mounted on buoyant platforms or substructures and connected to the seabed using mooring lines and anchors, typically in water depths exceeding 60 m.[15] From the total offshore wind resource potential of 4.2 GW, more than 65% is in deep waters, requiring floating platforms (Figure H-3).[16]

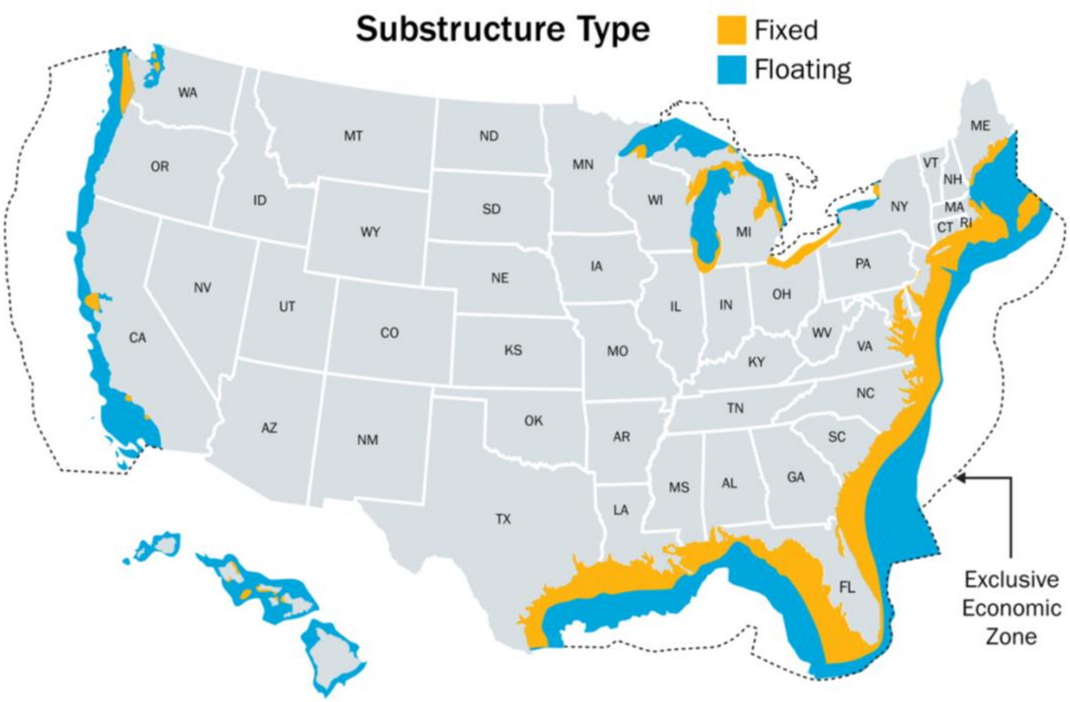


Figure H-3. Offshore wind substructure type by water depth (60 m). ***Image from the National Renewable Energy Laboratory***[17]

[15] This water depth is not a hard limit and floating substructures might get deployed in water depths shallower than 60 meters (m) depending on economic feasibility and siting considerations.
[16] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.
[17] Adapted from: Musial, W., P. Beiter, P. Schwabe, T. Tian, T. Stehly, et al. 2017. *2016 Offshore Wind Technologies Market Report*. https://www.energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf.

Floating offshore wind energy development is anticipated to take place along the Pacific Coast, Gulf of Maine, Hawaii, and deeper water areas off the entire U.S. coastline. Furthermore, it is at an earlier technological and commercial stage, and more research, development, and demonstration (RD&D) is needed to lower costs to the point where the technology can be widely cost competitive across coastal regions. More work is also needed to expand coastal infrastructure for floating offshore wind, advance manufacturing practices, and build a domestic supply chain to pave the way for widespread deployment.[18] Because there have only been a small number of floating offshore wind energy projects deployed, more research is needed to characterize potential impacts of floating systems on the marine environment, and to design systems to maximize the potential for ocean co-use.

The Initiatives

This DOE offshore wind energy strategy proposes to advance offshore wind energy deployment through four major initiatives, each using DOE's broad portfolio of resources and capabilities to catalyze the technology's development in the near and long terms and establish the United States as a global leader in this space. These DOE initiatives (shown in Figure H-4) address the specific research and development (R&D), supply chain, and deployment needs associated with offshore wind technologies, transmission, and co-generation.

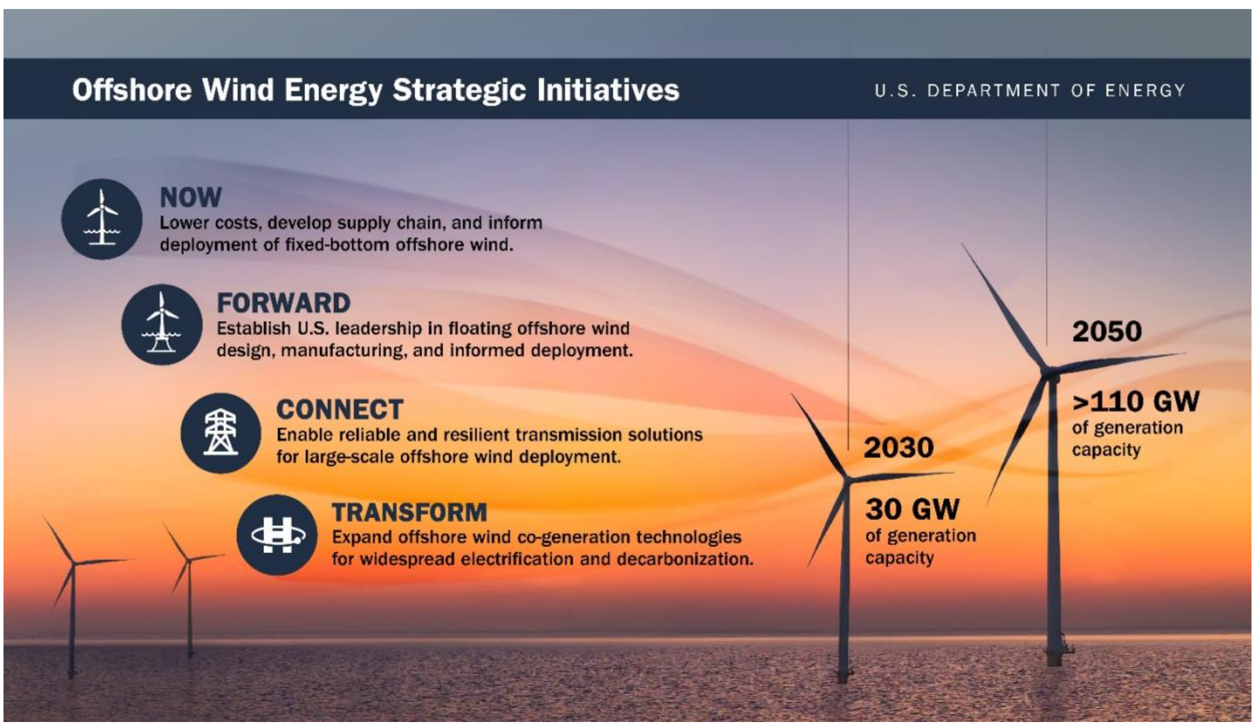


Figure H-4. Strategic initiatives for offshore wind energy to become a critical part of the nation's decarbonized energy sector and climate solution

[18] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States.* https://www.nrel.gov/docs/fy23osti/84710.pdf.

NOW

Near-term Offshore Wind

To meet the Biden administration's 30-GW-by-2030 goal and unlock a pathway to 110 GW by 2050, DOE is establishing the Near-term Offshore Wind (NOW) initiative. This initiative promotes the development of fixed-bottom offshore wind energy by lowering costs, spurring supply chain development, and informing expanded, sustainable, and just deployment. NOW features the following R&D efforts to:

- Reduce the cost of fixed-bottom offshore wind to $51/megawatt-hour (MWh) by 2030 from 2021 levels of $73/MWh[19] by:
    - Optimizing the design of wind turbines and wind plant layouts through enhanced understanding of the short- and long-term U.S. offshore wind resource and meteorological, ocean, and geophysical characteristics. This optimization would reduce costs through higher energy production, longer wind turbine system lifetimes, and lower development expenses and material use.
    - Upscaling of wind turbines through systems engineering and testing, validating, and demonstrating the many innovations that will enable larger, more powerful turbines (e.g., superconducting generators, active turbine controls) while exploring the need for, costs and benefits of, and pathways to standardizing turbine sizes.
    - Developing installation, operations, and maintenance strategies that reduce complexity and labor at sea while mitigating adverse impacts on the ocean environment (e.g., remote maintenance, noise mitigation measures during installation).
- Support the development of a robust domestic offshore wind supply chain to grow to more than 30 GW of fixed-bottom installations and operations by:
    - Publishing road maps of offshore wind supply chain needs, including ports, manufacturing, and Tier 2 (subassemblies) and Tier 3 (subcomponents) suppliers, informed by holistic analysis.
    - Convening and coordinating with stakeholders to advance effective and efficient supply chain planning and development.
    - Promoting the development and adoption of serial production practices in domestic manufacturing facilities through dedicated design studies and sector coordination efforts.
    - Supporting the development of construction, operations, and maintenance vessels by assessing needs and gaps, conducting R&D to advance and demonstrate clean-fuel vessels, and facilitating access to financing to fill critical vessel needs.
    - Facilitating the deployment of offshore wind power plants through federal financing.

[19] Stehly, T. and P. Duffy. 2022. *2021 Cost of Wind Energy Review*. https://www.nrel.gov/docs/fy23osti/84774.pdf.

    - Supporting the development of a diverse, equitable, and inclusive future offshore wind energy workforce by analyzing the timing and geography of future workforce needs and establishing a network to ensure coordinated development of programming and expanded training programs to fill key workforce gaps.
- Inform just, sustainable, and timely development of fixed-bottom offshore wind energy by:
    - Supporting community engagement and social science to understand impacts on communities and economies and work to ensure that underserved communities benefit from offshore wind energy development.
    - Supporting research to evaluate, avoid, minimize, and mitigate impacts on ocean co-uses, including fishing, tribal equities, and other federal missions. Engaging in R&D to improve the recyclability of wind turbine blades.
    - Developing technologies and practices to reduce radar system interference from offshore wind turbines.
    - Supporting research to understand and reduce environmental impacts of fixed-bottom offshore wind energy deployment in the United States, including developing monitoring and impact mitigation technologies that will help inform project design and operation as well as reduce environmental impacts on marine ecosystems and wildlife.
    - Collecting and analyzing data for informed decision-making about offshore wind energy lease area delineation for fixed-bottom facilities; through these activities DOE could support the Bureau of Ocean Energy Management's decision-making through analysis, resource and physical data collection activities, and techno-economic tools.

FORWARD

Floating Offshore Wind Advanced Research and Development

To unlock a pathway to 110 GW by 2050, U.S. offshore wind energy must extend into deeper waters, comprising about two-thirds of the nation's potential.[20] [21] In September 2022, the Biden administration announced a goal of deploying 15 GW of floating offshore wind capacity by 2035.[22] Floating offshore wind will enable the U.S. West Coast, Gulf of Maine, and deeper waters offshore all U.S. coasts to tap into this powerful resource. Because the floating offshore wind energy industry—and related technologies—are relatively new, the United States can assume a leadership role in commercializing these technologies on a large scale. The Floating Offshore Wind Advanced Research and Development (FORWARD) initiative establishes U.S. leadership in floating offshore wind design, manufacturing, and deployment by addressing the most urgent RD&D, supply chain, and siting needs. In recognition of its great potential and the critical need to address RD&D challenges,

[20] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.

[21] Using a water depth threshold of 60 m between fixed-bottom and floating offshore wind.

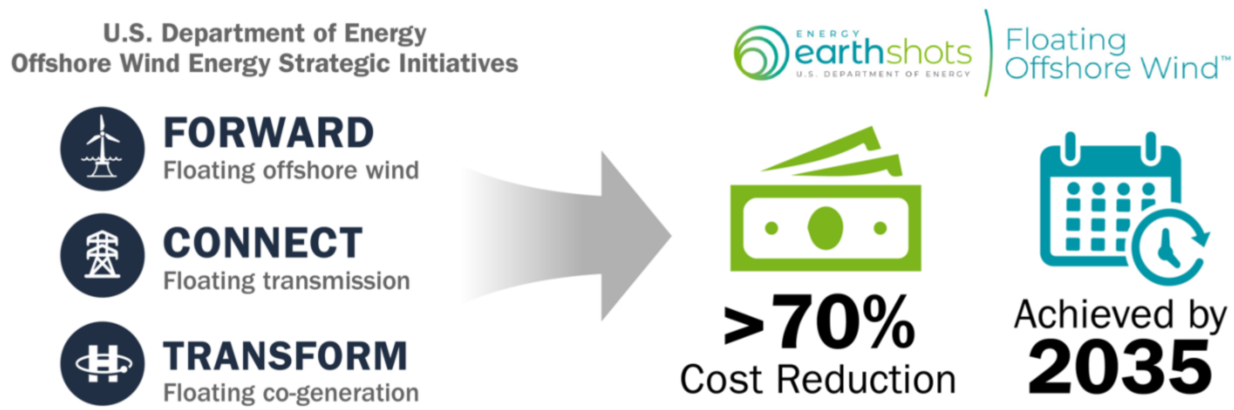
[22] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

DOE, the U.S. Department of the Interior, U.S. Department of Commerce, and U.S. Department of Transportation launched the Floating Offshore Wind Shot^{TM} (Box H-1) in September 2022.[23] This Energy Earthshot combines FORWARD with the floating activities from CONNECT and TRANSFORM for a holistic and impactful push to bringing floating offshore wind to U.S. waters (

Figure H-5). For instance, developing critical transmission technologies (CONNECT), such as dynamic cables for floating offshore wind applications, is part of the Floating Offshore Wind Shot.

Box H-1. Floating Offshore Wind Shot

In September 2022, the Floating Offshore Wind Shot was announced to drive U.S. leadership in floating offshore wind design, development, and manufacturing. This is an interagency effort led by DOE, the U.S. Department of the Interior, U.S. Department of Commerce, and U.S. Department of Transportation. Achieving the Energy Earthshot targets will help America tackle the remaining technical challenges to address the climate crisis and more quickly reach the Biden administration's goal of equitably reaching net-zero carbon emissions by 2050 while creating good-paying jobs and growing the economy.[24] The Floating Offshore Wind Shot includes an ambitious goal to reduce the cost of floating offshore wind energy by at least 70%, to $45/MWh by 2035 for deep sites far from shore.[25]



[23] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

[24] The White House. 2021. "FACT SHEET: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability." https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability.

[25] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

Figure H-5. Alignment of the DOE offshore wind energy strategy with the Floating Offshore Wind Shot

FORWARD, with support from DOE, aims to:

- Reduce the cost of floating offshore wind energy in deep waters to $45/MWh by 2035 from today's estimated $150/MWh[26] by:
    - Enabling use of increasingly more efficient and larger wind turbines through integrated turbine and floating platform system designs, components, and controls while evaluating and exploring pathways to increase wind turbine size and improve floating system design standardization.
    - Developing serial manufacturing practices in domestic manufacturing facilities.
    - Advancing systems engineering and controls co-design to reduce weight, increase efficiency, and reduce costs.
    - Supporting the development of new mooring, anchoring, dynamic cables, and floating substation concepts for deep-water deployment.
    - Developing operations and maintenance strategies and increasing wind turbine reliability to reduce periods of non-operation and reduce labor at sea through remote system health monitoring, inspection, and maintenance capabilities incorporating artificial intelligence and predictive maintenance.
- Support the development of a domestic supply chain to facilitate deployment of 15 GW or more by 2035 by:
    - Developing analyses and road maps of manufacturing, port, and supply chain investment needs along the West Coast, Gulf of Maine, and other U.S. regions
    - Convening stakeholders and collaborating with federal agencies, states, and the floating offshore wind energy industry to develop and execute plans to fill high-priority supply chain gaps in alignment with analyses and road maps.
    - Advancing serial manufacturing for a range of wind turbine components, with an initial emphasis on turbine platforms.
    - Tailoring design of floating systems, installation, and manufacturing practices to align with U.S. infrastructure and manufacturing capabilities.
    - Filling critical gaps in U.S. vessels, manufacturing facilities, and floating offshore wind plants through federal financing.
    - Identifying and supporting the workforce needed to install and operate floating offshore wind facilities while promoting workforce diversity, equity, inclusion, and accessibility.
- Inform just, sustainable, and timely development of floating offshore wind energy in deep waters by:

[26] This RD&D cost goal was formulated in the Floating Offshore Wind Shot for a deep-water site (1,000 m) and 125 kilometers from the point of interconnection.

- Leveraging lessons learned from fixed-bottom development to ensure underserved communities benefit from floating offshore wind development.
- Supporting community engagement in floating offshore wind development planning and conducting social science and socioeconomic research to understand the impacts of offshore wind energy on coastal communities and economies.
- Funding research to characterize, avoid, minimize, and mitigate potential environmental impacts and promote co-use of ocean space, including for fisheries, tribal equities, and other federal missions, with a focus on the unique impacts and geographies of floating offshore wind energy development.
- Developing technologies and practices to reduce radar interference from floating offshore wind turbines.
- Supporting research to inform the siting, development, and operations of floating offshore wind systems in deep-water habitats in coordination with federal and state agencies, with a near-term focus on the West Coast.

CONNECT

Transmission Solutions for Large-Scale Offshore Wind Energy Development

The coastal bulk transmission systems in most U.S. regions are currently not equipped to accommodate large amounts of new offshore wind energy and developing transmission offshore is complicated and largely uncharted territory for the United States. Developing transmission infrastructure introduces a wide range of technical, regulatory, social, and environmental issues falling under many jurisdictions at the federal, state, and regional levels. Collaborative, proactive, and long-term transmission planning and phased grid development is vital to the increased certainty and pace of offshore wind energy development. Transmission solutions must not only be cost-effective, but also reduce environmental and ocean co-use impacts. As a result, the CONNECT initiative aims to facilitate the development of and investment in transmission infrastructure solutions for large-scale offshore wind deployment and enhanced grid reliability and resilience through key partnerships, analysis, planning, R&D, and transmission infrastructure. The goals of CONNECT are to:

- Coordinate and inform planning for a transmission system that integrates offshore wind energy with the U.S. electricity grid by:
  - Convening and coordinating planning efforts for the design and construction of an offshore wind transmission network that serves individual projects and regional power markets and is integrated into the onshore transmission system.
  - Conducting analyses to inform regional transmission development, including analysis of future offshore wind transmission topologies, the benefits and costs of transmission options, identification of routing trade-offs, and spatial analysis to reduce use conflicts.
  - Providing technical assistance for regional planning entities and communities.
- Support technology innovation to increase offshore grid reliability, resilience, and interoperability by:

- Facilitating R&D on cybersecurity, control systems, and power electronics to reduce energy losses and increase the value of offshore wind to the power system.
- Developing or refining technologies to increase the performance, reliability, and interoperability of offshore wind transmission such as high-voltage direct current (HVDC) applications, improved electrical hardware for reliable operations in harsh ocean environments, dynamic power cables and floating substations, and interoperable controls, communications, and protection equipment.

- Support expansion of reliable and resilient grid infrastructure by:
  - Coordinating with federal and state agencies to identify the investment priorities for transmission manufacturing facilities to enable more than 110 GW of offshore wind capacity by 2050.
  - Supporting critical investments in transmission infrastructure through federal loan guarantees, grants, and other mechanisms as part of the Building a Better Grid Initiative.[27]

TRANSFORM

Expanded Offshore Wind Co-Generation

TRANSFORM aims to support the technical innovation of clean energy solutions needed to decarbonize all segments of the economy. The TRANSFORM initiative will advance offshore wind co-generation technologies, also known as wind-to-X technologies, which use offshore wind energy to produce another energy solution, such as hydrogen co-generation, in support of widespread electrification and a net-zero economy. Offshore wind energy can be a key enabler of this transition because it can be deployed at utility scale, mitigates the land-use requirements of other generation sources, and can be coupled (on land or offshore) with other clean energy technologies. TRANSFORM will fund technology R&D activities, establish demonstration projects to prove technical viability, and facilitate DOE loans that support investments into co-generation from offshore wind. Specifically, the goals of TRANSFORM are to:

- Promote storage and "wind-to-X" technologies from offshore wind energy by:
  - Advancing coupled wind-storage systems to enable their widespread adoption and address intermittency challenges associated with variable renewable energy generation; this effort includes techno-economic analysis of offshore storage to inform its economic deployment and R&D to advance coupled offshore wind-storage systems to extend their use cases and performance in different power markets.
  - Optimizing clean-fuel co-generation technologies to transition the transportation and agriculture industries to full decarbonization (e.g., clean hydrogen[28]); this includes

[27] DOE. Building a Better Grid Initiative. https://www.energy.gov/gdo/building-better-grid-initiative#:~:text=The%20Department%20of%20Energy's%20(DOE's,system%20to%20create%20a%20more.

[28] Efforts are coordinated with activities outlined in the "DOE National Clean Hydrogen Strategy and Roadmap," which responds to legislative language set forth in Section 40314 of the Bipartisan Infrastructure Law and was published in September 2022 as a draft for public comment. https://www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html

conducting techno-economic analysis of hydrogen and other clean fuels to inform economic deployment and hybridization strategies and R&D to advance safe hydrogen and other clean-fuel production technologies.

  - Supporting research and demonstration of wind co-generation, also known as wind-to-X technologies, including energy storage and clean-fuel production, and the establishment of offshore energy hubs as a center for operations, transmission, and storage facilities.

- Support the development of offshore wind energy hubs by:
  - Investigating the potential for offshore wind energy hubs to serve as important multisector tools in a net-zero economy; this includes analyzing techno-economic feasibility and regional needs for offshore wind hubs to evaluate trade-offs and coordinate planning.
  - Conducting R&D to lower the cost and increase the efficiency of hubs to incorporate wind energy with other technologies to optimize energy and space use and avoid, minimize, and mitigate any adverse environmental effects.
  - Establishing and coordinating offshore wind energy hubs to demonstrate their technical feasibility and support financing to facilitate offshore wind energy hub development.

DOE Contributing Offices

DOE seeks to build on the expertise, capabilities, and resources across a range of its offices to promote offshore wind energy (Figure H-6). This document identifies the many opportunities for DOE action, including the many offices that might engage in the focus areas of this strategy. These areas include R&D to lower costs; efforts to promote just, sustainable, and timely deployment; transmission research and coordination; stakeholder engagement; supply chain development; and many other key facets of offshore wind energy deployment. Each office contributes to one or more critical areas of need.

