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NATIONAL OFFSHORE WIND STRATEGY

Facilitating the Development of the Offshore Wind Industry in the United States

U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF THE INTERIOR

Notice

This report is being disseminated by the U.S. Department of Energy (DOE) and the U.S. Department of the Interior (DOI). As such, this document was prepared in compliance with Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) and information quality guidelines issued by both DOE and DOI. Though this report does not constitute "influential" information, as that term is defined in agencies' information quality guidelines or the Office of Management and Budget's Information Quality Bulletin for Peer Review, the report was reviewed internally prior to publication. This report has benefitted from review by the National Renewable Energy Laboratory, DOE's Wind Energy Technologies Office, and DOI's Bureau of Ocean Energy Management.

Introductory Message

There has never been a more exciting time for offshore wind in the United States. By the end of 2015, the U.S. Department of the Interior awarded 11 commercial leases for offshore wind development that could support a total of 14.6 gigawatts of capacity. In May 2016, the U.S. Department of Energy identified three innovative demonstration projects that have made significant progress toward producing power. In addition to these noteworthy achievements, we are looking forward to the first commercial offshore wind energy facility in the United States—the Block Island Wind Farm—beginning commercial operation before the close of 2016.

With almost 80% of U.S. electricity demand located in coastal states and total offshore wind energy technical potential equal to about double the nation's demand for electricity, offshore wind energy has the potential to contribute significantly to a clean, affordable, and secure national energy mix. Realizing the potential of offshore wind energy in the United States will require addressing key challenges in technology and cost, supporting effective stewardship of our natural resources, and increasing understanding of offshore wind's benefits and costs.

Our agencies are uniquely poised to provide leadership in addressing these key challenges. Recognizing the significant opportunity for our nation, we have worked closely together and solicited significant public input over the past 18 months to compose a joint national offshore wind strategy. This report highlights the potential value of offshore wind to the nation, and presents a credible set of approaches and actions to facilitate the responsible development of a U.S. offshore wind industry.

On behalf of the offices we represent, we express our deep gratitude to the hundreds of individuals across federal and state governments, industry, academia, research institutions, and the environmental community for their meaningful contributions to this national strategy for offshore wind. Their expertise, vision, and passion herald a bright future for offshore wind energy in the United States.

We are confident that our nation stands at the forefront of a strong domestic offshore wind industry. It is our hope that this document will continue to serve as a guide for key decision-makers within our agencies, as well as within the broader offshore wind energy community, over the next 5 years and beyond.

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List of Acronyms

AEP	annual energy production
BOEM	Bureau of Ocean Energy Management
CapEx	capital expenditure
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
GHG	greenhouse gas
GW	gigawatt
ITC	investment tax credit
lidar	light detection and ranging
LACE	levelized avoided cost of energy
LCOE	levelized cost of energy
metocean	meteorological and oceanographic
MW	megawatt
nm	nautical mile(s)
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
m	meter(s)
O&M	operation and maintenance
OCS	Outer Continental Shelf
OREC	Offshore Renewable Energy Credit
OpEx	operational expenditure
PTC	production tax credit
PPA	power purchase agreement
R&D	research and development
REC	Renewable Energy Credit
RFF	Request for Feedback
RODEO	Real-time Opportunity for Development Environmental Observations
RPS	renewable portfolio standard
TIV	turbine installation vessel
WEA	wind energy area

Executive Summary

Offshore wind energy holds the promise of significant environmental and economic benefits for the United States. It is an abundant, low-carbon, domestic energy resource. It is located close to major coastal load centers, providing an alternative to long-distance transmission or development of electricity generation in these land-constrained regions. Once built, offshore wind farms could produce energy at low, long-term fixed costs, which can reduce electricity prices and improve energy security by providing a hedge against fossil fuel price volatility.

Realizing these benefits will require overcoming critical challenges in three strategic themes: 1) reducing the costs and technical risks associated with domestic offshore wind development, 2) supporting stewardship of U.S. waters by providing regulatory certainty and understanding and mitigating environmental risks of offshore wind development, and 3) increasing understanding of the benefits and costs of offshore wind energy.

The U.S. Department of Energy (DOE), through its Wind Energy Technologies Office, and U.S. Department of the Interior (DOI), through its Bureau of Ocean Energy Management (BOEM), have jointly produced this updated national strategy to facilitate the responsible development of offshore wind energy in the United States. In doing so, the agencies accounted for progress made since the last national offshore wind strategy released in 2011, and utilized significant input from the offshore wind community. This strategy highlights the gaps that need to be addressed by the offshore wind community as a whole, and provides a suite of actions that DOE and DOI are positioned to undertake to address these gaps and help the nation realize the benefits of offshore wind development.

The United States Needs a National Approach to Offshore Wind Development

The national energy landscape has changed significantly since the first national strategy for offshore wind was released in 2011. The first domestic offshore wind farm is scheduled for commercial operation in 2016, and there are now 11 active commercial leases along the Atlantic Coast. The United States took steps toward a low-carbon future through its commitments at the Paris Climate Conference, the promulgation of the Clean Power Plan,[1] and legislative action, such as the extension of the renewable energy production tax credit and investment tax credit. Coastal states have increased their demand for renewable energy deployment through renewable portfolio standards and other mandates. Many legacy fossil fuel, nuclear, and renewable generators are set to retire because of age, cost, or as part of the move toward lower-carbon sources of electricity. Land-based wind energy generation in the United States has increased nearly 60% and utility-scale solar generation increased more than 1,300% [1] relative to 2011. Most of this renewable generation is located far from coastal load centers, and long-distance transmission infrastructure has not kept pace with this rapid deployment. At the same time, the offshore wind market has matured rapidly in Europe, and costs are now falling. These trends suggest that offshore wind has the opportunity to play a substantial role as a source of domestic, large-scale, affordable electricity for the nation.

DOE and DOI developed this strategy as a joint document and have a single overarching goal in its implementation, which is to facilitate the development of a robust and sustainable offshore wind industry in the United States. The agencies will coordinate on the implementation of many of the specific actions they intend to undertake to support achievement of this goal. In recognition of their unique and complementary roles, and consistent with their missions and authorities, DOE and DOI each identified the actions they plan to address, and set individual objectives against which they will measure progress. These objectives are as follows:

- DOE aims to reduce the levelized cost of energy through technological advancement to compete with local electricity costs, and create the conditions necessary to support DOE's *Wind Vision*[2] study scenario levels [2] of deployment by supporting the coexistence of offshore wind with the environment, coastal communities, and other users of ocean space.
- DOI aims to enhance its regulatory program to ensure that oversight processes are well-informed and adaptable, avoid unnecessary burdens, and provide transparency and certainty for the regulated community and stakeholders.

DOE and DOI solicited significant stakeholder and public input to inform this document through a DOE Request for Information and a DOI Request for Feedback, as well as a jointly hosted public workshop. Feedback received through these efforts was critical to DOI and DOE in defining the challenges facing offshore wind presented in this document, as well as suggesting potential federal actions to address them.

Offshore Wind Represents a Significant Opportunity to the Nation

A number of factors demonstrate the realistic and substantial opportunity that offshore wind presents to the United States:

- **U.S. offshore wind resources are abundant.** Today, a technical potential of 2,058 gigawatts (GW) of offshore wind resource capacity are accessible in U.S. waters using existing technology. This is equivalent to an energy output of 7,200 terawatt-hours per year—enough to provide nearly double the total electric generation of the United States in 2015.
- **Significant siting and development opportunities are available today in U.S. waters.** By the end of 2015, DOI had awarded 11 commercial leases for offshore wind development that could support a total of 14.6 GW of capacity in areas already vetted for preliminary siting conflicts through extensive intergovernmental and stakeholder coordination. BOEM has a number of potential wind areas that are currently in the planning stages.
- **Electricity demand growth and scheduled power plant retirements in coastal states provide significant opportunity for offshore wind development.** If the 86 GW of offshore wind studied in the *Wind Vision* study scenario[3] were developed by 2050, offshore wind would make up 14% of the projected demand for new electricity generation in the coastal and Great Lakes states.
- **In some locations, offshore wind could be competitive with incumbent forms of generation in the next decade.** A new cost analysis by the National Renewable Energy Laboratory shows credible scenarios for cost reductions below $100/megawatt-hour by 2025 in some areas of the United States, and more widely around the country by 2030. Assuming near-term deployment of offshore wind at a scale sufficient to support market competition and the growth of a supply chain, development of offshore wind energy in markets with relatively high electricity costs, such as the Northeast, could be cost-competitive within a decade.
- **Deploying offshore wind could lead to significant electrical system benefits for system operators, utilities, and ratepayers.** Because of its low marginal costs of production and the fact that offshore winds in many regions tend to be strong at times of peak demand, offshore wind energy can lower wholesale electricity prices in many markets. Offshore wind can also decrease transmission congestion and reduce the need for new long-distance transmission.
- **A robust offshore wind industry would lead to significant positive environmental and economic external benefits.** Assuming the *Wind Vision* study scenario deployment level of 86 GW offshore wind by 2050, national benefits could be:
  - **Reduced greenhouse gas emissions.** A 1.8% reduction in cumulative greenhouse gas emissions—equivalent to approximately 1.6 billion metric tons of carbon dioxide—could save $50 billion in avoided global damages.
  - **Decreased air pollution from other emissions.** The United States could save $2 billion in avoided mortality, morbidity, and economic damages from cumulative reductions in emissions of sulfur dioxide, nitrogen oxides, and fine particulates.
  - **Reduced water consumption.** The electric power sector could reduce water consumption by 5% and water withdrawals by 3%.
  - **Greater energy diversity and security.** Offshore wind could drive significant reductions in electricity price volatility associated with fossil fuel costs.
  - **Increased economic development and employment.** Deployment could support $440 million in annual lease payments into the U.S. Treasury and approximately $680 million in annual property tax payments, as well as support approximately 160,000 gross jobs in coastal regions and around the country [2].[4]

Key Challenges Remain

To support a robust and sustainable offshore wind industry in the United States, challenges across three strategic themes need to be overcome.

- **Reducing costs and technology risks.** Today, the cost of offshore wind energy is too high to compete in most U.S. markets without subsidies. However, continued global market growth and research and development investments across the following three action areas could significantly reduce the costs of offshore wind toward competitive levels:
  - **Offshore wind power resource and site characterization.** A better understanding of the unique meteorological, ocean, and seafloor conditions across U.S. offshore wind development sites will allow for optimized designs, reduced capital costs, greater safety, and less uncertainty in preconstruction energy estimates, resulting in reduced financing costs.

- **Offshore wind plant technology advancement**. Increasing turbine size and efficiency, reducing mass in substructures, and optimizing wind plants at a systems level for unique U.S. conditions can reduce capital costs and operating expenses and increase energy production at a given site.
- **Installation, operation and maintenance, and supply chain solutions.** The complexity and risk associated with installation and operation and maintenance activities requires specialized infrastructure that does not yet exist in the United States. Reducing or eliminating the need for specialized assets, along with leveraging the nation's existing infrastructure, will reduce capital and operating costs in the near term and help unlock major economic development and job creation opportunities in the long term.

- **Supporting effective stewardship.** Effective stewardship of the nation's ocean and Great Lakes resources will be necessary to allow for the development of a sustainable offshore wind industry in the United States. DOI, through BOEM, oversees the responsible development of energy on the Outer Continental Shelf. Offshore wind developers, financiers, and power purchasers need confidence in a project's ability to navigate regulatory and environmental compliance requirements in a predictable way. To improve this balance and support effective stewardship, action is needed in the following two areas:
  - **Ensuring efficiency, consistency, and clarity in the regulatory process**. Further work can be done to improve consistency and identify and reduce unnecessary burdens in BOEM's existing regulatory process. This may include establishing more predictable review timelines and maintaining a reasonable level of flexibility given the early stage of the industry's development.
  - **Managing key environmental and human-use concerns**. More data need to be collected to verify and validate the impacts of offshore wind development on sensitive biological resources and existing human uses of ocean space. Improved understanding and further collaboration will allow for increased efficiency of environmental reviews and tighter focus on the most important issues.
- **Increasing understanding of the benefits and costs of offshore wind.** Building a better understanding of the impacts of offshore wind on the electricity grid, unique electricity market costs and benefits, and environmental externalities can help create the conditions needed for near-term deployment.
  - **Offshore wind electricity delivery and grid integration**. Impacts of significant offshore wind deployment on grids need to be better understood at state and regional levels, and the costs and benefits associated with different offshore transmission infrastructure configurations and strategies need to be characterized.
  - **Quantifying and communicating the benefits and costs of offshore wind**. The environmental and economic benefits and costs associated with offshore wind need to be quantified and communicated to key stakeholders to inform decisions on near-term offtake agreements, other project-specific matters, and policies affecting offshore wind.

A Robust and Credible Plan for Federal Action

Federal government action can supplement the work of states, utilities, the wind industry, the environmental community, researchers, and other stakeholders to facilitate offshore wind development. DOE and DOI aim to provide essential federal leadership to help overcome certain challenges and help the nation to realize the benefits of offshore wind. This strategy lays out 34 concrete actions in seven action areas that DOE and DOI can take to facilitate responsible, robust, and sustainable offshore wind development in the United States.

Notes

1. The Clean Power Plan is a policy aimed at combating anthropogenic climate change (global warming) that was first proposed by the Environmental Protection Agency in June 2014, under the administration of President Barack Obama. The final version of the plan was unveiled by President Obama on August 3, 2015. On February 9, 2016, the Supreme Court stayed implementation of the Clean Power Plan pending resolution of legal challenges to the plan in the D.C. Circuit. *https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants*.
2. The *Wind Vision* study takes America's current installed wind power capacity across all facets of wind energy (land-based, offshore, and distributed) as its baseline and assesses the potential economic, environmental, and social benefits of a scenario in which U.S. wind power supplies 10% of the nation's electrical demand in 2020, 20% in 2030, and 35% in 2050 [2].
3. The study scenario is not a goal or future projection for wind power. Rather, the *Wind Vision* scenarios comprise an analytical framework that supports detailed analysis of potential costs, benefits, and other impacts associated with future wind deployment. The study scenario comprises a range of cases spanning plausible variations from central values of wind power and fossil fuel costs.
4. Cumulative benefits are reported on a Net Present Value basis for the period of 2013 through 2050; annual benefits reflect the impact in current dollars for the year noted (e.g., 2050). Greenhouse gases, air pollution, and water benefits are estimated from the combined land-based and offshore wind system impact and proportionately allocated to offshore based on its share of total wind generation. In contrast, gross jobs, lease payments, and property taxes are estimated specifically for offshore wind based on expected capacity additions and servicing requirements anticipated in the *Wind Vision* study scenario.

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1.0 Introduction

1.1 Opportunity for the Nation

In 2015, the U.S. Department of Energy (DOE) released *Wind Vision: A New Era for Wind Power in the United States* [2], a landmark report evaluating future pathways for the U.S. wind industry and analyzing, for the first time, the full benefits and costs of a future in which wind delivers 35% of U.S. electricity by 2050. The report looked at some of the economic, energy system, and environmental benefits of offshore wind, and found that realizing the *Wind Vision* study scenario of 86 gigawatts (GW) of offshore wind deployment by 2050 would have significant benefits to our nation. These include:

- **Reduced greenhouse gas (GHG) emissions**. A 1.8% reduction in cumulative GHG emissions—equivalent to 1.6 billion metric tons of carbon dioxide—through 2050 could save $50 billion in avoided global damages.
- **Decreased air pollution from other emissions**. The United States could save $2 billion in avoided mortality, morbidity, and economic damages from cumulative reductions through 2050 in emissions of sulfur dioxide, nitrogen oxides, and fine particulates.
- **Reduced water consumption**. The electric power sector could reduce annual water consumption by 5% and annual water withdrawals by 3% in 2050.
- **Greater energy diversity and security**. The nation could experience significant reductions in electricity price volatility associated with fossil fuel costs.
- **Increased economic development and employment**. This increase could amount to $440 million in annual lease payments to the U.S. Treasury and approximately $680 million in annual property tax payments, as well as support approximately 160,000 gross jobs in coastal regions and around the country [2].[5]

The potential of offshore wind as a renewable energy resource in the United States is enormous. A robust and sustainable U.S. offshore wind industry could decrease GHG emissions, diversify the nation's energy portfolio, generate affordable power for homes and businesses, and revitalize key economic sectors [2–4]. With nearly 80% of the U.S. electricity demand located in coastal states and a total offshore wind resource roughly double the national consumption of electricity [1], offshore wind has the potential to contribute significantly to a clean, affordable, and secure national energy mix.

Though the United States generates more electricity from land-based wind than any other country, there are presently no offshore wind turbines operating in U.S. waters [5–6]. The first U.S. project is expected to commence operation offshore Block Island, Rhode Island, in late 2016, and several more could be operational before 2020. The offshore wind market is maturing quickly in Europe and Asia; as of the end of 2015, more than 12 GW of offshore wind capacity had been installed globally [7], and the cost of offshore wind energy is now trending downward in Europe through experience, increased competition in the offshore wind market, and innovation. Recent analysis suggests that much of the cost-reduction progress seen in European markets can translate to the United States as developers leverage best-available European technologies and adapt them to the unique conditions of the United States [5].

Realizing the substantial benefits of offshore wind in the United States, however, will require overcoming a number of key technological, regulatory, environmental, and market challenges. For example, the costs of offshore wind need to fall substantially, and the supply chain needs to be developed. The regulatory process for offshore wind could be further optimized, and data gaps associated with environmental impacts need to be addressed. The unique set of costs and benefits associated with offshore wind energy needs to be better quantified and communicated to policymakers and stakeholders to allow for their full consideration in decisions about offshore wind projects and policies.

The federal government can play a leadership role in addressing these challenges. DOE and the U.S. Department of the Interior (DOI) have come together to develop this strategy document, which highlights the potential value of offshore wind to the nation and presents a credible set of approaches and actions to facilitate the responsible development of a sustainable and robust offshore wind industry in the United States.

1.2 Key Trends Motivating the National Offshore Wind Strategy

Much has changed in the U.S. energy landscape and the offshore wind industry since DOE, in collaboration with DOI, released the first national offshore wind strategy document in 2011 (see text box) [8]. The policy environment has evolved to include stronger directives and incentives at the federal and state levels for the reduction of greenhouse gases and the expansion of renewable energy in which offshore wind can play a significant part. Lower projected costs and maturing markets in Europe and Asia signal the potential viability of offshore wind energy technology in the U.S. market [5]. In this context, the industry needs a new assessment of the costs and benefits of offshore wind to the country, and an updated strategy for federal engagement and investment in offshore wind research, development, demonstration, deployment, and federal oversight of offshore wind projects.

Falling Costs Globally

As of mid-2015, 250 GW of offshore wind capacity had been announced in the global development pipeline [5]. Studies indicate that there is significant potential for further cost reduction through continued deployment and learning curve effects, investment in research and development (R&D), industrialization of the supply chain, and improvements in financing. In the European market, achieving European Union goals for the offshore wind levelized cost of energy (LCOE) of 100 € per megawatt-hour (MWh) (approximately $112/MWh) by 2020 appears increasingly likely [9–13].

Emerging Federal Climate and Renewable Energy Policies

In 2015, the Environmental Protection Agency finalized the Clean Power Plan, which sets standards to reduce carbon dioxide emissions in the electricity sector by 32% by 2030 from 2005 levels [14]. Under the plan, states will be required to develop and submit plans to reduce electricity sector emissions through the development of low-carbon generation sources and other investments. Offshore wind resources can significantly increase the potential for some land or transmission-constrained coastal states to meet targets with in-state renewable resources, and reduce the difficulty and, potentially, the cost of achieving their targets under the Clean Power Plan.[6]

In 2015, the United States also made substantial commitments to reduce GHG emissions to 26%-28% below 2005 levels by 2025 under the Paris Agreement on climate change reached at the United Nations Framework Convention on Climate Change's 21st Conference of the Parties (COP 21) in December 2015. The Clean Power Plan is a key building block to reaching this commitment. The United States also joined 20 countries and private investors to launch Mission Innovation, an international group of public and private sector global leaders aiming to "reinvigorate and accelerate global clean energy innovation with the objective to make clean energy widely affordable" [15]. Under Mission Innovation, the United States has pledged to double its government clean energy R&D investment over the next 5 years.

A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States [8]

In 2011, DOE, in collaboration with DOI, released *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* [8]. This strategy outlined the actions DOE and DOI would pursue to support and accelerate the development of an offshore wind industry in the United States by reducing the cost of energy and decreasing deployment timelines. In this report, DOI announced the development of a new initiative to facilitate siting, leasing, and construction of new projects. DOE, for its part, launched a series of investments totaling more than $250 million in targeted technical research and development, partnerships to address market barriers, and implementation of demonstration projects to showcase advanced technologies with the potential to reduce offshore wind costs in the United States.

In December 2015, Congress enacted a multiyear extension of the renewable energy production tax credit (PTC) and business energy investment tax credit (ITC) in the 2016 Consolidated Appropriations Act (P.L. 114-113). The wind energy PTC and ITC were thereby extended through 2016 at 100% of their 2015 value. After 2016, the PTC and ITC will decrease in 20% annual increments to 40% of their 2015 value in 2019. This longer-term policy approach is significant to the industry, and renewable energy projects starting construction prior to the end of the period will qualify.

State Renewable Energy and Climate Objectives

States have also taken significant steps that support offshore wind development. As of June 2016, 29 states and the District of Columbia now have renewable portfolio standards (RPSs) that require utilities to sell a specified percentage or amount of renewable energy. Several states in particular have established aggressive renewable energy targets. Both California and New York, for instance, include a 50% target by 2030, whereas Hawaii has set a goal of 100% by 2045 [16]. A few states also have specific mechanisms that provide special consideration for offshore wind. For example, the Maryland Offshore Wind Energy Act of 2013 provides for Offshore Renewable Energy Credits (ORECs) for sourcing up to 2.5% of the state's electricity supply from offshore wind energy starting in 2017. It requires consideration of peak load price suppression and limiting rate impacts [17].

U.S. Offshore Wind Deployment Begins

The first commercial offshore wind project in the United States completed construction off the coast of Rhode Island in August 2016. The 30-MW Block Island Wind Farm is expected to be operational by late 2016. If successful, the project will mark the beginning of offshore wind's contributions to the nation's energy portfolio, and could signal the advent of a viable U.S. offshore wind energy market and provide invaluable lessons learned to support future development. Several additional projects could be operating by 2020, including three DOE Advanced Technology Demonstration Projects in New Jersey, Ohio, and Maine—Fishermen's Energy Atlantic City Windfarm, Lake Erie Energy Development Corporation's Icebreaker project, and the University of Maine's New England Aqua Ventus I—which, as of August 2016, are in the final design and planning phase. A total of nearly 16 GW have been proposed for development in the United States [5].

1.3 The Federal Government's Role in Domestic Offshore Wind Energy

The U.S. government has a substantial role to play in facilitating the development of a robust and sustainable offshore wind industry in the United States. For example, the federal government can move forward with investments in research and development that are not being undertaken by industry as a result of real or perceived cost or risk, or because of the long payoff times associated with these investments. These programs can result in technological innovations that reduce cost and environmental impacts of energy technologies. Furthermore, federal programs can engage other agencies to leverage resources and co-address issues related to wind energy development, or, where appropriate, develop partnerships with or facilitate technology transfer to industry to ensure that innovations make it to market.

The Wind Energy Technologies Office within DOE's Office of Energy Efficiency and Renewable Energy supports the development, deployment, and commercialization of wind energy technologies. DOE works with a variety of stakeholders to identify and support R&D efforts that improve technology performance, lower costs, and help responsibly deploy technologies that efficiently capture the abundant wind energy resources in the United States. DOE provides R&D funding across a number of areas, including Offshore Wind Advanced Demonstration Projects; wind plant technology advancement, manufacturing advancement, and testing; grid integration; wind resource assessment; the mitigation of market barriers such as environment and siting challenges; stakeholder engagement and outreach; and workforce development.