	NOW			FORWARD			CONNECT	TRANSFORM
	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Transmission Development	Co-Generation Applications
Advanced Materials and Manufacturing Technologies Office	●	●		●	●		●	●
ARPA-E	●			●			●	●
Grid Deployment Office							●	●
Hydrogen and Fuel Cell Technologies Office		●			●			●
Loan Programs Office	●	●	●	●	●	●	●	●
Office of Clean Energy Demonstrations	●			●			●	●
Office of Cybersecurity, Energy Security, and Emergency Response							●	
Office of Economic Impact and Diversity		●	●		●	●	●	●
Office of Electricity							●	●
Office of Manufacturing and Energy Supply Chains	●	●		●	●		●	●
Office of Science	●			●				
Vehicle Technologies Office		●			●			
Water Power Technologies Office	●	●	●		●	●	●	●
State and Community Energy Programs			●			●	●	●
Wind Energy Technologies Office	●	●	●	●	●	●	●	●

Figure H-6. Alignment of DOE office expertise and potential engagement with strategic initiatives

Note: ARPA-E = Advanced Research Projects Agency – Energy

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U.S. Department of Energy Strategic Contributions Toward 30 Gigawatts and Beyond

Authors

The authors of this report are:

Jocelyn Brown-Saracino, U.S. Department of Energy (DOE)

Philipp Beiter, National Renewable Energy Laboratory (NREL)

Helena Pound, DOE

Nathan McKenzie, DOE

Jian Fu, DOE

Gary Norton, DOE

Genevra Harker-Klimes, DOE

Naomi Lewandowski, DOE

Katherine Ball, DOE

Cynthia Bothwell, DOE

Joy Page, DOE

Patrick Gilman, DOE.

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List of Acronyms

ARPA-E	Advanced Research Projects Agency – Energy
AMMTO	Advanced Materials and Manufacturing Technologies Office
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CESER	Office of Cybersecurity, Energy Security, and Emergency Response
DHS	U.S. Department of Homeland Security
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
ED	Office of Economic Impact and Diversity
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FORWARD	Floating Offshore Wind Advanced Research and Development
FWS	U.S. Fish and Wildlife Service
GDO	Grid Deployment Office
GW	gigawatt
HVDC	high-voltage direct current
HFTO	Hydrogen and Fuel Cell Technologies Office
ISO	independent system operator
km	kilometer
LCOE	levelized cost of energy

LPO	Loan Programs Office
m	meter
MARAD	U.S. Maritime Administration
metocean	meteorological ocean
MW	megawatt
MWh	megawatt-hour
NOAA	National Oceanic and Atmospheric Administration
NOW	Near-term Offshore Wind
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
OCED	Office of Clean Energy Demonstrations
OE	Office of Electricity
R&D	research and development
RD&D	research, development, and demonstration
RDD&D	research, development, demonstration, and deployment
RTO	regional transmission operator
SC	Office of Science
SCEP	State and Community Energy Programs
VTO	Vehicle Technologies Office
WETO	Wind Energy Technologies Office
WPTO	Water Power Technologies Office

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1 An All-of-DOE Strategy for Unlocking the Potential of Offshore Wind Energy in the United States

Offshore wind is a growing source of reliable and clean energy around the world, with over 50 gigawatts (GW) installed across more than 250 global projects.[29] Building on decades of wind energy research, demonstration, and development (RD&D) sponsored by the U.S. Department of Energy (DOE) and its partners, this technology now has the potential to become a critical enabler of economywide decarbonization in the United States. DOE aims to bring its full suite of resources to bear to advance offshore wind energy's potential contributions to decarbonization and economic development.

Today's offshore wind systems are among the largest rotating structures ever built (Figure 1). Wind turbines are mounted onto substructures that are fixed to the seabed by piles, or—in deeper waters—are mounted on buoyant substructures and connected to the seabed using mooring lines and anchors. Offshore wind holds the promise of reliably serving the energy and fuel needs of coastal load centers, revitalizing related manufacturing and port industries, and mitigating the land use of onshore generation resources. The possible scale of offshore wind energy's deployment and its access to the nation's highest and most reliable wind speeds makes this generation source a highly critical infrastructure investment. With a technical resource potential exceeding 4,200 GW in water depths up to 1,300 meters (m), offshore wind could theoretically meet today's U.S. electricity demands by more than three times.[30] [31] A single offshore wind plant can deliver gigawatts of energy to coastal load areas, which tend to suffer from transmission congestion and limited space to site utility-scale land-based renewable energy generation.

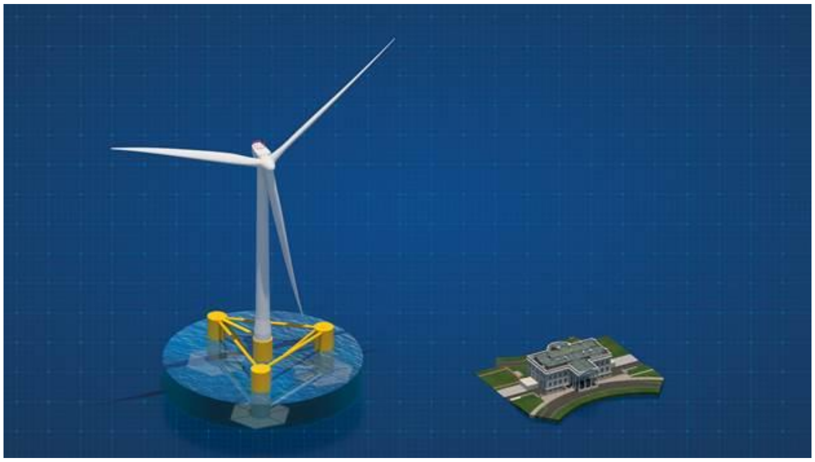

Figure 1. The size of a 15-megawatt floating offshore wind turbine system compared to the White House.
Illustration by Besiki Kazaishvili, National Renewable Energy Laboratory (NREL)

[29] All offshore wind energy market data are as of May 2022, unless indicated otherwise. Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.
[30] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.
[31] U.S. Energy Information Administration. 2022. *Annual Energy Outlook 2022.* https://www.eia.gov/outlooks/aeo/narrative/pdf/AEO2022_Narrative.pdf

As part of DOE's critical role in enabling the nation to usher in the energy system of the future, this document presents a departmentwide offshore wind strategy for DOE's contribution to accelerating offshore wind energy development in the United States and unlocking its climate and economic benefits. This strategy represents DOE's role as a part of the Biden administration's all-of-government approach to advancing offshore wind energy. Furthermore, it focuses on achieving the Biden administration's goals of deploying 30 GW of offshore wind by 2030,[32] 15 GW of floating offshore wind by 2035,[33] and establishing a path to 110 GW or more of offshore wind by 2050,[34] all in support of the administration's broader goal of an economy with net-zero carbon emissions by 2050.[35]

This strategy articulates a coordinated set of strategic initiatives that leverage DOE capabilities, resources, and tools, including research, development, demonstration, and deployment (RDD&D); technical assistance; analysis and modeling; stakeholder engagement; and public financing. Through the coordinated and focused approach outlined in this document, DOE intends to lower the cost of energy, inform just and sustainable development, build a domestic supply chain, and ensure reliable and resilient transmission for both floating and fixed-bottom offshore wind energy technologies. Meeting these goals requires a thoughtful, organized approach and coordination and partnership with a diverse range of public and private entities.

This strategy builds on DOE's 2022 *Offshore Wind Energy Strategies*[36] report, which outlines regional and national strategies to accelerate and maximize the effectiveness, reliability, and sustainability of U.S. offshore wind energy deployment and operation. While the 2022 report outlined at a national level what it might take to reach 30 GW of U.S. offshore wind energy by 2030, this DOE offshore wind energy strategy delves into DOE's role and specific initiatives needed to meet this goal. This strategy was developed with input from a variety of stakeholders including offices from across DOE, other federal agencies, DOE national laboratories, state representatives, industry, nongovernmental organizations, sector stakeholders, and others.

[32] 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.

[33] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

[34] 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.

[35] 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." 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/.

[36] U.S. Department of Energy (DOE). 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

2 U.S. Offshore Wind Energy Today

In March 2021, DOE, the U.S. Department of the Interior (DOI), and U.S. Department of Commerce (DOC) announced a national goal to deploy 30 GW of offshore wind capacity by 2030 and establish a pathway to 110 GW by 2050.[37] In September 2022, the U.S. Department of the Interior further built on the existing deployment goals by announcing the goal to deploy 15 GW of floating offshore wind by 2035.[38] These goals were established in support of reaching net-zero emissions economywide by no later than 2050.[39] These planning and deployment activities have been supported by years of offshore wind energy RD&D by DOE and its federal partners, in combination with state-level offshore wind procurement policies. DOI's Bureau of Ocean Energy Management (BOEM) is responsible for all leasing and permitting on the Outer Continental Shelf (OCS), where most offshore wind energy deployment will occur, and their regulatory process is supported by other federal resource and research agencies.[40] As of May 2022, the offshore wind pipeline in 10 states reached 40,083 megawatts (MW) in capacity and U.S. states have already set policies that aim to procure 39 GW by 2040.[41] Some coastal states plan for 50% or more of their electricity to come from offshore wind in the coming decades.

Federal and state goals provide planning certainty for offshore wind energy investors and communities. Detailed strategies can help identify the most feasible pathways and investments, coordinate among government entities and stakeholder groups, and establish accountability toward reaching these goals. Through this strategy, DOE lays out its role in contributing to meeting the nation's offshore wind deployment targets and advancing the sustainable and just development of offshore wind.

As of November 2021, the first commercial-scale projects are under construction and offshore wind energy is taking hold in many U.S. coastal areas.

The U.S. offshore wind energy sector is at a critical phase in its development. As of May 2022, two smaller-scale projects (42 MW) are in operation, with more than 930 MW under construction along the Atlantic Coast.[42] Altogether, the total pipeline capacity exceeds 40 GW

[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] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

[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." 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] U.S. Department of Interior, Bureau of Ocean Energy Management, https://www.boem.gov/

[41] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.

[42] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.

with projects at varying stages of development.[43] Further, recent passage of Inflation Reduction Act,[44] with tax credits for clean energy and manufacturing, has the potential to support both offshore wind market growth, as well as the development of a domestic supply chain.[45]

In October 2021, BOEM announced its *Offshore Wind Leasing Path Forward 2021-2025*,[46] indicating plans to hold up to seven new offshore wind lease auctions including the New York Bight, Carolina Long Bay, central Atlantic, Gulf of Maine, northern and central California, Oregon, and the Gulf of Mexico by 2025.

The nation's oceans are a unique habitat for diverse species and used for a multitude of human activities, ranging from energy extraction, fishing, and military training and operations to shipping, recreational use, and more. To ensure shared and sustainable use of this important resource, we need to obtain a clearer understanding of the co-use needs associated with offshore wind energy development.

Technology solutions have arisen for a diverse U.S. coastline

Offshore wind systems can be distinguished into fixed-bottom and floating (Figure 2). Deploying offshore wind energy across all major U.S. coastal areas requires using both types of substructures because of varying water depths (Figure 3). Fixed-bottom substructures are attached to the seabed by piles or suction buckets and are typically deployed in water depths of 60 m or less. Furthermore, they have a successful track record spanning several decades around the world. Floating substructures are buoyant and connected to the seabed using mooring lines and anchors. This substructure type tends to be deployed in water depths exceeding 60 m.[47] The first multiturbine floating offshore wind demonstration project was deployed in 2017 in Scotland, and floating offshore wind is expected to transition to commercial-scale deployment in the United States by the mid-to-late 2020s.[48] In the United States, the Atlantic Coast and Gulf of Mexico both tend to have shallower water depths that are suitable for fixed-bottom offshore wind. The Pacific Coast, Hawaii, Great Lakes, and far-from-shore areas across all U.S. coastlines have water depths that exceed 60 m, which makes floating substructures the preferred choice.

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[43] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.

[44] Inflation Reduction Act of 2022. H.R.5376. 117th Congress. 2022. https://www.congress.gov/bill/117th-congress/house-bill/5376/text.

[45] The White House, "Building A Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action," January 2023, https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

[46] Bureau of Ocean Energy Management (BOEM). 2021. "Offshore Wind Leasing Path Forward 2021-2025." https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/OSW-Proposed-Leasing-Schedule.pdf.

[47] This water depth is not a hard limit and substructure type might depend on economic feasibility and siting considerations.

[48] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.

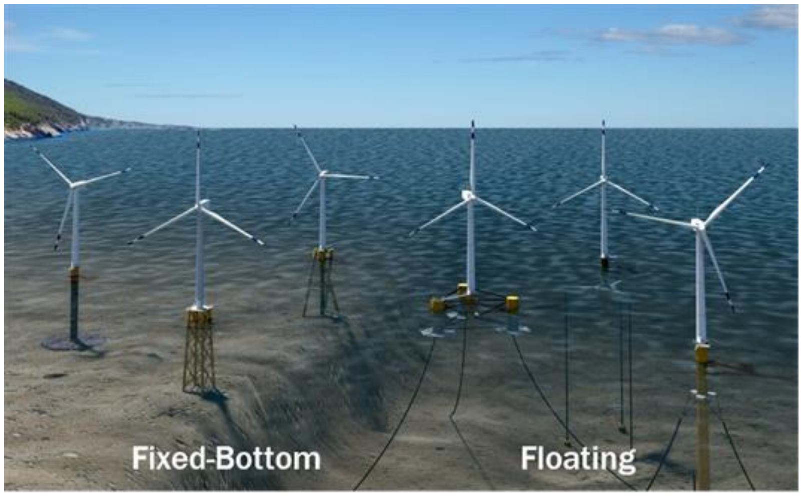

Figure 2. Fixed-bottom and floating offshore wind substructure types. ***Illustration by Josh Bauer, NREL***

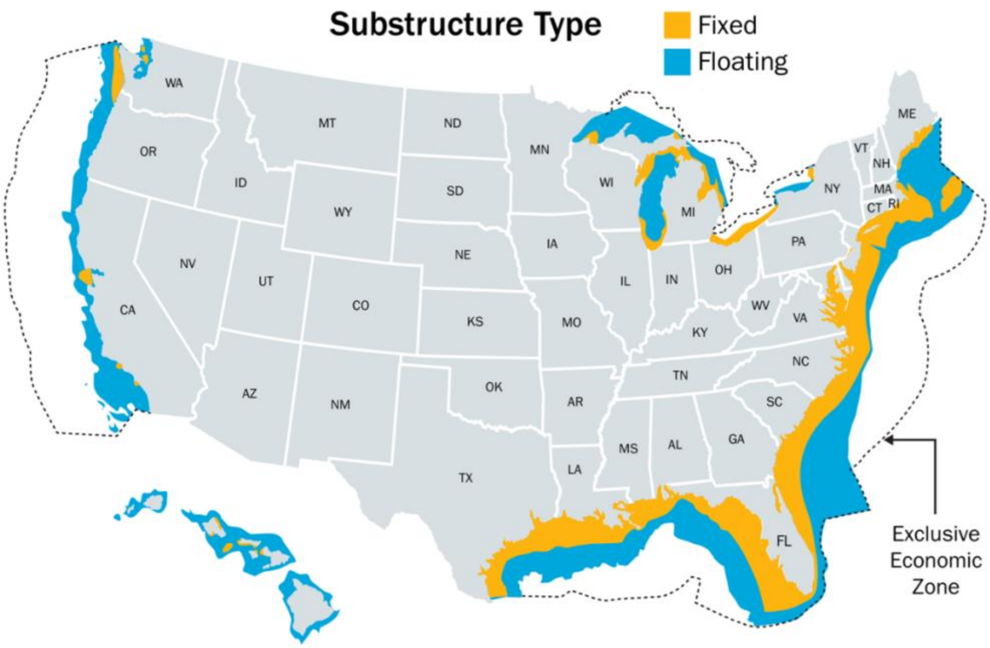

Figure 3. Offshore wind substructure type by water depth (60 m).[49] ***Image from NREL***[50]

Continued innovation, testing, and validation are needed to extend the deployment of offshore wind energy to all U.S. coasts, advance the required transmission build-out, provide affordable energy to consumers, and prepare this generation source to serve the energy and siting needs that will arise in the future.

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[49] Fixed-bottom substructures tend to be deployed in water depths shallower than 60 m. This is not a hard limit and depends on siting considerations and economic feasibility.

[50] Adapted from: Musial, W., P. Beiter, P. Schwabe, T. Tian, T. Stehly, et al. 2017. "2016 Offshore Wind Technologies Market Report." https://www.energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf.

3 Time To Act: The Offshore Wind Energy Opportunity

The Biden administration and many states along U.S. coastlines have recognized the potential that offshore wind holds for the nation's energy future. With a vast resource, offshore wind can power many coastal load centers, with manufacturing, siting, and environmental benefits extending to the entire nation.

A vast resource to power the nation

The winds atop U.S. waters are one of the largest untapped energy sources in the country. A total resource potential of 4.2 terawatts has been estimated offshore the United States,[51] which is more than three times the total electricity-generating capacity operating in the country in 2021 (Figure 4).[52] Reaching the 30-GW-by-2030 goal would generate enough electricity to power over 10 million American homes. Offshore wind energy offers states and regions a means to meet their decarbonization goals with utility-scale projects often exceeding 1 GW in capacity for a single project. Attaining the 30-GW-by-2030 deployment goal could set the country on a path toward deploying at least 110 GW of offshore wind capacity by 2050,[53] including 15 GW of floating offshore wind by 2035. These levels of deployment would supply nearly 6% of the nation's electricity from offshore wind by 2050.[54]

[51] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.
[52] U.S. Energy Information Administration. 2022. *Annual Energy Outlook 2022.* https://www.eia.gov/outlooks/aeo/narrative/pdf/AEO2022_Narrative.pdf.
[53] 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.
[54] Lantz, E., G. Barter, P. Gilman, D. Keyser, T. Mai, et al. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030.* https://www.nrel.gov/docs/fy21osti/80031.pdf.

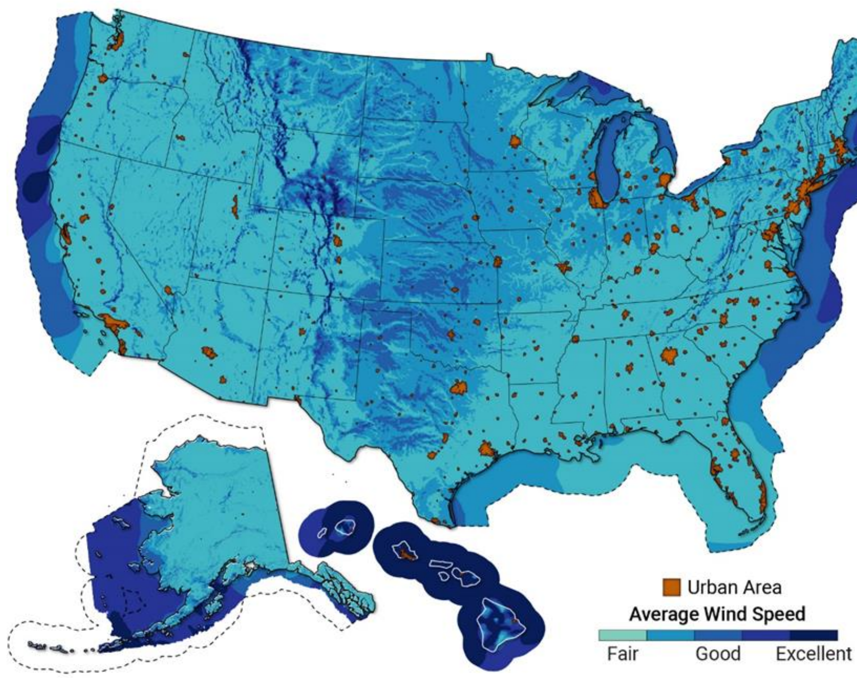

Figure 4. The Offshore wind resource is in proximity to major urban areas. *Figure from NREL*

Revitalized manufacturing and tens of thousands of well-paid and lasting jobs

Component manufacturing, installation, and operation of offshore wind energy is labor-intensive and has the potential to create nearly 135,000 diverse jobs by 2050 that would pay at or above the national average and sustain more than $12 billion a year in offshore wind project capital investments, with a projected aggregate project investment through 2030 of $97 billion.[55] Project development at this scale would spur additional investments of more than $22 billion for supply chain development, port revitalization, vessel construction, transmission component manufacturing, wind power plant operations, and onshore assembly facilities (Figure 5).[56] To install and operate 30 GW of offshore wind energy, more than 2,100 wind turbines, 34 new manufacturing facilities of each $200-400 million in investment volume, over 11,000 kilometers (km) of transmission and array cables, 5 wind turbine installation vessels (WTIVs), 10 feeder barges, 58 crew transfer vessels, and 4 cable-lay vessels are needed.[57]

[55] Lantz, E., G. Barter, P. Gilman, D. Keyser, T. Mai, et al. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030.* https://www.nrel.gov/docs/fy21osti/80031.pdf.
[56] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.
[57] Shields, M., R. Marsh, J. Stefek, F. Oteri, R. Gould, et al. 2022. *The Demand for a Domestic Offshore Wind Energy Supply Chain*. https://www.nrel.gov/docs/fy22osti/81602.pdf.
Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.

Figure 5. Investments in manufacturing facilities needed to establish a supply chain by 2030[58]

By establishing the United States as a major leader in the global offshore wind energy industry, the country could not only serve domestic demand, but create export opportunities to support a global offshore wind and transmission pipeline. Around the world, more than 368 GW of capacity is in various project development stages, translating to a project capital investment volume exceeding $1 trillion.[59] [60]

[58] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.
[59] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022. *Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.
[60] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.

The Inflation Reduction Act adds new tools to incentivize offshore wind project and supply chain development

The Inflation Reduction Act, which passed in August of 2022,[61] extends and expands tax credits for clean energy and manufacturing. These tax credits have the potential to support offshore wind market growth, as well as the development of a domestic supply chain[62] and may help address challenges some projects are currently facing associated with rising costs. Additionally, new funds made available through the Bipartisan Infrastructure Law and Inflation Reduction Act may help address needs associated with transmission development, port infrastructure, and supply chain development.[63] [64]

A vital part of the future energy system

Offshore wind can generate large amounts of reliable power because wind speeds tend to be higher, more consistent, and less turbulent over water than land. 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 suffer from transmission constraints or limited land available for new utility-scale wind or solar power plants. For these and other reasons, offshore wind can be a key contributor in many U.S. energy markets to achieving a zero-carbon electricity grid by 2035 and a net-zero emissions economy by 2050.[65] Offshore wind has the potential of reducing wholesale prices by more than $25/megawatt-hour (MWh) on average through "merit order effects" that result from displacing natural gas generation.[66] Offshore wind's role could extend beyond the power sector by producing hydrogen and other fuels for the decarbonization of the industrial, agricultural, transportation, and maritime sectors.

[61] Inflation Reduction Act of 2022. H.R.5376. 117th Congress. 2022. https://www.congress.gov/bill/117th-congress/house-bill/5376/text.