DOI's Bureau of Ocean Energy Management (BOEM) is responsible for ensuring that offshore renewable energy development in federal waters takes place in a responsible and sustainable manner. BOEM currently regulates offshore wind projects through four distinct phases: planning, leasing, site assessment, and construction and operations. BOEM engages key stakeholders throughout this process, and early communication with interested and potentially affected parties is critical to managing possible conflicts. BOEM's offshore wind authorization process includes establishing intergovernmental task forces; issuing leases, including commercial leases, limited leases, and research leases; and reviewing plans that describe specific offshore wind project proposals. Under its statutory authority, BOEM is responsible for ensuring fair return to the American public for the use of submerged lands to generate revenue from the production of electricity. Since 2009, BOEM has made more than 1.18 million acres of submerged land available on the Outer Continental Shelf (OCS) for potential wind development, and generated more than $16.4 million through competitive auctions for its leases.

1.4 Development of a Robust Offshore Wind Strategy

Significant public engagement informed the development of this document. In May 2015, DOE issued a Request for Information to solicit stakeholder feedback regarding the implementation of the 2011 strategy, the key challenges currently facing domestic offshore wind energy, and potential paths forward for continued investment in offshore wind energy technology [2–4]. DOE received 40 responses from a wide variety of stakeholders on issues ranging from the need for power purchase mechanisms to technology development concerns.

In addition, BOEM issued a Request for Feedback (RFF) in September 2015, inviting public comments on any aspects of the agency's renewable energy program that are either particularly effective or ineffective and burdensome. BOEM received 57 responses from a range of stakeholders, relating to numerous aspects of its renewable energy program [18]. When developing this strategic planning document, BOEM carefully considered the comments received in response to the RFF.

In December 2015, DOE and DOI convened a public workshop in Washington, D.C. The goals of the workshop were twofold: identify stakeholders' top priorities to better enable DOE and DOI to facilitate the development of the offshore wind industry in the United States, and articulate each agency's respective role in the offshore wind energy development process. The workshop presented information on DOE's and BOEM's actions in offshore wind energy to date, and a 2016 analysis by the National Renewable Energy Laboratory (NREL) on the major costs and benefits of offshore wind energy deployment in the United States. Specific discussions were held in a number of topic areas. Feedback from these sessions directly informed the actions that are outlined in Chapter 3 and Chapter 4 [19].

1.5 A Framework for Federal Action to Facilitate Offshore Wind Development in the United States

This document presents a framework for federal action intended to help facilitate the responsible development of a robust and sustainable offshore wind industry in the United States. DOE and DOI collaboratively developed this strategy, and will continue to coordinate on its implementation. Consistent with their individual authorities and missions, DOE and DOI also developed complementary, agency-specific objectives against which progress can be measured within each agency:

- DOE aims to reduce the LCOE through technological advancement to compete with local electricity costs, and create the conditions necessary to achieve *Wind Vision*-level deployment through market-barrier-reduction activities.
- DOI aims to enhance its regulatory program to ensure that oversight processes are well-informed and adaptable, avoid unnecessary burdens, and provide transparency and certainty for the regulated community and stakeholders.

To meet these agency-specific objectives, DOE and DOI will coordinate their activities across three strategic themes and seven action areas as shown in Table 1.1. These themes and action areas are intended to address the critical issues identified through analysis as well as feedback from stakeholders described earlier.

Three chapters follow this introduction. Chapter 2 presents the value proposition represented by offshore wind in the United States, based both on the findings of the *Wind Vision* and a new NREL analysis of the U.S. offshore wind resource, opportunities for growth, and cost reduction pathways. Chapter 3 outlines the key challenges facing offshore wind across the three strategic themes and seven action areas, describes progress made to date, and articulates the remaining gaps for future action by all offshore wind stakeholders to ultimately overcome these challenges. Finally, Chapter 4 identifies the specific actions that DOE and DOI plan to undertake to achieve their objectives under this strategy.

Table 1.1. Key Strategic Themes and Action Areas

Strategic Themes	Action Areas
1. Reducing Costs and Technology Risks	1. Offshore Wind Power Resource and Site Characterization 2. Offshore Wind Plant Technology Advancement 3. Installation, Operation and Maintenance, and Supply Chain Solutions
2. Supporting Effective Stewardship	1. Ensuring Efficiency, Consistency, and Clarity in the Regulatory Process 2. Managing Key Environmental and Human-Use Concerns
3. Increasing Understanding of the Benefits and Costs of Offshore Wind	1. Offshore Wind Electricity Delivery and Grid Integration 2. Quantifying and Communicating the Benefits and Costs of Offshore Wind

Notes

5. Cumulative benefits are reported on a Net Present Value basis for the period of 2013 through 2050 using a discount rate of 3%; annual benefits reflect the impact in current dollars for the year noted (e.g., 2050). Greenhouse gas emissions, air pollution, and water benefits are estimated from the combined land-based and offshore wind system impact and proportionately allocated to offshore based on its share of total wind generation. In contrast, gross jobs, lease payments, and property taxes are estimated specifically for offshore wind based on expected capacity additions and servicing requirements anticipated in the *Wind Vision* study scenario.

6. On February 9, 2016, the Supreme Court stayed implementation of the Clean Power Plan pending resolution of legal challenges to the plan in the D.C. Circuit.

2.0 The Value of Offshore Wind

2.1 Introduction

Demonstrating a significant potential for offshore wind to achieve economic viability over a wide range of sites in the United States is central to facilitating its development. The value of offshore wind depends not only on achieving lower life-cycle costs, but also on a number of building blocks, including an abundant wind resource; substantial siting and development opportunities; sufficient market opportunity; a credible path to achieve competitive cost; demonstrated economic potential; and offshore wind's wider energy system, environmental and economic development benefits as shown in Figure 2.1. This chapter highlights these value proposition building blocks that can enable commercial success, which point to significant future economic potential for offshore wind in the United States as a significant contributor to a cost-effective, reliable, low-carbon U.S. energy portfolio.

Abundant Resource

The technical potential of U.S. offshore wind is more than double total U.S. electricity consumption [20]. A 2016 resource analysis done by NREL updates the previous national resource assessment studies [21] and refines and reaffirms that the available offshore wind resource is sufficient for offshore wind to be viable and a large-scale contributor to the electric energy supply. Experience from other renewable technologies, such as land-based wind and solar energy, shows that site development is highly selective, representing a small percentage of the overall resource potential. Abundant resources allow for siting flexibility so that projects may avoid the most conflicted areas. As such, the DOE *Wind Vision* study scenario for 2050 would require the United States to use only 4.2% of the total technical resource potential area.

Substantial Siting and Development Opportunities

As of May 2016, there are 11 active commercial leases in the Atlantic Ocean with the potential to support initial deployment of about 14.6 GW of offshore wind [5].[7] Since 2011, the siting and regulatory process for offshore wind energy has matured and advanced significantly in the United States. In federal waters, BOEM has implemented a process through careful planning and public outreach by which offshore wind resource areas are screened to avoid or mitigate many potential conflicts.

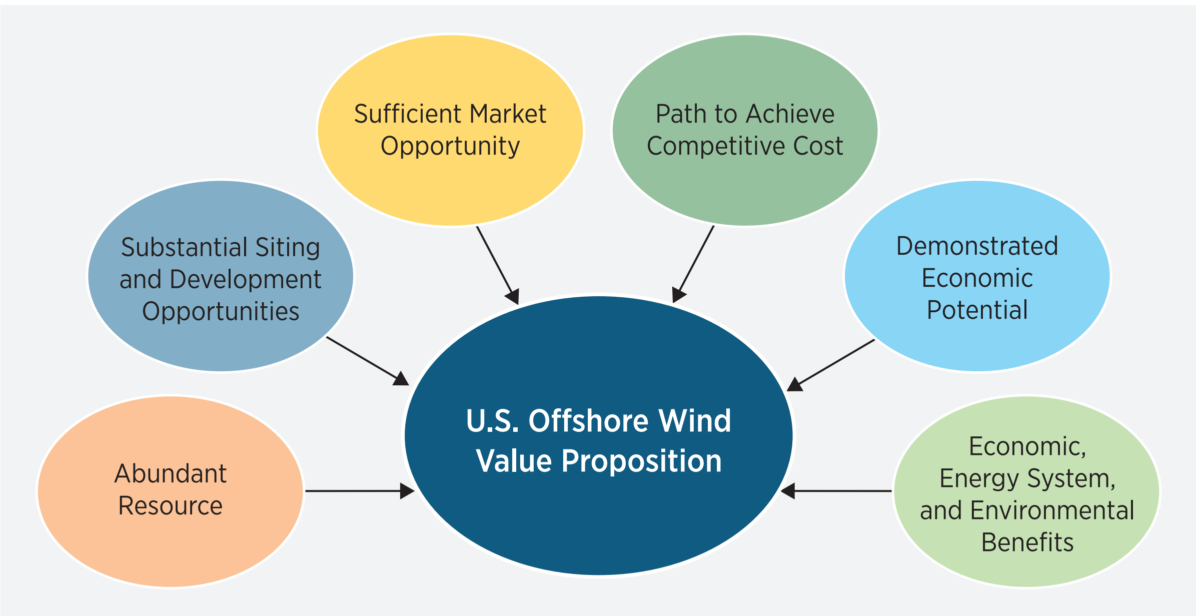


Figure 2.1. Building blocks comprising the offshore wind value proposition for the United States

Sufficient Market Opportunity

The *Wind Vision* study scenario deployment of 86 GW by 2050 would meet 14% of the projected demand for new generation in the coastal and Great Lakes states in 2050. As the existing fleet of electric-generating units ages and retires and the demand for electricity increases over time, the need for new electric-generation supply grows, creating opportunities for a new type of generation to be built. Recent analysis reveals that the opportunity space in the electricity generation market will be large enough to include newcomers like offshore wind while maintaining a diversity of generation on the grid [22].

Path to Achieve Competitive Cost

Through technology improvements, efficiencies gained through economies of scale, and deployment experience, offshore industry cost models now show credible scenarios for cost reductions below $100/MWh at many sites in the United States by the year 2030 [23]. Although the LCOE for offshore wind in 2015 is still high relative to other, more mature energy sources, this analysis of trends over the next 15 years substantiates possible cost reduction pathways that lead toward economic viability with little or no incentives for some U.S. coastal regions [23]. Specific challenges associated with these cost reductions, as well as actions required to achieve them, are explored in more depth in Chapter 3 and Chapter 4.

Demonstrated Economic Potential

The economic potential for offshore wind in the United States cannot be determined by LCOE alone. The economic viability of offshore wind depends heavily on the system prices for electricity being sold in local and regional markets where offshore wind might be deployed. To identify sites that are the most economical, researchers evaluated offshore wind LCOE relative to local electricity prices using a geospatial model [23]. The study results revealed competitive LCOE values under future scenarios that are highly dependent on local electricity prices, and which varied significantly among U.S. coastal locations [1].

Economic, Energy System, and Environmental Benefits

Offshore wind offers the potential for a unique set of tangible economic, environmental, and energy system benefits, such as higher capacity value, wholesale electricity price suppression, and transmission congestion relief.

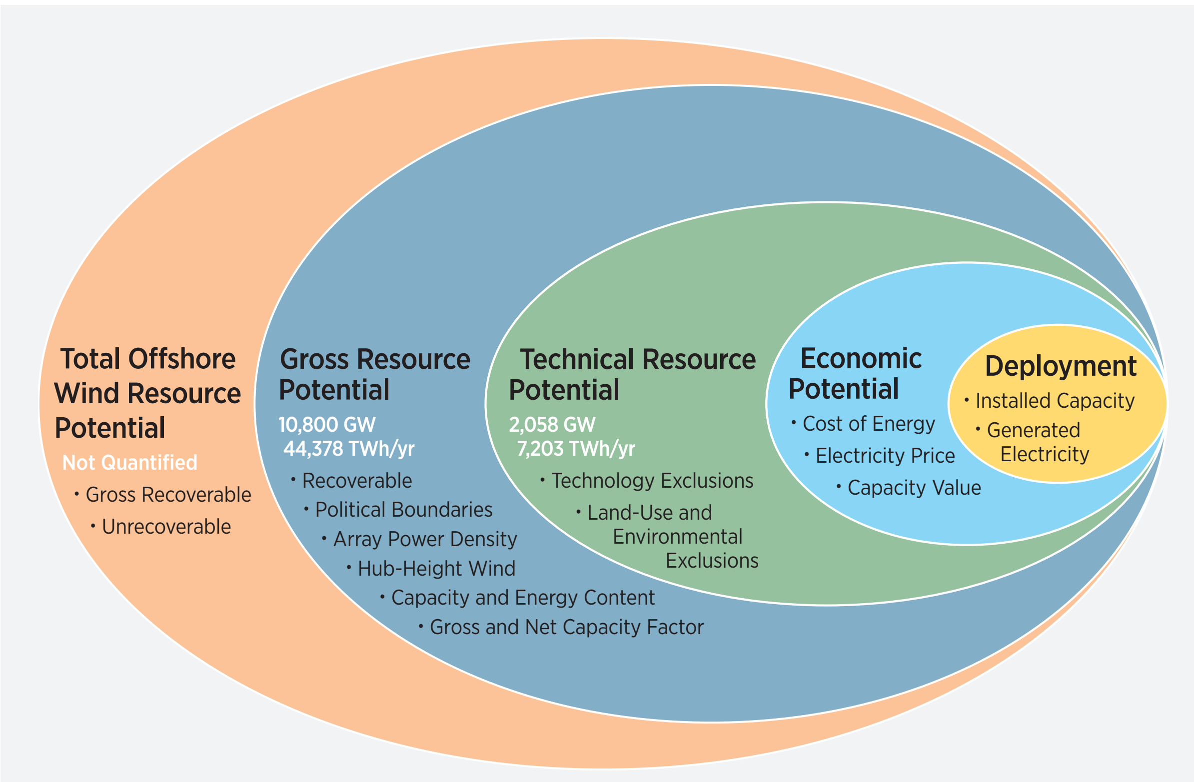


Figure 2.2. Offshore wind energy resource classification framework [24]

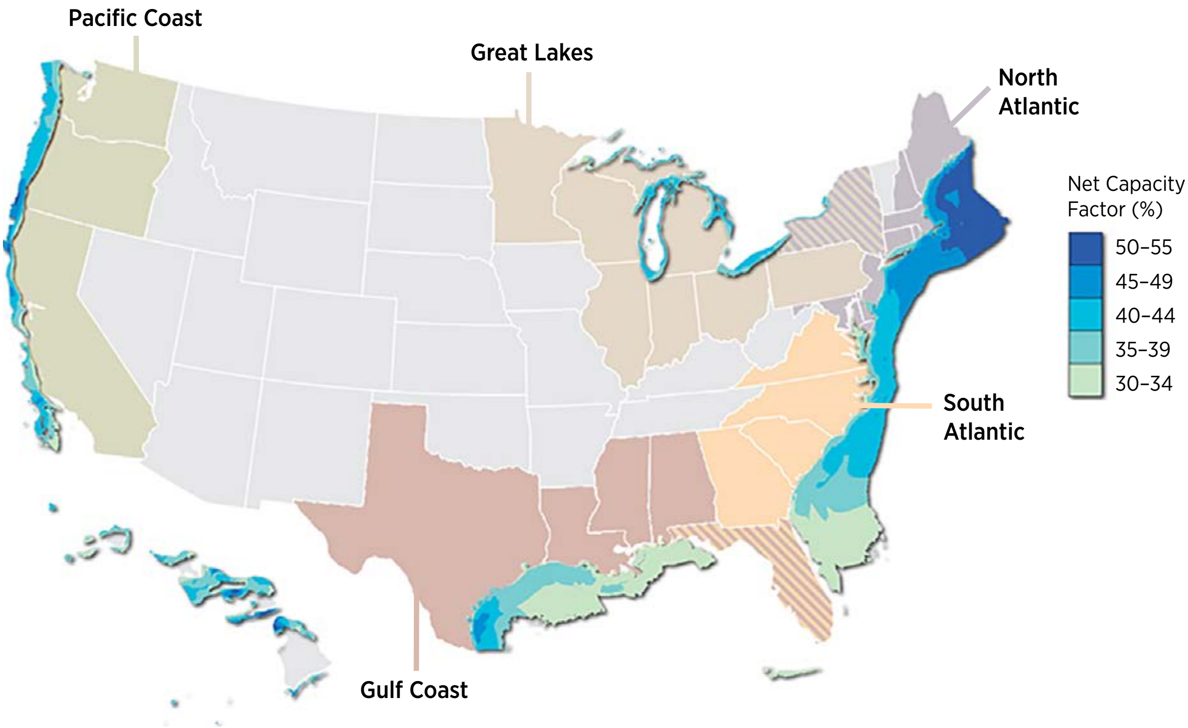


Figure 2.3. Net capacity factor for technical potential energy resource at 100 m with technical exclusions for five U.S. offshore wind resource regions

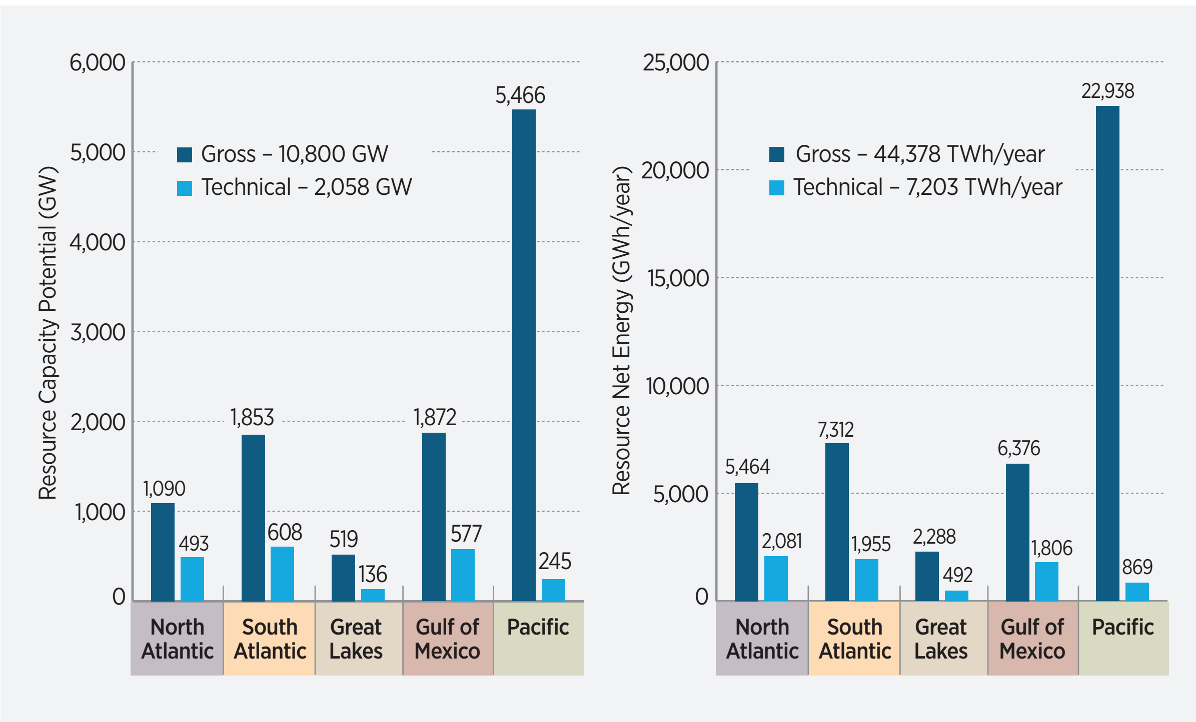


Figure 2.4 Capacity (left) and net energy (right) offshore wind resource estimates for five U.S. offshore wind resource regions

Offshore wind also offers societal benefits normally associated with low-carbon renewables. For example, the *Wind Vision* study scenario shows offshore wind could reduce GHG emissions by nearly 2%, add 160,000 domestic jobs, and reduce water consumption by the electric power sector by 5% by 2050 [2]. These benefits are likely to raise the value of offshore wind in many states or regions. Although they may not contribute directly to the bottom line for offshore wind project developers, these advantages can be added to other societal benefits commonly associated with low-carbon renewables [25].

2.2 Abundant Resource

The expansive offshore wind resource is the foundation of the offshore wind value proposition. The U.S. resource is robust, abundant, and regionally diverse, allowing for offshore wind development to be located near load centers with some of the highest electric rates in the United States [26]. In many of the most populated regions, these coastal wind resources can provide in-state power generation at a large scale. The Atlantic Ocean, Great Lakes, Gulf of Mexico, West Coast, and Hawaii all contain significant offshore wind resources, and projects have been proposed in each of these areas.

In 2010, the first U.S. offshore wind energy resource assessments were completed by NREL [21]. Using current industry knowledge, an updated 2016 offshore wind resource assessment [20] refined and reaffirmed the abundance of the available offshore wind resource. The updated resource assessment also provides a framework for resource classification (see Figure 2.2) [24], that describes the offshore wind resources in terms that help promote consistency with broader renewable resource potential capacity classification schemes [27]. Some of the significant highlights and changes featured in the *2016 Offshore Wind Energy Resource Assessment for the United States* include:

- Expanding the gross resource area from 50 nautical miles (nm) to 200 nm from the territorial sea baseline to correspond to the U.S. Exclusive Economic Zone [26], using wind speed data provided from the Wind Integration National Dataset Toolkit [28]
- Increasing the reference hub height to 100 meters (m) (previously 90 m) to reflect projected 5-year technology trends for the U.S. market [5]
- Lowering the capacity power density from 5 MW/square kilometer (km^2) to 3 MW/km^2 to adjust for greater array spacing [29–30], and to provide consistency with the *Wind Vision*
- Assessing energy production potential, including geospatial estimates of gross and net capacity factor
- Applying technical exclusions to count resources only in regions with wind speeds over 7 meters per second, water depths over 1,000 m, and icing environments where current technology is feasible[8]
- Applying land-use and environmental exclusions to eliminate areas with known conflicts [31].

With the expansion of the gross recoverable resource potential capacity area to the 200-nm Exclusive Economic Zone boundary, the U.S. gross recoverable resource potential capacity is calculated at 10,800 GW, compared to the 4,150 GW gross potential in the 2010 study. On an energy basis, the U.S. gross recoverable resource potential capacity was calculated to be 44,378 terawatt-hours (TWh) per year. In moving from the gross recoverable resource potential capacity to the technical potential capacity, about 80% of the OCS area was unsuitable using the current technology. The remaining technical potential capacity is 2,058 GW, with an energy generation potential of 7,203 TWh/year, which is almost double the electric consumption of the United States.[9]

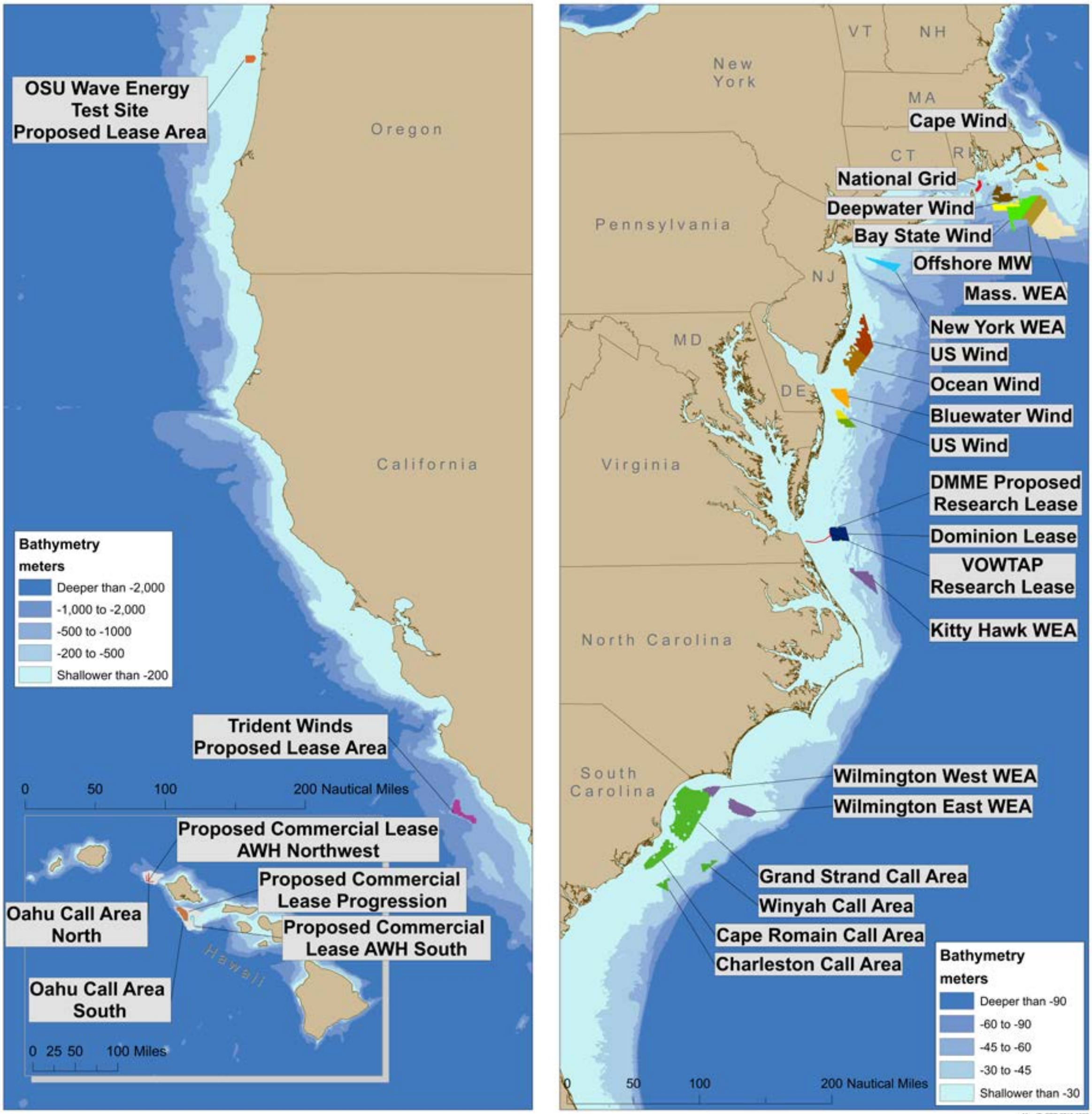
These U.S. resource totals have been divided into the five regions shown in Figure 2.3 (as defined in the *Wind Vision*). Taking into account potential wind plant system losses ranging from 12% to 23% (e.g., wake effects, electric power transmission, and offshore accessibility), the net capacity factor for the technical resource potential capacity is also shown in Figure 2.3.

Figure 2.4 shows the abundance of the U.S. offshore wind technical resource potential capacity and how it is distributed among all five *Wind Vision* regions.

Assuming the DOE *Wind Vision* study scenario deployment of 86 GW is realized, approximately 4% of the technical resource area (about 1% of the gross resource area) would need to be developed. This would equate to approximately 7% of the U.S. electric consumption [2]. Each region is capable of contributing to a viable offshore wind industry by supporting significant deployment and the development of a robust supply chain and supporting infrastructure.

2.3 Substantial Siting and Development Opportunities

An efficient, clearly defined federal regulatory process that encourages collaboration with stakeholders is essential for the development of the nascent offshore wind industry in the United States, and is a necessary building block of the offshore wind value proposition. As of 2016, there are 11 active commercial leases in the Atlantic Ocean, with the potential to support initial deployment of about 14.6 GW of offshore wind based on a standard capacity density assumption of 3 MW/km^2 [5]. BOEM's leases provide the exclusive right to submit development plans and conduct any BOEM-approved activities. It is vital that the offshore wind development



Source: BOEM

Figure 2.5. BOEM-defined areas for potential renewable energy development as of August 2016

process be conducted in a manner that is environmentally responsible, transparent, fair, and safe. This will help instill confidence in developers, utilities, and investors that future markets will materialize.

Since 2011, the siting and regulatory process for offshore wind energy in U.S. federal waters has matured and advanced significantly under the management of BOEM. Although there has been activity in both state and federal waters, the 2016 *Offshore Wind Energy Resource Assessment for the United States* reports that more than 88% of the technical offshore wind resource potential capacity area (over 606,000 km^2) in the United States is in federal waters [20]. As such, to build the 86 GW of offshore wind by 2050 in the *Wind Vision* study scenario, most of the development would likely take place on the OCS under federal jurisdiction. Figure 2.5 identifies the current location and approximate size of BOEM's proposed wind energy areas (WEAs) and other wind development zones that have been proposed, leased, or are under development in federal waters. Several other projects have also been proposed in areas outside the designated WEAs and in state waters that can be added to the number of total sites available.

Currently, BOEM has a number of potential wind areas in the planning phase. In addition, developers can submit unsolicited lease requests for offshore wind development outside of designated WEAs, as is currently being done offshore of the Pacific Coast and Hawaii [5]. In the next decade, the commercial development of floating wind technology that can be deployed in deeper waters (greater than 60 m) is expected. This capability would allow for the leasing of new areas that are located farther from shore (e.g., off the Atlantic Coast), or in areas like the Pacific Coast where current fixed-bottom technology would not be possible at a large scale. Finally, offshore wind development in the Great Lakes is poised to open up freshwater sites that are outside of BOEM's jurisdiction [5]. Together with a stable pipeline of potential power purchase agreements (PPAs), these existing and future siting opportunities can provide the necessary development capacity to support the development of a pipeline sufficient to justify the development of a robust and sustainable domestic supply chain and infrastructure.

2.4 Sufficient Market Opportunity for Offshore Wind in U.S. Coastal Regions

As the existing fleet of electric-generating units ages and retires and the demand for electricity is projected to increase, on average, over time [32], there is a growing need for new generation to be built. Recent studies show that there will be enough demand for new power in the coastal regions of the United States (including the Great Lakes region)[10] such that growth in offshore wind consistent with the *Wind Vision* study scenario between 2015 and 2050 can, in principle, be accommodated when considering electricity demand and retirements [22].[11] Further analysis will need to refine these findings to identify any operational, economic, or transmission-related constraints. Demonstrating sufficient market opportunity provides an essential building block for the offshore wind value proposition and can assist policymakers in regional and national energy planning for an initial assessment of future electricity needs.

The opportunity space is defined as the difference between the expected generation from existing power plants and the expected electrical load at a defined point in the future. To determine the opportunity space, retirements from the existing electricity-generating fleet are compared to projected electrical load growth based on Energy Information Administration [32] projections. Scheduled and age-based retirements are taken into account without consideration for early retirements or lifetime extensions caused by policy or project economics. Projecting into the future, the opportunity space increases because electrical demand is expected to grow by an average annual load growth of 0.66% (compound annual growth rate) in the United States through 2050 [22]—a time period when many power plants are expected to reach their life expectancy and retire. The opportunity space can be filled by any generation source that satisfies the system needs. Figure 2.6 shows the electrical load for U.S. coastal regions compared to the expected electric generation by major generation type (i.e., coal, gas/petroleum, nuclear, and renewables) between 2015 and 2050.

In Figure 2.6, the opportunity space is the yellow wedge that grows over time as generation plants retire and electrical demand increases. Table 2.1 compares these data to the prescribed *Wind Vision* study scenario for 2020, 2030, and 2050.

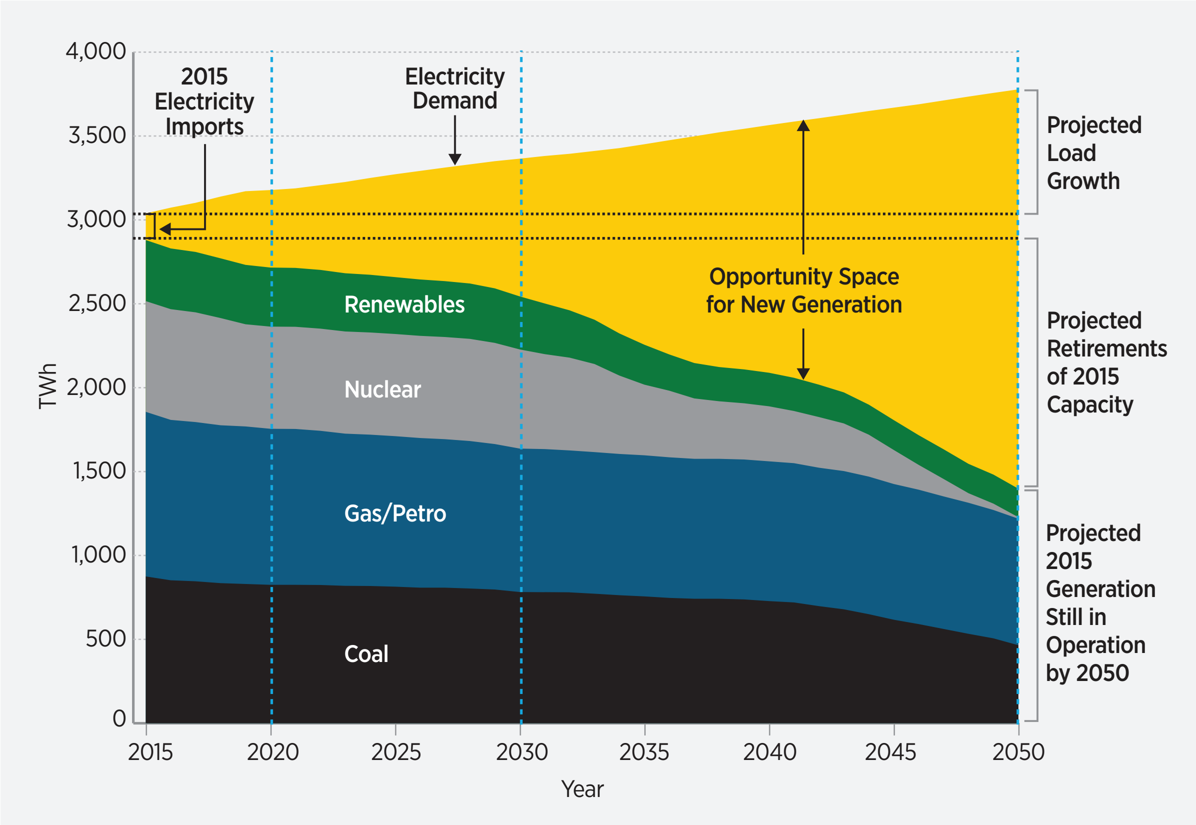


Figure 2.6. Scheduled and age-based retirements and load growth create opportunity for new offshore wind generation in coastal regions [22]

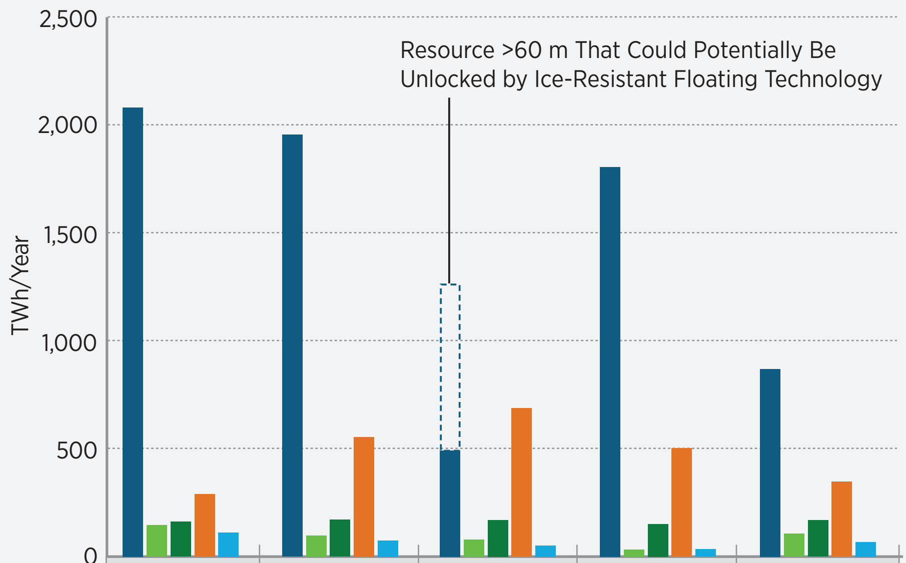
Table 2.1. Offshore Wind Market Opportunity for U.S. Coastal Regions Compared to the *Wind Vision* [2], [22]

	2020	2030	2050
Wind Vision Capacity Installed (GW)	3	22	86
Wind Vision Energy Delivered (TWh/yr)	12	87	339
Opportunity Space (U.S. Coastal Regions) (TWh/yr)	462	821	2,380
Opportunity Space Utilization by Offshore Wind	3%	11%	14%

The opportunity space for offshore wind development is far greater than the *Wind Vision* study scenario deployment. As shown in Table 2.1, from 2020 to 2050, the utilization of the opportunity associated with the *Wind Vision* study scenario increases from only 3% to 14% of the entire U.S. coastal region opportunity space.

For detailed energy planning, however, regional data and additional analysis are needed. Figure 2.7 shows the opportunity space in relation to the offshore wind technical resource potential (Figure 2.3) for each *Wind Vision* target year: 2020, 2030, and 2050, in each of the five regions. It also compares these numbers to the regional energy production associated with the *Wind Vision* study scenario.

Offshore wind resources are significantly greater than the market opportunity, meaning that the *Wind Vision* study scenario of 86 GW of deployment by 2050 would entail developing only a small fraction of the total U.S. technical potential. In the Great Lakes, however, the market opportunity space actually exceeds the technical potential by 2050. This excess is because the market opportunity space is relatively high (688 TWh/yr) and because of a limited technical resource given the analysis criteria imposed. Water depths greater than 60 m were not considered as technical resource potential in the Great Lakes because a technology for floating foundations able to resist surface ice floes in freshwater does not yet exist. However, Figure 2.7 illustrates the Great Lakes resource potential capacity that could become available if new technologies for floating foundations were developed to address this limitation.



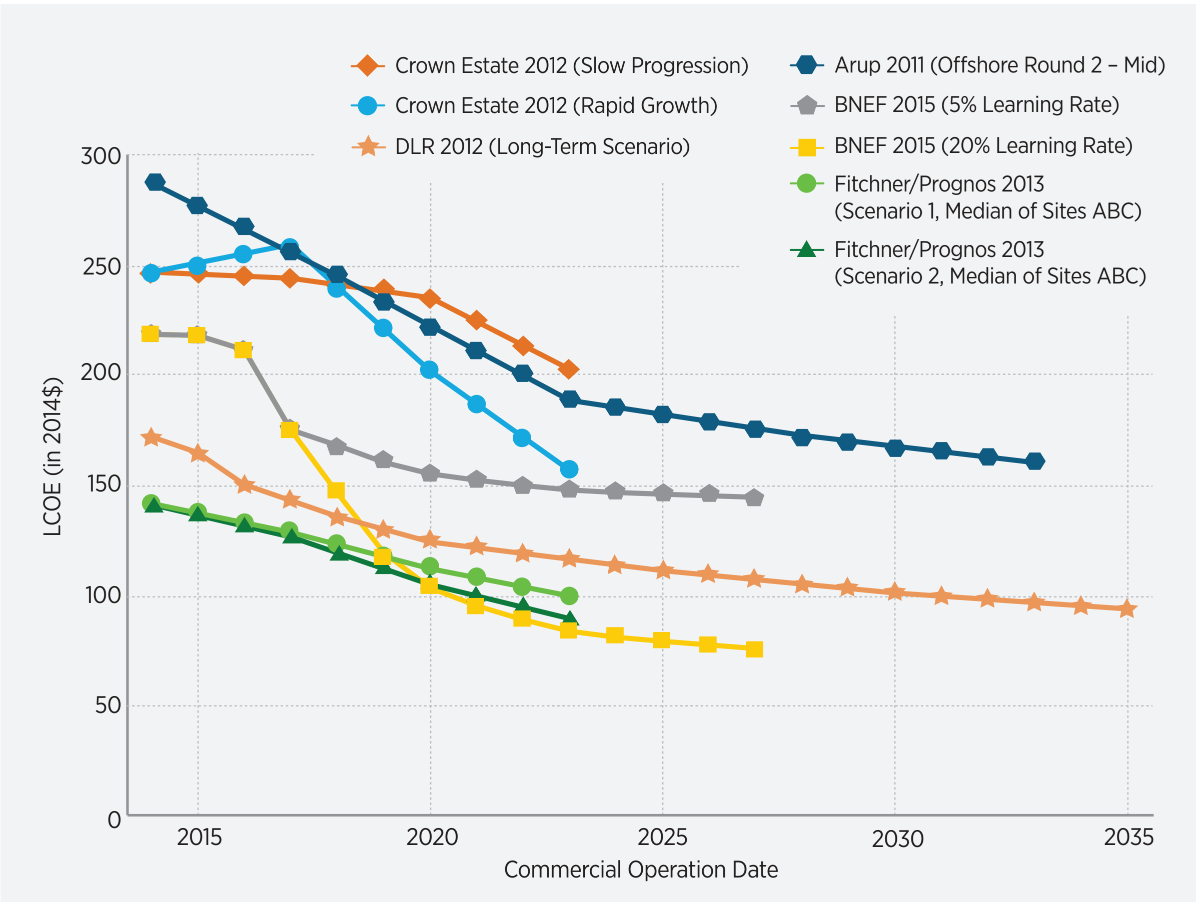
	North Atlantic	South Atlantic	Great Lakes	Gulf Coast	Pacific Coast
Technical Resource Potential	2,081	1,955	492	1,806	869
2020 Opportunity Space	145	98	80	33	106
2030 Opportunity Space	161	170	170	151	168
2050 Opportunity Space	289	555	688	502	348
2050 Wind Vision Scenario	112	75	51	34	68

Figure 2.7. Resource potential energy and opportunity space exceed requirements for the 86-GW *Wind Vision* study scenario[12] [2], [22]

2.5 Path to Achieve Competitive Cost

The offshore wind industry in Europe has realized significant cost reductions as the industry and supply chain have grown and matured. Analysis of projects installed or reaching final investment decision between 2010 and 2014 have indicated the LCOE of offshore wind projects installed in the United Kingdom has reduced from £136/MWh to £121/MWh, representing an 11% reduction in LCOE [33]. This evidence suggests that the United Kingdom will be able to reach its cost reduction trajectory of £100/MWh by 2020. The European Commission has set slightly more aggressive targets for offshore wind LCOE reduction with goals of less than €100/MWh by 2020 and less than €70/MWh by 2030 [34].

Recent spatial-economic modeling of the U.S. offshore wind technical resource area shows that offshore wind has the ability to achieve cost levels at or below $100/MWh by 2030 [23]. This level of LCOE has the potential to be competitive in many U.S. regions with relatively high electricity prices. The economic model shows that between 2015 and 2030, average cost reductions of approximately 5% can be achieved annually, and by 2030, offshore wind may become competitive in parts of the North Atlantic. These modeled U.S.-based cost data correspond to recent European cost reduction estimates as shown in Figure 2.8. The alignment of these cost reduction trends strongly depends on continued global technology innovation (e.g., increase in turbine size) in conjunction with increasing levels of domestic deployment and future market visibility, leading to the near-term establishment of a sustained domestic supply chain [23, 35].[13]



Sources: Crown Estate 2012 [9]; Department of Energy and Climate Change Offshore Round 2 [36]; ARUP Offshore Round 2 [37]; Bloomberg New Energy Finance (BNEF) [38]; German cost reduction study [10]

Figure 2.8. International levelized cost of electricity estimates for offshore wind (2014–2033)

Renewable technologies have historically seen considerable cost decreases as a result of technology advancements, large-scale production, and commercialization. For instance, between 2008 and 2014, costs for land-based wind in the United States decreased by approximately 40% [2] as deployment levels grew by a compound annual growth rate of 17% [39]. Cost reduction is a key requirement for long-term growth of the offshore wind industry. In 2011, the *National Offshore Wind Strategy* [8] focused on developing cost reduction strategies as one if its primary goals. The emphasis on cost reduction continues to be the critical driver for the industry. Industry-wide technology innovations, deployment experience from Europe and Asia, and maturing European supply chains can be leveraged by the first U.S. offshore wind projects. Further cost decreases can be realized through reducing risk (and risk perception) to early projects, addressing U.S.-specific challenges (e.g., hurricanes, deeper water), and incentivizing markets to stimulate local supply chains and infrastructure development [5].

In 2015 alone, more than 3,000 MW of new offshore wind projects began operations globally, reaching a total of 12,105 MW by year-end [7, 40]. These project developments, primarily in Europe, offer cost data that can serve as the baseline for U.S. cost projections and to identify cost reduction pathways. Because the first U.S. offshore wind project will not come online for commercial operation until late 2016, U.S. developers will leverage European offshore wind technology and industry experience heavily while accounting for significant physical and economic differences.[14] Similarly, current cost models and cost reduction pathway analysis will help establish baseline and cost trends from the global offshore wind experience ([2]; see Figure 2.8).

Figure 2.9 shows potential LCOE reductions over time for sites across the entire offshore wind technical potential area. LCOE ranges widely at any given point in time. In 2015, LCOE values ranged from $130/MWh to $450/MWh, reflecting the wide diversity of U.S. site conditions, including variations in the quality of the wind resource, water depth, distance from shore, and meteorological ocean criteria for operation and maintenance (O&M). The decrease in LCOE from $185/MWh (fixed bottom) and $214/MWh (floating) in 2015 to $93/MWh (fixed bottom) and $89/MWh (floating) in 2030 [23] for the cost reduction scenarios demonstrates the substantial cost reduction potential and significant

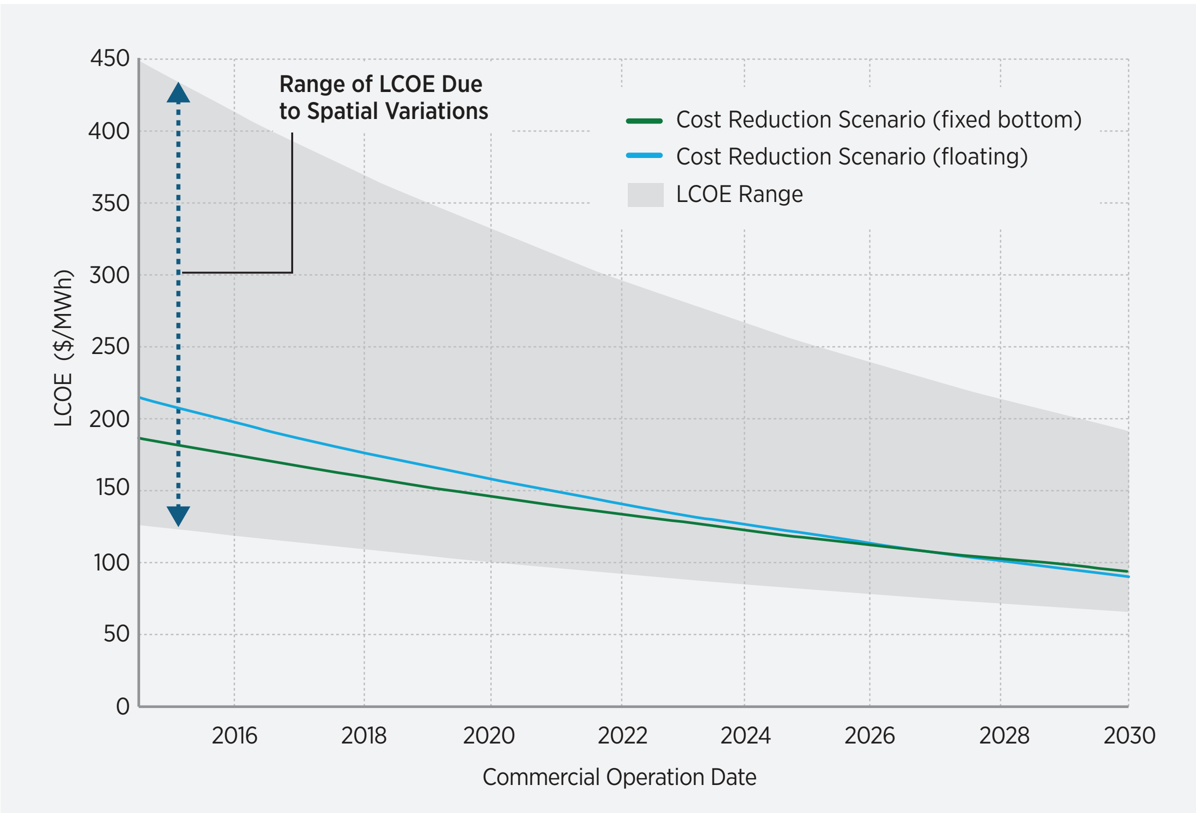
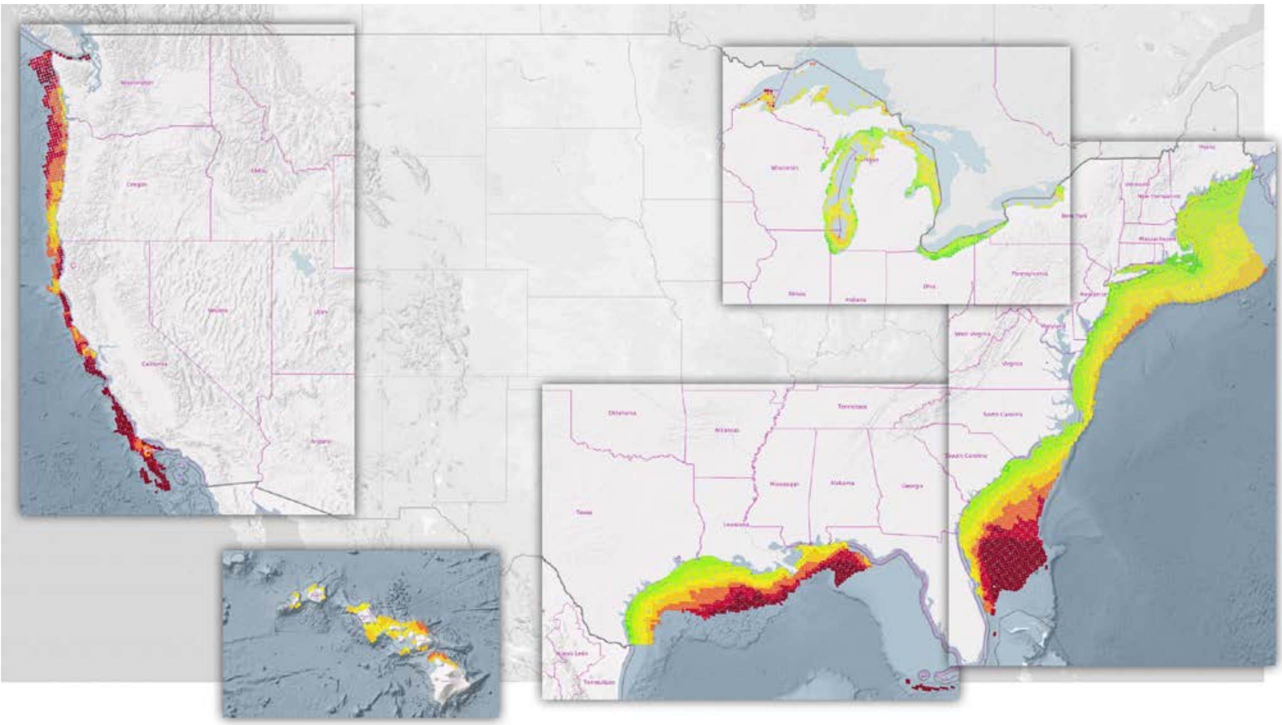