[62] The White House, "Building A Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action," January 2023, https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

[63] The White House, "Building A Better America: A Guidebook to the Bipartisan Infrastructure Law for State, Local, Tribal, and Territorial Governments, and Other Partners," May 2022, https://www.whitehouse.gov/wp-content/uploads/2022/05/BUILDING-A-BETTER-AMERICA-V2.pdf

[64] The White House, "Building A Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action," January 2023, https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

[65] Lantz, E., G. Barter, P. Gilman, D. Keyser, T. Mai, et al. 2021. *Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030*. https://www.nrel.gov/docs/fy21osti/80031.pdf.

[66] Mills, A., D. Millstein, S. Jeong, L. Lavin, R. Wiser, M. Bolinger. *Estimating the Value of Offshore Wind Along the United States' Eastern Coast*. https://eta-publications.lbl.gov/sites/default/files/osw_value_es_final.pdf.

Offshore wind siting complements land-based generation sources

As a reliable and increasingly affordable renewable energy source, offshore wind provides energy to coastal population centers where there is often a scarcity of sites for other large-scale renewable energy development. Approximately 70% of current U.S. electricity demand is in coastal states with limited transmission connectivity to areas of land-based wind and solar generation in the center of the country.[67] As the nation transitions toward full decarbonization of its economy, the siting of renewables on land will become more challenging and the resource characteristics less favorable. Utility-scale electric-generating projects can be built offshore, adjacent to populated load centers and in coordination with other ocean activities.

Offshore wind has a unique opportunity to redefine justice in energy development

Offshore wind energy is a new sector in the United States that offers a unique opportunity to redefine the terms of how utility-scale electricity generation can benefit all parts of society. Much of offshore wind energy development takes place along coastlines with disadvantaged communities in their broader vicinity. As a result, offshore wind energy can benefit those communities through diverse, lasting, and meaningful employment opportunities for generations to come. Revitalized port areas generate tax revenue and support service industries in adjacent regions. To realize these benefits, targeted outreach, opportunities to participate in decision-making, and educational programs are needed. More broadly, offshore wind offers states along U.S. coasts a pathway toward a net-zero economy with procurement and transmission development in their own hands. A local supply of energy can offer a fairer share of the many benefits of energy development.

Environmental benefits

Offshore wind provides carbon-free energy, helping offset water consumption and air pollution that would otherwise be caused by conventional power generation sources. Air quality benefits from reduced sulfur dioxide, nitrogen oxides, fine particulate matter, and carbon dioxide can be expressed in monetary terms. Depending on the location of an offshore wind project these benefits from reduced emissions range from $26/MWh to more than $100/MWh.[68] As such, offshore wind mitigates climate change and its impacts on wildlife and ecosystems. These environmental benefits are realized by the entire nation.

[67] Shields, M., J. Stefek, F. Oteri, M. Kreider, E. Gill, et al. 2023. *A Supply Chain Road Map for Offshore Wind Energy in the United States*. https://www.nrel.gov/docs/fy23osti/84710.pdf.
[68] Mills, A., D. Millstein, S. Jeong, L. Lavin, R. Wiser, M. Bolinger. *Estimating the Value of Offshore Wind Along the United States' Eastern Coast*. https://eta-publications.lbl.gov/sites/default/files/osw_value_es_final.pdf.

4 An Offshore Wind Energy Vision for the Nation

In recognition of offshore wind energy's vast resource and economic potential, DOE and its partner agencies share the following common vision (Figure 6):

> A future in which offshore wind is a critical part of the nation's decarbonized economy and climate solution. A future in which offshore wind development is economic, reliable, sustainable, just, and timely.

This vision imagines a future in which:

- The United States plays a global leadership role in fixed-bottom and floating offshore wind development.
- Offshore wind energy is a key enabler to decarbonizing the electric system and the economy and revitalizing coastal economies.
- And offshore wind serves energy consumers, coastal communities, the workforce, and environment alike.

Figure 6. U.S. offshore wind vision

Offshore Wind Energy Development Challenges the Nation Must Address

To unlock the promise that offshore wind energy holds for the nation and achieve the offshore wind vision, challenges need to be addressed. Building off the *Offshore Wind Energy Strategies* report, developed in partnership with key agencies with critical roles in offshore wind, including DOI and DOC, DOE describes key challenges for U.S. offshore wind and the role that it and other parties can play in addressing them (Figure 7).

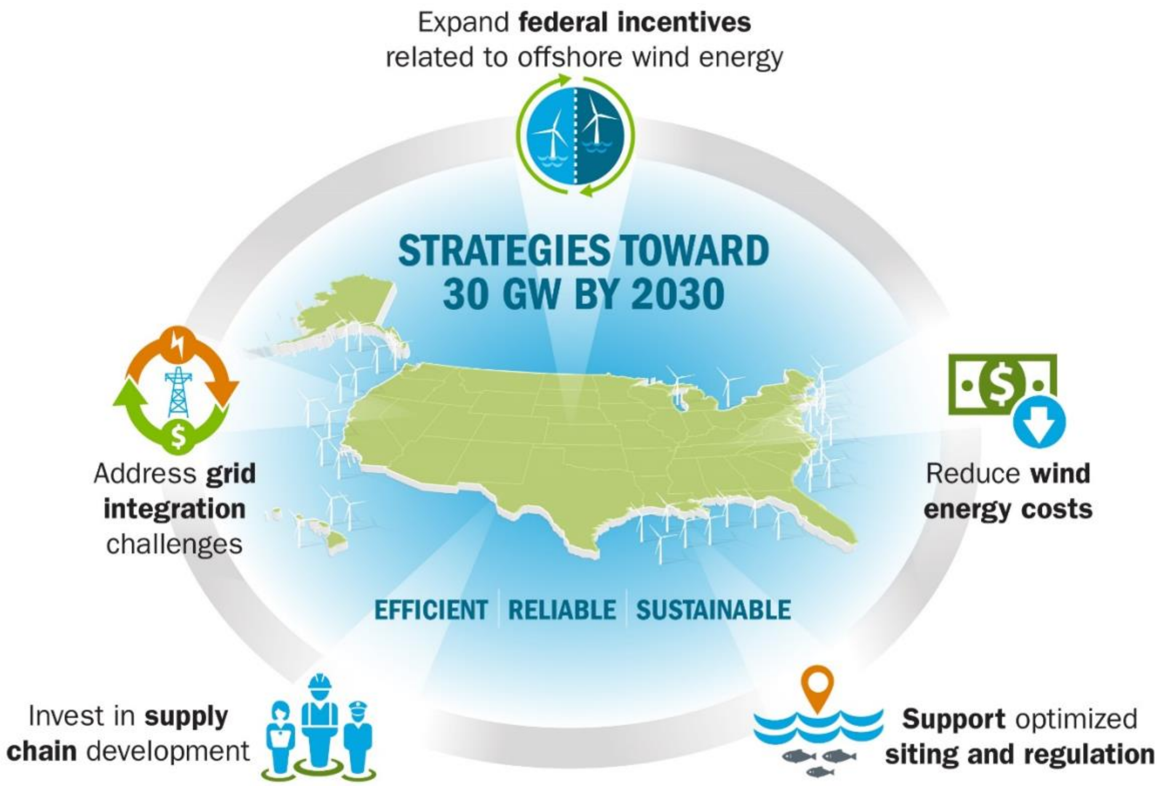

Figure 7. Key needs to achieving 30 GW by 2030 and more than 110 GW by 2050. ***Figure modified from "Offshore Wind Energy Strategies"*** [69]

Need Area #1: Reducing offshore wind energy costs

The cost of energy from offshore wind energy generation tends to be above that of many alternative electricity-generation technologies for several reasons: relatively nascent technology, the challenges of the marine environment, the cost of bringing power to shore via long submarine cables, and less-established supply chains. Because of lower commercial maturity and fewer global deployments to date, offshore wind projects using floating substructures are currently more expensive than fixed-bottom substructures. Additionally, at the time of publication offshore wind projects are facing challenges associated with rising costs due to inflation and rising cost of capital.

[69] DOE. 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

Table 1. Reducing Offshore Wind Energy Costs

Motivation	Further reductions in fixed-bottom and floating technologies costs could enable greater utility-scale energy production from offshore wind across all major U.S. coastal regions, offering an economically viable solution to help power the transition to a net-zero carbon economy.
DOE's Role	Reducing the cost of energy of fixed-bottom and floating offshore wind through technology advancements is at the core of DOE's mission and fostered through targeted research, development, and demonstration (RD&D). Innovative technology solutions tailored to unique U.S. design conditions and new means of manufacturing, installing, and decommissioning offshore wind can lead to cost reductions. For many of these RD&D activities, DOE will assume a leadership role in supporting the research proposed in this strategy. Further, there is a virtuous relationship between deployment and cost reductions and DOE action that help facilitate offshore wind deployment will also help reduce cost.
Other Actors	Industry, academic institutions, National Science Foundation (NSF), BOEM, Bureau of Safety and Environmental Enforcement (BSEE)

Need Area #2: Support optimized siting and regulation

The number of lease areas will need to grow significantly over the next decade to meet state and federal deployment goals and the leasing and permitting process will need to be predictable, transparent, and timely. This growth will need to occur in a manner that promotes ocean co-use, is environmentally sustainable, benefits underserved communities, and is environmentally just. There is a need to support tool development and research to characterize and, where necessary, minimize and mitigate impact on the natural environment and on ocean co-users, and provide communities with tools and research insights that will maximize their benefits from offshore wind energy development.

Table 2. Support Optimized Siting and Regulation

Motivation	Responsible siting and project permitting can enable steady growth of a thriving industry and economically benefit coastal communities while ensuring environmental protection.
DOE's Role	Inform just and sustainable siting and operation of wind plants through research and technology development to understand, avoid, minimize, and mitigate impacts on wildlife, fisheries, and other ocean co-uses; research to characterize and minimize impacts to radar systems; social science; and community engagement; these efforts support the decision-making of the Bureau of Ocean Energy Management (BOEM) and agencies involved in offshore wind energy permitting and help communities engage in planning processes.
Other Actors	BOEM, National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), U.S. Department of Defense (DOD), Federal Aviation Administration (FAA), U.S. Department of Homeland Security (DHS), nongovernmental organizations, academic institutions, fisheries, tribes, community organizations

Need Area #3: Investing in supply chain development

Supply chain development for the nation's first commercial-scale offshore wind projects is underway but must be greatly accelerated to meet targets. Meeting offshore wind deployment goals will require port and vessel construction and upgrades, manufacturing research and development (R&D), infrastructure investments, and workforce development—all tailored for U.S. conditions.

Table 3. Supply Chain Development

Motivation	Strategic supply chain expansion can ensure that the Biden administration's goals are met, domestic manufacturing facilities and the workforce are utilized, and products are tailored to local needs and standards. Investing sufficiently in manufacturing, ports, vessels, and a diverse U.S. workforce will reduce transport costs, increase the pace at which projects are able to deploy, and could contribute to energy justice objectives.
DOE's Role	Conduct and disseminate analyses and promote coordination among manufacturers, project developers, and state, federal, and local governments on meeting supply chain and workforce needs and making targeted domestic investments; perform R&D to improve manufacturing processes and infrastructure and tailor both to U.S. conditions; support federal financing for supply chain infrastructure.
Other Actors	BOEM, U.S. Department of Commerce (DOC), NSF, U.S. Department of Labor (DOL), U.S. Department of Transportation, states, industry, unions, tribes, community organizations

Need Area #4: Addressing grid integration challenges of offshore wind

The U.S. transmission system requires significant investment and reinforcement to meet the growing demands of a decarbonized economy and increasingly extreme weather events. This is especially true along many parts of the nation's coast where the transmission infrastructure is insufficient to accommodate gigawatts of offshore wind energy at the scale envisioned by the Biden administration of enabling 110 GW or more by 2050. RD&D is needed to increase reliability and resilience, enable long-distance transmission, and develop the dynamic cable and offshore substation technologies for floating offshore wind energy in deeper waters. Integrated, interregional planning supported by system analysis and federal financial support can help ensure transmission infrastructure sufficient to meet U.S. deployment goals.

Table 4. Offshore Wind Grid Integration

Motivation	Cost-effective, reliable, and resilient grid integration is necessary to enable large-scale incorporation of offshore wind energy into the nation's power grid and future energy mix without long delays or lost opportunities and ensure that the Biden administration's offshore wind deployment goals are met on time.
DOE's Role	Conducting long-term transmission analyses, providing support for technology innovation and cost reductions, analyzing the domestic supply chain for transmission components, encouraging infrastructure investments, and providing financial support for deployment; also supporting R&D to increase offshore wind grid reliability and resilience and enable long-distance transmission and transmission through cables in deeper waters.
Other Actors	BOEM, Federal Energy Regulatory Commission (FERC), NOAA, tribes, states, independent system operators (ISOs)/regional transmission operators (RTOs), utilities, public utility commissions, and coastal communities

Need Area #5: Expand federal incentives related to offshore wind energy

The 2022 *Offshore Wind Strategies Report*[70] addressed many of the offshore-wind-policy-related needs that could bolster market demand. However, as this document describes DOE-specific capabilities, it does not focus on establishing or expanding federal incentives. DOE provides a supportive role by performing various analyses that can help inform the need for and impacts of federal offshore wind energy incentives.

Table 5. Expanding Federal Incentives Related to Offshore Wind Energy

Motivation	Federal incentives related to offshore wind energy may reduce the risk of offshore wind deployment and manufacturing and accelerate timelines. Federal incentives will also encourage economic development, create jobs, provide economic benefits for communities, advance technology, reduce costs, and accelerate deployment. Such near-term advancements will help the offshore wind energy industry scale up at the pace needed to contribute sufficiently to deployment and decarbonization goals.
DOE's Role	Support research and analyses to inform regulatory agencies and decision makers on the need for and impacts of federal incentives.
Other Actors	Congress

The five challenges discussed earlier apply to both fixed-bottom and floating offshore wind technologies, but the pathway to address these challenges differs. Fixed-bottom offshore wind energy has been deployed around the world at the gigawatt scale and tends to be less expensive than floating technologies. Cost reductions for fixed-bottom offshore wind stem from economies of scale, optimization of wind turbines and wind plants through an improved understanding of meteorological ocean (metocean) dynamics, and research to tailor wind turbine system designs to U.S. conditions (such as infrastructure, manufacturing, hurricanes, and soil conditions). A rapid and coordinated expansion of a domestic supply chain and port and transmission infrastructure are needed to meet the administration's deployment targets in time. Floating offshore wind energy is at an earlier technological and commercial stage. While many fixed-bottom cost reduction pathways also apply to floating technologies, more fundamental RD&D is needed to develop the technology solutions to access the deep waters offshore the nation's coasts at a reasonable cost, ensure reliable operations, and deploy innovative manufacturing and port solutions.

[70] DOE. 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

5 DOE Offshore Wind Energy Strategy Activities

Goal

In recognition of the role DOE provides for the nation to usher in the energy system of the future, this document outlines a departmentwide offshore wind strategy. This strategy aims to support transformative initiatives that accelerate wind energy development in the United States and unlock its climate and economic benefits, as part of a broader all-of-government approach to advancing the domestic offshore wind industry. This strategy outlines an all-of-DOE strategic approach to achieve the Biden administration's goals of deploying 30 GW of offshore wind energy by 2030, 15 GW of floating offshore wind energy by 2035, and putting the country on a path to 110 GW or more of offshore wind energy by 2050.

Impacts

In partnership with its federal agency partners, DOE is well-positioned to support the nation on its course toward making this vision a reality by:

- Advancing offshore wind energy technology, driving down costs, and tailoring designs to U.S. conditions.
- Developing transformative manufacturing techniques that utilize U.S. capabilities.
- Informing and supporting the development of a robust domestic supply chain, including the development of a ready and robust domestic workforce.
- Informing the expanded, just, and sustainable development of offshore wind energy.
- Ushering in new transmission technology and infrastructure to allow for large-scale offshore wind grid penetration that enhances grid reliability and resilience.
- Ensuring that offshore wind energy can play a key role in economywide decarbonization.

Partners

A large number of federal agencies have a role to play in developing offshore wind energy. DOE's efforts will complement and, in many cases, support the work of fellow federal agencies, including BOEM, which has authority to lease offshore wind areas on the Outer Continental Shelf. In execution of this strategy, DOE will work with other federal agencies on areas of RDD&D; technical assistance; and stakeholder engagement, as shown in Table 6.

Table 6. Key Relevant Federal Roles and Expertise

Activity Area	Key Agencies
Physical and Environmental Research	BOEM, NOAA, FWS, NSF
Technology Development	BOEM, NOAA, BSEE
Supply Chain/Manufacturing	BOEM, U.S. Maritime Administration (MARAD), DOC, Army Corps of Engineers
Transmission	BOEM, FERC, NOAA
Community Engagement and Co-Use	BOEM, NOAA, DOD, DHS, FAA, FWS

In addition to interagency collaborations, DOE recognizes the critical roles that states, developers, manufacturers, ocean co-users, environmental groups, nongovernmental organizations, tribes and tribal nations, unions, public utility commissions, RTOs/ISOs, and the general public have to play in the deployment of offshore wind energy. Each stakeholder group has unique perspectives and experiences that can benefit deployment in a variety of ways. The rapid pace needed for clean energy deployment requires an inclusive approach that includes participation and partnership among all relevant stakeholders, not just federal agencies. The strategy presented here includes extensive stakeholder engagement and gatherings to ensure that the valuable knowledge of these groups is incorporated into DOE's approach to offshore wind energy deployment.

DOE Offices

This strategy articulates a coordinated approach for advancing offshore wind energy across the range of DOE offices with relevant capabilities and expertise, as articulated in Figure 8. A full description of the roles of each office can be found in Appendix B.

	NOW			FORWARD			CONNECT	TRANSFORM
	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Transmission Development	Co-Generation Applications
Advanced Materials and Manufacturing Technologies Office	●	●		●	●		●	●
ARPA-E	●			●			●	●
Grid Deployment Office							●	●
Hydrogen and Fuel Cell Technologies Office		●			●			●
Loan Programs Office	●	●	●	●	●	●	●	●
Office of Clean Energy Demonstrations	●			●			●	●
Office of Cybersecurity, Energy Security, and Emergency Response							●	
Office of Economic Impact and Diversity		●	●		●	●	●	●
Office of Electricity							●	●
Office of Manufacturing and Energy Supply Chains	●	●		●	●		●	●
Office of Science	●			●				
Vehicle Technologies Office		●			●			
Water Power Technologies Office	●	●	●		●	●	●	●
State and Community Energy Programs			●			●	●	●
Wind Energy Technologies Office	●	●	●	●	●	●	●	●

Figure 8. DOE Office Capabilities in Each Initiative
Note: ARPA-E = Advanced Research Projects Agency – Energy

6 Strategic Initiatives

This DOE strategy identifies the overarching goals and actions needed to achieve the administration's offshore wind energy deployment goals and advance the offshore wind sector in the United States. These actions include considering the range of resources within DOE that could be used to advance those goals, and the ways in which the various DOE offices could collaborate on these efforts. This strategy focuses on actionable measures for DOE to take within the next 5 years to reach the administration's short-, medium-, and long-term offshore wind deployment and sector development goals.

The strategy is organized into four major initiatives that each address a different facet of the offshore wind energy industry as well as major challenges (Figure 9. Major DOE strategic initiatives for offshore wind energy

). Together, these initiatives form a comprehensive strategy for DOE to meet its offshore wind energy vision. The four initiatives address the varying stages of commercial readiness of enabling technologies and solutions:

1. Near-term Offshore Wind (NOW) meets the near-term needs of fixed-bottom offshore wind technologies to meet the 30-GW-by-2030 goal.
2. Floating Offshore Wind Advanced Research and Development (FORWARD) advances U.S. leadership in floating offshore wind technology design, manufacturing, and deployment.
3. CONNECT seeks to enable reliable and resilient transmission infrastructure for large-scale offshore wind deployment through R&D, planning, analysis, and infrastructure development support.
4. TRANSFORM prepares offshore wind to enable widespread electrification of the economy.

Each of these initiatives is described in the remainder of this section.

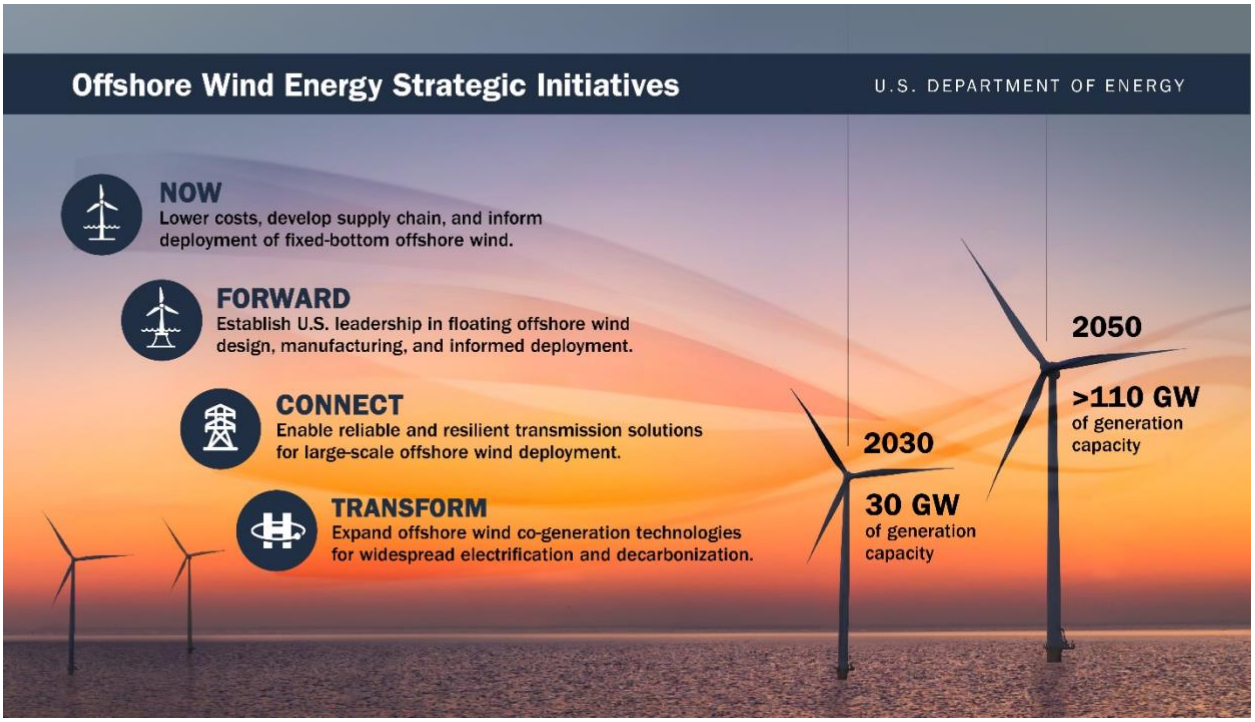

Figure 9. Major DOE strategic initiatives for offshore wind energy

NOW: Near-term Offshore Wind

The NOW initiative focuses on catalyzing fixed-bottom offshore wind energy development to help meet the Biden administration's goal of 30 GW by 2030 and unlock a pathway to 110 GW by 2050. This initiative addresses needs associated with fixed-bottom technologies, the first substructure type to be deployed in the United States on a commercial basis.

NOW aims to address three primary objectives:

- Objective 1. Reduce the cost of fixed-bottom offshore wind energy to $51/MWh by 2030 from a 2021 baseline of $73/MWh.
- Objective 2. Support the development of a domestic supply chain to grow to more than 30 GW of fixed-bottom installations and operations.
- Objective 3. Inform just, sustainable, and timely development of fixed-bottom offshore wind energy.

These objectives reflect the challenges discussed in Section 4 that are critical to offshore wind energy deployment.

Objective 1: Reduce the cost of fixed-bottom offshore wind to $51/MWh by 2030 from 2021 levels of $73/MWh

More than 50 GW of offshore wind capacity has been deployed globally on fixed-bottom substructures. This is the predominant type of foundation planned for projects that are scheduled for commissioning by 2030. By reducing the cost of fixed-bottom offshore wind by 30% (Figure

10), [71] this power generation source will become an economically attractive choice at more locations, extend to additional uses (e.g., fuels production), and benefit ratepayers through lower electricity bills.[72]

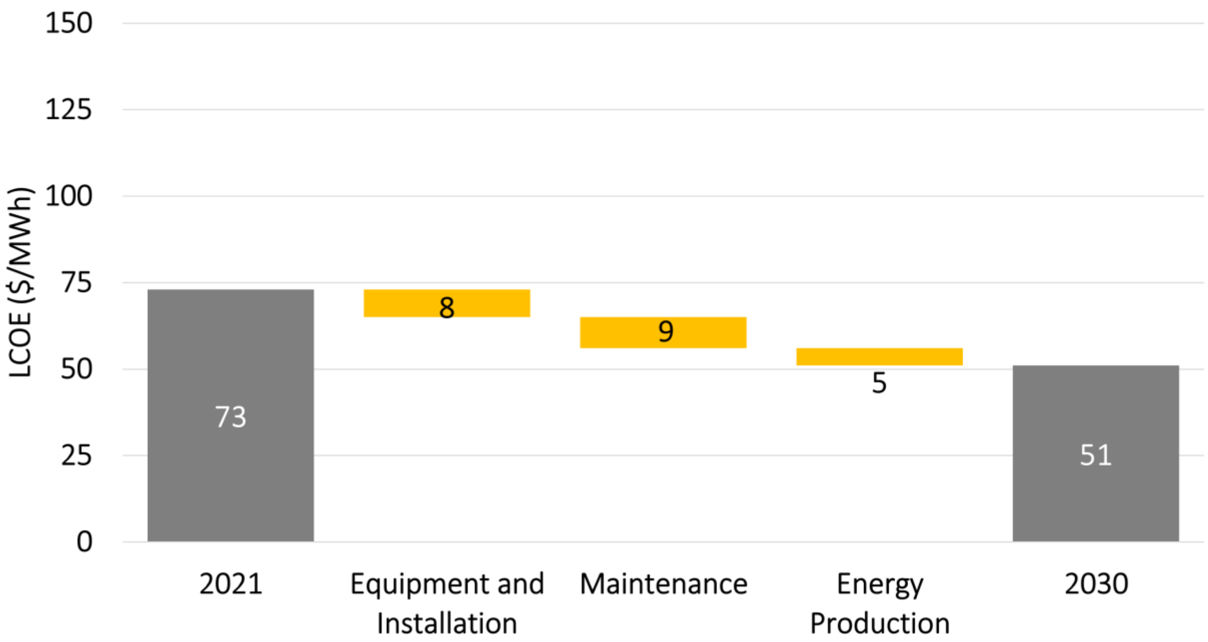

Figure 10. The cost of fixed-bottom offshore wind energy.[73]
Note: Costs are estimated to decline through lower expenditures in equipment, installation and maintenance, as well as higher energy production. Denoted in $2018 consistent with Stehly and Duffy (2022). LCOE = levelized cost of energy

As illustrated by the European progression of offshore wind energy to large-scale deployment over the two past decades, cost reduction can be achieved via multiple contributing factors. Ultimately, a combination of economies of scale of the wind turbine and plant; higher energy production; and efficiencies in manufacturing lead to a lower levelized cost of energy (LCOE).[74] Lower LCOE results in increased commercial competitiveness and deployment of the generation technology. To attain $51/MWh by 2030 for fixed-bottom offshore wind, the RDD&D activities focus on several drivers that have cost-reducing impacts in the near term (i.e., within the next 5–10 years). Because of the systemic nature of wind energy (i.e., changes in one component affecting other components of the turbine system), these drivers typically need to be considered jointly.

This need for a systems approach dictates that unique aspects of U.S. waters in factors such as average sea states, extreme weather (e.g., hurricanes), ice loading, and seabed characteristics

[71] Stehly, T. and P. Duffy. 2022. *2021 Cost of Wind Energy Review*. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/84774.pdf.
[72]Brown, A., P. Beiter, D. Heimiller, C. Davidson, P. Denholm, et al. 2016. *Estimating Renewable Energy Economic Potential in the United States. Methodology and Initial Results*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20.64530. https://doi.org/10.2172/1215323.
[73] Stehly, T. and P. Duffy. 2022. *2021 Cost of Wind Energy Review*. https://www.nrel.gov/docs/fy23osti/84774.pdf.
[74] Beiter, P., J. Rand, J. Seel, E. Lantz, P. Gilman, et al. 2022. “Expert perspectives on the wind plant of the future.” *Wind Energy*. https://onlinelibrary.wiley.com/doi/full/10.1002/we.2735.

relative to other parts of the globe need to be considered to ensure domestic deployment of reliable and cost-effective wind turbine components and overall wind farm configurations. Similarly, to realize optimized costs, offshore wind energy technology needs to adapt to the differing design conditions between coastal regions of the United States. In addition, consideration must be given to the availability of suitable U.S. ports and vessels infrastructure and potential upgrade costs.

There are three DOE activity areas that address NOW Objective 1 to reduce fixed-bottom costs (NOW-1, NOW-2, and NOW-3). They are described as follows.

NOW-1: Wind resource and site characterization to lower risks and increase energy capture

There is incomplete knowledge of the physics of offshore wind, and gaps in available meteorological, oceanographic, and geotechnical data relevant to wind farm design costs, reliability, and optimal energy production. Increased data analysis and knowledge of offshore conditions can result in better wind farm array layouts, and more certain wind energy yield forecasts, thereby lowering financial risks. Improved offshore data also inform development of advanced computational modeling capabilities that help refine wind turbine, substructure, and system control designs to enhance cost efficiency and performance. Through its research portfolio, DOE supports advanced measurement techniques and analysis protocols to enable systematic and standardized offshore site data collection in all coastal regions; public dissemination of raw data and compiled reports; and development of complex predictive models for use in resource characterization, technology design, and array and control optimization.

Table 7. NOW-DOE Wind Resource and Site Characterization Activities

Goal	Through data collection and analysis and advancing computational modeling capabiities, significantly increase the understanding of the U.S. offshore wind resource, metocean conditions, and subsea characeristics to reduce engineering risks and increase the accuracy of energy forecasting.
Activities	NOW-1.1: Collect meteorological and oceanographic measurements to provide data for wind turbine design optimization and site evaluation. NOW-1.2: Conduct studies and enhance modeling capabilities to better characterize wind turbine wake dynamics and interarray effects to optimize wind farm layouts and control strategies for U.S. weather conditions. NOW-1.3: Characterize climate trends to improve accuracy of long-term performance modeling, and assess the potential impact on U.S. offshore wind farm operations and economics. NOW-1.4: Improve near- and long-term wind energy production forecasting to reduce uncertainties in grid interactions and power markets.
DOE Offices	Wind Energy Technologies Office (WETO), Office of Science (SC)
Key Federal Partners	NOAA, BOEM, NSF

NOW-2: Enabling larger wind turbines through systems engineering while evaluating standardization needs

Fixed-bottom offshore wind energy has performed successfully worldwide for more than 20 years and has reached cost-competitiveness with other generation sources in several energy markets globally. A competitive cost level in U.S. markets can be achieved through a two-pronged approach focused on increased wind turbine size and industrializing manufacturing. These two approaches require careful supply chain analysis and development of turbine components that enable continued component innovation without major supply chain disruptions. Enabling RD&D includes upscaling of key turbine system components for U.S. manufacture while increasing energy yield and operating lifetimes. Such improvements are tied to many secondary innovations that reduce the weight of components (e.g., through superconducting generators) or ensure high performance (e.g., through active wind turbine controls). To reduce LCOE from a combination of these secondary innovations, a systems engineering approach can be advantageous to holistically consider all elements of the operating wind plant including the wind turbine, tower, substructure, and power delivery subsystem, along with installation and maintenance activities over the project lifetime. Economies of scale can be achieved through a two-prong approach: increased size and industrializing manufacturing. These two approaches require careful analysis and development of turbine components that enable continued standardized component innovation without major supply chain disruptions. Further, DOE emphasizes the importance of designing for unique U.S. conditions and infrastructure, including extreme weather events, subsea soil conditions, domestic port and vessel capacities, and manufacturing and workforce capabilities.

Table 8. NOW-DOE Activities to Enable Larger Wind Turbines

Goal	Lower costs through integration of higher-capacity wind turbines and systems engineering.
Activities	NOW-2.1: Refine large, next-generation wind turbine component designs for higher energy yield and increased efficiency, lower weight, active controls, and extended operating life and evaluate benefits of and pathways to standardization. NOW-2.2: Support reliability research and design standards for resilience in extreme weather in all U.S. coastal areas. NOW-2.3: Establish or upgrade testing facilities to accommodate and validate performance of larger wind turbines and component subsystems. NOW-2.4: Research applicability of advanced materials to decrease component costs, increase wind plant life span, and promote recyclability.
DOE Offices	WETO, SC, Advanced Materials and Manufacturing Technologies Office (AMMTO)
Key Federal Partners	NSF

NOW-3: Reduce costs and adverse impacts of installation, operation, and maintenance activities

Installing, operating, and maintaining fixed-bottom offshore wind energy systems involves highly complex procedures in challenging working conditions. The available methods, tools, and vessel capabilities to carry out these procedures need to evolve to lower safety risks, reduce overall costs, and avoid potentially adverse environmental impacts. LCOE can be lowered by reducing costly transit time and labor hours at sea, limiting the need for large crane vessels, and avoiding disruption of power production by minimizing maintenance-related shutdowns. Potential adverse effects on marine wildlife can be mitigated by reducing installation noise. Reducing the use of vessels and using more efficient propulsion systems and alternate fuels can also benefit wildlife and the environment more broadly through reduced emissions of carbon dioxide and other pollutants.

Examples of targeted R&D to address these challenges and opportunities include:

- Automated maintenance procedures using remote above- and below-surface inspection and servicing technologies coupled with artificial intelligence capabilities for condition monitoring that have the potential to significantly increase the operating lifetime of offshore systems while reducing work hours at sea.
- Limiting noise resulting from driving foundation piles into the seabed through use of new substructure designs, quieter tools, and better noise mitigation methods to extend seasonal installation windows by decreasing concerns of adverse impacts during marine mammal migrations.

DOE is well-qualified to lead research efforts in this space given its experience in applied technology development, capabilities in coupled systems modeling and virtual testing, its environmental research portfolio, and its experience in data analysis and dissemination when partnering with other agencies and industry to address complex challenges.

Table 9. NOW-DOE Activities to Reduce Costs and Impacts from Installation, Operation, and Maintenance

Goal	Develop innovative installation, operation, and maintenance tools applicable to fixed-bottom wind turbine systems to reduce overall costs and the potential for adverse impacts on the ocean environment.
Activities	NOW-3.1: Improve installation methods and technologies to reduce complexity, labor at sea, and vessel needs. NOW-3.2: Develop quieter installation and operation methods and technologies to avoid adverse impacts on the environment. NOW-3.3: Develop intelligent operations capabilities incorporating refined simulation and monitoring to improve wind farm performance modeling, planning, and operational decisions. NOW-3.4: Advance autonomous maintenance by developing tools and strategies that reduce costly on-site maintenance needs, increase safety, and prolong wind turbine life.
DOE Offices	WETO, AMMTO, SC
Key Federal Partners	BOEM, NOAA, BSEE

Objective 2: Support the development of a domestic supply chain for fixed-bottom offshore wind to enable more than 30 GW

A robust, cost-efficient, and lasting supply chain is formed when investors have sufficient "market certainty" based on a relatively certain project pipeline, sufficient information about the sector needs over time, offtake certainty, and coordination platforms and networks at the sector, state, regional, and federal levels. Such a supply chain can be fostered by making manufacturing and sector data and analysis publicly available, offering coordination platforms, and supporting investments deemed too risky for private sector entities. To help build a fixed-bottom offshore wind energy industry capable of installing at least 30 GW by 2030, DOE is focused on supply chain formation within the next 5−10 years.

There are four DOE activity areas to address NOW Objective 2 to develop a fixed-bottom domestic supply chain (NOW-4, NOW-5, NOW-6, and NOW-7). They are described as follows.

NOW-4: Conduct analyses to develop road maps to meet fixed-bottom offshore wind supply chain needs

Conducting analyses and developing road maps that outline future supply chain needs and projected gaps will provide clarity to manufacturers, developers, federal and state agencies, labor organizations, and communities. Road maps based on informed projections of offshore wind energy project development help to estimate near- and long-term industry needs from various tiers of suppliers that range from major equipment and various materials and components to fabrication facilities, ports, and logistics requirements. Gap analyses help determine where investment and other forms of support can best build U.S. supply chain capabilities to increase the domestic content of offshore wind farms and avoid crippling bottlenecks and project delays due to materials shortages and component or fabrication lead times. Continued and updated analysis and road mapping will also proactively address labor needs, both in terms of required skillsets and training, and overall workforce size broken down by supplier type.

The road map must be developed with engagement from diverse and underserved communities.

DOE can act as a facilitator for creating and updating such a road map and coordinating supply chain development because of its central role in energy policymaking and regular consultation and coordination activities with key stakeholder groups in the public and private sectors.

Table 10. NOW- DOE Actions to Develop a Fixed-Bottom Offshore Wind Supply Chain Road Map

Goal	Expedite development of a robust domestic offshore wind energy supply chain to meet national energy and economic development goals
Activities	NOW-4.1: Conduct holistic analyses of near-term supply chain needs to facilitate fixed-bottom offshore wind energy deployment. NOW-4.2: Develop and regularly update a nationwide supply chain road map, with a near-term focus on meeting fixed-bottom deployment needs based on the project development pipeline.
DOE Offices	WETO, AMMTO, Office of State and Community Energy Programs (SCEP), Loan Programs Office (LPO)
Key Federal Partners	BOEM, MARAD, DOC

NOW-5: Develop industrial-scale domestic manufacturing practices

Manufacturing at industrial scale and in a serial fashion is critical to reducing the cost of fixed-bottom offshore wind energy and accelerating the speed at which fixed-bottom offshore wind is deployed. Larger quantities of wind turbines, substructures, electrical cables, and other wind farm components result in economies of scale that reduce costs and increase the rate of installations. R&D on designs and material specifications of key components such as wind turbine blades can yield a wide adoption of serial fabrication practices in the U.S. offshore wind sector, as well as identify critical materials for which supply needs to be ensured.

DOE is well-positioned to develop serial manufacturing practices and explore related design changes and new materials through the Advanced Materials and Manufacturing Technologies Office (AMMTO) and other DOE offices. These practices can then be potentially financed through federal loan guarantees to establish commercial-scale production facilities.

Table 11. NOW-DOE Activities to Develop Domestic Manufacturing for Fixed-Bottom Offshore Wind

Goal	Develop tailored manufacturing practices in domestic facilities for serial and efficient production of fixed-bottom offshore wind components and materials.
Activities	NOW-5.1: Conduct analyses to identify manufacturing capabilities and needs to determine critical R&D and facility investments. NOW-5.2: Evaluate design of blades, substructures, towers, and other wind turbine components for serial manufacturing to expedite low-cost offshore energy deployment. NOW-5.3: Develop manufacturing and logistics solutions optimized for the domestic supply chain to reduce costs and expedite offshore wind energy deployment. NOW-5.4: Address gaps in key domestic manufacturing capabilities through loans and loan guarantees and other mechanisms to support commercial-scale manufacturing. NOW-5.5: Research and develop recycling methods and standards for broad adoption into regulations and industry use.
DOE Offices	WETO, AMMTO, LPO

NOW-6: Support domestic vessel, ports, and wind power plant development

Specialized vessels and port facilities are required for assembly, marshalling, installation, and operation of fixed-bottom offshore wind farms. Building on analytical data gained through surveys, databases, and road mapping, DOE can help quantify general and regional port, vessel, and wind farm infrastructure needs. In addition to projecting numbers required, this analysis will identify parameters, such as vessel types by function, lifting capacities of fixed and floating cranes, and physical requirements of ports for carrying out various operations.

DOE offices and sister agencies can support maritime decarbonization through technology development, demonstration, and public financing of low-emission vessels incorporating novel propulsion designs and alternative fuels.

Table 12. NOW-DOE Activities to Support Domestic Vessels, Ports, and Wind Plants

Goal	Support development of the ports and vessels sector to meet near-term fixed-bottom deployment and cost goals.
Activities	NOW-6.1: Identify and report on the quantities and types of vessel and ports needed to inform investment opportunities and government support initiatives. NOW-6.2: Contribute to maritime vessel decarbonization through R&D and demonstration of clean propulsion systems. NOW-6.3: Invest in vessel construction, upgrades, and repurposing to install and operate fixed-bottom offshore wind energy facilities. NOW-6.4: Finance offshore wind plants through federal loans to promote fixed-bottom offshore wind energy deployment.
DOE Offices	WETO, LPO, Vehicles Technologies Office (VTO), Office of Clean Energy Demonstrations (OCED)[75], Hydrogen and Fuel Cells Technologies Office (HFTO)
Key Federal Partners	MARAD

NOW-7: Support the development of a robust U.S. offshore wind energy workforce

A well-trained workforce is critical to enable learning, standardization, and efficient manufacturing and operations while maintaining high safety standards. A domestic workforce can provide good-paying U.S. jobs and apprenticeships that can bolster communities and facilitate timely construction and operation. Emphasis on diversity, equity, and inclusion principles is crucial to workforce development and training programs, particularly in underserved communities. DOE can identify future workforce needs through its understanding of technological and industry developments years in advance of their introduction and help implement appropriate training programs, while ensuring equitable and just opportunities are available. The fixed-bottom offshore wind energy sector requires rapid training of a workforce of 12,300−49,000 full-time employees annually between now and 2030.[76]

[75] OCED does not currently have authority or appropriations for these activities.
[76] Shields, M., R. Marsh, J. Stefek, F. Oteri, R. Gould, et al. 2021. *The Demand for a Domestic Offshore Wind Energy Supply Chain*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-81602. https://www.nrel.gov/docs/fy22osti/81602.pdf.

Table 13. NOW-DOE Activities to Develop a Domestic Workforce for Fixed-Bottom Offshore Wind

Goal	Support the identification and development of skills needed to install fixed-bottom offshore wind, promote diversity, and attract skilled workers to the sector.
Activities	NOW-7.1: Conduct workforce analyses to anticipate future training needs and establish a road map to address workforce needs. NOW-7.2: Convene stakeholders to coordinate regional workforce development and training. NOW-7.3: Standardize and expand offshore wind energy training programs at community colleges, universities, and apprenticeship programs to promote workforce development. NOW-7.4: Establish career pathways that promote diversity and facilitate career transitions.
DOE Offices	WETO, Office of Economic Impact and Diversity (ED)
Key Federal Partners	BOEM, MARAD

Objective 3: Inform just, sustainable, and timely development of fixed-bottom offshore wind energy

To deploy 30 GW of fixed-bottom offshore wind energy along U.S. coasts by 2030, multiple considerations need to be balanced, such as impacts from offshore wind energy development on marine life and other human uses of the ocean.

A just, sustainable, and timely development process can be supported, in part, by informing the various stakeholders and decision makers about the trade-offs of offshore wind energy development and encouraging opportunities to exchange ideas and resolving conflicts. This process begins with the collection and analysis of relevant environmental and social data. DOE can support the development of responsible fixed-bottom offshore wind deployment through RD&D activities that are focused on filling knowledge gaps regarding impacts, developing solutions to avoid, minimize, and mitigate impacts where needed, and supporting community engagement. These activities are crucial to first understanding environmental, economic, and social needs and concerns, and then addressing those needs and concerns. In addition to BOEM's lead role in siting and leasing, various local, state, and federal entities are involved in planning fixed-bottom offshore wind energy development. DOE has a collaborative role with other federal agencies in conducting research and providing unbiased information and data to evaluate trade-offs.

There are three DOE activity areas to address NOW Objective 3 to inform just, sustainable, and timely fixed-bottom development (NOW-8, NOW-9, and NOW-10). They are described as follows.

NOW-8: Support community engagement, ocean co-use, and social science

DOE helps evaluate, avoid, minimize, and mitigate the effects of offshore wind energy on communities, ocean users, tribal equities, and the missions of other federal agencies. Various local, state, and federal entities are involved in planning fixed-bottom offshore wind energy development. DOE has a partnership role with other federal agencies in conducting research about the impact of this technology on other human co-use needs, marine life, and community well-being and can act as a trusted source for unbiased information to inform site-selection trade-offs. DOE's community engagement and social science efforts aim to support procedural, recognition, and distributive justice to help reach community consent, project acceptance, and energy justice. Ocean co-use needs such as radar users, commercial and recreational fishers, aquaculture, federal marine life population surveys, tribal treaty rights and other equities, and other marine activities must be carefully considered. Such research and engagement can promote community involvement and understanding, which is crucial to ongoing offshore wind energy deployment efforts. DOE plans to evaluate both how to support ocean co-use, as well as potential co-location of activities such as aquaculture.