Figure 2.9. Levelized cost of electricity for potential offshore wind projects from 2015 to 2030 over technical resource area [23]

Commercial Operation Date – 2015



Levelized Cost of Energy ($/MWh)

<=100 · 100–125 · 125–150 · 150–175 · 175–200 · 200–225 · 225–250 · 250–275 · 275–300 · >300

Figure 2.10. Regional heat maps of levelized cost of electricity for project commercial operation dates of 2015 (above), 2022, and 2027 (p. 17). [23]

variation among local resource and costs in U.S. coastal regions. Although the model used in this analysis does not consider LCOE reduction as a function of deployment or supply chain maturity, the full realization of the cost reductions presented above strongly depends on near-term deployment, as well as sustained investment in technology and the supply chain. The impact of those investments on LCOE will be discussed in Chapter 3.

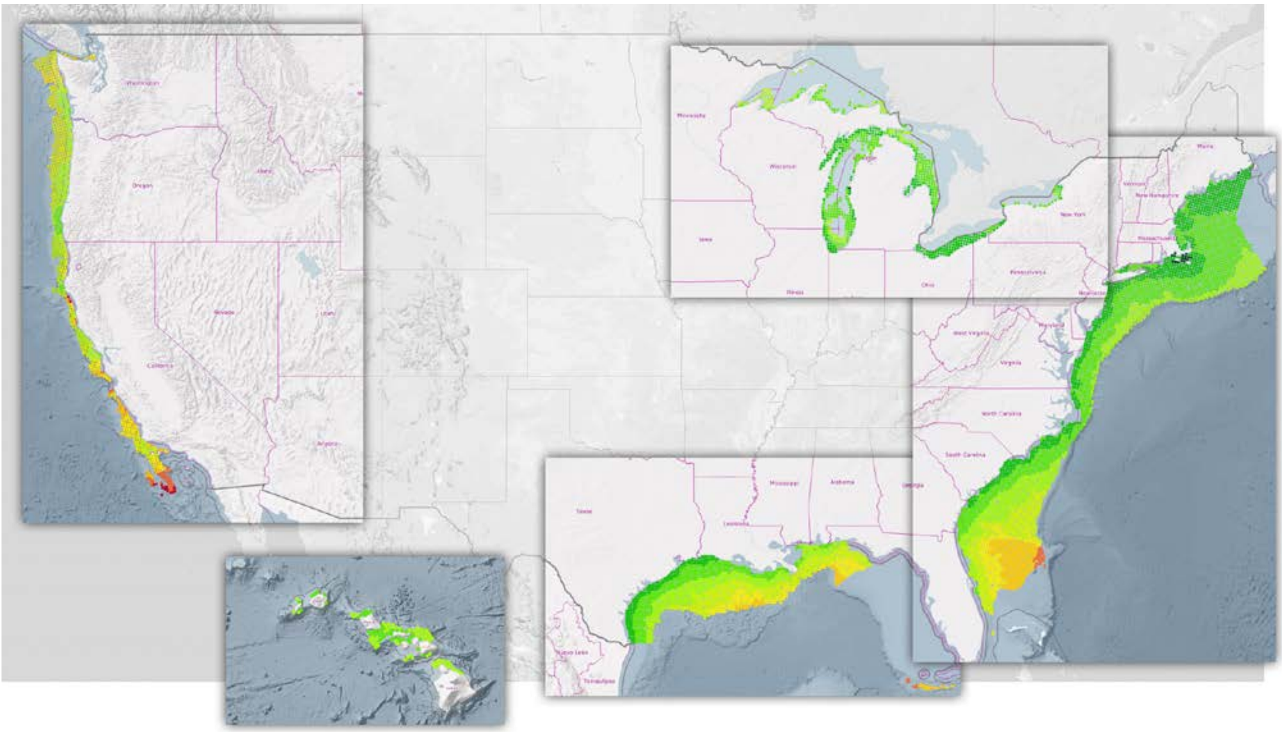
Figure 2.10 illustrates the same data spatially, showing LCOE for a range of sites for project commercial operation dates of 2015, 2022, and 2027 over the technical resource area described in Section 2.3.[15] For a given year, the maps show a wide range of modeled LCOE values across a region that represent a comprehensive set of geospatial cost variables including:

- The quality of the wind resource
- Turbine accessibility as a result of varying sea states
- Distance from shore
- Water depth
- Substructure suitability
- Availability of critical infrastructure.

Not surprisingly, the maps show lower LCOE in the regions where wind speeds are known to be higher and water depths are lower. They also show that sites closer to shore have lower LCOE because electric transmission and O&M costs are lower.

Figure 2.10 also shows reductions of LCOE from year to year at a given location, with green shades indicating lower LCOE values. These temporal changes in LCOE are generally the result of a different set of factors related to technology advancement and market development. Among the drivers of these time-dependent cost reductions are technology advancements that lower the cost for capital expenditures (CapEx), such as turbine, substructures, and electrical infrastructure; operations; or financing, or conversely, factors that raise annual energy output of the turbines. The maps show that the benefits of technology and market advancement are realized at most sites uniformly in time.

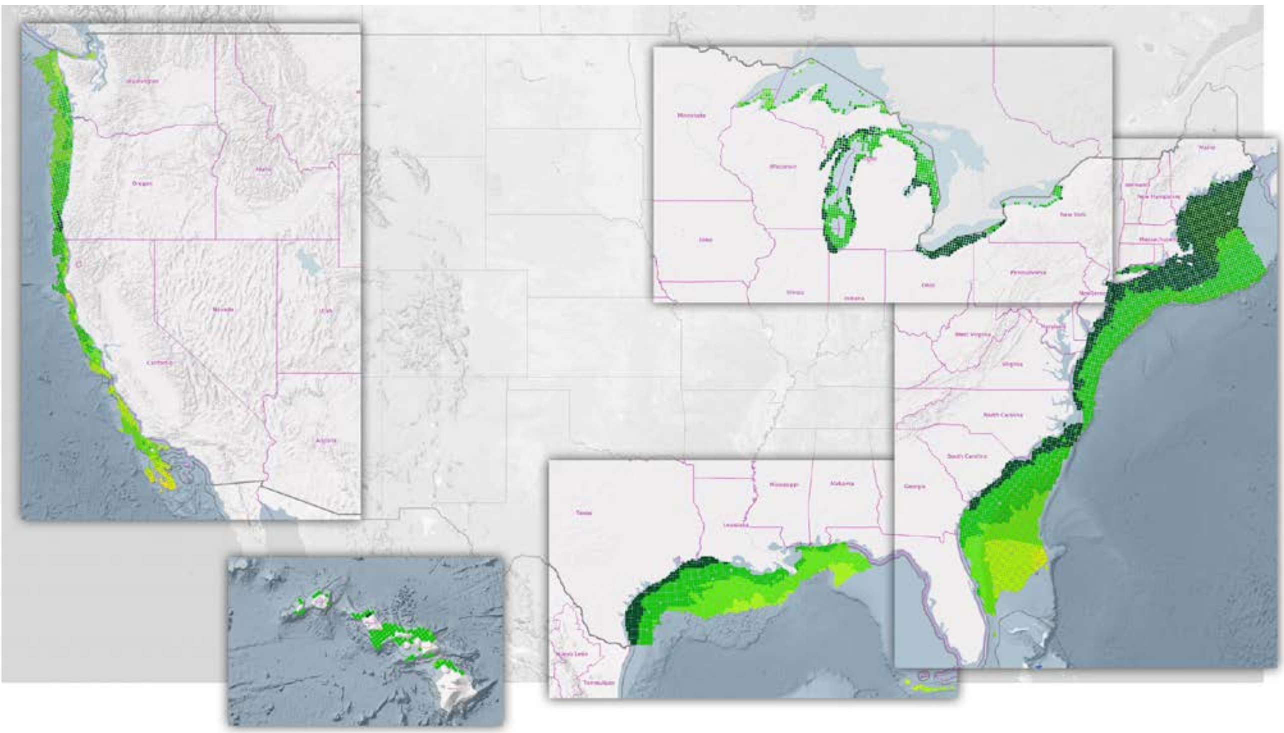
Commercial Operation Date – 2022



Levelized Cost of Energy ($/MWh)

● <=100 ● 100–125 ● 125–150 ● 150–175 ● 175–200 ● 200–225 ● 225–250 ● 250–275 ● 275–300 ● >300

Commercial Operation Date – 2027



2.6 Demonstrated Economic Potential for Offshore Wind Energy

The economic potential for offshore wind energy cannot be determined by LCOE alone. The economic viability of offshore wind also depends on the prices for electricity and capacity being sold in local and regional markets in which offshore wind might be deployed. Economic models reveal that a significant number of offshore wind sites with relatively low LCOE that coincide with high electricity prices may be economically viable with limited or no subsidy by 2030 [23]. Because of the high geographic variation in costs and electricity prices among U.S. coastal areas, the timing of when certain sites might achieve economic viability through technology advancement and cost reduction varies considerably (Figure 2.11). Among U.S. coastal areas, offshore wind sites in the Northeast region are among the most likely to be cost-competitive within the next 10–15 years. To realize these cost reductions, near-term (and higher-cost) projects would need to move forward to enable the learning, deployment experience, and supply chain development that will likely be necessary—along with technology research and development needs and actions like those described in Chapters 3 and 4—to achieve competitive costs in the future.

Although the cost of offshore wind, which is often expressed in terms of LCOE, is a fundamental component of the technology's economic viability and competitiveness in the market, the wider electricity system value from offshore wind is equally important. Offshore wind projects depend on future wholesale electricity prices and capacity market prices within their local electricity market region. These factors can be represented through levelized avoided costs of energy (LACE),[16] a measure of the potential revenue from wholesale electricity prices and capacity that is available to a new generator absent other revenue streams such as tax credits or Renewable Energy Credits (RECs) [32]. LACE varies regionally and by technology and

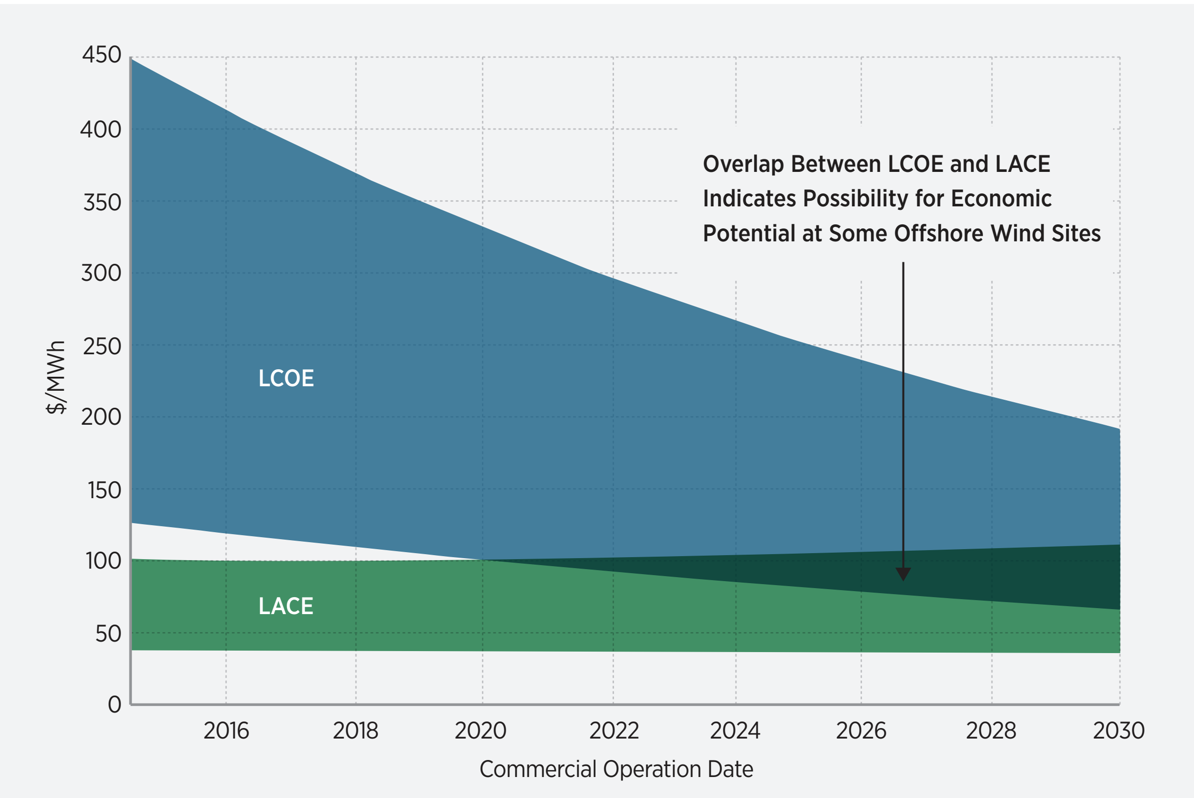


Figure 2.11. Comparison of levelized cost of energy and levelized avoided cost of energy estimates from 2015 to 2030

represents "a measure of what it would cost the grid to generate the electricity that is otherwise displaced by a new generation project" [32]. A comparison of LCOE and LACE can provide an indication of whether the value from a project exceeds its costs at a given location and this difference may be compared with other available technologies to determine the technology with the highest net economic value.

A 2016 spatial-economic analysis for offshore wind [23] includes a comparison of offshore wind LCOE with LACE at thousands of potential sites in U.S. waters. Figure 2.11 depicts the declining offshore wind LCOE together with the range of LACE estimates from 2015 to 2030 on a national scale. LACE across U.S. coastal areas is generally expected to increase gradually over time "as a result of rising costs for power generation and delivery" [32]. The lower-bound LCOE and higher-bound LACE start to overlap by 2019, and the coincidence of LCOE with LACE estimated for potential U.S. offshore wind sites increases over time. This indicates that a growing number of U.S. offshore wind sites will be able to find their required costs met by available revenue from prevailing pricings for electricity and capacity even without any project-specific government support schemes. The LCOE-LACE comparison in Figure 2.11 [23] can serve as a high-level indicator of the economic market potential for offshore wind within the next 15 years. In other words, offshore wind sites that achieve this market potential indicated by LACE greater than LCOE are likely competitive relative to other contenders vying for the new electric generation market opportunity space. Moreover, the analysis shows that in the future there could be ample sites with this economic market potential to meet growing offshore wind demand.

2.7 Economic, Energy System, and Environmental Benefits of Offshore Wind Energy

The value of offshore wind extends well beyond the wholesale electric cost at which it can provide electricity to consumers. Projected reductions in LCOE and increases in the technology's system value, LACE, over time indicate that offshore wind energy is likely to offer electricity at increasingly competitive rates. However, offshore wind like all sources of generation offers a set of additional benefits to consumers, utilities, and local economies that are unique to its production profile, generation sites, and technology that are not counted in the modeled LCOE data shown in Figure 2.10. These additional benefits may add substantial value. Most of these benefits, shown as they relate particularly to offshore wind in Figure 2.12, can be quantified or even monetized to help supplement the case for economic viability or to support policy decisions.

Marginal Price Suppression

The marginal cost of energy in deregulated electricity markets is generally set by the highest-priced available generator required to support demand at any given point in time. With no fuel costs and comparatively low variable operating costs, the marginal generating costs of offshore wind—like most renewables—is close to zero. As such, the low marginal generation costs associated with offshore wind can displace more expensive generating assets from the dispatch stack, which in turn can reduce the market clearing price that is paid to all generators. Therefore, offshore wind has the potential to suppress wholesale and retail electricity prices. GE Power [41] estimates that with 20% wind energy penetration in the service territory of the Independent System Operator of New England, the locational marginal price across this region could be reduced by $9/MWh if high wind speed offshore locations were developed. Similarly, despite a first-year above-market PPA price of $187/MWh, it was estimated that the 468-MW Cape Wind project would decrease wholesale electricity prices by an average of $1.86/MWh [42], and the associated total cost savings to the consumer was projected to average $286 million annually, totaling $7.2 billion over 25 years. DOE's *Wind Vision* [2] indicates that offshore wind may have a more significant impact in lowering wholesale electric prices in coastal states than land-based wind has in other regions. This additional advantage is attributed to the tendency for offshore wind to coincide with peak summer loads and have a diurnal pattern aligned with peak demand.

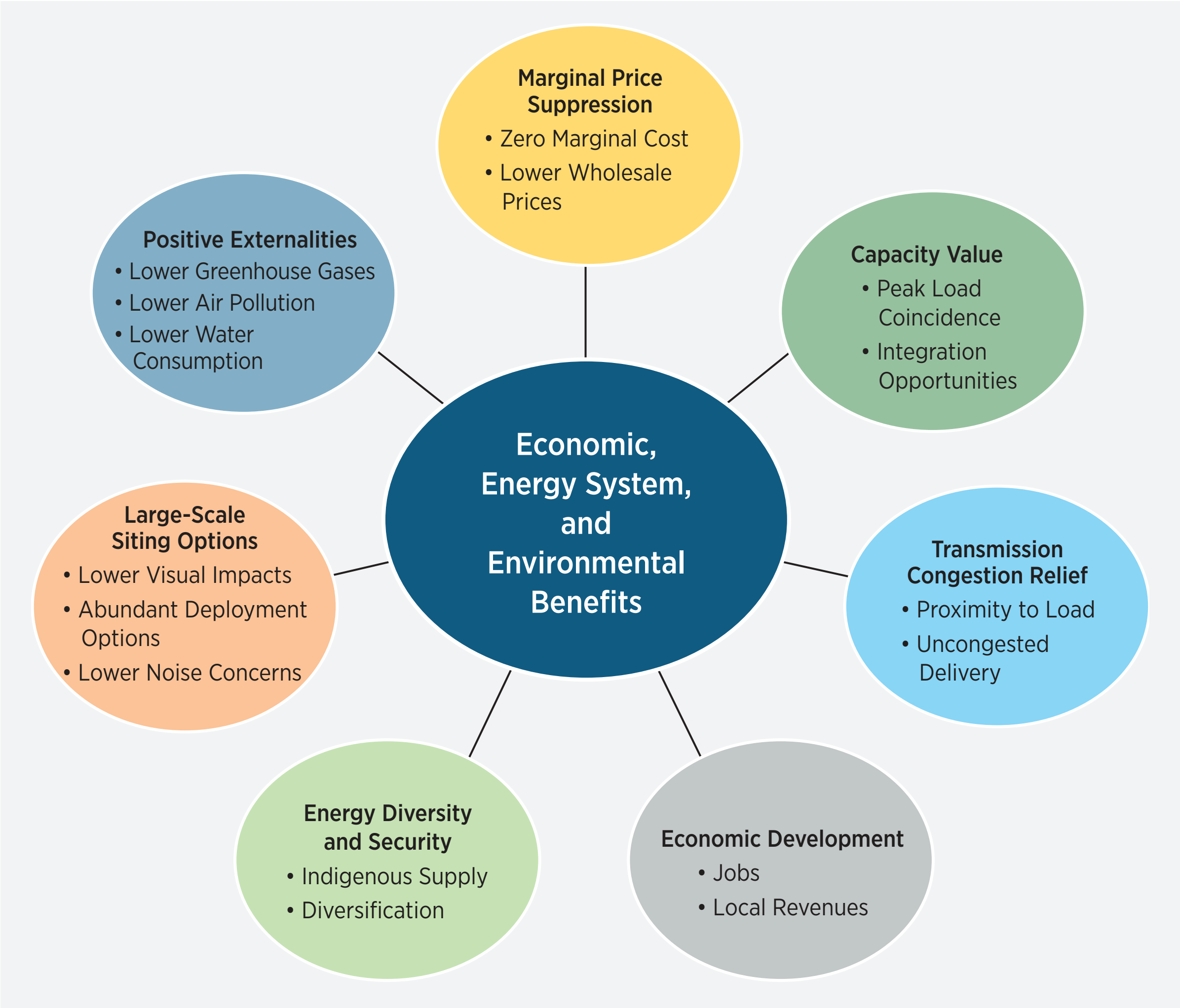


Figure 2.12. Economic, energy system, and environmental benefits of offshore wind

Capacity Value

The capacity value of offshore wind is the amount of generation that can be relied on to meet load during peak hours. Offshore wind can play an integral part in ensuring system reliability during times of peak demand or in the event of a mechanical or electrical failure from other generators. Winds are typically more energetic and less turbulent offshore than on land, and the resource availability and production characteristics of offshore wind tend to coincide better with load peaks [43]. Offshore wind also exhibits a comparatively stable and less variable average power output. These characteristics have been shown to lower system costs. A recent study commissioned by DOE found that deploying 54 GW of offshore wind around the country would reduce annual production costs by $7.68 billion, delivering a value to the system from offshore wind of $41/MWh [44]. In certain regions, offshore wind characteristics can also complement some other renewable generation sources such as land-based wind or solar photovoltaics [45]. In California, offshore winds show afternoon and evening diurnal peaks that coincide with peak loads, whereas land-based winds tend to peak at night. Estimated capacity values for offshore wind range between 24% for California [46] to 40% for New York [47]. An analysis from GE Power [41] estimated the 3-year average capacity value for offshore wind in Independent System Operator of New England territory to range from 47% to 51% in a scenario with the best-suited wind sites available for development. The corresponding capacity values for land-based wind ranged from 34% to 35%.