Table 14. NOW-DOE Activities to Support Community Engagement, Ocean Co-Use, and Social Science for Fixed-Bottom Offshore Wind Energy Development

Goal	Engage communities in planning of fixed-bottom offshore wind energy development and conduct socioeconomic analyses and R&D to increase the opportunities for offshore co-uses; avoid, minimize, and mitigate adverse impacts; identify trade-offs; and increase public acceptance of offshore wind energy development.
Activities	NOW-8.1: Identify communities impacted by offshore wind energy development and the socioeconomic impacts on those communities to inform costs and benefits of offshore wind development. NOW-8.2: Identify community benefit structures and policies that help coastal communities move toward equitable distribution of costs and benefits of offshore wind energy development. NOW-8.3: Provide fact-based information and facilitate regular information exchange with stakeholders to increase support for ocean co-uses. NOW-8.4: Establish technical assistance programs that help communities identify trade-offs in offshore wind energy development and enable a fact-based discourse on offshore wind. NOW-8.5: Improve understanding of ocean co-use needs and potential impacts of offshore wind energy deployment on fisheries, marine surveys, tribal equities, and other federal missions to inform R&D on impact minimization solutions. NOW-8.6: Develop tools and technologies to mitigate impacts from offshore wind energy on radar interference.
DOE Offices	WETO, ED, LPO, Water Power Technologies Office (WPTO)
Key Federal Partners	BOEM, NOAA, DHS, DOD, FAA

NOW-9: Support environmental research to understand, avoid, minimize, and mitigate risk

While offshore wind energy impacts on wildlife, marine environments, and commercial species have been well-studied around the world, the newness of development in U.S. waters results in the need for further research. Such research can inform effective mitigation and management practices and lead to improved siting. DOE will collaborate with other federal agencies to assess the environmental costs and benefits of offshore wind energy, and, where necessary, develop solutions to mitigate any adverse impacts and promote best practices.

Table 15. NOW-DOE Environmental Research Activities to Understand, Avoid, Minimize, and Mitigate Risk from Fixed-Bottom Offshore Wind

Goal	Understand and reduce environmental impacts of fixed-bottom offshore wind energy deployment, in coordination with partner agencies, to promote environmental sustainability, ocean co-use, and enhanced permitting efficiency.
Activities	NOW-9.1: Identify priority research needs and gaps associated with U.S.-specific environmental concerns to inform research efforts. NOW-9.2: Develop and validate wildlife, fisheries, and habitat monitoring and modeling technologies and methods to observe potential changes associated with offshore wind energy development. NOW-9.3: Improve understanding of transmission and cable routing impacts to reduce effects on wildlife, fisheries, and habitats. NOW-9.4: Collect data to fill gaps in baseline knowledge before construction to inform siting processes. NOW-9.5: Improve understanding of environmental impacts of fixed-bottom offshore wind energy development to inform sustainable deployment practices. NOW-9.6: Develop and validate impact minimization and mitigation tools and technologies to reduce potential adverse impacts on wildlife. NOW-9.7: Disseminate environmental and resource knowledge to stakeholder groups to inform regulatory siting processes.
DOE Offices	WETO, WPTO
Key Federal Partners	BOEM, NOAA, FWS

NOW-10: Share data and tools to support the delineation of additional lease areas

In order to deploy 110 GW or more of offshore wind energy by 2050, additional areas will need to be identified for development. This process necessitates data collection, analysis, and tools for a careful evaluation of siting characteristics including wind resource, costs, marine logistics, cultural resources, and ocean-co-use and environmental characteristics. BOEM leads the siting and leasing of offshore wind energy in federal waters. DOE can inform these siting decisions through RD&D in technology development, economics, wind resource, and infrastructure needs. DOE has the data collection, analysis, and modeling expertise across different disciplines to provide data to the site delineation process.

Table 16. NOW-DOE Activities to Support Lease Area Delineation for Fixed-Bottom Offshore Wind Energy

Goal	Collect and analyze data to inform decisions about offshore wind lease area delineation for fixed-bottom facilities
Activities	NOW-10.1: Develop tools and methods and collect siting data to help identify the best-suited locations for offshore wind energy. NOW-10.2: Provide technical support to identify the best-suited locations for offshore wind energy.
DOE Offices	WETO, SC
Key Federal Partners	BOEM, NOAA

FORWARD: Floating Offshore Wind Advanced Research and Development

To support DOI's goal of deploying 15 GW of floating offshore wind energy by 2035, deployment must extend to deeper waters, which comprise about two-thirds of the U.S. offshore wind energy potential.[77] [78] This expansion will enable the U.S. West Coast, Gulf of Maine, and deeper water areas off all U.S. coasts and the Great Lakes to tap into offshore wind's energy potential. FORWARD will establish U.S. leadership in floating offshore wind design, manufacturing, and informed deployment by addressing the most urgent RDD&D, supply chain, and siting goals for deploying floating offshore wind.

In recognition of its great potential and the critical need to address RD&D challenges and advance the technology from its multiturbine demonstration stage to commercial deployment, the Floating Offshore Wind Shot™ (see Box 1) was launched in September 2022.[79] The Energy Earthshots initiative aims to accelerate breakthroughs for more abundant, affordable, and reliable clean energy solutions.

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[77] Lopez, A., R. Green, T. Williams, E. Lantz, G. Buster, B. Roberts. 2022. "Offshore Wind Energy Technical Potential for the Contiguous United States." https://www.nrel.gov/docs/fy22osti/83650.pdf.
[78] Using a water depth threshold of 60 m between fixed-bottom and floating offshore wind.
[79] The Floating Offshore Wind Shot. https://www.energy.gov/eere/wind/floating-offshore-wind-shot.

Box 1. Floating Offshore Wind Shot

In September 2022, the Floating Offshore Wind Shot was announced to grow the amount of renewable energy available in the country by driving U.S. leadership in floating offshore wind design, development, and manufacturing. The shot is an interagency effort led by DOE, DOI, DOC, and U.S. Department of Transportation. Achieving the Energy Earthshot targets will help the United States tackle the remaining technical challenges to address the climate crisis and more quickly meet the Biden administration's goal of equitably reaching net-zero carbon emissions by 2050 while creating good-paying jobs and growing the economy. The Floating Offshore Wind Shot includes an ambitious goal to reduce the cost of floating offshore wind energy by at least 70%, to $45/MWh by 2035 for deep sites far from shore.80

DOE's efforts in supporting the Floating Offshore Wind Shot are encompassed in the FORWARD initiatives, as well as the floating-relevant portions of the CONNECT and TRANSFORM initiatives (Figure 11). Additionally, many of the advances made under NOW will directly apply to FORWARD initiatives.

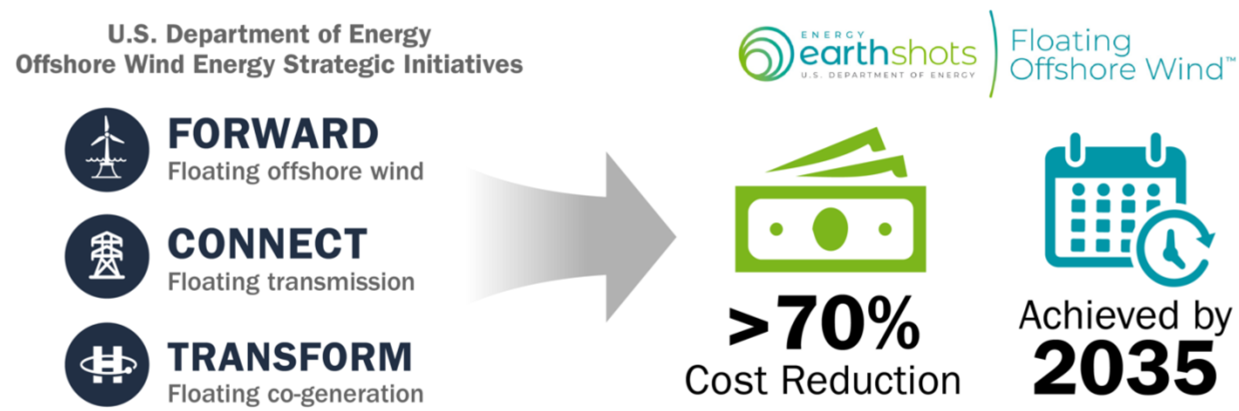

Figure 11. Alignment of DOE offshore wind strategy with the Floating Offshore Wind Shot

FORWARD aims to address three primary objectives:

- Objective 1. Reduce the cost of floating offshore wind energy in deep waters to $45/MWh by 2030 from today's $150/MWh.
- Objective 2. Support the development of a domestic floating offshore wind supply chain that grows to gigawatt-scale deployment by 2035.
- Objective 3. Inform just, sustainable, and timely development of floating offshore wind energy in deep waters.

The FORWARD initiative specifically addresses technical challenges associated with floating offshore wind technologies, which have not yet been deployed at scale in the United States.

[80] The Floating Offshore Wind Shot. https://www.energy.gov/eere/wind/floating-offshore-wind-shot.

While floating offshore wind energy is at an earlier stage of development than fixed-bottom, both in the United States and globally, the potential resource is vast and the technological development to reduce costs and expand deployment are critical for reaching net-zero carbon emission goals.

Objective 1: Reduce the cost of floating offshore wind in deep waters to $45/MWh by 2035 from today's $150/MWh

As of 2021, only 123 MW of floating offshore wind capacity was deployed globally; however, there is a growing pipeline of over 60 GW under development. This technology type is expected to transition from a multiturbine demonstration to full commercial deployment by the mid-to-late 2020s.[81] The primary goal of the Floating Offshore Wind Shot is to reduce the cost of floating offshore wind energy in deep waters (Figure 12). This generation source will broaden the reach of offshore wind energy by making it an economically viable option along the Pacific Coast, Gulf of Maine, and many other deep-water regions off the U.S. coasts. It can also power additional uses (e.g., fuels production) and benefit ratepayers through lower bills as the shot's goal is attained.[82] DOE also aims to support work that will contribute to reaching DOI's goal of deploying 15 GW of floating offshore wind energy by 2035.

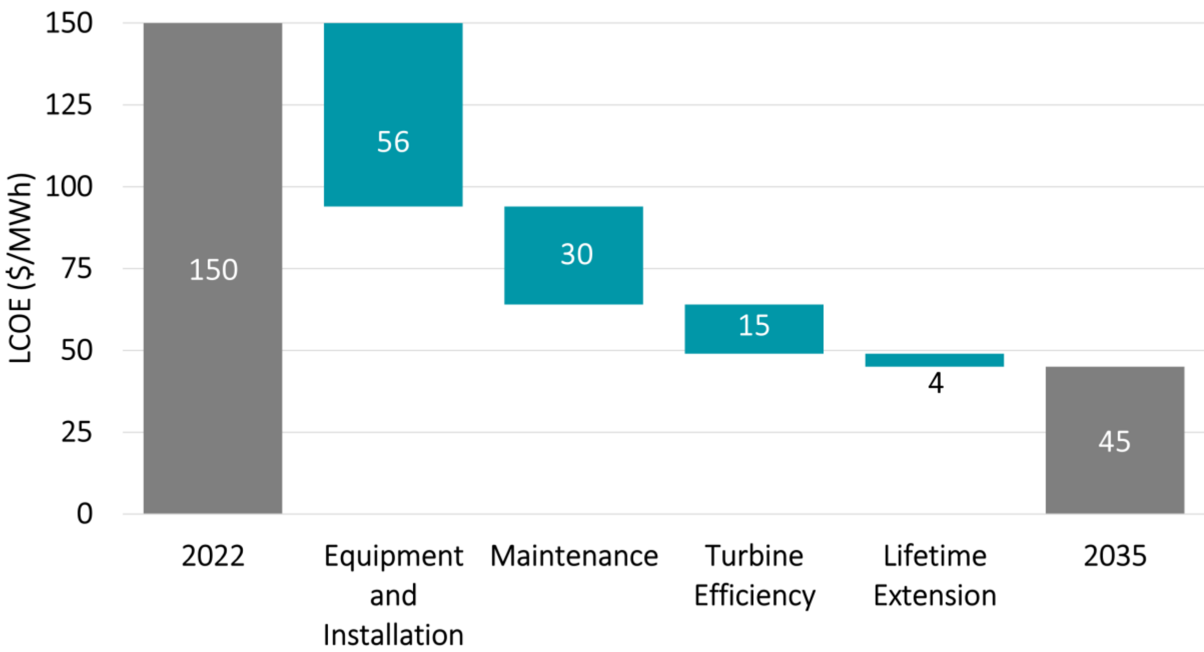

Figure 12. Cost reduction of floating offshore wind energy from a modeled 2022 baseline and 2035.[83]
Note: Denoted in $2022.

[81] Musial, W., P. Spitsen, P. Duffy, P. Beiter, M. Marquis, et al. 2022.*Offshore Wind Market Report: 2022 Edition*. https://www.energy.gov/sites/default/files/2022-08/offshore_wind_market_report_2022.pdf.
[82] DOE. 2022. *Offshore Wind Energy Strategies*. https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.
[83] Analysis conducted for the DOE Floating Offshore Wind Shot; DOE. 2022. "Floating Offshore Wind Shot." https://www.energy.gov/eere/wind/floating-offshore-wind-shot.

There are three DOE activity areas to address FORWARD Objective 1 to reduce fixed-bottom costs (FORWARD-1, FORWARD-2, and FORWARD-3). They are described as follows.

FORWARD-1: Wind resource and site characterization to lower risks and increase energy capture of floating offshore wind systems

Floating offshore wind deployment is concentrated in areas with deep water, and near-term development will largely occur in regions of the country that have not previously seen offshore wind energy development activity. Many of the NOW-1 activities that pertain to characterizing offshore winds and developing advanced computational modeling capabilities will also apply to floating projects. However, there are gaps in site-specific data collection, in understanding regionally specific trends, and in model development that need to be addressed in FORWARD-1. Increased data analysis and knowledge of offshore conditions can result in better floating wind plant array layouts and more certain wind energy yield forecasts, thereby lowering financial risks. There is a particular need to be able to forecast extreme weather events and climate trends to inform long-term structural load calculations and lower risks when designing floating wind turbine, platform, and mooring systems. Floating systems are inherently dynamic, with certain degrees of movement in response to coupled wind and wave conditions. Being able to accurately predict the performance of an individual system and its mooring configuration requires accurate metocean and water depth data as well as high-fidelity models able to integrate many factors. Similarly, understanding the array dynamics and impacts on energy production within a proposed wind plant layout requires specialized data and computational tools.

Through its research portfolio, DOE supports advanced measurement techniques and analysis protocols to enable systematic and standardized offshore site data collection in all coastal regions including the Great Lakes; public dissemination of raw data and compiled reports; and development of complex predictive models for use in resource characterization, technology design, and array and control optimization.

Table 17. FORWARD-DOE Wind Resource and Site Characterization Activities

Goal	Improve understanding of wind resource and other site characteristics in deeper waters to reduce costs and engineering risks through tailored floating wind turbine, array, and platform design; and to increase accuracy of energy projections through more reliable forecasting of metocean conditions, thereby lowering project risks.
Activities	FORWARD-1.1: Collect meteorological and oceanographic data in U.S. regions suitable for floating offshore wind energy deployment to optimize integrated wind turbine, platform, and mooring designs. FORWARD-1.2: Conduct studies and enhance modeling capabilities to better characterize floating wind turbine wake dynamics and interarray effects to optimize wind plant layout and control strategies of floating offshore wind plants. FORWARD-1.3: Analyze and characterize climate trends that may impact the economics and operations of floating offshore wind plants along U.S. coasts and improve the accuracy of long-term performance modeling. FORWARD-1.4: Improve near- and long-term wind speed and energy production forecasting for floating offshore wind arrays to reduce uncertainties in grid management and power markets
DOE Offices	WETO, SC
Key Federal Partners	BOEM, NOAA

FORWARD-2: Facilitate high-impact floating offshore wind turbine system innovation while evaluating standardization needs

There are multiple floating offshore wind energy demonstration projects globally, with large commercial projects in various planning phases. Several generations of increasingly larger wind turbines are likely to be introduced globally and in the United States, offering lower costs through economies of scale. Floating offshore wind energy projects might ultimately be better suited for larger wind turbines than fixed-bottom projects because the turbines can be mounted onto floating platforms in port (rather than at sea), reducing installation risk and costs. Planning and research must consider this upscaling trend because it can offer high-impact cost reductions if tailored to U.S. site, supply chain, and port infrastructure conditions. This consideration should include trade-offs between savings derived from larger wind turbines versus a mature supply chain. To incorporate larger turbines, a systems engineering approach needs to consider the interdependencies of floating offshore wind and integrate all elements holistically, including the wind turbine, tower, floating platform, controls, and power delivery subsystem, along with installation and maintenance over the project lifetime.

Costs can be reduced using integrated turbine and platform designs, informed by trade-off studies that identify cost-cutting options such as weight reduction, along with optimized controls strategies that yield higher performance and improve reliability and resiliency. Other R&D should be targeted at advanced mooring (e.g., synthetic materials), anchoring, dynamic cables, new materials (e.g., steel vs. concrete applications), and floating substation concepts for deep waters, and on designing for serial production (e.g., modular structures, use of advanced materials, and three-dimensional printing).

Technology design, process research, and testing supported by DOE offices can demonstrate technical viability for potential financing, including through federal loan guarantees, to establish commercial-scale production.

Table 18. FORWARD-DOE Activities to Enable Larger Wind Turbines

Goal	Reduce costs by enabling higher-rated wind turbines and integrated turbine and floating platform system designs.
Activities	FORWARD-2.1: Integrate floating wind turbine and platform systems to enhance performance, increase standardization, increase reliability and resiliency during extreme weather events, and prolong lifetime, and evaluate benefits of and pathways to standardization. FORWARD-2.2: Innovate design testing, simulation, and validation capabilities for larger wind turbines, floating platforms, and mooring technologies. FORWARD-2.3: Improve components through integrated control co-design engineering approaches. FORWARD-2.4: Develop mooring, anchoring, dynamic cable, and floating substation technologies that are fully integrated with the wind turbine and platform design to decrease floating array costs, reduce seabed footprint, expand opportunities for ocean co-use, and increase energy transfer efficiency. FORWARD-2.5: Co-design floating wind turbine systems and port infrastructures to facilitate port investments tailored for floating offshore wind. FORWARD-2.6: Provide support for demonstration and testing of floating platform technologies in deep waters to evaluate their technical viability and performance.
DOE Offices	WETO, AMMTO, Advanced Research Projects Agency – Energy (ARPA-E), SC

FORWARD-3: Advance installation, operation, and maintenance of floating offshore wind systems

Installation, operations, and maintenance activities can be key drivers in reducing the cost of floating offshore wind energy if carried out at scale through highly standardized and efficient methods. At the same time, minimizing adverse impacts on the ocean environment is required to ensure that operations are sustainable and ocean co-users are respected. Cost reductions can be achieved through approaches such as fewer needs for heavy-lift cranes, novel anchor installation techniques, reduction of draft, and buoyancy aids, and tow-to-port maintenance capabilities. Research under NOW-3 on automating maintenance procedures using remote above- and below-surface inspection and servicing technologies coupled with artificial intelligence capabilities for condition monitoring will be adapted and enhanced to increase the operating lifetime of floating systems while reducing work hours at sea.

DOE is well-qualified to lead research efforts in this space given its experience in applied technology development, capabilities in coupled systems modeling and virtual testing, its environmental research portfolio, and its experience in data analysis and dissemination when partnering with other agencies and industry to address complex challenges.

Table 19. FORWARD-DOE Activities to Reduce Costs and Impacts from Installation, Operation, and Maintenance

Goal	Enable innovative installation, operation, and maintenance methods for floating wind turbine systems to ensure worker safety, reduce overall costs, and minimize the potential for adverse impacts on the ocean environment.
Activities	FORWARD-3.1: Improve installation methods and technologies as part of overall system engineering to reduce costs, accommodate larger wind turbines, and reduce transportation risks. FORWARD-3.2: Develop installation and operation methods and technologies that avoid, minimize, and mitigate adverse impacts on the environment and ocean co-use. FORWARD-3.3: Develop intelligent operations by refining simulation and monitoring capabilities for wind plant performance modeling, planning, and operational decisions. FORWARD-3.4: Advance autonomous maintenance by developing tools and strategies that reduce costly on-site maintenance needs, increase safety, and prolong wind turbine life.
DOE Offices	WETO, AMMTO, SC, ARPA-E
Key Federal Partners	BOEM, BSEE, NOAA

Objective 2: Support the development of a domestic supply chain to deploy 15 GW or more by 2035

The United States seeks to establish leadership in floating offshore wind energy, a role that will be supported in large part by the development of a domestic supply chain. A robust, cost-efficient, and lasting supply chain is formed when investors have sufficient "market visibility" of a relatively certain project pipeline, sufficient information about the sector needs, and coordination platforms and networks at the sector, state, regional, and federal levels. Such a supply chain can be fostered by making data and analyses available, offering ways for the community and stakeholders to connect, and supplementing investments that are deemed too risky for private sector entities. To achieve a floating offshore wind energy supply chain capable of installing and operating commercial-scale floating wind facilities, RD&D activities must focus on near-term drivers, including the most pressing manufacturing, port, and vessel advancements (i.e., within the next 5−10 years).

There are four DOE activity areas to address FORWARD Objective 2 to develop a domestic supply chain (FORWARD-4, FORWARD-5, and FORWARD-6, and FORWARD-7). They are described as follows.

FORWARD-4: Conduct analyses to develop a road map to meet floating offshore wind energy supply chain needs

Expanded floating offshore wind supply chain analyses and road maps with long-term time horizons are needed to meet the mutual supply chain goals of manufacturers, offshore wind developers, federal and state agencies, labor organizations, and communities. This effort is particularly crucial to identifying floating-technology-specific needs along the West Coast, Gulf of Maine, and other U.S. regions, and where the fixed-bottom supply chain or other offshore industries may be used or repurposed. Supply chain needs unique to floating wind energy include the large floating platforms themselves, anchors, mooring lines, and assembly facilities and services.

Road maps based on informed projections of floating offshore wind energy project development can help estimate near- and long-term industry needs. These needs include equipment, material and component suppliers, fabrication facilities, ports, and logistics. Gaps analyses will determine where investment and other forms of support can best build U.S. supply chain capabilities to increase domestic content of floating offshore wind plants and avoid crippling bottlenecks and project delays due to materials shortages and component or fabrication lead times. Analysis and road mapping will also proactively inform labor needs, both in terms of required skillsets and training, and overall workforce size broken down by supplier type. A supply chain of the scale needed to meet domestic wind energy industry projections comprises many company and facility types that are widely dispersed. In developing a road map, it is essential to consider community benefit opportunities by engaging diverse and underserved communities in many areas while avoiding negative environmental and economic consequences.

This approach can lead to cost efficiencies because it avoids redundancies and supply chain issues. DOE can act as an independent facilitator for establishing such a road map and coordinating supply chain development because of its central role in energy planning and regular consultation and coordination activities with key stakeholder groups.