Offshore Wind May Help Enable Greater Renewable Energy Penetration: The California Case

California recently enacted an increase in its renewable energy electric generation mandates to 50% by 2030, up from a realized total 25% in 2014 [48]. Diversity in renewable generation as it expands can help reduce the cost of meeting these targets and mitigate some of the challenges posed by large contributions by any one resource type. In California, offshore wind can play a significant role to complement and enable greater penetration by the state's vast solar and land-based wind resources.

Figure 2.13 shows how offshore wind may help mitigate challenges associated with the "Duck Curve." Shown below, this figure shows net load (modeled load minus land-based wind and solar generation) on March 31 in years 2012–2020 [49]. As more solar generation is added to the grid during this time, it is able to meet an increasingly large portion of daytime load, but the grid also requires increasing amounts of other generation to ramp up to meet evening peaks as the sun goes down. Preliminary investigation of some possible California offshore wind sites, from near the Channel Islands to the Oregon border, indicate that available offshore wind peaks in the late afternoon into the evening, with substantial generation throughout the evening hours. Diversifying the portfolio with offshore wind could therefore help to reduce evening ramping requirements and ease the path toward 50% renewables by 2050.

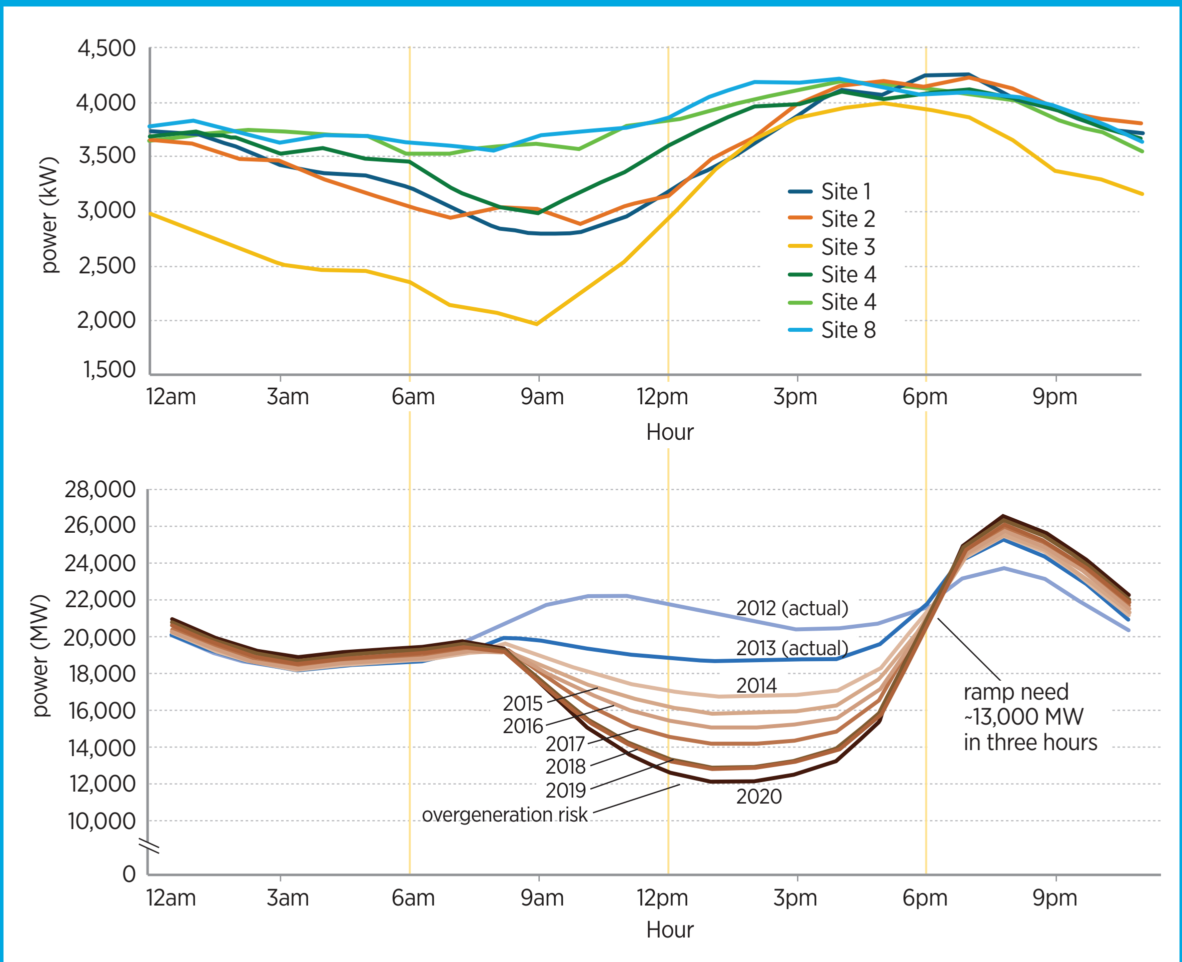


Figure 2.13. The "Duck Curve" and modeled generation profiles for 6-MW offshore wind turbines at six California sites. Adding offshore wind into California's electricity portfolio may help alleviate overgeneration and ramping challenges as solar and land-based wind penetration continue to grow [49–50].

Transmission Congestion Relief

Offshore wind can also provide a hedge against the need to build new transmission. It can be located near the highly populated coastal load centers that have some of the highest electricity rates in the United States [8]. It can provide an alternative to long-distance transmission of land-based wind power from the interior to the coasts [2], while reducing grid congestion and associated electric transmission costs and losses. Transmission congestion, particularly on the Eastern Seaboard and in California, has led to curtailment of economic resources and higher energy prices for electricity consumers.

Economic Development

The offshore wind industry requires a local infrastructure, which in turn may lead to local economic benefits, including jobs and economic growth. By the end of 2014, the European offshore segment employed 75,000 workers [51]. The *Wind Vision* study scenario [2] estimates that 32,000–34,000 offshore wind-related jobs around the country could be created by 2020, increasing to 76,000–80,000 in 2030 and 170,000–181,000 by 2050. In addition, by 2050, the *Wind Vision* study scenario estimates that $440 million in annual lease payments and $680 million in annual property tax payments could flow into local economies.

Energy Diversity and Security

Development of offshore wind can provide a physical hedge against uncertain fuel prices and provide insurance against the impact of volatile and unpredictable fuel prices or changes in emissions policy [52]. Thirteen out of 28 coastal states, which tend to have the highest electricity prices in the nation, import out-of-state electricity to support electricity demand [53]. With land and transmission constraints that may prevent the large-scale exploitation of land-based wind, solar, or other renewables in coastal states, offshore wind could also allow states to generate power using in-state renewable resources and increase control over their energy supplies.

Large-Scale Siting Options

Siting land-based wind or other utility-scale renewable energy projects is complex because of concerns about impacts to human communities, other land uses, and wildlife. Although potential impacts to wildlife and other users of the ocean can present siting conflicts offshore, BOEM's process provides a structured approach to minimizing impacts, and issues such as noise from operational turbines as well as visual impacts to adjacent residents diminish with distance from shore. In coastal states with high population densities and limited available land, BOEM has made available sites representing gigawatts of potential capacity that would be difficult to replicate for land-based wind or other large-scale renewable energy development.

Positive Externalities

Offshore wind can claim many of the same positive externalities as other renewable resources, which in most areas of the United States are often not valued through policy incentives, but can be quantified and compared to the social cost of other energy sources [25]. According to the *Wind Vision* study scenario, these benefits can include:

- **Reduced greenhouse gas emissions.** The study indicates that 1.8% reduction in cumulative GHG emissions (1,600 million tonnes of carbon dioxide equivalents) through 2050, saving $50 billion in associated global damages.
- **Reduced public health impacts as a result of lower air pollution.** Under the *Wind Vision* study scenario, approximately $2 billion in avoided mortality, morbidity, and cumulative emissions in sulfur dioxide, nitrogen dioxide, and fine particulate matter can be realized by 2050.
- **Lower water usage in the electric sector.** The study estimated 5% less water consumption and 3% less water withdrawals for the electric power sector annually [2].

Notes

7. The New Jersey WEA auction was held in late 2015, which added approximately 4.2 GW of potential generating capacity to the 10.4 GW potential reported in [5]. The 14.6 GW also does not include call areas and wind energy areas (WEAs) that have not yet been auctioned. Note that the lease area capacity density values presented here may vary slightly from WEA capacity values levels published by BOEM because of differences in the estimation methods.
8. Excluded areas include water depths greater than 1,000 m [54], wind speeds lower than 7 meters per second [21], and water depths greater than 60 m (in the Great Lakes). Note that when the depth exclusions are considered, the resource area shrinks significantly on the West Coast because of a narrower continental shelf and deeper waters close to shore. Yet, it is important to note that there are several areas on the East Coast where the resource area extends beyond the previous 50-nm boundary.
9. The Energy Information Administration estimated total U.S. electricity consumption in 2014 to be about 3,863 terawatt-hours (TWh) [55].
10. U.S. coastal regions assessed in [22] include states in the Pacific Coast, Gulf Coast, Great Lakes, and North and South Atlantic as defined in the *Wind Vision* [2].
11. The NREL study used a methodology derived from the *Wind Vision* [2].
12. The *Wind Vision* prescribes fractions of the 2050 energy (339 TWh/yr from Table 2.1) offshore wind generation by region according to the following percentages: North Atlantic 33%, South Atlantic 22%, Great Lakes 15%, Gulf Coast 10%, and Pacific Coast 20%.
13. It is important for U.S. offshore wind stakeholders to acknowledge that domestic cost reductions of a magnitude similar to those predicted in Europe can only be achieved with a U.S. supply chain that can generate the learning and scaling effects needed for substantial cost reductions, including the necessary labor skills development and infrastructure (e.g., assembly ports or vessels [56]). A pipeline of U.S. offshore wind projects is critical for the establishment of a domestic supply chain. European supply chain development has been incentivized by "ambitious national programmes and financial incentives that limit risk, and [have] thus attract[ed] investors to the sector" [57] and driven by a pipeline of projects.
14. Some key differences between European and U.S. markets include currency exchange rates, existing infrastructure, supply chain maturity, vessel availability (e.g., Jones Act requirements), workforce readiness, and physical characteristics of the offshore wind siting environment. The cost could also be influenced by U.S.-specific political considerations, including regulatory structure, tax code, and incentive programs [5].
15. The analysis was conducted for the entire lower 48 United States and Hawaii.
16. Levelized avoided cost of energy is a "measure of what it would cost the grid to generate the electricity that is otherwise displaced by a new generation project" [32]. It captures the marginal value of energy (or electricity prices as a proxy) and capacity value to represent the potential revenue available to a project owner from the sale of energy and generating capacity [32]. The capacity value can vary among different technologies and may be one of the benefits of offshore wind (see Chapter 3).

3.0 Major Action Areas for U.S. Offshore Wind Industry Development

To facilitate the responsible development of a robust and sustainable offshore wind industry in the United States, as well as realize the benefits of offshore wind deployment, a number of challenges need to be addressed. The solutions associated with these challenges can be grouped into three broad strategic themes. First, to be competitive in electricity markets, offshore wind costs and U.S.-specific technology risks need to be reduced. Second, environmental and regulatory uncertainties need to be addressed to reduce permitting risks and ensure effective stewardship of the OCS. Third, to increase understanding of the benefits of offshore wind to support near-term deployment, the full spectrum of the electricity system and other economic, social, and environmental costs and benefits of offshore wind need to be quantified and communicated to policymakers and stakeholders. This chapter looks at each of these strategic themes and ties them to seven discrete action areas (see Table 3.1) in which further work is needed to overcome the challenges mentioned here.

Table 3.1. National Offshore Wind Strategy Strategic Themes and Action Areas

Strategic Themes	Action Areas
1. Reducing Costs and Technology Risks	1. Offshore Wind Power Resources and Site Characterization 2. Offshore Wind Plant Technology Advancement 3. Installation, Operation and Maintenance, and Supply Chain Solutions
2. Supporting Effective Stewardship	1. Ensuring Efficiency, Consistency, and Clarity in the Regulatory Process 2. Managing Key Environmental and Human-Use Concerns
3. Increasing Understanding of the Benefits and Costs of Offshore Wind	1. Offshore Wind Electricity Delivery and Grid Integration 2. Quantifying and Communicating the Benefits and Costs of Offshore Wind

3.1 Strategic Theme 1: Reducing Costs and Technology Risks

As established in Chapter 2, the current estimated cost of offshore wind is too high to support widespread deployment; however, investments in technology, an expanded supply chain, and building the industry knowledge in the United States can have significant cost-reduction impacts. Modeled deployment and cost-reduction scenarios reveal that offshore wind can become competitive with local electricity costs in many parts of the country by 2030 [23]. They also reveal that there are significant cost savings to be realized through continued global market growth and R&D to reduce capital and operating expenditures across the following three broad action areas:

- **Offshore wind power resource and site characterization**. A better understanding of the unique meteorological, ocean, and seafloor conditions at sites proposed for development in the United States will allow for optimized designs, reduced capital costs, greater safety, and less uncertainty in preconstruction energy estimates, which can reduce financing costs.

- **Offshore wind plant technology advancement**. Increasing turbine size and efficiency, reducing cost in substructures, and optimizing wind plants at a system level for unique U.S. conditions can reduce capital costs and increase energy production at any given site.
- **Installation, O&M, and supply chain solutions**. The complexity and risk associated with installation and O&M activities require specialized infrastructure that does not yet exist in the United States. Identifying strategies to reduce the need for specialized assets, along with leveraging the nation's existing infrastructure will reduce capital and operating costs in the near term and help unlock economic development opportunities in the long term.

Action Area 1.1: Offshore Wind Power Resource and Site Characterization

Problem Statement

Physical site conditions along the U.S. coastline bear some similarities to those in the established European market. However, there are key differences requiring additional scientific and engineering assessment. Currently, there is a significant lack of data describing meteorological, oceanographic, and geologic/man-made conditions at potential project sites offshore of the United States. There is also a lack of standardized methodologies for gathering these data. This deficiency translates into increased uncertainty and risk, and ultimately increases the capital costs of offshore wind projects.

Current Baseline

More than 2,000 GW [24] of offshore wind energy technical potential exists in the United States. Excluding Alaska,[17] these resources cover more than 10,000 miles along the U.S. coastline—including the Atlantic, Gulf, and Pacific Coasts of the continental United States, Great Lakes, and Hawaii—and vary significantly in their meteorological and oceanographic (metocean), and geological conditions.

High-quality U.S. coastal and offshore wind and oceanographic observations exist, such as those gathered in the National Oceanic and Atmospheric Administration's (NOAA's) National Data Buoy Center network. But they collect only near-surface measurements of the atmosphere and are often too far from potential WEAs to determine specific oceanographic conditions at a given site. Very few wind observations are collected at hub height, and without the existence of U.S. meteorological towers similar to the German FINO metocean research stations [58-60],[18] it is difficult to validate wind observation and model data. New technologies, such as light detection and ranging (lidar) buoys, have recently been deployed in the North Atlantic and the Great Lakes.

Observational data on extreme conditions at wind turbine hub height are also scarce. Tools such as the Weather Research and Forecasting Model have the potential to supplement and augment the observational data, but are currently not validated for U.S.-specific conditions in the offshore environment. Efforts are underway to improve these models for land-based wind.[19] Similarly, promising models exist for producing modeled data of hurricanes, which would benefit from observational data available to validate these models [61].

Site-specific metocean characterization studies are required for the design and development of each planned offshore wind project. At present, there are no consensus standards or guidelines for the collection and interpretation of site-specific metocean data with respect to design and operation of offshore wind energy projects in the United States. As a result, data collection for wind resource assessment and estimation of extreme environmental conditions is pursued in a variety of ways. This can potentially result in uncertain or varied reliability for projects developed on the OCS.

A considerable body of observational geological data exists for the OCS, but is not well suited for use in offshore wind energy development. These observational data sets are largely confined to nearshore areas or the shelf/slope break, whereas potential offshore wind development sites are typically located between these two areas.

Work to Date

To advance the state of offshore wind site characterization in the United States, DOI and DOE have funded a number of projects in meteorological, oceanographic, and geological assessment, as well as project planning and design for the purpose of facilitating safe and cost-effective project development.

Work at DOI consists of a number of efforts to support the development of consensus site characterization guidelines and assess and advance site assessment methods. For example, DOI is undertaking a geophysical and geotechnical methodologies study that analyzes the advantages and disadvantages of various methodologies and equipment choices that are used for assessing site conditions and cultural resource identification. In addition, BOEM has an ongoing study that investigates, verifies, and recommends identification and site clearance methodologies to identify and address unexploded ordinance. The data collected in these studies will support the submission of Construction and Operations Plans (COPs) consistent with federal regulations.

DOI has also published guidelines to clarify the information requirements for COPs, including survey results and other information needed for compliance with the OCS Lands Act, National Environmental Policy Act (NEPA), and other applicable laws and regulations. In addition, DOI funded geological survey work in an area offshore Virginia and benthic habitat mapping and assessment for areas offshore North Carolina and South Carolina to inform and support its renewable energy leasing processes.

A 2011 DOE Funding Opportunity Announcement (FOA) resulted in 12 research projects that aimed to advance the characterization of wind resources and other data critical to wind plant feasibility assessment, siting, and facility design. Other projects funded at DOE national laboratories included metocean data collection from the DOE Advanced Technology Demonstration Project sites, providing offshore wind resource characterization through lidar buoys and reference facility research, as well as sediment and scour research.

Remaining Gaps

Collecting Metocean Data Through Validated Methods

The OCS and Great Lakes regions continue to be underobserved because of the difficulty of obtaining data over such remote and expansive areas. This creates uncertainty in siting, design criteria, projected performance, and regulation—and ultimately the cost of energy. Reducing this uncertainty makes tangible progress toward achieving reduced LCOE and enhanced regulatory oversight.

Although representing a significant CapEx that may only be relevant to potential sites within the local area, offshore metocean facilities for offshore wind in U.S. waters similar to the German FINO[20] towers would generate metocean data that would be readily accepted by the community for project development, design, and other purposes. These facilities—or existing towers in Europe or elsewhere—could also serve as a reference for the validation of new, less capital-intensive technologies and methods such as lidar buoys.

If accepted by the financial community, lidar buoy data could serve as a less-expensive, portable alternative for gathering metocean observational data needed to develop offshore wind energy sites. A network of these buoys in applicable areas could collect enough data to allow for interpolation at smaller scales, as well as tuning and validation of Weather Research and Forecasting or other models in U.S.-specific metocean conditions. Collecting these data along with complementary data from existing infrastructure into a single repository or portal could facilitate development.

A significant opportunity in engineering design assessment is the acquisition of considerable hurricane metocean data. Data sets describing relevant hurricane wind profiles—speeds and directions as a function of time up to the uppermost reaches of a turbine—would help significantly reduce uncertainty and allow for more sophisticated analysis and modeling leading to more cost-effective siting, design, operation, and maintenance of a U.S. offshore wind energy fleet.

Standardizing Metocean and Geophysical and Geotechnical Data Collection Methods

Geophysical and geotechnical investigations can be conducted in a multitude of ways with a wide variety of methods and equipment. Standardizing data gathering and procedures could reduce the burden on developers, as could collecting all of the available data in a single repository or portal.

Current DOI regulations require submittal of geophysical and geotechnical survey data in the COP. Certain metocean data are required to be submitted in each project's Facility Design Report. Although DOI has published updated guidelines for geophysical and geotechnical data on its website, its existing requirements for metocean data collection are general in nature, thereby allowing for a wide variety of data collection methods. Supporting the development of standard data collection guidelines would help foster consistency in project designs as well as bestow a necessary level of certainty for developers to determine the effort required to provide the data.

Understanding Intraplant Flows

A better understanding of wind conditions inside wind plants and their effects on reliability and annual energy production (AEP) could also have a significant impact on the cost of offshore wind energy. Turbines inside wind plants interact with each other in complicated ways. The wake behind one turbine can reduce the energy captured by another and increase wear and tear on key components. Quantifying turbine-to-turbine interactions is one focus of a current major DOE initiative: Atmosphere to Electrons.[21] Greater understanding of these flows could lead to plant-level optimization of design and operation, increase AEP and reliability, and reduce uncertainty in wind resource assessment—all of which ultimately lead to lower LCOE.

Action Area 1.2: Offshore Wind Plant Technology Advancement

Problem Statement

Offshore wind technologies have matured significantly over the past 25 years as a result of extensive global research, development, and market growth. With this maturation, significant cost reductions have been realized. This research, development, and growth must continue for offshore wind to compete on an unsubsidized basis. R&D is also needed to adapt existing European technologies to the unique conditions of the U.S. market and enable cost-effective deployment.

Current Baseline

A vast majority of the global project pipeline and installed capacity are in saltwater at depths less than 40 m, distances from shore under 40 km, and at project sizes under 500 MW [5]. State-of-the-art wind turbines have reached nameplate capacities of 6 and 8 MW [5]. Prototype turbines with 10 MW could be deployed as early as 2020 [62]. At European sites, 8-MW turbines are planned to be deployed atop monopile, fixed-bottom substructures in water depths between 10 and 40 m by highly specialized, heavy-lift European vessels [5].

Though monopile, fixed-bottom substructures currently dominate the global market with 75% market share by capacity [5], this prevalent substructure technology may not be economically feasible in water depths up to and exceeding 60 m. To access sites in greater water depths, fixed foundations with wider footprints are needed, such as jacket structures or floating foundations. Currently, floating technology is significantly less prevalent, with only five operating commercial-scale prototypes worldwide as of mid-2015 [5].

With a variety of geological conditions, and more than 58% of the estimated U.S. technical resource potential capacity at depths greater than 60 m [20], the U.S. market requires a variety of fixed-bottom and floating substructure technology solutions.

Design standards for turbines and substructures are critical to ensuring the safe deployment of offshore wind projects and enabling access to financing. The varied bathymetry, metocean conditions, and geologic conditions experienced in the waters offshore the United States limit the applicability of design standards based on experience gained in European seas. Current structural design standards in Europe use safety factors that may be lower than what is needed to achieve an appropriate level of structural reliability for offshore wind turbines in the United States. In contrast, recent developments off the coast of Japan indicate that a direct application of Japanese designs [63], such as those depicted in their typhoon-class turbines, might result in overdesigned, costly turbines for the OCS.

Work to Date

Deepwater Wind's Block Island Wind Farm is scheduled to be the first offshore wind project in the United States. The project will be installed in state waters off the coast of Rhode Island and is scheduled to commence operations in the fall of 2016. This project utilizes five 6-MW direct-drive turbines designed and manufactured by GE Power in Europe that will be installed atop four-legged-jacket fixed-bottom substructures designed by domestic companies.

Other projects currently in the U.S. development pipeline include DOE's Advanced Technology Demonstration Projects. These three projects include state-of-the art turbines planned for one novel fixed-bottom jacketed substructure technology and one floating substructure technology along the Atlantic Coast, and one fixed-bottom suction bucket foundation design for deployment in freshwater conditions in the Great Lakes.

DOE's demonstration projects are planned to be highly instrumented for measuring metocean conditions, structural loads, power production, and environmental data. To benefit the U.S. offshore wind industry, data collected during the demonstrations will be made available to the public 5 years after project completion.

Since 2011, DOE has funded multiple efforts to facilitate advancements in offshore wind turbine technologies. The fiscal year (FY) 2011 U.S. Offshore Wind Technology Development FOA made federal funding available to 19 projects for the purpose of reducing the cost of offshore wind energy through technology innovation, testing, and risk reduction. Similarly, the FY11 Next Generation Drivetrain FOA awarded funding to six projects for the purpose of developing next-generation drivetrain technologies to reduce capital, O&M, and replacement costs, and increase lifetime energy production. National laboratory projects funded during those 4 years yielded major advances in offshore wind computational tools, high-resolution modeling, and rotor development. DOE concurrently funded the construction of two world-class testing facilities—the Clemson University Wind Turbine Drivetrain Test Facility and the Massachusetts Clean Energy Center's Wind Technology Testing Center—to provide unique capabilities for developing and testing offshore wind drivetrains and blades on a larger scale.

Since 2005, BOEM and the DOI's Bureau of Safety and Environmental Enforcement (BSEE) have supported research on operational safety and pollution prevention related to offshore renewable energy development through the DOI's Technology Assessment Program (TAP), formerly known as the Technology Assessment Research Program. As of the beginning of 2016, the Renewable Energy Research Program has expended over $2 million to fund 27 studies that have been completed with final reports posted on both the BOEM and BSEE websites.[22] Five new studies are expected to receive funding in 2016, with a total budget of up to $700,000. The studies have focused on five general areas: fixed-bottom turbines, floating wind turbines, standards and regulations, environment, and inspections and safety.

Remaining Gaps

Significant opportunities remain to reduce offshore wind costs in the United States. These opportunities require further investment in R&D, such as:

- Creating advanced substructure technologies to address conditions such as deep water and weak seabed soils
- Reducing the cost, risk, and need for specialized infrastructure to install offshore wind facilities
- Eliminating unscheduled maintenance through technologies such as prognostic health monitoring and management that can predict component failures and take corrective action
- Developing and validating design practices for hurricanes and other extreme conditions prevalent at U.S. sites
- Reducing energy loss caused by interactions between turbines
- Creating design tools that allow for the development of offshore wind turbines and substructures as coupled systems.

Both floating and fixed-bottom offshore wind technologies show promise for the U.S. market. Chapter 2 presents a 2016 NREL analysis that shows that although floating technologies are more expensive than fixed-bottom technologies at this time, floating technologies have the potential to achieve costs that are equal to or even lower than fixed-bottom technologies by 2030 (see Figure 2.9).[23] The advantages of floating technology include the possible reduction of site conflicts, access to higher winds in waters farther offshore, and a larger resource base. Floating technology also offers the potential for reduced marine operations during construction and installation, and in O&M. Floating technologies could allow for final turbine assembly, commissioning, and major maintenance in port at quayside, in a wide range of weather conditions and using generally available equipment. Quayside assembly and maintenance could present significant cost savings and risk reduction compared to the current practice of utilizing specialized infrastructure to conduct major construction activities offshore, particularly as developers begin to look at more challenging sites in deeper water and more extreme metocean conditions.

R&D in technology can lower offshore wind LCOE in three primary ways: by reducing upfront capital expenditures (CapEx), such as the cost of project development, turbines, substructures, and installation; increasing the potential AEP of a turbine or wind project, and reducing operational expenditures (OpEx), such as maintenance. Figure 3.1 and Figure 3.2 show potential cost reductions in each of these pathways between 2015 through 2030 for fixed-bottom and floating offshore wind technologies [24].

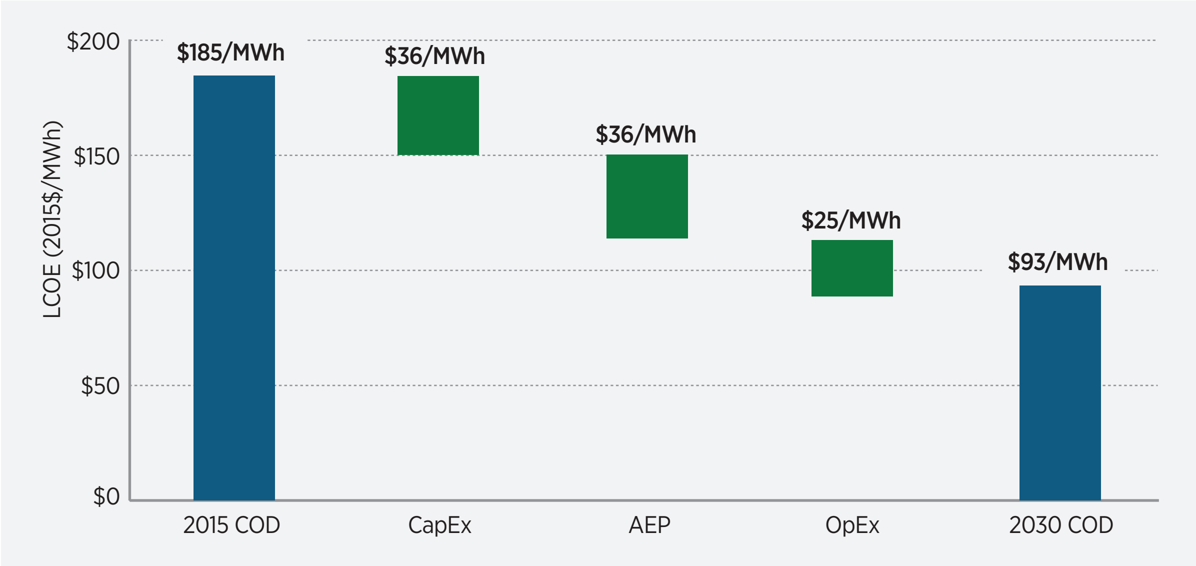


Figure 3.1. Modeled fixed-bottom offshore wind cost reduction pathways to 2030 [23]

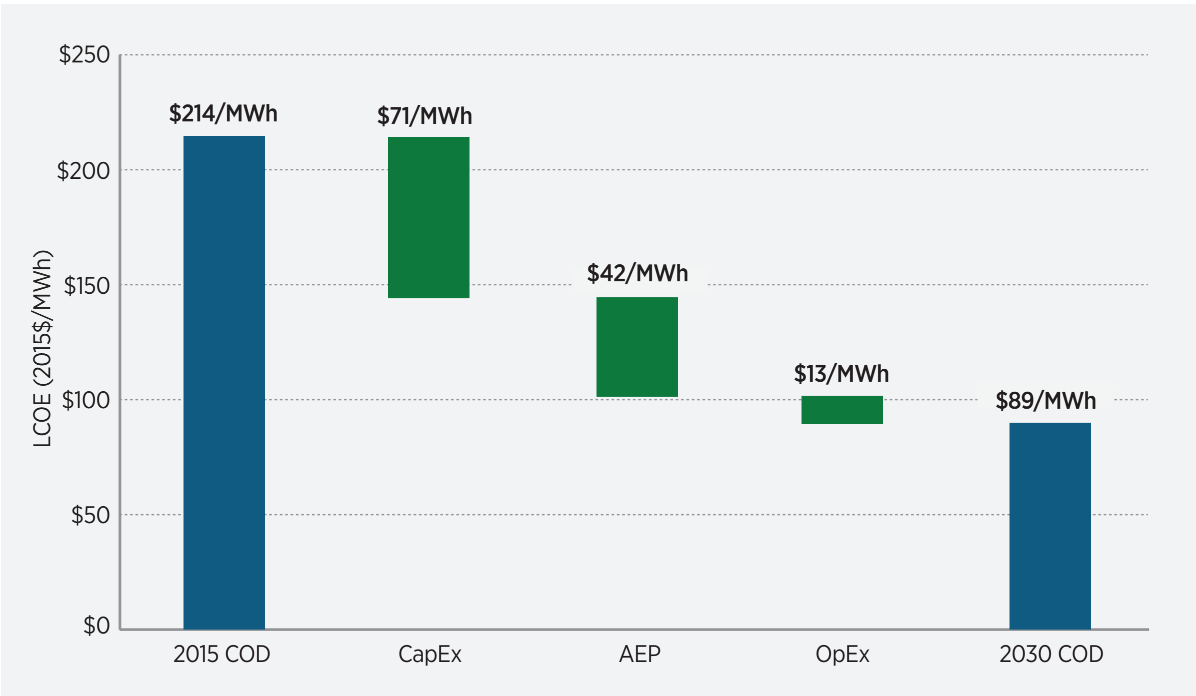


Figure 3.2. Modeled floating offshore wind cost reduction pathways to 2030 [23]

Capital Expenditure Reductions

CapEx comprises the largest component of offshore wind plant costs. Based on European market data, while average turbine ratings have risen, average CapEx has declined and is expected to continue to decline through 2020, ranging from $4,500–$5,200/kW [5]. Complex marine operations and balance-of-system costs (e.g., cabling) make installing each individual foundation and turbine expensive. Attaining plant capacity with fewer, larger turbines allows for lower installation costs and balance-of-system costs. Installation costs may be further reduced by simple, lightweight, mass-producible foundations. Balance-of-system costs may be further reduced through the optimization of a wind plant's layout. For example, balance-of-system costs could be reduced by configuring a wind plant with tighter turbine spacing without sacrificing power performance. Optimized layout configurations could be enabled by implementing advanced control strategies.

Turbines

Growth in wind turbine size and capacity can drive significant CapEx reductions. As turbines are expected to grow in size from the current 6-MW class up to 10 MW by 2030, balance-of-plant costs, including installation, substructures, and cables, among other things, will decrease on a project basis. Tools that enable technology developers to consider the turbine and substructure as a single system will enable design optimization that will drive further cost reduction, particularly in floating systems. As designers begin to develop turbines larger than 10 MW, the industry may see radical solutions that reduce nacelle and rotor weight, such as superconducting generators—particularly relevant to floating foundations—and downwind rotors with more flexible blades. Turbine technology innovations may also facilitate cost reductions associated with AEP and OpEx as described below.

Figure 3.3. Six different offshore wind substructure types. The three on the far left are fixed-bottom substructures (monopile, jacket, and inward battered guide structure [also known as a twisted jacket]), and the three on the right are floating substructures (from left: semisubmersible, tension leg platform, and spar). *Illustration by Josh Bauer, NREL*

Substructures

Fixed-bottom and floating substructure technologies can be improved to lower CapEx through fully integrated designs that optimize the turbine, controls, and substructure as a single system.

Given that the lease areas BOEM has identified to date in the mid-Atlantic region are in water less than 60 m deep, and a significant portion of economically viable sites in the United States will be in shallow water [24], continued engineering and research that focus on fixed-bottom substructures will still have a significant impact in the U.S. offshore wind market. Although the European market has expanded the design envelope of conventional monopiles to include extra-large diameter designs to accommodate state-of-the-art turbines in North Sea projects, weak soil conditions in some U.S. regions will require different and innovative substructure types, such as jackets, suction buckets, or gravity-based structures. Designing foundations for serial production and simplicity will reduce the cost and complexity of fabrication as well as significantly lower capital costs.

Cost-effective floating systems represent a significant opportunity in the United States. Fifty-eight percent (1,194 MW) of the U.S. offshore wind technical resource potential lies in waters deeper than 60 m [24], which is likely beyond the economic reach of current fixed-bottom offshore wind technologies. Floating systems could enable quayside turbine construction, commissioning, and major component maintenance and replacement, thereby eliminating specialized turbine installation vessels (TIVs) and reducing the costs of major repairs. Floating oil and gas infrastructure and fixed-bottom wind turbines offer a baseline, but differ significantly in dynamics and scale.

Similarly, design standards and practices for offshore wind substructures tailored toward U.S. site-specific conditions have the potential to decrease risks and costs in the design process. Reducing or mitigating risk through community-accepted, U.S.-specific standards[24] capable of being integrated into BOEM/BSEE regulations has the potential to significantly lower the cost of offshore wind energy.

Installation

Innovation in installation methods can also result in further cost reduction [12, 24]. Given the cost and complexity of marine operations and the need for specialized installation vessels, investment in floating systems, self-lifting turbines, float-and-flip spar systems, and other innovative installation technologies may negate the need to invest in TIVs. These technologies could also significantly reduce noisy construction activities and concerns about impacts on marine mammals and other sensitive species. This improvement could increase the length of daily and seasonal installation windows and ultimately reduce the total installation time, cost, and risk.

Increasing Annual Energy Production

The net AEP of offshore wind turbines has also been rising over time [5]. Investment in technologies to increase the efficiency of wind turbines as well as their availability, lessen unscheduled maintenance, or improve accessibility for performing maintenance in harsh marine conditions will result in cost reductions resulting from increased AEP.

Rotor Size

Through innovative rotor technology and controls, a better understanding of wind resource conditions, and design experience, turbines with larger rotors have been driving capacity factors higher and allowing for greater power production in lower wind speed regimes. These bigger rotors are able to capture more energy more efficiently, which is a trend that is expected to continue [5]. As rotor size has increased, so has the hub height, which adds incrementally to the power output by taking advantage of winds that generally get stronger higher up. Although individual turbine energy production improves, entire wind plant system losses can lead to a decrease in AEP by up to 20% [64]. However, through integrated wind plant design and optimization, total net AEP can be increased significantly.

Turbine Availability and Access

Increasing the accessibility to turbines for normal and unscheduled maintenance can improve total AEP by reducing downtime. This will be very important along the Pacific Coast, where average sea states are more severe than the Atlantic and North Sea [33, 24].

Operational Expenditure Reductions

OpEx, which covers all costs incurred between the commercial operation date and decommissioning [5], makes up approximately 20% of total LCOE [35] over the lifetime of an offshore wind project. Offshore wind turbines generally have higher maintenance costs than land-based turbines as a result of more difficult accessibility [26] and harsh operating conditions. Advances in turbine reliability and prognostic health monitoring and management that allow fewer onsite maintenance operations and turn unscheduled maintenance into scheduled maintenance will drive significant reductions in OpEx. For example, turbines with a component showing wear that could lead to premature failure could automatically reduce production to extend the life of that component until the next scheduled maintenance. Additionally, new turbine technologies that have fewer moving parts and otherwise reduce the likelihood and severity of major component failures have the potential to further reduce O&M costs and LCOE.

Action Area 1.3: Installation, Operation and Maintenance, and Supply Chain Solutions

Problem Statement

The project pipeline for offshore wind in the United States as of 2016 is not adequate to support the supply chain needed for a cost-competitive industry, or to realize associated local economic development benefits. A lack of dedicated assets and experience makes cost-effective, Jones Act-compliant (see text box below) strategies for installing, operating, and maintaining offshore wind farms challenging.

Current Baseline

The U.S. offshore wind supply chain leverages expertise and experience from around the world. It may also leverage experiences from related industries, such as offshore oil and gas, but these assets are geographically dispersed and generally far from locations planned for near-term offshore wind development. The total U.S. supply chain is not well inventoried and lacks the workforce, port facilities, and particularly the vessels needed to efficiently support a domestic industry.

Dispersed Domestic Supply Chain

Fabrication facilities in the Gulf of Mexico traditionally used by the oil and gas industry have the capacity to fabricate offshore wind substructure components; however, they are not set up for the type of serial production that is required to achieve significant cost savings [65]. Even though these facilities are currently exploring involvement in East Coast offshore wind projects (and served the Block Island Wind Farm), the availability and cost of these assets is tied closely to oil prices. Similarly, although the infrastructure and vessel requirements for floating offshore wind projects are less burdensome and specialized than for fixed-bottom offshore wind, fabrication and port facilities on the West Coast are less robust, and represent a significant supply chain gap.

Local economic development benefits are important for obtaining PPAs. In New Jersey, for example, projects have to pass a net economic benefit test to qualify for an Offshore Renewable Energy Credit (OREC). Currently, however, manufacturers of major offshore wind components, such as turbines and electrical infrastructure, are concentrated in Europe. Until several projects have been built and there is certainty in the long-term project pipeline, these manufacturers will be unlikely to invest in U.S. facilities specific for offshore wind, and the domestic workforce will remain largely inexperienced, creating a burdensome learning curve for the offshore wind domestic industry.

Installation, Operation, and Maintenance Challenges

To reduce costs, the offshore wind industry is trending toward bigger turbines and taller towers, leading to the demand for larger, purpose-built vessels and infrastructure support. Accordingly, early U.S. developers have planned creative (and potentially risky) installation strategies to use specialized European TIVs in a Jones-Act-compliant manner (see text box) [66], or adapt the existing U.S. fleet to work in the difficult wind and wave conditions of first-generation offshore wind sites.

The current U.S. fleet of heavy-lift boats and other vessels may be able to support installation of some of the first U.S. offshore wind projects, but many are likely to require purpose-built TIVs. Currently, there are a limited number of these types of vessels that are equipped to handle the weight and height requirements necessary to install the latest 6- to 8-MW turbine technology [67].

The Jones Act and Offshore Wind Energy

The Jones Act originates from the Merchant Marine Act of 1920, prohibiting the transportation of passengers or merchandise between points in the United States in any vessel other than a vessel built in, documented under the laws of, and owned and operated by citizens of the United States. In general, this means that all vessels transporting passengers or merchandise between two points in the United States, such as a port and an offshore wind installation, must be U.S.-flagged vessels with a U.S. crew and ownership. Points in the United States are defined as any point on land, such as a port, and locations within 3 nm from shore. Although the general applicability of the Jones Act to offshore wind is well-established, some aspects of how it may apply to particular projects or circumstances are unresolved [68].

Even fewer can install state-of-the-art turbines in transitional depths of 30 to 60 m, which are prevalent in the United States [5]. Engaging European vessels may require inefficient and risky installation strategies to navigate under Jones Act requirements. Typically, TIVs book years in advance and can cost between $300,000 and $850,000 per day to operate [5], and U.S. developers would have to incur additional mobilization and demobilization costs to engage these vessels. The supply chain on the West Coast of the United States is considerably less developed than the East Coast or the Gulf; however, West Coast depths will likely require floating foundations, which may not require purpose-built installation vessels.

Marine operations mean that O&M costs of offshore wind facilities are significant, and are largely driven by two factors: 1) the distance between the project and the maintenance facilities, and 2) the prevailing wind and wave conditions at the project site [5]. Purpose-built O&M vessels are being constructed in Europe to adapt to particular site conditions, and the first U.S.-flagged O&M vessel was launched in 2016 to service the Block Island Wind Farm [69]. Although the U.S. workforce has limited O&M offshore wind field experience, there are many lessons to be learned from Europe and opportunities to gain experience as the industry matures.

Safely delivering technicians, equipment, and turbine components to project sites is an additional challenge. Under current regulations, renewable energy lease holders on the OCS are required to provide a safety management system that outlines the safety measures that will be utilized during its OCS activities; however, safety requirements have not yet been well defined.

Work to Date

Since 2011, DOE has invested about $1.3 million in studies to build an understanding of the supply chain assets that will be needed in the United States to support a robust offshore wind industry. These studies address port readiness [70]; manufacturing, supply chain, and workforce [56]; and vessel needs [71], each under a variety of deployment assumptions through 2030.

DOI built on DOE's port readiness work with a more detailed study of East Coast ports on the modifications that would be needed to support offshore wind energy construction. Although many of the required capabilities are available at today's ports, the primary exception is the ability to handle the weight of the heaviest wind turbine components [72]. There are many innovative ways (e.g., logistics, equipment) to adapt a port to service offshore construction. BOEM also funded a study assessing current infrastructure requirements and identified changes to West Coast port facilities that may be necessary to support floating wind projects. The study concludes that if no modifications are made, developers of commercial-scale projects will most likely utilize a network of ports to provide fabrication and assembly support [72].

DOI has also begun taking steps to better clarify its safety requirements for offshore wind projects. DOI's TAP provides a research element that supports its OCS standards and regulations. Research associated with TAP includes a wide spectrum of topics related to offshore operations in the OCS, including renewable energy. Through TAP, DOI has conducted studies[25] that provide an example safety management system for an offshore wind facility [73–74]. These studies found that many of the same safety and environmental management system requirements DOI uses for the offshore oil and gas industry could be applied to ensure the health and safety of an offshore wind workforce. TAP studies also examined land-based and international offshore inspection practices related to wind turbine facilities and associated electrical transmission systems.

To manage safety and environmental oversight of offshore wind construction and operations, DOI will soon be transferring inspection and enforcement responsibilities from BOEM to BSEE. When DOI created BOEM and BSEE in FY12, it did not transfer the safety and environmental enforcement functions for renewable energy to BSEE as it did for oil and gas activities on the OCS. Instead, those responsibilities were to be retained by BOEM until an increase in activity justified transferring the inspection and enforcement functions to BSEE. With initial construction of OCS projects expected to commence in the near future, BOEM and BSEE are working together to plan and implement this transition. A transition team is engaged in the effort to redesignate the renewable energy regulations in 30 Code of Federal Regulations (CFR) Part 585 between the two bureaus, and is also working to develop an outreach and communication plan to clarify the roles and responsibilities of each bureau to lessees and other stakeholders.

Remaining Gaps

Establishing the supply chain for the offshore wind industry and realizing the efficiencies and cost reductions that will come with it ultimately depends on a stable and significant project pipeline. Exploring mechanisms that would reduce the costs of initial supply chain investments and maximize the use of current assets can help alleviate supply chain challenges in the interim.

Mechanisms available to support the financing and construction of TIVs need to be explored. Constructing a U.S.-flagged installation vessel would free developers from depending on European vessels, but competition between multiple vessels in the United States is likely to be needed before significant cost reductions are possible. Before that happens, it is essential to conduct an inventory of existing U.S. assets that can support installation, operation, and maintenance activities for offshore wind facilities, as well as identify ways to use these assets in the most cost-effective, least risky way.

The United States also needs a set of clear safety standards and regulations. Existing research and lessons learned from operational offshore wind facilities worldwide provide a sufficient foundation for DOI to develop safety regulations, guidelines, and procedures. Further, this information would provide DOI with the ability to establish criteria for conducting inspections of offshore renewable energy facilities to protect the safety of the structures and foundations and provide a safe environment for onsite personnel, as well as anyone working in the surrounding lease area.

3.2 Strategic Theme 2: Supporting Effective Stewardship

Effective stewardship of the nation's ocean resources will be necessary to support an offshore wind industry in the United States. DOI, through BOEM, oversees the responsible development of energy on the OCS. It is important for developers to have certainty when navigating the regulatory and environmental compliance processes. To support effective stewardship of these resources, the following action areas are needed:

- **Ensuring efficiency, consistency, and clarity in the regulatory process**. BOEM has significantly increased the efficiency of the regulatory process over the past several years. Nevertheless, further work can be done to ensure that existing requirements are not overly burdensome, such as providing more predictable review timelines.
- **Managing key environmental and human-use concerns**. To ensure that offshore wind is developed in a sustainable manner, more data need to be collected regarding the impacts of offshore wind on existing human uses of ocean space and sensitive biological resources. In addition, some issues could be retired as they are resolved to improve the efficiency of environmental reviews and allow for a greater focus on the most significant risks and impacts.

Action Area 2.1: Ensuring Efficiency, Consistency, and Clarity in the Regulatory Process

Problem Statement

Although progress has been made to improve the offshore wind planning, leasing, and approval processes, developers still face significant obstacles in the regulatory oversight process that will need to be overcome to facilitate efficient and responsible offshore wind development.

Current Baseline

The OCS Lands Act imposes a number of obligations on BOEM when conducting its offshore wind oversight processes. For example, BOEM must ensure that projects are developed in an environmentally responsible and safe manner that considers other uses of the OCS, and must coordinate with relevant federal agencies and affected state and local governments when moving forward with its offshore wind authorization process. Though BOEM is the lead federal agency, there are many other agencies that issue authorizations or are otherwise involved in or potentially affected by offshore wind projects, including the Army Corps of Engineers, U.S. Coast Guard, NOAA, the U.S. Department of Defense, and the National Park Service.

At the time *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* (2011) was released, the first offshore wind projects were progressing through BOEM's regulations and the considerable uncertainty regarding the process timelines and cost was regarded by stakeholders as one of the most pressing challenges to industry [8]. Since then, several developers have completed portions of the permitting process and BOEM has made strides in the planning and leasing of the OCS for offshore development, as well as identifying and remedying issues associated with its oversight processes.

For the Atlantic OCS, BOEM has conducted commercial wind planning and leasing processes for areas off the coast of six states, and is continuing with these processes for another three states. The agency has established 13 Task Forces across the country and issued 11 commercial wind leases along the Atlantic Coast—9 through the competitive lease sale process and 2 noncompetitively. BOEM is in the process of establishing an additional Task Force with the State of California. These competitive lease sales have generated $16.4 million in auction revenue for more than 1.18 million acres in federal waters. BOEM has also issued a research lease to the Commonwealth of Virginia and approved a Research Activities Plan for that project.

In the Pacific Region, BOEM has initiated the commercial leasing process for an area off the coast of Oregon. Further, BOEM has published a Call for Information and Nominations for two areas offshore Hawaii, and a Request for Interest for one area offshore California.

BOEM's Approach to Authorizing Offshore Wind Activities

BOEM's offshore wind authorization process includes four phases: 1) planning, 2) leasing, 3) site assessment, and 4) construction and operations.