Table 20. FORWARD-DOE Actions to Develop a Floating Offshore Wind Supply Chain Road Map

Goal	Facilitate the development of a robust domestic supply chain for floating offshore wind systems to meet national energy and economic development goals.
Activities	FORWARD-4.1: Develop analyses and road maps of manufacturing, port, and supply chain investment needs along the West Coast, Gulf of Maine, and other U.S. regions. FORWARD-4.2: Convene stakeholders and collaborate with federal agencies, states, and the floating offshore wind industry to develop and execute plans to address high-priority supply chains informed by DOE analyses and road maps.
DOE Offices	WETO, AMMTO, SCEP, LPO
Key Federal Partners	BOEM, DOC, MARAD

FORWARD-5: Develop industrial-scale domestic manufacturing practices

Manufacturing at industrial scale and in a serial fashion are critical to reducing the cost of floating offshore wind energy and accelerating the speed at which it is deployed. Larger quantities of wind turbines, platforms, electrical and mooring cables, and other components result in economies of scale that reduce costs and increase the rate of installations. To realize the full potential of economies of scale, a domestic supply chain is needed. Furthermore, it can help establish the United States as a leader in floating offshore wind energy manufacturing and deployment. DOE is well-positioned to develop serial manufacturing practices and explore related design changes and new materials through its Advanced Materials and Manufacturing

Technologies Office and other offices. These practices can then be potentially financed through federal loan guarantees to establish commercial-scale production facilities.

Table 21. FORWARD-DOE Activities to Develop Domestic Manufacturing for Floating Offshore Wind Energy

Goal	Promote tailored manufacturing practices that allow for efficient, scaled production of floating offshore wind energy components in domestic facilities.
Activities	FORWARD-5.1: Conduct manufacturing analyses and identify investment needs for serial production of wind turbine platforms, blades, and other components. FORWARD-5.2: Optimize floating systems to reduce weight, tailor for serial manufacturability, and integrate with larger wind turbines. FORWARD-5.3: Develop solutions optimized for domestic supply chains and materials to reduce costs and expedite floating offshore wind energy deployment. FORWARD-5.4: Support development of relevant manufacturing facilities through loan guarantees and other mechanisms. FORWARD-5.5: Research and develop wind turbine component recycling methods and standards for broad adoption in regulations and by industry.
DOE Offices	WETO, AMMTO, LPO, ARPA-E

FORWARD-6: Support domestic vessel, ports, and wind plant development

Floating wind turbine systems are likely to be fully or partially assembled in deep-water ports and towed to the wind plant sites using Jones-Act complaint tug/tow vessels. DOE is well-positioned to identify wind farm and vessel needs along with fabrication, assembly, and marshalling port requirements in partnership with U.S. Department of Transportation and other federal agencies. Life cycle costs of floating offshore wind energy can be reduced through improved vessel and port configurations that accommodate larger wind turbines, massive floating platforms, and wet storage locations while maintaining safe and sustainable operations. Clean propulsion systems can contribute to reducing carbon emissions from installation and maintenance activities.

DOE offices and sister agencies can support maritime decarbonization through technology development, demonstration, and public financing of low-emission vessels incorporating novel propulsion designs and alternative fuels.

Table 22. FORWARD-DOE Activities to Support Domestic Vessels, Ports, and Wind Plants

Goal	Support development of ports and vessels to meet long-term floating offshore wind energy deployment and cost goals.
Activities	FORWARD-6.1: Contribute to maritime vessel decarbonization through R&D and demonstration of clean propulsion systems. FORWARD-6.2: Support analysis and design of shipyard infrastructure and ports to service floating offshore wind energy needs. FORWARD-6.3: Invest in vessel construction, upgrades, and repurposing to install and operate floating offshore wind facilities. FORWARD-6.4: Finance offshore wind plants through federal loans to promote floating offshore wind energy deployment.
DOE Offices	WETO, VTO, OCED[84], LPO, HFTO
Key Federal Partners	MARAD

FORWARD-7: Support the development of a robust U.S. floating offshore wind energy workforce

The development of floating offshore wind energy will require a domestic workforce that is ready. To ensure the United States has trained workers ready to assume jobs when and where they are needed across a large range of job types, the country will need insight into future workforce needs and gaps, their timing, and geography. Where gaps are likely to arise, there will also need to be a coordinated effort to develop workforce programming to fill those gaps. A domestic workforce would provide good-paying jobs and apprenticeships that can bolster communities and facilitate timely construction and operation. Workforce development and training programs should emphasize diversity, equity, and inclusion principles to reach underserved communities. Planning for workforce development will also allow the floating offshore wind energy industry to fully utilize the domestic workforce, and ensure a successful transition from fossil-fuel jobs, as well as that jobs are based in underserved communities and that training programs support workforce diversity.

[84] OCED does not currently have authority or appropriations for these activities.

Table 23. FORWARD-DOE Activities to Develop a Domestic Workforce for Floating Offshore Wind Energy

Goal	Support the identification and development of skills needed to install floating offshore wind energy systems, promote diversity, attract skilled workers to the sector, and position the U.S. workforce as a global leader.
Activities	FORWARD-7.1: Conduct workforce analyses to anticipate future training needs and establish a road map to address workforce needs. FORWARD-7.2: Convene stakeholders to coordinate regional workforce development and training. FORWARD-7.3: Standardize and expand floating offshore wind training programs at community colleges, universities, and apprenticeship programs to promote workforce development. FORWARD-7.4: Establish career pathways that promote diversity and facilitate career transitions.
DOE Offices	WETO, ED
Key Federal Partners	BOEM, MARAD

Objective 3: Inform just, sustainable, and timely development of floating offshore wind energy in deep waters

Floating offshore wind energy development is in the early stages in the United States. As a result, there is a need for additional research to inform future development in the nearer term and in decades to come. In addition, there is an opportunity to use that research, as well as experience gained from U.S. fixed-bottom offshore wind development, in a way that avoids, minimizes, and mitigates adverse impacts on marine and human environments; promotes environmental justice; engages communities; and revitalizes coastal economies. BOEM leads this objective, with DOE playing a supportive role through research, technical assistance, and community engagement.

Just, sustainable, and timely development can be supported, in part, by informing the various stakeholders and decision makers about the trade-offs of offshore wind energy development and encouraging the exchange of ideas and resolving controversies. This process begins with collecting and analyzing critical social and environmental data, including co-use needs. A just, sustainable, and timely offshore wind energy industry respects ocean co-users and tribal treaty rights and other equities and seeks to avoid, minimize, and mitigate any negative environmental, economic, or social impacts. DOE can support responsible floating offshore wind deployment through activities that generate data and make those data publicly available. DOE also acts as an unbiased facilitator of stakeholder consultation and engagement. These activities are crucial to first understanding environmental, economic, and social needs and concerns and then addressing those needs and concerns. While some of the communities involved will be the same for fixed-bottom and floating offshore wind, the potential specific impacts and solutions are likely to be different, reinforcing the need for open dialogue throughout the development process.

There are three DOE activity areas to address FORWARD Objective 3 to inform just, sustainable, and timely development (FORWARD-8, FORWARD-9, and FORWARD-10). They are described as follows.

FORWARD-8: Support community engagement, ocean co-use, and social science

DOE will help evaluate, avoid, minimize, and mitigate the effects of floating offshore wind energy on federal missions, communities, and ocean users in a proactive manner as development planning advances in the United States. Specifically, it seeks to engage with coastal stakeholders and support social science to understand the impacts of floating offshore wind on communities and economies. These activities can promote procedural, recognition, and distributive justice to help reach community consent, project acceptance, and energy justice. Such research and engagement can promote community involvement and understanding, which are crucial to offshore wind energy deployment efforts. Ocean co-use needs, such as federal missions (e.g., radar use, federal stock surveys), commercial and recreational fishing, and other marine activities must be carefully considered and DOE plans to conduct a feasibility assessment of co-locating offshore wind with aquaculture facilities. DOE will focus on the regions and communities where floating offshore wind energy will be developed.

Table 24. FORWARD-DOE Activities to Support Community Engagement, Ocean Co-Use, and Social Science for Floating Offshore Wind Energy Development

Goal	Engage communities in offshore wind energy development planning, socioeconomic analyses, and R&D to increase the opportunities for offshore co-uses; avoid, minimize, and mitigate impacts; identify trade-offs; and increase public acceptance of offshore wind development.
Activities	FORWARD-8.1: Identify communities impacted by floating offshore wind energy development and the socioeconomic impacts on those communities to inform policies and investments. FORWARD-8.2: Establish community engagement structures that prioritize ocean co-use to maintain environmental integrity and coastal livelihoods. FORWARD-8.3: Identify community benefit structures and policies that help coastal communities move toward equitable distribution of costs and benefits of offshore wind energy development. FORWARD-8.4: Provide fact-based information and facilitate regular information exchange with stakeholders to increase support for ocean co-uses. FORWARD-8.5: Establish technical assistance programs to help communities identify trade-offs in offshore wind development and enable a fact-based discourse on offshore wind energy. FORWARD-8.6: Improve understanding of ocean co-use needs and potential impacts of offshore wind energy deployment on fisheries, marine surveys, tribal equities, and other federal missions to inform R&D on impact minimization solutions. FORWARD-8.7: Develop tools and technologies to mitigate impacts from offshore wind energy on radar interference in areas with deep ocean waters.
DOE Offices	WETO, ED, WPTO, LPO
Key Federal Partners	BOEM, NOAA, DOD, DHS, FAA

FORWARD-9: Support environmental research to understand, avoid, minimize, and mitigate risk

Given the newness of commercial-scale development of floating offshore wind energy, both domestically and abroad, there are knowledge gaps regarding the unique impacts of this technology on wildlife, commercially fished species, and the marine environment. Much knowledge can be leveraged from fixed-bottom and pilot-scale offshore wind energy development; as such, DOE will focus research efforts in this area on the novel impacts of floating offshore wind and on the regions where this technology will be developed. DOE aims to support the development of responsible floating offshore wind energy deployment through RD&D activities that are focused on evaluating and developing tools (where needed) to minimize the impacts of floating offshore wind on marine species and environments. DOE will work collaboratively with other federal agencies to support R&D that assesses environmental costs and benefits and develops solutions to mitigate any adverse impacts.

Table 25. FORWARD-DOE Environmental Research Activities to Understand, Avoid, Minimize, and Mitigate Risk From Floating Offshore Wind Energy

Goal	Understand and reduce environmental impacts of floating offshore wind energy deployment in coordination with partner agencies to promote environmental sustainability, ocean co-use, and efficient permitting.
Activities	FORWARD-9.1: Identify priority research needs and gaps associated with U.S.-specific environmental concerns across federal agencies to ensure region-specific environmental sustainability. FORWARD-9.2: Develop and validate wildlife, fisheries, and habitat monitoring and modeling technologies to provide data on wildlife distributions associated with offshore wind energy development. FORWARD-9.3: Improve understanding of transmission and cable routing impacts to reduce effects on wildlife, fisheries, and habitats. FORWARD-9.4: Collect data to fill gaps in baseline knowledge before performing construction in deep-water regions to inform the regulatory siting process. FORWARD-9.5: Improve understanding of environmental impacts of floating offshore wind development to inform impact minimization tools. FORWARD-9.6: Develop and validate impact minimization and mitigation tools to reduce potential harm to wildlife and fisheries. FORWARD-9.7: Disseminate environmental and resource knowledge to stakeholder groups to inform regulatory siting processes.
DOE Offices	WETO, WPTO
Key Federal Partners	BOEM, NOAA, FWS

FORWARD-10: Share data and tools to support the delineation of additional deep-water lease areas

Opening deeper waters to offshore wind energy development enables access to a much greater resource, but the progression of development areas needs to be planned responsibly to avoid unanticipated effects. As a result, more data will be required further offshore, and tools for careful evaluation of siting characteristics that consider the wind resource, costs, marine logistics, and other human and environmental uses will be needed. DOE can play a critical role in informing these siting decisions through its unique combination of RD&D capabilities in the areas of technology development, economics, wind resource, and infrastructure. DOE has the data collection, analysis, and modeling expertise across different disciplines to provide informed and independent data to the site delineation process.

Table 26. FORWARD-DOE Activities to Support Lease Area Delineation for Floating Offshore Wind Energy

Goal	Collect and analyze data to further support informed decisions about offshore wind lease area delineation for floating facilities.
Activities	FORWARD-10.1: Develop tools and methods and collect siting data to help identify the best-suited locations for floating offshore wind energy. FORWARD-10.2: Provide technical support for monitoring and lease area development to identify the best-suited locations for floating offshore wind energy.
DOE Offices	WETO, SC
Key Federal Partners	BOEM, NOAA

Shared Activities of Research Between NOW and FORWARD

While focused on fixed-bottom (NOW) and floating (FORWARD) offshore wind energy technologies, respectively, there are many areas of research that are shared between the two initiatives (Figure 13). While some of the identified RD&D efforts are substructure-specific, many others are cross-cutting in nature. The regional focus of fixed-bottom and floating offshore wind energy deployment will also guide the timing of the efforts described in NOW and FORWARD.

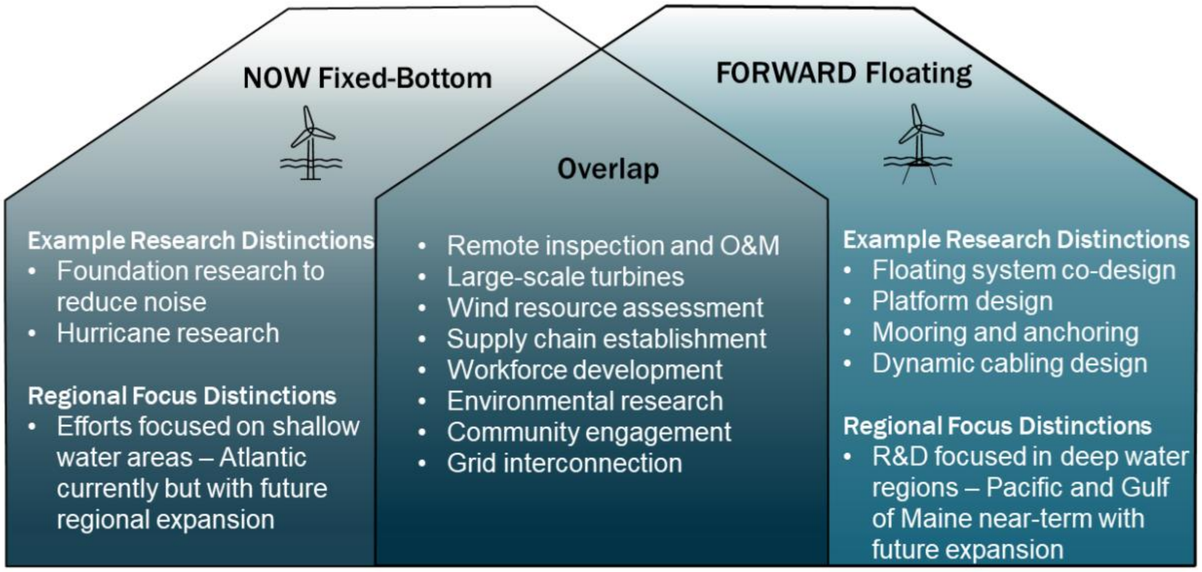

Figure 13. Shared activities of research between NOW and FORWARD
Note: O&M = operations and maintenance

CONNECT: Transmission solutions for large-scale offshore wind energy deployment

CONNECT aims to facilitate the transmission infrastructure development necessary to interconnect and integrate offshore wind energy into the U.S. power grid and enhance the reliability and resilience of the power system. In most U.S. regions, coastal bulk transmission is not equipped to accommodate a utility-scale injection of offshore wind.

Key efforts within CONNECT include:

- Supporting regional transmission planning and coordination to identify practicable pathways to integrate more than 110 GW of offshore wind energy by 2050.
- Providing technical assistance for transmission planning and technical readiness to regional planning entities and communities.
- Advancing high-voltage direct current (HVDC) technologies, control systems, and power electronics to increase energy output and the range of services from offshore wind and support reliable grid operations.
- Supporting the development of U.S. standards to operate offshore wind grids.
- Providing financial support through loans, grants, and other financing mechanisms to facilitate infrastructure development.
- Coordinating with and furthering the critical work being done by the Building a Better Grid Initiative to modernize the onshore grid.

CONNECT-1: Coordinate and inform transmission development

To integrate large amounts of electricity from offshore wind, shared offshore wind transmission will need to be developed along U.S. coastlines and connected to the broader land-based grid, requiring onshore upgrades. To do this in a timely, cost-effective manner that enhances overarching system reliability and resilience, analysis of future offshore wind topologies and their costs, benefits, and siting options is needed. To develop this transmission, particularly interregional transmission, coordination is needed among a complex set of stakeholders, with DOE helping convene those entities to carve out a path forward. With the industry facing challenges such as long development timelines, supply chain concerns, and limited corridors and interconnection points, interregional planning will increase cost effectiveness by evaluating a larger set of transmission needs over the long term. This comprehensive, integrated approach will also bring a sustained focus on affected stakeholder groups to make sure planning is done in an equitable way, like reducing onshore impact by identifying existing federal land and interconnection coordination, sharing of wind energy lease revenues, and exploring community benefit agreements.

Table 27. CONNECT-DOE Activities to Coordinate and Inform Transmission Development

Goal	Convene and coordinate planning efforts for the design and construction of an offshore wind transmission network(s); such a network will serve both individual projects and regional power markets, inform the benefits and costs of transmission options, and reduce use conflicts.
Activities	CONNECT-1.1: Convene parties within regions to facilitate transmission solutions that allow for 30 GW of offshore wind energy by 2030 and 110 GW or more by 2050. CONNECT-1.2: Develop recommendations, action plans, and road maps for offshore wind transmission planning, permitting, and policy to identify practicable pathways, trade-offs, and opportunities for offshore transmission development. CONNECT-1.3: Support equity by encouraging allocation of economic costs and benefits of transmission development among affected stakeholder groups and providing technical assistance to maximize the benefits to communities.
DOE Offices	WETO, ED, Grid Deployment Office (GDO), Office of Electricity (OE), SCEP
Key Federal Partners	BOEM, FERC

CONNECT-2: Develop optimized transmission infrastructure solutions

To develop offshore wind transmission in a timely, cost-effective manner that enhances overarching system reliability and resilience, analysis of future offshore wind topologies and their costs, benefits, and siting options is needed. Modeling different transmission scenarios is a complex process that relies on high-quality data and an understanding of power systems. The infrastructure that is needed to effectively implement these scenarios is costly and has a long lead time for development, requiring a clear plan across a wide geographic area and over time. DOE has the national transmission system's perspective and access to climate research that can help develop resilient scenarios for the future, as well as the associated infrastructure. When designed thoughtfully, the transmission needed to interconnect offshore wind resources can add new system capabilities and reduce costs to ratepayers. Interregional, meshed-connection transmission topology can be particularly impactful for offshore wind integration because of its potential to reduce the overall amount of transmission infrastructure offshore while improving system reliability and reducing large electricity price disparity between neighboring regions. DOE is also able to support standards development including standard functional requirements and standard designs that can enable future offshore grid expansion, as one-off designs are not going to be viable to meet long-term deployment goals. Standardization for transmission components promotes interoperability and reduces burden on the supply chain. It also lowers overall system cost for ratepayers, because using standard rated equipment minimizes the need for transformers and substation equipment on offshore platforms.

Table 28. CONNECT-DOE Activities to Develop Transmission Solutions

Goal	Collect data and conduct analysis to inform regional transmission development tailored toward local infrastructure needs for offshore wind energy and support transmission development.
Activities	CONNECT-2.1: Analyze scenarios for an integrated transmission system that can accommodate more than 110 GW of offshore wind energy and provide topology and interconnection priorities to transmission planners. CONNECT-2.2: Assess grid resilience during extreme weather and geological events that might affect offshore wind energy. CONNECT-2.3: Support the development of U.S. standards to operate an offshore wind grid.
DOE Offices	WETO, GDO, OE, SCEP, LPO
Key Federal Partners	BOEM, FERC

CONNECT-3: Ensure a cybersecure, reliable, and resilient grid

The security, reliability, and resiliency of the transmission system is critical to keep society functioning safely. Offshore wind control systems continually need to be updated and refined to increase their ability to support the grid by providing a variety of services. The transmission grid must operate reliably and resiliently under various conditions with increasing levels of offshore wind energy. DOE has experience with power system security and can support cutting-edge research to ensure the transmission system remains secure while identifying potential threats (physical and cyber) to the system and solutions to make the whole system more resilient. In addition to improving offshore wind control systems, it will be important to recommend modifications to North American Electric Reliability Corporation reliability standards are implemented by transmission planners and system operators, in the context of offshore transmission. This will be key for upgrading our existing standards to keep them relevant in new, offshore applications, but to also design new standards around multiterminal HVDC.

Table 29. CONNECT-DOE Activities to Ensure a Cybersecure, Reliable, and Resilient Grid

Goal	Develop technologies and strategies to increase the performance, reliability, and resiliency of onshore and offshore wind transmission systems.
Activities	CONNECT-3.1: Advance control systems and wind turbine power electronics to increase offshore wind energy's ability to support reliable grid operation. CONNECT-3.2: Enhance onshore and offshore transmission network reliability under various grid conditions to deliver offshore grid energy services when needed. CONNECT-3.3: Improve physical and cybersecurity tools and practices to avoid outages. CONNECT-3.4: Evaluate equitable market rules for offshore wind energy to provide a full suite of services to the power system.
DOE Offices	WETO, OE, GDO, Office of Cybersecurity, Energy Security, and Emergency Response
Key Federal Partners	FERC

CONNECT-4: Develop critical transmission technologies

Support of innovation and infrastructure development to promote transmission reliability in U.S. conditions is well-aligned with DOE's mission to stimulate fundamental and long-term technology solutions, where feasible, in collaboration with industry. This research will answer questions such as whether and how the power density of a HVDC converter and power rating of subsea cables (including dynamic cables) can be further increased, and how costs can be further reduced to facilitate technology adoption. The research activities will also develop standards for the offshore wind energy grid of the future and incentivize innovation and competition in offshore equipment manufacturing. These efforts will lead to the development of proper financing mechanisms that can motivate domestic transmission manufacturing investment, which is critical for U.S. offshore wind energy deployment at scale.

Table 30. CONNECT-DOE Activities to Develop Transmission Technologies

Goal	Develop technologies to increase the performance and reliability of offshore wind transmission and support the use of loans to facilitate the development of critical cables (high-voltage direct current [HVDC]), substations, and electrical infrastructure.
Activities	CONNECT-4.1: Advance HVDC and other power electronics applications to increase the energy output and range of services from offshore wind energy. CONNECT-4.2: Improve planning, design, installation, and maintenance for electrical cables and offshore substations to reduce energy losses, increase community acceptance, and increase reliable operations in harsh ocean environments. CONNECT-4.3: Develop interoperability standards to facilitate more competitive product selection and support expansion. CONNECT-4.4: Optimize dynamic cables and floating substation designs to reduce costs and enable floating offshore wind energy in deep waters. CONNECT-4.5: Identify and finance critical transmission manufacturing investments to enable more than 110 GW of offshore wind by 2050.
DOE Offices	WETO, OE, AMMTO, LPO, GDO, ARPA-E
Key Federal Partners	BOEM, FERC

TRANSFORM: Expanded offshore wind co-generation technologies

Economywide decarbonization requires vast amounts of zero-carbon energy. Therefore, the TRANSFORM initiative will advance offshore wind co-generation technologies, also known as wind-to-X technologies, which use offshore wind energy to produce another energy solution, such a hydrogen co-generation, in support of widespread electrification and a net-zero economy. Offshore wind holds the potential to be a key enabler of this transition because it can be deployed at utility scale and coupled (onshore or offshore) with other clean energy technologies. Several advances in technology and coupling with storage, hydrogen, and fuels production are needed to make full decarbonization a reality.

Key efforts within TRANSFORM include:

- Conducting techno-economic analyses to identify the use cases and trade-offs from offshore-wind-coupled storage, hydrogen, and clean fuels production.
- Advancing the efficiency and safety of hydrogen conversion and other wind-to-X production systems from offshore wind energy.
- Supporting the demonstration and development of coupled offshore wind storage, hydrogen, and wind-to-X production systems.
- Evaluating the feasibility and supporting the development of offshore wind energy hubs in the United States.

TRANSFORM-1: Advance and demonstrate offshore wind energy storage solutions

Integrating effective energy storage solutions with offshore wind plants will enable more widespread and efficient deployment of offshore wind. As offshore wind energy is variable and uncertain in nature and potentially subject to curtailment, there is a need to understand the cost and benefit of potential designs that incorporate storage alternatives with offshore wind energy and how to make these designs more efficient under a variety of conditions and power markets. DOE has the expertise to identify and support feasible and flexible energy storage solutions and their potential impacts.

Table 31. TRANSFORM-DOE Activities to Advance Offshore Wind Energy Storage Systems

Goal	Enable widespread adoption of coupled offshore wind storage systems to help balance electricity production and demand and increase the value of offshore wind energy to the power system.
Activities	TRANSFORM-1.1: Conduct techno-economic analysis of offshore wind energy storage systems to inform their economic deployment. TRANSFORM-1.2: Support the development of coupled offshore wind storage system designs to extend their use cases and performance in different power markets. TRANSFORM-1.3: Demonstrate coupled offshore wind storage systems to show their technical viability and performance. TRANSFORM-1.4: Support the deployment of coupled offshore wind storage systems to help ensure financial investments.
DOE Offices	WETO, OE, OCED, LPO
Key Federal Partners	BOEM

TRANSFORM-2: Advance and demonstrate wind-to-X technologies

Converting the electricity generated from offshore wind into hydrogen or other clean fuels can help decarbonize the transportation, industrial, and agricultural sectors. There is a need for additional research on various wind-to-X technologies to identify the best use cases at different locations, and increase generation process efficiency, reliability, and safety. Specific R&D challenges include optimizing shared components and controls and innovating overall, integrated offshore plant designs to enable more cost-efficient solutions. DOE understands the processes involved in safely converting different forms of energy and can work closely with other government agencies to assess the effectiveness of offshore uses. Efforts are coordinated with activities outlined in the *DOE National Clean Hydrogen Strategy and Roadmap*, which responds to legislative language set forth in Section 40314 of the Bipartisan Infrastructure Law and published in September 2022 as a draft for public comment.[85]

[85] DOE. 2022. *DOE National Clean Hydrogen Strategy and Roadmap (Draft)*. https://www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html.

Table 32. TRANSFORM-DOE Activities to Advance Wind-to-X Technologies

Goal	Optimize wind-to-X technologies that can transition industry and agriculture to full decarbonization, increasing the value and revenue opportunity to the power, industrial, agricultural, transportation, and building sectors.
Activities	TRANSFORM-2.1: Conduct techno-economic analysis of hydrogen and other clean fuels to inform its economic deployment as well as hybridization strategies at different locations TRANSFORM-2.2: Advance the efficiency and safety of hydrogen and other clean fuels production from offshore wind energy to increase the spectrum of potential use cases. TRANSFORM-2.3: Advance other technologies powered by offshore wind energy to support decarbonization in industry and agriculture. TRANSFORM-2.4: Demonstrate offshore wind-to-X applications at scale to show their technical viability and performance. TRANSFORM-2.5: Finance and support the deployment of wind-to-X applications at scale to show the technical feasibility of the technology.
DOE Offices	WETO, HFTO, OCED, LPO
Key Federal Partners	BOEM

TRANSFORM-3: Evaluate the feasibility and, if appropriate, support the development of offshore wind energy hubs

Co-locating offshore wind energy operation and maintenance bases with transmission, fuel conversion facilities (e.g., wind-to-X), and other maritime uses can reduce the cost of offshore wind and optimize ocean spatial use (and avoid terrestrial land use). There is a need to understand the value of offshore energy hubs at different locations and the interaction and facility needs of different hub applications. Through initial research to potential demonstration projects and funding, the value of energy islands, which are where multiple facilities are co-located, can be assessed and informed decisions made for future developments.

Table 33. TRANSFORM-DOE Activities to Advance Offshore Wind Energy Hubs

Goal	Conduct feasibility studies and RD&D to enable regional offshore wind energy hubs that jointly serve the offshore wind, transmission, and maritime economy sectors to reduce costs and ocean space needs.
Activities	TRANSFORM-3.1: Analyze the techno-economic feasibility of and regional needs for offshore wind energy hubs to evaluate trade-offs and coordinate planning. TRANSFORM-3.2: Conduct R&D that lowers costs and increases efficiency of hubs, optimizing energy and space use through wind energy incorporated with other technologies. TRANSFORM-3.3: Demonstrate and coordinate offshore wind energy hubs to show their technical feasibility. TRANSFORM-3.4: Support financing to facilitate offshore wind energy hub development.
DOE Offices	WETO, HFTO, OCED, LPO, ARPA-E
Key Federal Partners	BOEM

7 Regional Research Strategies

Each coastal region of the United States has a unique set of ecological, geological, social, and economic characteristics that influence offshore wind energy deployment. These regional attributes inform many aspects of offshore wind deployment, including the type of technology, lease sale sequencing, supply chain and transmission infrastructure, and socioeconomic and environmental concerns. In many cases, regional characteristics lead to specific wind turbine technology needs, such as hurricane risk, sediment type, icing conditions, water depth, and oceanographic and atmospheric conditions. While much of the work that DOE supports is national in scope, this strategy also seeks to address these regional R&D, community, and economic development needs. This section describes the focus and sequencing of proposed DOE offshore wind energy activities that meet regionally specific needs. The sequencing of the activities presented in this strategy document is informed by a range of considerations, including BOEM.

leasing plans and regional deployment potential influenced by resource and market potential. This strategy also attempts to be forward-looking and proactive. DOE has a role to play in helping advance future technologies and encourage new potential deployment by reducing technology costs and addressing barriers.

North Atlantic and Mid-Atlantic

This region is characterized by an abundant wind resource in both shallow (<60 m) and deep (>60 m) waters. The lease areas released up to mid-2022 have all been suitable for fixed-bottom technologies in the shallower areas and are primarily located in the North Atlantic. The Mid-Atlantic is expected to follow, as BOEM has proposed lease sales in 2023. Given the immediacy of fixed-bottom offshore wind energy development in the North and Mid-Atlantic, a portion of the activities in the NOW and CONNECT initiatives will apply to or focus on this region, particularly those aimed at addressing near-term deployment challenges (Figure 14). For example, DOE aims to support environmental research in this region, particularly aimed at reducing impacts to commercial fisheries and protected species (e.g., the North Atlantic right whale). Given that this region will have the first commercial-scale offshore wind plants, DOE will seek to address related supply chain and transmission needs. DOE is also actively working on R&D to address floating offshore wind needs in the Gulf of Maine, with a growing focus on addressing issues related to commercial-scale deployment in the future.

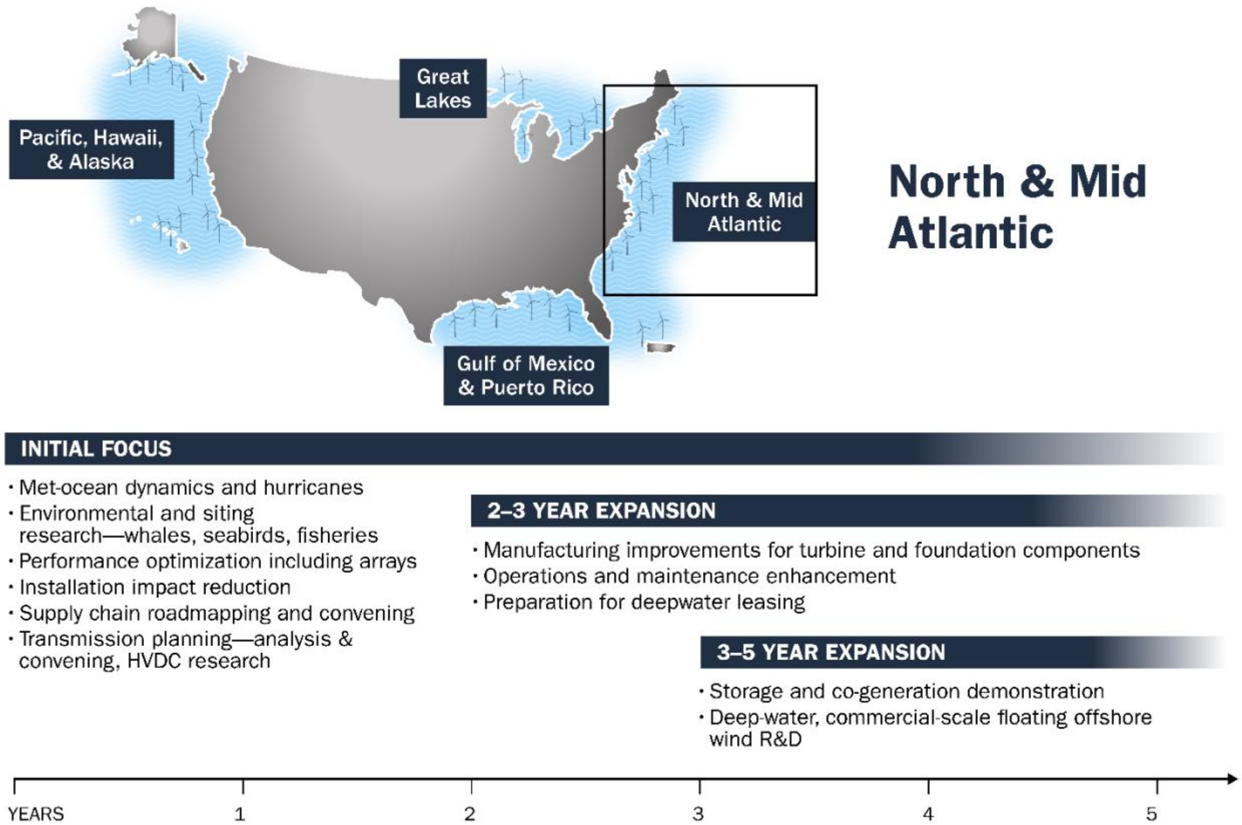

Figure 14. Regional needs and areas of potential research in the North and Mid-Atlantic.
Figure created by NREL

Pacific, Hawaii, and Alaska

This region is mainly characterized by very deep waters that will require floating offshore wind energy technologies. As BOEM has already initiated the lease sale process off the coast of California, this region will likely host the first floating offshore wind plants in the United States and is planning for future lease sales off Oregon in 2023. Alaska has a large amount of offshore wind resource, but also has significant land-based wind resources, which limits market demand for offshore wind energy. To address deep-water, floating offshore wind challenges, the FORWARD initiative includes many of the floating-specific activities needed to support environmental, supply chain, and transmission development research in this region (Figure 15). DOE also proposes a major focus on technology development cost reduction and needs surrounding floating platforms and mooring and anchoring systems in deep waters. As planning for floating offshore wind energy advances in Hawaii, DOE will support R&D to help inform the cost-effective, just, and sustainable development of this technology in this region.

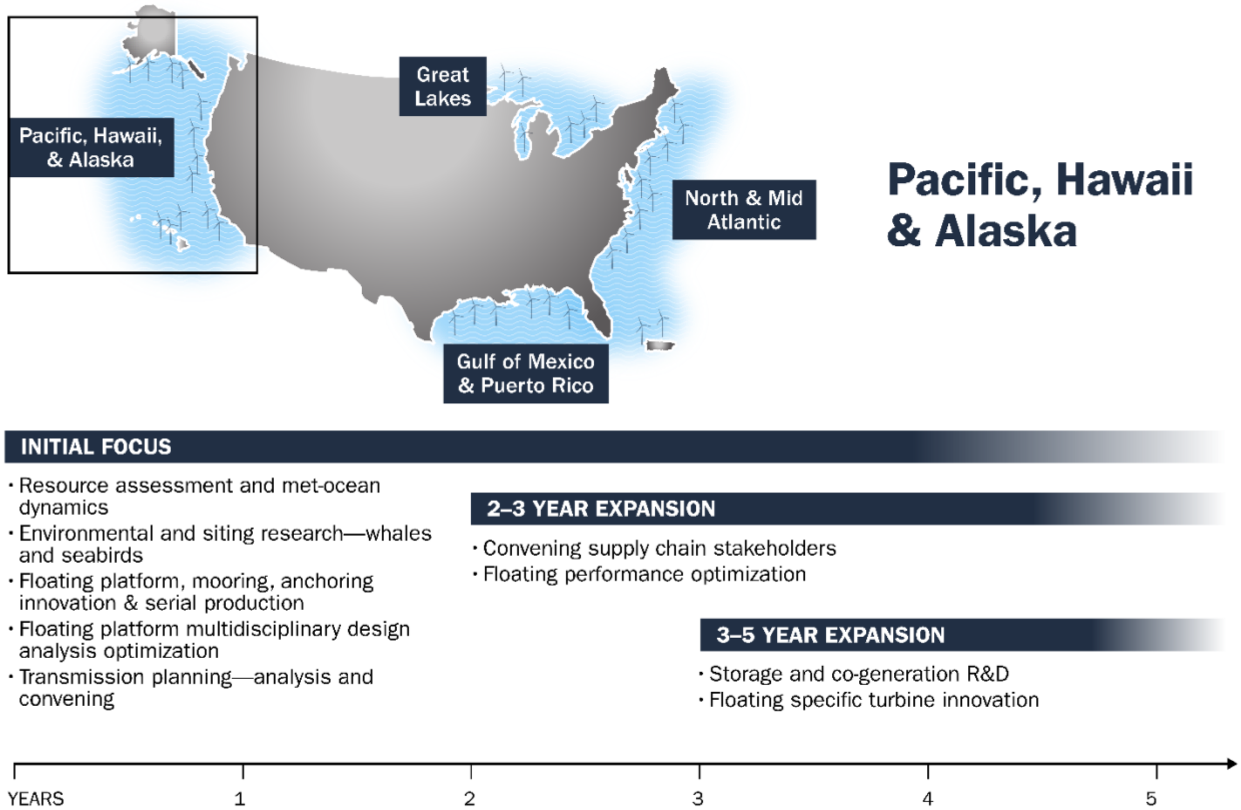

Figure 15. Regional needs and areas of potential research in the Pacific, Hawaii, and Alaska.
Figure created by *NREL*

Gulf of Mexico and Puerto Rico

This region is characterized by an abundant wind resource in both shallow (<60 m) and deep (>60 m) waters, which will require fixed-bottom and floating technologies to develop fully. Most near-term development in the Gulf of Mexico is likely to be focused on fixed-bottom resources, given their current lower costs. While these regions do not yet have active lease sales, BOEM plans to auction lease areas in the Gulf of Mexico in early 2023. Early efforts in this region will focus on initial techno-economic and environmental analyses to prepare the region for potential deployment (Figure 16). This region is prone to harsh hurricanes and low soil strength, both of which are critical wind turbine and array design considerations. Creating a supply chain road map will help promote efficient infrastructure development and include existing oil-and-gas infrastructure that may be repurposed. This region's history in oil and gas may help facilitate co-generation technologies and transmission solutions by using existing pipelines. Activities in each initiative will also support environmental research in this region, particularly associated with commercial and recreational fisheries and migratory birds. DOE has been evaluating the potential for offshore wind energy development off Puerto Rico as part of a larger energy assessment for the island.[86] BOEM was given new authority under the Inflation Reduction Act, which allows for lease sales in Puerto Rico waters, much of which is deep enough for floating offshore wind energy.[87]

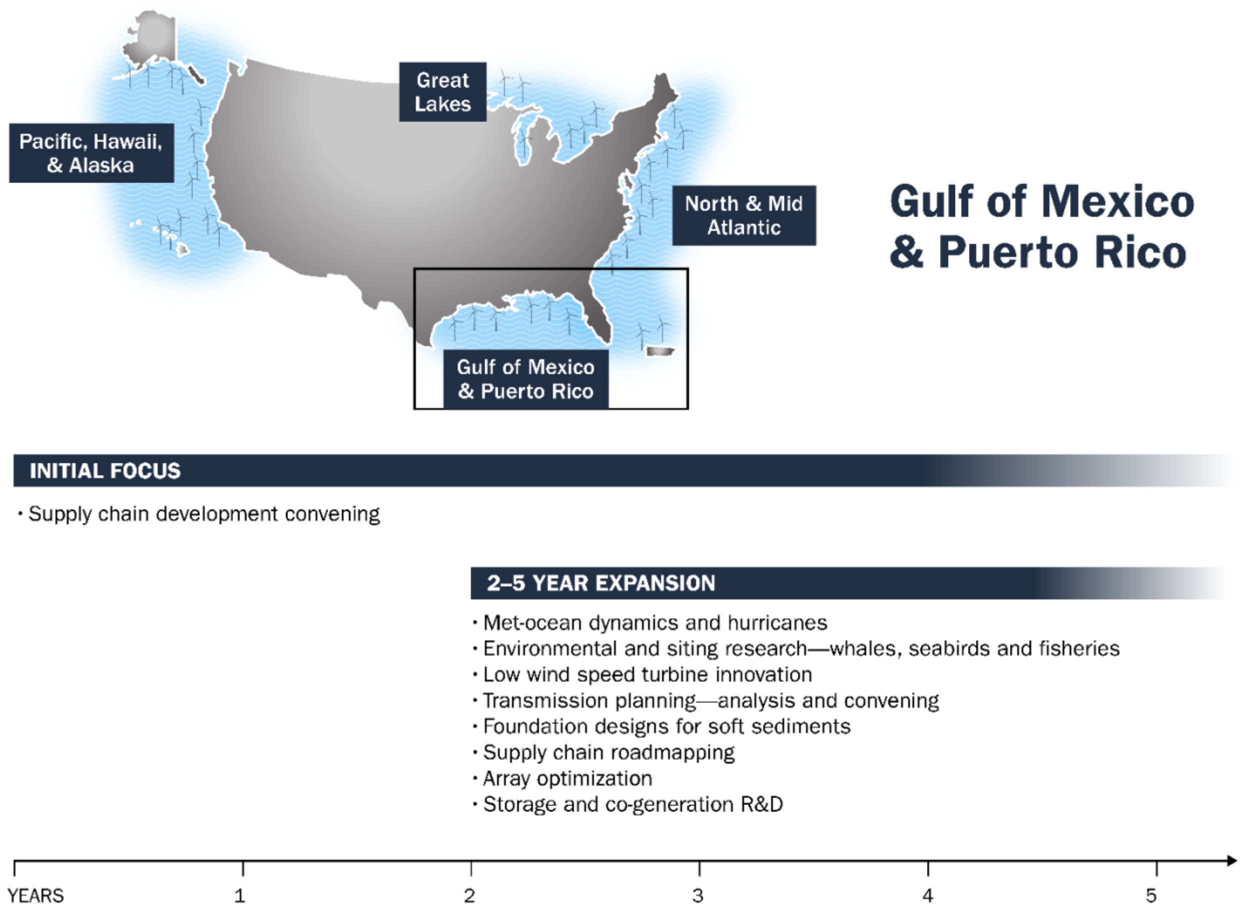

Figure 16. Regional needs and areas of potential research in the Gulf of Mexico and Puerto Rico.
Figure created by NREL

Great Lakes

This region is unique because it is landlocked and not leased under BOEM jurisdiction, but rather under individual states' jurisdictions, with the Army Corps of Engineers leading National Environmental Policy Act assessments for areas outside of state waters. Lake Erie is broadly suitable for fixed-bottom technologies, whereas the other lakes will generally require floating technologies for projects that are not near the shore. Early efforts in this region will focus on initial techno-economic and environmental analyses to consider and inform potential deployment

[86] Duffy, P., G. Zuckerman, T. Williams, A. Key, L. Martinez-Tossas, O. Roberts, N. Choquette, J. Yang, H. Sky, N. Blair. 2022. *Wind Energy Costs in Puerto Rico Through 2035*. NREL/TP-5000-83434. https://www.nrel.gov/docs/fy22osti/83434.pdf.
[87] Inflation Reduction Act of 2022. H.R.5376. Section 50251 (43 U.S.C. 1331). 117th Congress. 2022. https://www.congress.gov/bill/117th-congress/house-bill/5376/text.

in the region (Figure 17). This region is prone to seasonal icing and challenging benthic conditions (e.g., soft sediments and bedrock). The supply chain is somewhat constrained by the Great Lakes Seaway, which is a series of locks that will limit vessel size. As a result, if there are no dedicated wind turbine installation vessels for the Great Lakes or advancements in vessel or wind turbine technologies, the size of turbines that can be deployed and the economies of scale in this region will be limited. Therefore, both attributes must be carefully considered in wind turbine and array design research, as well as supply chain analyses.