Planning and Analysis

Once a state has expressed interest in the development of wind energy resources off its coast, the planning process typically begins with the establishment of an Intergovernmental Renewable Energy Task Force. The Task Force consists of relevant federal and potentially affected state, local, and tribal officials. BOEM works with each Task Force to identify an area or areas of the OCS to consider for commercial wind energy leasing and subsequent development and/or review of unsolicited applications for commercial wind leases that are submitted by specific developers. Though the Task Force is not a decision-making body, BOEM coordinates with the members of each Task Force to inform how and whether renewable energy planning and leasing should proceed. In particular, Task Force members help inform BOEM's decision-making by identifying important resources and uses that may conflict with commercial wind energy development.

After delineation of a planning area in coordination with the applicable Task Force and/or receipt of an unsolicited application identifying a particular area from a developer, BOEM will typically publish one or more Federal Register notices (e.g., a Request for Interest, Call for Information and Nominations) to determine whether there is competitive interest in the area identified and gather comments from the public.

Leasing

If there is competitive interest, BOEM will initiate a competitive planning and leasing process, including area identification. During this process, the agency considers all relevant information received to date, including public comments and nominations received

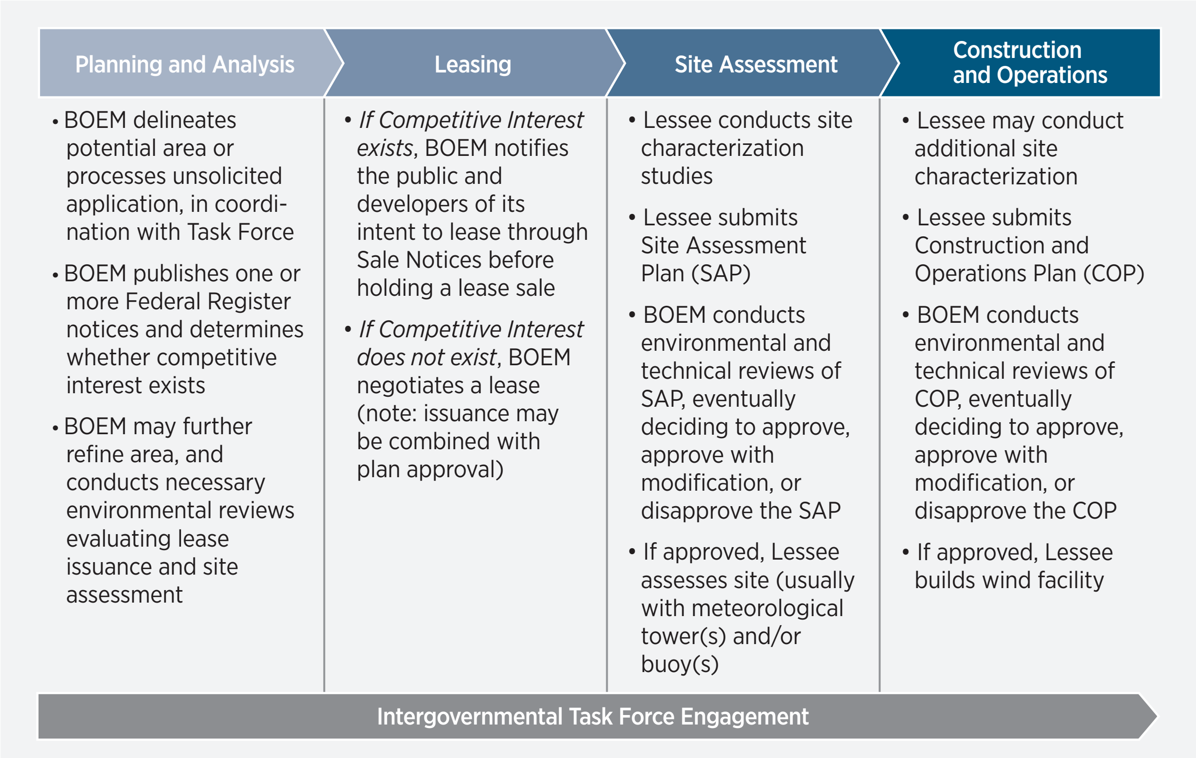


Figure 3.4. The four stages of BOEM's wind authorization process [75]

in response to a Request for Interest or Call for Information and Nominations. This approach helps balance potential commercial wind development against other uses of the area and environmental concerns associated with offshore wind development. If BOEM is able to identify an area that appears suitable for offshore wind development through this process, that area is referred to as a WEA. BOEM will then conduct the necessary environmental reviews and consultations to inform a potential leasing action for the WEA. During this review, BOEM will consider the reasonably foreseeable impacts associated with lease issuance, associated site-characterization surveys, and site assessment activities (e.g., installation and operation of meteorological towers and/or buoys). BOEM may then publish sale notices detailing the proposed lease sale and hold an auction to award one or more leases to the winning bidder(s).

If BOEM determines there is no competitive interest in a requested potential lease area, then after the completion of necessary environmental reviews, BOEM may, if deemed appropriate, begin negotiating the terms of a lease with the interested developer prior to issuing a lease.

Site Assessment

After lease issuance, the lessee begins the site assessment phase, and has approximately 5 years to complete the necessary site characterization and assessment activities to gather information to support its commercial proposal. If a lessee is proposing to install a meteorological tower and/or buoy to gather wind and oceanographic resource data on the leasehold, it must submit a Site Assessment Plan (SAP) that describes these activities for BOEM's review and approval. If the proposed activities and their effects are outside the scope of BOEM's previous environmental reviews and consultations, additional review and consultation may be necessary.

Construction and Operations

The final phase of the process—construction and operations—begins with the submission of the lessee's Construction and Operations Plan (COP). The COP contains the lessee's detailed plan for the construction and operation of a wind energy project in the lease area. BOEM will conduct thorough engineering and environmental reviews of the COP, likely including an Environmental Impact Statement under NEPA. After the approval, or approval with modifications, of a COP, the lessee would develop and submit its Facility Design Report and Fabrication and Installation Report. The lessee may commence fabrication and installation of its facility once BOEM has reviewed these reports and any of its objections to them have been resolved. BOEM's offshore wind leases typically include a 25-year operations term. At the end of the operations term, the lessee will be required to decommission its project.

Once a lease is acquired, BOEM requires that a lessee pay rental and operating fees (to ensure "fair return" to the nation for use of the OCS), and that the lessee provide financial assurance to protect the government's interests.

Work to Date

BOEM has made important progress in granting access to the OCS for renewable energy development, and the agency has been incorporating lessons learned and identifying and implementing improvements to the program where appropriate. For example, BOEM has promulgated two changes to its regulations since they were published in 2009. The first change, finalized in 2010, eliminated a redundant step in BOEM's noncompetitive leasing process. In 2014, BOEM finalized a rulemaking to change certain plan submission timelines that were proving unworkable for developers.

BOEM has also developed a number of national and regional guidelines to provide its renewable energy lessees with additional information and guidance for compliance with its regulations, standards, and other requirements. For example, BOEM has developed guidance documents that provide the information recommended for inclusion in an SAP and COP, and a series of survey guidelines, including those for providing the recommended geophysical, geotechnical, and hazard information; biological data; and archaeological and historic property information.

DOE's current and former Offshore Wind Advanced Technology Demonstration Projects have helped to exercise the regulatory process on both the state and federal level. Specifically, Principle Power's WindFloat Pacific project in Oregon and Aqua Ventus in Maine have presented regulators with alternative floating foundation technologies that required analysis from a new perspective. The Commonwealth of Virginia, working with Dominion Energy's Virginia Offshore Wind Technology Advancement Project, was issued the first research lease in federal waters. Activities under these awards have also helped the community of cooperating agencies to become familiar with offshore wind energy and its siting processes.

Remaining Gaps

BOEM has received suggestions for specific changes to its regulatory process that could make it more efficient for developers. Stakeholders have recommended that BOEM reduce the burden of certain requirements, shorten and increase certainty associated with review timelines, and improve coordination among agencies and stakeholders during the regulatory process. Some suggestions are described below.

Reducing the Burden of Regulatory Requirements for Meteorological Buoys

Under BOEM's current regulations, a lessee is required to submit a SAP when proposing to install a meteorological buoy and/or meteorological tower in its lease area. Because BOEM's experience reviewing SAPs is limited, it is reasonable to anticipate that the process of reviewing and approving a SAP could take several months. In previous environmental reviews, BOEM has concluded that the environmental impacts associated with deploying a buoy are not significant under certain conditions. As such, there is an opportunity for BOEM to reconsider its requirements associated with buoy deployment.

Decommissioning Financial Assurance Requirements

BOEM's current decommissioning financial assurance regulations require a lessee to submit financial assurance covering the anticipated decommissioning costs of the proposed offshore wind project prior to installing facilities approved in a COP. Commenters have argued that this would increase the cost of energy from a project with little added public benefit. According to commenters, providing for flexibility to offer decommissioning financial assurance later in the operations term would help ensure that decommissioning requirements are met in a manner that does not disadvantage offshore wind developers relative to other forms of new power generation.

Ensuring Effective and Timely Plan Reviews

Stakeholder feedback has suggested that BOEM's plan-review process needs to be more transparent, predictable, and expeditious to reduce scheduling uncertainty and financial risk. A factor contributing to regulatory complexity is that many agencies have roles in the offshore wind project authorization process and there are challenges to aligning numerous entities at different levels of government. The number of permits and authorizations required for the realization of an offshore wind project can be daunting for developers.

Title 41 of the Fixing America's Surface Transportation Act (P.L. 114-94)[26] (FAST-41), requires the facilitating or lead agency of a major infrastructure project to establish and publicly track a concise Coordinated Project Plan for coordinating participation in, and completion of, any required federal authorizations and environmental reviews, including a permitting timetable that outlines the dates by which all reviews and authorizations must be made.[27] BOEM will track COP reviews through FAST-41, and there may be additional steps that the organization can take to create a predictable plan-review process.

Feedback from developers also suggests that it is not practical to submit a COP that includes all project specifics, and that a degree of flexibility would allow developers to make certain project-design decisions—such as which turbine to use—at the more commercially advantageous time later in the project-development process. This could potentially be accomplished by implementing the "design envelope" environmental review approach that is employed in certain European nations. With this approach, the environmental review is conducted by resource area, to include the greatest potential impact from a range of design options and parameters.

Enhancing Coordination Around Lease Area Identification

Many RFF comments from stakeholders highlighted the need for BOEM to better coordinate with other ocean users as the agency identifies potential areas for leasing (e.g., fishermen and vessel operators). One commenter also recommended that BOEM reach out to NREL during the planning process to help ensure that areas preliminarily identified are suitable for development.

Other commenters recommend that BOEM consider a more regional approach to planning than is currently provided for in BOEM's Task Force process. For instance, one RFF commenter argues that the state-by-state Task Force approach can unintentionally exclude the interests of states other than the "lead" state, resulting in issues being raised late in the process. BOEM has made adjustments to its outreach and coordination strategy for certain areas to try to better account for regional issues (e.g., realigning the planning and leasing process for the Wilmington West and East WEAs with the process for the South Carolina Call Areas, and conducting outreach in a number of states to ensure regional input into the New York WEA leasing environmental review process). However, comments indicate that as BOEM continues to identify new areas for offshore wind development, it may be able to make adjustments to its typical Task Force establishment process to ensure that planning and leasing efforts are better informed.

Action Area 2.2: Managing Key Environmental and Human-Use Concerns

Problem Statement

Much has been learned about how offshore wind facilities could impact environmental resources and human activities; however, some impact assumptions are founded in predictive information rather than in empirical research. The construction and operation of the first U.S. offshore facilities provides the opportunity to verify the analysis of previous studies, address impacts and use conflicts based on field-verified information, and promote regulatory certainty and ensure sound stewardship of the OCS.

Current Baseline

As noted in Section 2.7, offshore wind development carries with it substantial positive environmental benefits, both on land and at sea, including significant reduction in cumulative GHG emissions, air pollution, and water usage by the energy sector [2]. Still, large-scale deployment requires responsible stewardship to ensure that direct impacts to wildlife, sensitive habitat, and existing uses are properly managed. Wildlife and human-use concerns associated with offshore wind include effects on migratory birds, marine mammals, and other sensitive species, as well as impacts to human communities and competing uses such as fisheries and radar systems.

Offshore biological surveys along the East Coast, including a DOE- and DOI-sponsored effort recently conducted by the Biodiversity Research Institute, indicate that bird abundance is generally greater in nearshore areas [76–77]. Additionally, most seabirds fly below the rotor swept area [78], whereas land and shorebirds migrating offshore generally fly at heights above the rotor swept zone [76, 79]. However, concerns still persist that offshore wind could displace birds from important habitats or create barriers to migration. Under the Endangered Species Act, BOEM consults with the U.S. Fish and Wildlife Service (FWS) to address potential impacts to threatened and endangered avian species. With respect to migratory birds, BOEM consults with FWS about potential impacts to these types of birds and may impose measures to lessen such impacts consistent with BOEM's obligations under its memorandum of understanding with FWS and Executive Order 13186, thereby furthering the objectives of the Migratory Bird Treaty Act.

Offshore wind facilities can also pose risks to marine mammals, protected under the Endangered Species Act and the Marine Mammal Protection Act, through noise related to surveys and construction—particularly pile-driving associated with fixed-bottom foundations. To address these impacts, BOEM consults with the National Marine Fisheries Service under the Endangered Species Act prior to approving such activities and requires developers to comply with any resulting required mitigation measures. In addition, developers may need to apply for incidental harassment authorization under the Marine Mammal Protection Act.

Offshore wind facilities may also impact human communities and competing uses in ways that affect important aspects of coastal culture and economies. Commercial and recreational fishermen have expressed concern that access to historic fishing grounds could be impacted by offshore development. The placement of permanent structures offshore could also affect shipping routes and navigation. In addition, air traffic control, air surveillance, weather, and navigational radar systems may be impacted by offshore wind turbines through increased clutter that may inhibit target detection, increase the generation of false targets, interfere with target tracking, and hinder weather forecasting [80]. These issues may be different from those caused by land-based wind turbines, given how radar signals propagate in the ocean environment. Lastly, coastal communities are often concerned about visual impacts, particularly with respect to important historic properties [81].

Work to Date

Since 2011, there has been a significant increase in knowledge of environmental resources and human uses where offshore wind development may occur and the impact that development may have on those resources. Numerous data-collection efforts have increased information regarding marine species distribution and abundance in regions of interest for offshore wind development around the nation. Studies have improved the understanding of and certainty associated with risks to birds and bats, and the potential effects of electromagnetic fields generated by interarray and power export cables on sensitive species. Studies have also led to best practices for lighting of offshore wind turbines, and sound source verification for high-resolution geophysical equipment and pile driving associated with offshore wind development and construction activities.

The availability of reliable data is vital for responsible and informed decision-making by governmental agencies and developers alike. BOEM gathers information about existing environmental and human-use conditions along the OCS and assesses potential impacts to determine which areas are appropriate for leasing and siting offshore wind facilities. Information that improves this foundational knowledge and is applicable beyond a single lease area[28] is generally understood to be the responsibility of federal agencies.

Developers are responsible for providing BOEM with site-specific information to inform how their renewable energy plans could affect the coastal, marine, and human environment. This information, in turn, supports BOEM's environmental analysis and helps determine what measures may need to be taken to avoid, minimize, or otherwise mitigate these impacts.[29] BOEM has developed a number of national and regional guidelines for renewable energy activities on the OCS. These informal documents are intended to provide lessees, operators, and developers with additional information to clarify and supplement regulatory requirements and plan development. Existing guidance can be found on BOEM's website: *http://www.boem.gov/National-and-Regional-Guidelines-for-Renewable-Energy-Activities/*. In 2015, BOEM published guidance for providing information on the social and economic conditions of fisheries, through the development of a fisheries engagement strategy.

BOEM's approval process includes the analysis of the environmental effects from the construction, operation, and decommissioning of offshore wind facilities. Without real-time observations of these activities, estimates, and conservative scenarios based on the best available information are used to make these determinations. These analyses would benefit from empirical studies of actual impacts.

The construction and operation of the first offshore wind facilities provide an opportunity for more detailed and empirical assessments of the environmental effects of offshore wind turbines. Thus, BOEM commissioned the Real-time Opportunity for Development Environmental Observations (RODEO) study in 2015. The objective of the study is to acquire real-time observations of the construction and initial operation of wind facilities to evaluate the environmental effects of future facilities. The study also offers the opportunity to address many of the environmental questions that are of concern to the public, as well as other federal, state, and local agencies. RODEO will measure and analyze air emissions, sound produced by construction and operations activities, seafloor disturbance associated with cabling and vessel anchoring, and visual impacts from construction and early operation. In addition to actual

Mid-Atlantic Ecological Baseline Study

DOE, in collaboration with a wide range of partners, including DOI, funded the Biodiversity Research Institute to conduct the first-of-its-kind Mid-Atlantic Ecological Baseline Study between 2011 and 2015. The study provides comprehensive baseline ecological data and associated predictive models and maps to regulators, developers, and other stakeholders to inform the siting and permitting of offshore wind energy. This 4-year effort provides an extensive data set on species of concern to the wind energy community, covering over 13,000 km^2 of ocean space including the Delaware, Maryland, and Virginia WEAs, while validating novel high-definition survey technologies. The results of this study will significantly reduce the effort required by developers working in the study area and will serve as a starting point for broad-scale and site-specific environmental risk analyses and evaluating potential measures to avoid and minimize risks to wildlife from human activity in the offshore environment. For more information, visit *http://www.briloon.org/mabs*

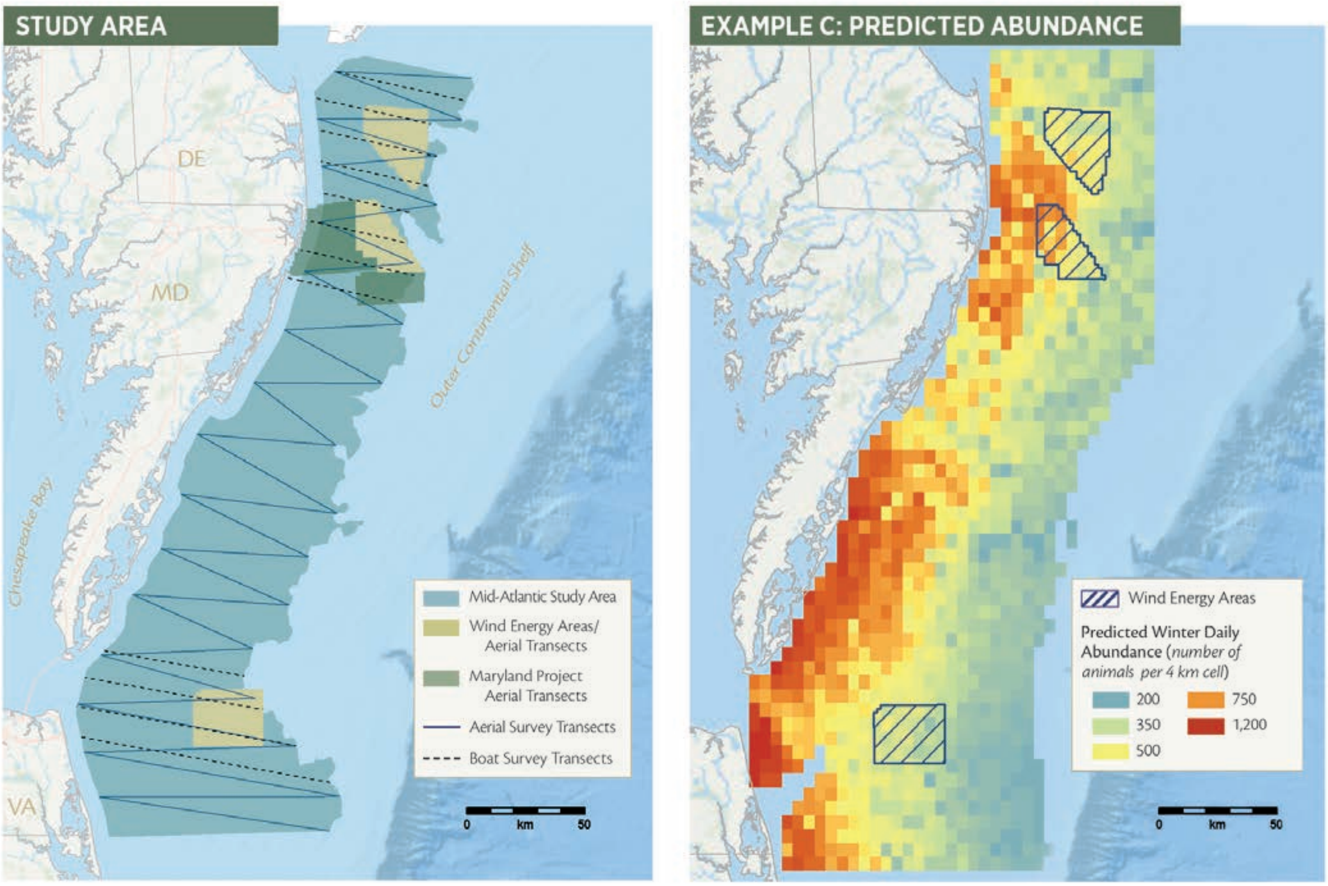


Figure 3.5. The Mid-Atlantic Ecological Baseline study area and survey transects (left), and an example study output showing predicted winter abundance of Northern Gannets in the study area

measurements, mitigation methodologies and testing of monitoring equipment are included as part of the study's obligations. BOEM contractors were in the field during the summer and fall of 2015 to take measurements at the site of the Block Island Wind Farm during and after installation of its foundations.

Additionally, in *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* (2011), DOE and DOI noted that although hundreds of environmental studies have been conducted in Europe at offshore wind farms, few studies have been done in U.S. waters given the lack of deployments to date. Since 2011, DOE has invested about $8 million related to these issues, and along with other federal agencies, has engaged in efforts to gather, analyze, and publicize data on environmental and competing use issues. These data will allow DOE to better inform stakeholders and policymakers on the extent of potential impacts of offshore development and begin to shed light on how those impacts might be mitigated. The largest of these efforts, the Mid-Atlantic Ecological Baseline Study, is described in the text box provided earlier.

Regarding the impacts of offshore wind on radar systems, DOE has funded a study modeling potential effects [80], and established a memorandum of understanding to mitigate wind turbine radar interference with the U.S. Department of Defense, Federal Aviation Administration, and NOAA to guide collective R&D efforts. These and other such efforts seek to avoid compelling individual developers to shoulder the high costs of more broadly applicable research and will build a common knowledge base.

Over the same period, BOEM has invested approximately $24 million in studies supporting renewable energy needs along the Atlantic Coast and more than $14 million along the Pacific Coast and Hawaii. The majority of these funds were spent on studies to better understand habitat and ecology on the OCS. Other areas of study included social science and economics, marine mammals and protected species, fates and effects,[30] as well as air quality, information management, and physical oceanography. The information obtained from these studies helps inform BOEM guidance and environmental analyses.

Remaining Gaps

The first generation of installed projects will help to establish and validate the actual effects and impacts of offshore wind development on biological communities, and narrow the range of potential effects that need to be monitored or mitigated at a given site. Collecting field data on impact-producing factors like construction noise and how these factors affect resources of concern like marine life will help to verify impact assumptions. Such information has the potential to distinguish which risks are significant or highly unpredictable—and therefore important to monitor and mitigate over the long term—from predictable and insubstantial risks that can be "retired" from consideration, monitoring, or mitigation.

From a human-use perspective, field experience also provides an opportunity to gain an understanding of the impacts of actual projects on issues such as radar interference. Although the effects of land-based wind development on various radar systems are well understood, there are unique considerations associated with how radar signals propagate over water that require closer attention. In addition, the first offshore projects will allow for the more robust development of social science that can better determine the drivers of public acceptance of and opposition to offshore wind in the United States. This knowledge can aid in the establishment of best practices for project developers and regulatory processes that better address stakeholder concerns and the development of appropriate mitigation measures.

Continued broad-scale and site-specific baseline assessment will remain valuable as the offshore wind industry develops. Given the expense associated with baseline data collection, it is likely that agencies will need to take an approach that combines site-specific, developer-collected, preconstruction surveys with surveys conducted for other broader scientific reasons (such as monitoring of North Atlantic Right Whale populations) into a coherent picture that supports offshore wind siting and plan reviews. As more developers prepare to submit COPs, additional guidance may be necessary to ensure that the data meet the needs of all the federal agencies involved.