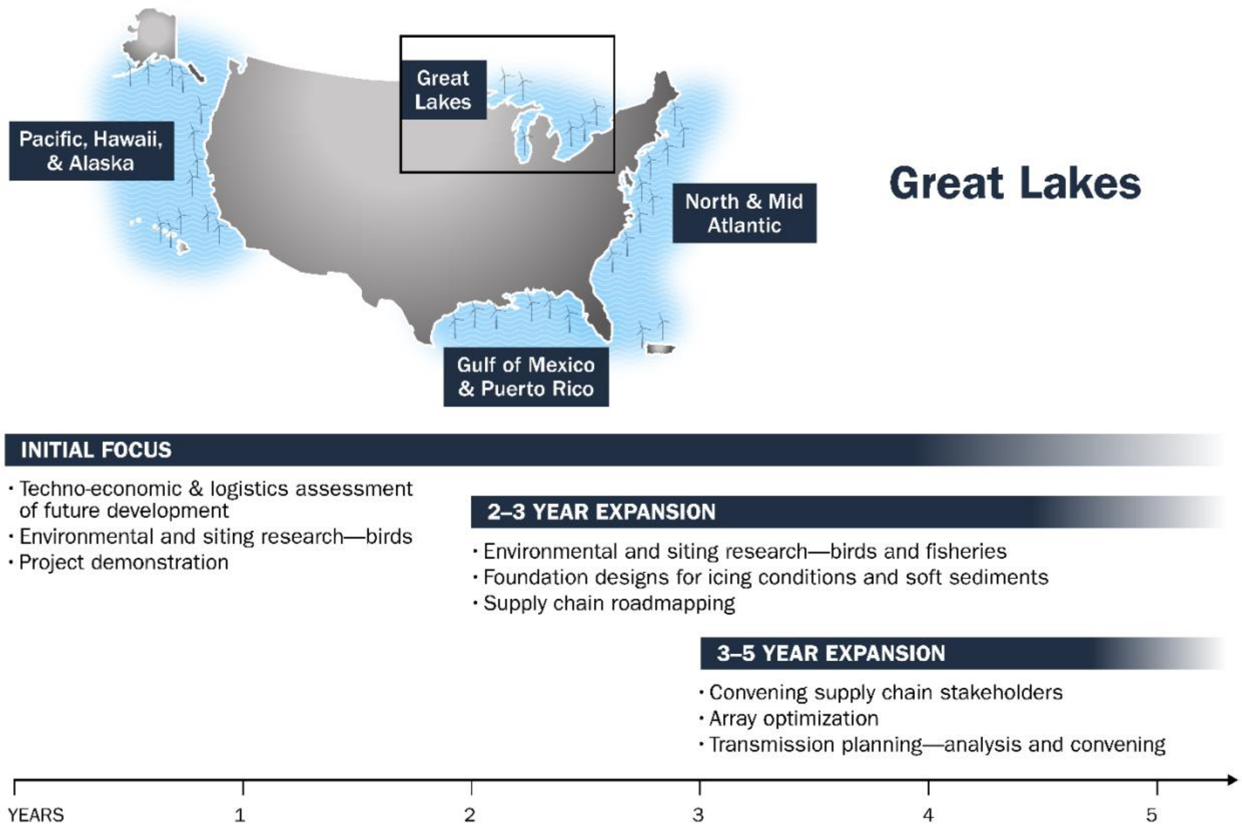

Figure 17. Regional needs and areas of potential research in the Great Lakes. *Figure created by NREL*

8 Conclusion

Offshore wind energy has a great opportunity to support the Biden administration's clean energy and decarbonization goals. With this strategy, DOE seeks to accelerate the development of U.S. offshore wind to deploy 30 GW by 2030 and establish a pathway to deploying 110 GW or more by 2050.[88] As part of this pathway, DOE also supports deploying 15 GW of floating offshore wind capacity by 2035.[89] In order to unlock offshore wind energy's full potential, DOE must continue to address both national-scale and regionally specific needs, including efforts to catalyze cost reductions, develop transmission solutions, promote efficient supply chain development, minimize impacts on the marine environment and ocean co-users, and ensure benefits to local communities.

This strategy provides a pathway to maximize opportunities while addressing challenges to building a cost-effective, reliable, and sustainable offshore wind energy industry. The four initiatives highlighted in this document—NOW, FORWARD, CONNECT, and TRANSFORM—focus on different aspects of offshore wind energy, which all need support to achieve their goals. Developing fixed-bottom and floating technologies, the transmission system, and future co-generation and energy storage can build a thriving supply chain, provide good-paying and secure jobs that are inclusive, and expand the domestic workforce. Combined with environmental sustainability, energy justice, and community engagement efforts, offshore wind can generate clean energy in a responsible manner. Ultimately, through the initiatives outlined in this document, DOE seeks to accelerate the growth of the offshore wind industry, building the capabilities and domestic workforce needed to make the United States a global leader and ensure that offshore wind is an integral part of the nation's clean energy future.

[88] 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.

[89] The White House. 2022. "FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy." https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy.

Appendix A. U.S. Department of Energy Roles

U.S. Department of Energy Contributions

Advance New Technology Solutions

Many of the challenges to meet the U.S. offshore wind energy goals can be addressed through accelerated technology innovation. Directing funds to the most promising innovation areas is at the core of the U.S. Department of Energy's (DOE) jurisdictional powers and capabilities. DOE's national laboratories, along with universities and research institutions, can address those fundamental science and technological challenges that present exceedingly high-risk investments for private sector entities yet can deliver high-impact solutions.

Coordinate Federal, State, Local, and Tribal Energy Planning

DOE can coordinate a whole-of-government effort to advance offshore wind energy development. The success of this strategy relies on DOE partnering and coordinating with numerous federal, state, local, and tribal government agencies and organizations; domestic and international private and public energy sectors; and DOE's national laboratories.

Provide Technical Assistance

DOE and the national laboratories, by drawing on their expertise and research, can provide technical assistance to federal, state, local, and tribal government agencies and organizations, as well as stakeholder groups, to inform the just and sustainable development of offshore wind energy. In this sector, DOE has a special role in providing technical assistance to the Bureau of Ocean Energy Management to inform the bureau's leasing and permitting activities.

Demonstrate Technical Feasibility

DOE has a history of successful demonstration projects that show the technical feasibility of new technologies. These projects help bridge basic science and in-field testing and are critical to exposing innovations to physical conditions as well as collecting performance data and demonstrating feasibility to investors.

Support Bankability and Commercial Deployment

While significant capital is available for decarbonization technologies, projects can still lack access to adequate funding. DOE's Loan Programs Office fills this gap in commercial deployment by serving as a bridge to bankability for innovative and high-impact energy technologies, providing companies with access to needed loans and loan guarantees when private lenders cannot or will not provide funding until a given technology has reached full market acceptance.

Appendix B. U.S. Department of Energy Offices

This section summarizes the missions and capabilities of the various offices within the U.S. Department of Energy (DOE) that have a role in offshore wind energy development. Areas where each office is currently engaged or could be engaged in offshore wind deployment are highlighted.

Advanced Materials and Manufacturing Technologies Office

The Advanced Materials and Manufacturing Technologies Office (AMMTO) is dedicated to improving the energy and material efficiency, productivity, and competitiveness of manufacturers across the industrial sector. Deployment of offshore wind energy requires a robust U.S. supply chain that will rely heavily on state-of-the-art manufacturing practices and facilities. AMMTO can leverage many of its areas of expertise, existing projects, and research facilities to contribute to a variety of offshore wind energy manufacturing needs, including wind turbine blade manufacturing, component production, assembly and installation methods, and wind turbine recycling. For example, the Institute for Advanced Composites Manufacturing Innovation has ongoing projects related to carbon-fiber and composite research for longer, more recyclable blades.[90] Ongoing efforts related to process and production design at Oak Ridge National Laboratory's Manufacturing Demonstration Facility[91] can be expanded upon to include offshore wind manufacturing needs for production in ports and at sea. The research and development performed by AMMTO will help facilitate the technology improvements needed to not only manufacture wind turbine systems at scale but also contribute to more efficient, lower-cost designs.

Advanced Research Projects Agency-Energy

The Advanced Research Projects Agency – Energy's (ARPA-E's) mission is to decrease the nation's dependence on foreign energy sources, reduce greenhouse gas emissions, improve energy efficiency, and maintain or reestablish U.S. scientific leadership in the energy sector. By funding high-risk, high-reward projects, ARPA-E seeks to accelerate the development of transformative technologies by mitigating the key technical risks that limit private sector investment. ARPA-E is already active in offshore wind energy development research, specifically floating offshore wind, through its Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS) program.[92] ATLANTIS seeks to design radically new floating offshore wind turbines by using control co-design techniques to maximize the rotor-area-to-total-weight ratio while maintaining or ideally increasing wind turbine generation efficiency and reducing operational expenses; building a new generation of computer tools to facilitate floating offshore wind turbine design; and collecting real data from full- and lab-scale experiments to validate floating offshore wind turbine designs and computer

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[90] Institute for Advanced Composites Manufacturing Innovation. Undated. "Project Reports." https://iacmi.org/innovation/project-reports.
[91] Oak Ridge National Laboratory. Undated. "User Facilities: Manufacturing Demonstration Facility." https://www.ornl.gov/facility/mdf.
[92] Advanced Research Projects Agency- Energy. 2019 "Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control." https://arpa-e.energy.gov/technologies/programs/atlantis.

tools. Many other ARPA-E programs may contribute to technology advancements relevant to offshore wind energy research, including the Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely and Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors programs, which will help address offshore wind transmission and grid integration challenges.

Office of Cybersecurity, Energy Security, and Emergency Response

The Office of Cybersecurity, Energy Security, and Emergency Response (CESER) addresses the emerging threats of tomorrow while protecting the reliable flow of energy to Americans today by improving energy infrastructure security and supporting DOE's national security mission. CESER's focus is preparedness and response activities to natural and man-made threats, ensuring a stronger, more prosperous, and secure future for the nation. CESER's work can be readily applied to offshore wind transmission needs to help ensure reliable integration of offshore wind energy into the grid.

Grid Deployment Office

The Grid Deployment Office (GDO) works to provide electricity to everyone, everywhere, by maintaining and investing in critical generation facilities to ensure resource adequacy, and by improving and expanding transmission and distribution systems. GDO was established in 2022; its Building a Better Grid Initiative administers Bipartisan Infrastructure Law and Inflation Reduction Act funds.[93] GDO activities are focused on large-scale deployment of established transmission and energy technologies required to address transmission needs across the country. It leads the National Transmission Planning studies and interregional and offshore wind transmission planning efforts, and helps lead the Offshore Wind Transmission studies, and convenes stakeholders.

Hydrogen and Fuel Cell Technologies Office

The mission of the Hydrogen and Fuel Cell Technologies Office (HFTO) is to enable the development of a portfolio of hydrogen and fuel cell technologies through applied research and technology development and demonstration, and to support diverse efforts to overcome institutional and market challenges. There is a growing interest in producing hydrogen from offshore wind energy to reduce the carbon footprint of hydrogen production, provide an alternative energy source in coastal regions, reduce transmission needs, and provide fuel to the marine industry sector. HFTO has the expertise to advance and optimize hydrogen production technologies from offshore wind energy. Research on hydrogen applications is already underway in HFTO's H2@Scale program, which aims to help develop offshore wind installation and service vessels that use hydrogen fuels.[94] HFTO is also a primary contributor in DOE's

[93] U.S. Department of Energy (DOE). 2022. "Building a Better Grid Initiative to Upgrade and Expand the Nation's Electric Transmission Grid to Support Resilience, Reliability, and Decarbonization." https://www.energy.gov/sites/default/files/2022-01/Transmission%20NOI%20final%20for%20web_1.pdf.
[94] DOE. Undated. "H2@Scale: Enabling affordable, reliable, clean, and secure energy across sectors." https://www.energy.gov/eere/fuelcells/articles/h2scale-handout.

Hydrogen Shot, a massive initiative that seeks to reduce the cost of hydrogen through production efficiency and market demand, to which offshore wind energy could contribute.

Loan Programs Office

The Loan Programs Office (LPO) serves as a bridge to bankability for innovative and high-impact energy technologies, providing them with access to needed loans and loan guarantees when private lenders cannot or will not provide funding until a given technology has reached full market acceptance. As a burgeoning industry, offshore wind energy has many areas that may benefit from federal loan guarantees, including supply chain facilities, offshore wind installation and service vessels, transmission infrastructure, and others. LPO can support the industry by financing first-of-a-kind production or manufacturing (that commercial banks will not) to prove that the technology is viable, and that the technical and commercial risk can be managed. The LPO's Title 17 Innovative Clean Energy Loan Guarantee Program[95] requires that projects avoid, reduce, utilize, or sequester greenhouse gas or air pollutant emissions, whereas the Advanced Technology Vehicles Manufacturing program,[96] provides loans for establishing manufacturing facilities for advanced technology vehicles that demonstrate improved fuel economy, which, subject to future DOE rulemaking, is expected to include marine vessels and other heavy duty-vehicles that could support manufacturing, transport, and installation for offshore wind.

Office of Clean Energy Demonstrations

The mission of the Office of Clean Energy Demonstrations (OCED) is to deliver clean energy technology demonstration projects at scale in partnership with the private sector to accelerate deployment, market adoption, and the equitable transition to a decarbonized energy system. There are many opportunities for demonstration projects to promote the offshore wind energy industry, including wind turbine system innovations (especially regarding floating platforms), transmission technology infrastructure, offshore wind energy storage systems, hydrogen co-generation technologies, and offshore wind energy hubs. Each of these areas are ripe for innovation and would benefit from a demonstration project, which would help validate technologies and establish market demand.[97]

Office of Economic Impact and Diversity

The mission of the Office of Economic Impact and Diversity (ED) is to identify and implement ways of ensuring that everyone is afforded an opportunity to participate fully in DOE's programs, opportunities, and resources. Energy justice and equity are critical to offshore wind energy deployment, as wind farms can provide energy security and economic prosperity to engaged communities. However, careful consideration must be taken to ensure that there is fair distribution of the costs and benefits of offshore wind energy development that actively promotes procedural, recognition, and distributive justice to help reach community consent, project

[95] DOE. Undated. "Innovative Clean Energy Loan Guarantees." https://www.energy.gov/lpo/innovative-clean-energy-loan-guarantees.
[96] DOE. Undated. "Advanced Technology Vehicles Manufacturing Loan Program." https://www.energy.gov/lpo/advanced-technology-vehicles-manufacturing-loan-program.
[97] OCED does not currently have authorization and appropriations for these activities.

acceptance, and energy justice. ED can provide guidance on best practices for the various areas of development including siting (e.g., wind facility, supply chain, and transmission infrastructure), workforce development, and ocean co-user coordination, among others. ED's Justice40 initiative focuses on disadvantaged communities that are disproportionally challenged by previous energy sourcing, climate change, energy burdens, and socioeconomic vulnerabilities.[98] Many of the coastal communities that will be most engaged in offshore wind energy development are considered disadvantaged communities, therefore the Justice40 initiative priorities will be implemented.

Office of Electricity

The mission of the Office of Electricity (OE) is to lead national efforts to modernize the electric grid; enhance security and reliability of the energy infrastructure; and facilitate recovery from disruptions to energy supply. It does this by informing policy solutions pertaining to electric grid reliability, and managing research, development, and demonstration activities for next-generation electric grid infrastructure technologies. Offshore wind energy deployment presents a unique challenge to the nation's electric grid. Not only does it represent a massive amount of power to be introduced, but it requires grid integration at coastal sites where points of interconnection are limited. In addition, the distance from shore requires advanced cabling and substation technologies. The Office of Electricity has already implemented extensive research projects on transmission hardware and software technologies as well as transmission planning. The Office of Electricity's leadership in transmission technology and planning is being leveraged to support regional offshore wind transmission studies.

Office of Manufacturing and Energy Supply Chains

The Office of Manufacturing and Energy Supply Chains (MESC) is responsible for strengthening and securing manufacturing and energy supply chains needed to modernize the nation's energy infrastructure and support a clean and equitable energy transition. Working in close coordination with AMMTO and OCED, MESC not only promotes the development of manufacturing processes and infrastructure, but also seeks to develop a robust domestic workforce that emphasizes diversity. Deployment of offshore wind energy requires a robust U.S. supply chain that will rely heavily on state-of-the-art manufacturing practices and facilities. Efforts led by MESC could contribute to many critical areas of offshore wind energy needs, including wind turbine blade recyclability, manufacturing optimization, and wind energy storage systems. The programs led by MESC will help facilitate the technology improvements needed to not only manufacture wind turbine systems at scale but also contribute to more efficient, lower-cost designs.

Office of Science

The Office of Science (SC) is the nation's largest supporter of basic research in the physical sciences, the steward of 10 of the nation's national laboratories, and the lead federal agency supporting fundamental research for energy production and security. SC has many existing

[98] White House. 2021. "Executive Order on Tackling the Climate Crisis at Home and Abroad." https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

programs and data sets that can be leveraged to benefit offshore wind energy deployment, primarily through the collection, analysis, and modeling of atmospheric data. SC's Biological and Environmental Research program has existing research and modeling efforts associated with wind resource characterization and meteorological ocean boundary layer interactions. The Atmospheric Radiation Measurement user facility collects and processes continuous climate measurements that can help inform modeling efforts.[99] The Earth and Environmental System Modeling program models capabilities in simulating climate variability and change, including consideration of common and extreme weather events on various timescales.[100] An understanding of wind resource variability is crucial to informing the design and controls of individual wind turbine systems and turbine system arrays.

State and Community Energy Programs Office

One of DOE's primary forums for engaging state and local governments, the Office of State and Community Energy Programs (SCEP), strategically coordinates with state and local leaders to integrate energy efficiency and renewable energy programs and best practices. In addition to the Biden administration's goal of deploying 30 gigawatts by 2030, state governments have announced their own ambitious offshore wind energy deployment goals. While offshore wind deployment will primarily occur in federal waters, some will be deployed in state waters, and as a result the supply chain and onshore transmission infrastructure will require significant state cooperation. SCEP's existing relationships with state energy agencies provides a robust framework to encourage and facilitate offshore wind energy coordination within and among states.

Vehicle Technologies Office

DOE's Vehicle Technologies Office (VTO) supports research, development, and deployment of efficient and sustainable transportation technologies that will improve energy efficiency and fuel economy and enable America to use less petroleum. Many marine vessels are needed to install offshore wind turbines and associated infrastructure, lay cables, and maintain and service offshore wind plants. While some of these vessels already exist, many will require upgrades or tailoring to facilitate offshore wind energy, and many more will need to be constructed. VTO's portfolio includes many areas of research that will benefit offshore wind vessel needs, including advanced batteries and electric drive systems, lightweight materials, advanced combustion engines, and alternative fuels. This work will not only help inform vessel design but promote low-emission vessels, helping ensure that offshore wind energy is deployed in an environmentally sustainable manner.

Water Power Technologies Office

The mission of the Water Power Technologies Office (WPTO) is to enable research, development, and testing of new technologies to advance marine energy as well as next-generation hydropower and pumped storage systems for a flexible, reliable grid. As many of the energy technologies of interest to WPTO are based at sea (e.g., marine and hydrokinetics), there

[99] DOE. Undated. "Atmospheric Radiation Measurement (ARM) user facility." https://science.osti.gov/ber/Facilities/User-Facilities/ARM.
[100] DOE. Undated. "Earth & Environmental Systems Modeling." https://climatemodeling.science.energy.gov/.

are many areas of overlap with offshore wind. These overlaps include infrastructure, such as floating platforms and transmission cabling, and marinization of all components to withstand harsh oceanic conditions. There is also a great deal of overlap in environmental research and community engagement practices, because responsible ocean co-use is prioritized by all ocean-based clean energy efforts. Existing research efforts led by WPTO can be leveraged to inform offshore wind energy deployment and careful collaboration can reduce redundant research efforts.

Wind Energy Technologies Office

The Wind Energy Technologies Office (WETO) invests in energy science research and development activities that enable the innovations needed to advance U.S. wind energy systems while continuing to address market and deployment barriers, including siting and environmental impacts. WETO is dedicated to driving down the cost of wind energy with more efficient, reliable, and predictable wind energy systems. WETO is DOE's lead office for offshore wind energy research, with ongoing research programs relevant to nearly every aspect of the industry. The technology development portfolio has many ongoing research and development and demonstration projects to optimize wind turbine system designs, including manufacturing considerations. WETO led the establishment of a road map for the offshore wind energy supply chain and analysis of the offshore wind workforce, which addresses specific needs associated with offshore wind deployment goals. WETO's modeling portfolio includes conducting wind resource and socioeconomic modeling to better inform costs and benefits. Its grid integration portfolio includes transmission studies as well as transmission technology research and development. WETO's environmental and siting portfolio includes wildlife and habitat research efforts on the East and West Coast to inform sustainable offshore wind energy deployment, and its radar mitigation portfolio includes research to reduce impacts to radar users, with both portfolios promoting ocean co-use. The social science and community engagement portfolio pursues research on community perspectives and community benefit structures and supports programs that involve and educate communities. Nearly all WETO programs have some relevance to offshore wind energy, either directly or indirectly.

Appendix C. Federal Partners

This section summarizes the missions and capabilities of other federal agencies that have a role to play in offshore wind energy development.

U.S. Department of Commerce

The U.S. Department of Commerce's mission is to create the conditions for economic growth and opportunity for all communities. The department houses numerous bureaus responsible for offshore wind energy stewardship and economic development, including:

- **The National Oceanic and Atmospheric Administration**. The National Ocean and Atmospheric Administration (NOAA) seeks to understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources.
- **U.S. Economic Development Administration**. The mission of the U.S. Economic Development Administration is to lead the federal economic development agenda by promoting innovation and competitiveness, preparing American regions for growth and success in the worldwide economy.

U.S. Department of Defense

- **U.S. Army Corp of Engineers**. The U.S. Army Corp of Engineers is the lead federal agency for National Environmental Policy Act 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.
- **Military Aviation and Installation Assurance Siting Clearinghouse**. The U.S. Department of Defense 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

- **U.S. Coast Guard**. 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 this particular waterway, and other missions.
- **U.S. Customs and Border Protection**. The U.S. Customs and Border Protection evaluates impacts to its maritime border protection missions and issues rulings determining whether offshore wind energy projects are in compliance with the Jones Act and Passenger Vessel Services Act.

U.S. Department of the Interior

The U.S. Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska natives, and affiliated island communities. The department houses numerous bureaus critical to offshore wind energy regulation and oversight in the United States including the:

- **Bureau of Ocean Energy Management**. The mission of the Bureau of Ocean Energy Management (BOEM) is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. BOEM is responsible for energy and mineral resource development in the Outer Continental Shelf, which 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 Policy Act analyses and associated consultations pertaining to various leasing actions.
- **Bureau of Safety and Environmental Enforcement**. The Bureau of Safety and Environmental Enforcement is tasked with developing workplace safety, environmental compliance, and enforcement strategies for offshore wind energy projects.
- **National Park Service**. The National Park Service is responsible for stewardship of the nation’s federal parks and engages in consultation with offshore wind energy projects on impacts to recreational uses and historical and archaeological resources.
- **Office of Natural Resources Revenue**. 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 American Indian lands.
- **U.S. Fish and Wildlife Service**. The mission of the U.S. Fish and Wildlife Service is to work with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. 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.

U.S. Department of Transportation

- **Federal Aviation Administration**. 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.
- **Maritime Administration** The mission of the Maritime Administration is to foster, promote, and develop the domestic maritime industry to meet the nation’s economic and security needs.

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) helps consumers obtain reliable, safe, secure, and economically efficient energy services at a reasonable cost through appropriate regulatory and market means and collaborative efforts. 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 regional transmission organization/independent system operator capacity, energy, and ancillary services markets, which affect offshore wind energy providers' compensation.

Advancing Offshore Wind Energy in the United States

U.S. Department of Energy Strategic Contributions Toward 30 Gigawatts and Beyond

30 GW
2030

110 GW
2050

U.S. DEPARTMENT OF
ENERGY

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