3.3 Strategic Theme 3: Increasing Understanding of the Benefits and Costs of Offshore Wind

An increased understanding of the benefits and costs of offshore wind can help support near-term deployment. Near-term deployment will be essential to realizing the cost reduction opportunities provided by R&D and enabling the development of a supply chain. To help improve understanding of offshore wind's benefits for near-term deployment, work will be needed in two areas:

- **Offshore wind electricity delivery and grid integration.** Impacts of significant offshore wind deployment on local grids need to be better understood, and the costs and benefits associated with offshore transmission infrastructure need to be characterized.
- **Quantifying and communicating the benefits and costs of offshore wind.** Environmental and economic benefits and costs associated with offshore wind need to be rigorously quantified and communicated to policymakers and stakeholders to inform decisions on near-term PPAs and policies related to offshore wind.

Action Area 3.1: Offshore Wind Electricity Delivery and Grid Integration

Problem Statement

Significant progress has been made to understand and address the challenges of integrating large amounts of variable renewable energy into the U.S. grid, but the unique challenges of large amounts of offshore wind have not been evaluated, particularly on the scales that are relevant to local system operators and utilities. Build-out of significant offshore transmission "backbones" have been proposed as a means to support such integration and provide broader value to the electrical system, and the benefits and costs of such infrastructure need to be well defined.

Current Baseline

In Europe, more than 12 GW of offshore wind capacity had been installed at the end of 2015, enough capacity in an average wind year to provide 1.5% of the European Union's total electricity consumption [82]. The grid infrastructure supporting this generation is significant, and includes 11 offshore grids operating in the North and Baltic Seas and another 21 currently being considered by grid operators [82]. This power is interconnected to the transmission and delivery infrastructure operated by member states and commissions, and as offshore wind penetration has grown, its impacts on system reliability and operating costs have been minimal. The future outlook from a technical perspective is positive as well. A 2010 analysis by the European Wind Energy Association concluded that "the capacity of the European power systems to absorb significant amounts of wind power is determined more by economics and regulatory frameworks than by technical or practical constraints." According to recent work by the International Energy Agency, offshore wind energy could account for 5% of global electricity generation by 2050 [83].

The United States has significant experience integrating land-based wind and other variable renewables. In 2015, nearly 5% of U.S. electricity was generated by wind energy [1], with Iowa generating more than 30% of its electricity from wind [6]. Further, much has been done to investigate the impacts of incorporating significant percentages of wind and other variable renewables into the grid. Numerous studies have shown that the grid operates reliably with wind energy contributions over 10%, with minimal impacts on network operating costs and the ability to operate reliably at much higher penetrations [84–85].

Recently, the DOE-funded *National Offshore Wind Energy Grid Interconnection Study* [44] also found that the primary barriers to offshore wind interconnection and integration in the United States are not technical or practical in nature, finding that "appropriate technologies exist for interconnecting large amounts of wind energy to the U.S. grid." Instead, the report advised that R&D efforts were best focused on the reduction of initial capital investment.

Work to Date

Since 2011, DOE has funded more than $2.4 million of R&D to better understand electric system impacts. The FY 2011 U.S. Offshore Wind: Removing Market Barriers FOA made funding available to 12 research projects for the purpose of facilitating deployment and reducing technical challenges facing the offshore wind industry.

These studies investigated the impact of changes to existing practices in power system operations, the role of forecasting, and the capability of supply- and demand-side technologies in providing the needed flexibility to integrate wind power into the existing grid.

BOEM's involvement in electric systems is limited, though NREL has recently delivered data inputs to BOEM and the California Public Utilities Commission to support the expanded capability and application of the California Renewable Portfolio Standard (RPS) Calculator to offshore wind energy. The RPS Calculator creates plausible portfolios of renewable resources needed to meet RPS policy goals, from inputs describing six sites able to support offshore wind before 2030. These inputs include parameters such as project cost, O&M costs, technology capacity factors, and hourly production profiles, and have been reviewed by NREL and industry offshore wind experts.

Remaining Gaps

Although the electrical system impacts may be largely analogous to land-based wind, there remain some key differences in the interconnection and integration of offshore wind energy onto the grid that need further investigation.

Continued interconnection and integration studies conducted over state and regional areas could help quantify the broad grid integration impacts (see Action Area 3.2: Quantifying and Communicating the Benefits and Costs of Offshore Wind) of adding significant amounts of offshore wind energy to the power system, but at a level of specificity relevant to local system operators and utilities. These studies could focus on issues such as the impact of offshore wind's coincidence with system loads, how its capacity value differs from land-based wind near coastal areas, and its influence on regional electricity markets. Such information could significantly benefit the offshore wind community by informing state policies critical to supporting development.

Beyond interconnection and integration studies, R&D on reducing initial capital costs—including the development of cables and compact high-voltage direct-current converters—could lower the financial barrier to entry, increasing offshore wind energy penetration and reducing the cost of offshore wind energy. According to the *2014–2015 Offshore Wind Technologies Market Report*, an increase in array system voltage has the potential to reduce CapEx through more efficient cable layout, decrease electrical losses (up to 75%), reduce the mass and number of substations, and increase reliability [5]. Yet, progress towards higher-voltage systems in the United States has been slower than anticipated [86].

European projects are currently adopting higher-voltage export cables to reduce CapEx on projects sited further offshore. At distances greater than 90–120 km, conventional high-voltage alternating-current electrical infrastructure becomes prohibitively expensive, and transmission system operators in Europe are starting to use recently introduced high-voltage direct-current technologies [5].

Action Area 3.2: Quantifying and Communicating the Benefits and Costs of Offshore Wind

Problem Statement

The greatest challenge facing near-term offshore wind deployment is the availability of above-market PPAs or other revenue streams sufficient to finance projects. Rigorously quantifying the full electricity market and environmental benefits and costs of offshore wind (as discussed in Section 2.7) and ensuring that they are effectively communicated to policymakers and key stakeholders can aid in the evaluation of projects and policies around offshore wind and improve the basis on which decisions are made.

Current Baseline

Much of the success of the European offshore wind energy market in the face of high costs can be attributed to long-term policy support. First-generation projects have benefited from aggressive climate and renewable energy targets as well as explicit price support mechanisms, such as feed-in tariffs, that provide a sufficient revenue stream to finance projects. The resulting cost reductions and industry experience gained have led policymakers in Europe to move away from setting fixed, above-market prices for offshore wind at a national level. They are now implementing more creative price support mechanisms, such as auctions, to encourage competition between developers [5], and more indirect support, such as lower-cost financing through government-backed green investment banks and export credit agencies that have attracted commercial lenders [87].

In the United States, federal incentives such as the renewable electricity PTC and business energy ITC have helped drive significant growth in renewables, particularly in land-based wind and solar energy. Because of the capital-intensive nature of offshore wind development, the ITC is more relevant, and its continuation may be a significant driver for near-term development.

As part of the Consolidated Appropriations Act of 2016 (P.L. 114-113), Congress extended the expiration date for the ITC, with a gradual step down of the credits from 30% in 2016 to 12% for projects commencing construction in 2019 [3].

As of late 2015, 29 states and the District of Columbia have RPSs to support the development of renewable energy [88]. Many of these states have unique market characteristics wherein offshore wind energy could play an important role in meeting renewable-energy-deployment and GHG-reduction targets. For instance, New York and California each have significant energy demand in coastal cities and aim to generate 50% of their electricity from renewable energy [88]. New England states have relatively high electricity prices, renewable energy targets, and land constraints that will likely require further consideration of offshore wind development if a significant portion of their energy is to come from in-state resources. Hawaii became the first state to commit to a 100% RPS in 2015 [89], and the state's limited terrestrial resources and high energy prices create a market ripe for offshore wind.

Given the relatively high cost of offshore wind compared to other renewables, specific mechanisms have been put into place in a few states that provide special consideration. For example, New Jersey passed legislation requiring the establishment of an OREC program, though the state has not yet established regulations that provide a funding mechanism for the program. The Maryland Offshore Wind Energy Act of 2013 provides for ORECs for up to 2.5% of the state's electricity supply from offshore wind energy, requiring consideration of peak load price suppression and limiting rate impacts. [17, 90].

Other states, such as Maine, Massachusetts, and Rhode Island, have pursued, to varying degrees of success, legislation that either mandates or allows for the consideration of factors other than cost—such as net economic benefits—in evaluating offshore wind PPAs. Four offshore wind PPAs have been finalized in the United States to date (though three have since been terminated). Effective bundled prices have ranged from approximately $180 to $240/MWh, with terms extending between 15 and 25 years [5].

All of the federal and state policies that have been implemented to support renewable energy, and offshore wind in particular, are motivated at least to some extent by the notion that deploying offshore wind or other renewables provides significant benefits—decreased carbon and other air pollution, fuel diversity, energy security, and economic development. A lack of rigorous and accepted means of quantifying such benefits, and particularly the unique combination of benefits of offshore wind, has been a substantial barrier to the evaluation of policies related to offshore wind as well as project-level PPAs.

Work to Date

Through the *Wind Vision,* DOE examined the costs and benefits of the development of 22 GW of offshore capacity by 2030 and 86 GW by 2050. The study examined potential reductions in GHGs, water usage, and risk; air pollution effects; energy diversity; and workforce and economic development impacts (see Chapter 2 for a more exhaustive look at the scenario). DOE closely tracks and reports on project development and cost trends both globally and in the United States through its periodic offshore wind market reports.

As a result of local infrastructure requirements associated with the sheer size of equipment and complexity of installation, operation, and maintenance activities, offshore wind can bring significant wind-related jobs and economic activity to coastal states, as it has in some coastal areas in Europe. According to the *Wind Vision*, the offshore wind deployment envisioned in the study scenario could result in the creation of 32,000–34,000 offshore wind-related jobs in 2020, increasing to 76,000–80,000 in 2030, and 170,000–181,000 in 2050 [2]. DOE studies utilizing the offshore wind Jobs and Economic Development Impact model show that an offshore wind industry in four coastal regions of the United States has the potential to support thousands of jobs because of robust workforce requirements, even at relatively conservative levels of deployment and domestic supply chain growth [56, 91].

Through its WINDExchange program and several wind Regional Resource Centers,[31] DOE has helped communities weigh the benefits and costs of offshore wind energy, understand the deployment process, and make wind development decisions. The goal of the Regional Resource Centers project is to make it easier for stakeholders and policymakers to decide if wind project development is appropriate for their communities by producing relevant, actionable, and fact-based information; and delivering that information to communities considering their options in a clean energy portfolio.

In 2015, DOE's State Energy Program awarded almost $600,000 to state agencies in New York, Maine, Massachusetts, and Rhode Island, in addition to the Clean Energy States Alliance, to develop a roadmap to a regional market for offshore wind. Through this DOE award, the states and Clean Energy States Alliance will examine how to identify achievable cost reductions associated with a pipeline of projects.

BOEM collects revenues from lessees, or potential lessees, in the form of acquisition fees for unsolicited lease requests, bonus bids from auctions, rent for leases that have been issued, and operating fees for leases that have been developed and are in operation. In response to comments received from stakeholders, BOEM has implemented a process that considers state policies that support offtake agreements and other incentive programs in designing its offshore wind energy auctions. In its recent New Jersey lease auction, for example, BOEM employed a multiple factor auction format that included nonmonetary factors of either up to a 25% credit to any bidder able to demonstrate that they had a PPA in the amount of 250 MW, or a 25% credit to any bidder able to demonstrate they had an approved or conditionally approved OREC order from the New Jersey Board of Public Utilities. BOEM offered similar nonmonetary factors in its Maryland auction, and other nonmonetary factors in its Massachusetts and Rhode Island lease auctions. BOEM will likely continue to consider including these nonmonetary factors in future auctions in recognition of agreements that it believes would substantially contribute to the success of an offshore wind project.

Remaining Gaps

Rigorously quantifying the full costs and benefits of offshore wind development in the context of both electricity markets and broader policy issues, such as economic development and climate change, will allow for better-informed discussion between offshore wind developers, regulators, public utilities commissioners, ratepayers, and clean energy advocates surrounding policies to support offshore wind and the approval of project-specific PPAs and incentives.

For electricity markets to fully value the attributes of offshore wind energy, these attributes need to be quantified and articulated to the public. In certain markets with locational marginal pricing, offshore wind development may drive down wholesale electricity costs. The wholesale prices of these markets vary by time and region, and incorporate three cost components: energy, transmission congestion, and transmission losses. Offshore wind development can help lower transmission congestion and losses by taking advantage of relatively short interconnection distances between project sites and urban electric grids in coastal and Great Lakes states. Because of winds that peak in the late afternoon and evening—coinciding with peak loads—offshore wind in many parts of the Atlantic and Pacific regions is also likely to have a higher capacity value than land-based wind. These factors suggest that offshore wind could help depress prices in these areas, and thus lower electricity prices for utilities in the short term [2].

Environmental and economic externalities associated with offshore wind development also need to be better quantified. For example, emissions reduction and water use figures associated with offshore wind in the *Wind Vision* were estimated from the effects of all wind generation deployed in the study scenario and proportionally allocated to offshore wind based on its share of total wind generation. There is an opportunity to conduct more robust analysis that isolates the benefits of offshore wind and is conducted on a regional or state scale. This type of examination would provide a more useful picture to policymakers that can contribute to carbon reduction efforts, such as the Clean Power Plan, or other state energy or environmental planning and policy development.

Stakeholders have suggested that BOEM take further steps to align its process with state policies and available offtake mechanisms. Although significant steps have been taken to ensure effective federal and state coordination (e.g., BOEM's intergovernmental OCS Renewable Energy Task Forces), such coordination can be complicated because state policies and political landscapes change and proposed projects are often proximate to more than one state.

BOEM has received suggestions to alter the existing operating fee payment formula. Developers suggest that certain adjustments to the calculation would enhance price stability and reduce uncertainty in the high-cost offshore operating environment. There is also an opportunity to more effectively link the relative economic potential of a WEA with the BOEM WEA planning process. Adding economic metrics to the delineation of WEAs could result in site selection that is more practically developable, providing an opportunity for more informed bidding.

Significant work needs to be done to put the information developed under this action area into the hands of policymakers, key stakeholders, and the general public. Although simple dissemination of the results of research, development, and other activities undertaken in implementing this strategy is critical to ensuring industry-wide impact, it is not enough. Investment is needed to translate the technical work and other action areas of this strategy into relevant and actionable information for policymakers and stakeholders, so that they can make educated decisions about offshore wind energy development.

Notes

17. Alaska's vast offshore wind resource is not yet counted, but as a result of its extensive coastline and enormous wind-driven wave climate, it will likely have the largest gross resource capacity of any state [58–60].
18. In January 2002, the Federal Government of Germany constructed three research platforms (*FINO1*, *FINO2*, and *FINO3*) in the North Sea and the Baltic Sea, on three potentially suitable sites in the immediate vicinity of major offshore wind farms that were at the planning and application stage.
19. Visit *http://energy.gov/eere/wind/downloads/wind-forecast-improvement-project-wfip-publicprivate-partnership-improving-short* for more information.
20. In German: Forschungsplattformen in Nord und Ostsee (FINO), translates to "Research Platforms in the North and Baltic Seas." See *http://www.fino-offshore.de/en/*.
21. See *http://energy.gov/eere/wind/atmosphere-electrons*.
22. See *www.boem.gov* and *www.bsee.gov*.
23. The cost reduction model considers investments made to technology innovation to reduce cost over time, including, but not limited to, wind turbine drivetrains, rotors, and control systems; balance of system (substructure, tower); electrical infrastructure; construction; decommissioning; and innovative solutions for operation and maintenance. These cost reduction scenarios were modeled by adapting European cost models from KIC InnoEnergy and BVG Consulting [12], and represent the average physical conditions of the current U.S. offshore wind lease areas. To address U.S.-specific market needs, the cost reduction model was modified to include electrical infrastructure and floating wind turbines. For more information, see [24].
24. Such standards should include methods to estimate fatigue life of mooring systems for floating offshore wind turbines, submarine power transmission cables, electric service platforms, and geotechnical design methods for determining long-term response for the cyclical loading of wind turbine substructures, and design of turbine towers and substructures to withstand high load factors of hurricanes.
25. *http://www.boem.gov/Inspection-Safety/*
26. *https://www.congress.gov/bill/114th-congress/house-bill/22/text*
27. Fixing America's Surface Transportation Act (P.L. 114-94) Section 41003.
28. Examples include the migratory pathways of seabirds, the effect of electromagnetic fields, and the impact of chemical spills.
29. This includes biological, geophysical, geological, hazard, and archaeological survey data.
30. "Fates and effects" refer to studies of the environmental consequences associated with human activities (e.g., the effects of electromagnetic fields on marine life).
31. See *http://energy.gov/eere/wind/windexchange*.

4.0 Federal Offshore Wind Strategy

Building on past efforts and seeking opportunities to address any remaining gaps in each of the seven action areas described in Chapter 3 will help the United States responsibly develop a robust and sustainable offshore wind industry. To make progress toward this vision, DOE and DOI have implemented a set of initiatives and collaborated, where possible and appropriate, across the three strategic themes and their seven corresponding action areas. Chapter 3 identified the current baseline and gaps in each of those action areas. This chapter outlines the federal offshore wind strategy, including the specific steps DOE and DOI plan to take to fulfill their respective objectives:

- DOE aims to reduce the levelized cost of energy through technological advancement to compete with local hurdle rates, and create the conditions necessary to achieve *Wind Vision*-level deployment through market-barrier-reduction activities.
- DOI aims to enhance its regulatory program to ensure that oversight processes are well-informed and adaptable, avoid unnecessary burdens, and provide transparency and certainty for the regulated community and stakeholders.

Communication and collaboration with stakeholders will be essential to the success of this strategy. DOE and DOI will disseminate the results and deliverables of the action areas discussed here through multiple channels and across a variety of audiences, and will work with stakeholders to ensure maximum impact and check progress against these objectives at multiple points over the next 5 years.

4.1 Strategic Theme 1: Reducing Costs and Technology Risks

Improvements in offshore wind site characterization and technology advancement can drive significant cost and risk reduction in offshore wind technology. To accomplish this, DOE and DOI intend to collaborate to help establish metocean data collection guidelines (e.g., wind, wave, water current, and tidal condition measurements) that increase the comparability and usefulness of data for wind project design and inform DOI's review of data submitted by lessees. DOE can invest in R&D to advance offshore wind technology and adapt it to unique U.S. conditions. Such investments can increase AEP and reduce offshore wind capital costs, O&M costs, and the cost of financing offshore wind projects.

Action Area 1.1: Offshore Wind Power Resource and Site Characterization

Geological and metocean conditions in the United States differ from those in the established European market. To reduce the risk and uncertainty of deployment along the Atlantic Ocean, Pacific Ocean, Gulf OCS, or the Great Lakes, the full range of geological and metocean conditions in these regions must be well characterized. To accomplish this, DOE and DOI will work jointly to establish acceptable methodologies for gathering metocean data standards and guidance. DOE can further invest in extensive data gathering, as well as ensure effective dissemination of those data.

Table 4.1. DOE and DOI Actions to Address Offshore Wind Power Resources and Site Characterization

Action	Lead Agency	Deliverable	Impact
1.1.1. Support Site Characterization Data Collection Guidance	Joint DOE and DOI	Metocean characterization methodology and data collection guidance specific to offshore wind	Standardized data collection and quality that minimizes uncertainty in operating and extreme conditions, increases safety, and reduces costs for developers
1.1.2. Gather and Disseminate U.S. Metocean and Geological Data	DOE	Increased geographic and temporal coverage of U.S. offshore metocean and geological data	Increased certainty in site conditions, better understanding of lease value, and improved design, leading to increased safety and lower costs for developers
1.1.3. Validate Innovative Site Characterization Methods	DOE	Validated low-cost metocean data collection technologies	Less cost and time required for metocean site characterization, increased certainty in AEP forecasts, and reduced financing costs for developers

Action 1.1.1: Support Site Characterization Data Collection Guidance

No standards exist for metocean data collection for offshore wind site characterization. DOI and DOE will facilitate the development of these standards and associated modeling tools by assembling national and international experts to create guidance for U.S. offshore wind developers. Developing guidelines for metocean data gathering would significantly reduce project design risk and uncertainty, increase reliability in offshore renewable energy projects, reduce capital costs, and ensure human safety and the protection of the natural environment on the OCS.

Action 1.1.2: Gather and Disseminate U.S. Metocean and Geological Data

Having a thorough understanding of the meteorological, oceanographic, and geologic data related to a specific offshore project site is essential for proper design, permitting, and O&M. As a result, there is significant value in continuing and expanding ongoing work by DOE in resource assessment and site characterization for both operating and extreme conditions in BOEM WEAs, as well as more broadly across U.S. waters. Early characterization of site conditions in WEAs would help better establish the value of a particular lease area up for auction, reduce design uncertainties and development costs, and improve preconstruction power production forecasts. Ultimately, such efforts could improve the return for taxpayers on leased sites as well as reduce capital costs for offshore wind developers. DOE will explore the use of a common portal to disseminate these data and ensure they are accessible to developers, financiers, insurers, and regulators.

Action 1.1.3: Validate Innovative Site Characterization Methods

Innovative site characterization technologies that are less capital-intensive than fixed meteorological towers could make gathering metocean data easier and less expensive. Among the most promising technologies are lidar buoys. Validating this technology could yield data acquisition that is more rapid, efficient, and accurate, as well as provide the data needed to design, permit, and finance offshore wind energy plants in the United States. DOE is positioned as a credible third party to conduct this validation, and will collaborate with European government facilities if needed. Once gathered, the value of these data could be increased significantly by collecting them in a repository or portal that is easily accessible to the community. Accessing the data through a single location could allow investors, developers, engineers, regulators, and other key stakeholders to identify trends that could be leveraged for the advancement of the industry.

Action Area 1.2: Offshore Wind Plant Technology Advancement

Technology advancement has the potential to enhance safety and reduce costs of offshore wind energy in a variety of ways. The informed design and operation of wind plants in accordance with accepted standards and regulations will minimize risks to personnel and assets, whereas technology advancements targeted at the major cost drivers of offshore wind energy LCOE will drive significant cost reductions globally. In order for these advancements to benefit the domestic market, however, they must address the unique requirements of U.S. sites, including deep water; extreme conditions, such as hurricanes; and weak and unconsolidated seabed soils. Targeted investment by DOE in the following areas can help level the cost of offshore wind energy to parity with other forms of generation by 2030 in several regions of the United States.

Table 4.2. DOE and DOI Actions to Address Offshore Wind Plant Technology Advancement

Action	Lead Agency	Deliverable	Impact
1.2.1. Demonstrate Advanced Offshore Wind Technology	DOE	Full-scale offshore wind technology demonstrations; comprehensive performance, metocean, and other data sets	Reduced perception of risk, including data to provide a baseline for the U.S. offshore wind community to develop lessons learned and hone in on areas with the largest opportunities for cost reduction
1.2.2. Advance Partnerships to Address Unique U.S. Offshore Challenges	DOE	Integrated, U.S.-specific offshore wind technology advances; thriving joint industry projects	Improved industry collaboration and knowledge transfer; reduced risks and costs associated with weak soils, deeper waters, hurricanes, and other U.S.-specific challenges
1.2.3. Improve Reliability of Offshore Wind Systems	DOE	Turbines and turbine subsystems designed and tested for higher reliability using proven methods, such as prognostic health monitoring	Reduced onsite O&M, less risk to personnel and assets, and ultimately, increased availability, AEP, and reduced OpEx
1.2.4. Develop Offshore Wind Energy Design Standards	DOE	Structural design standards specific to offshore wind for U.S. conditions, particularly floating substructures and structures in hurricane-prone areas	Optimized designs; reduced project capital costs, technology risk, and financing and insurance costs

Action 1.2.1: Demonstrate Advanced Offshore Wind Technology

The Advanced Technology Demonstration Projects are currently a major focus of DOE's efforts in offshore wind and represent an opportunity to validate novel technologies that have significant potential to reduce the cost of energy both in the United States and globally. These projects, which are scheduled to be installed by 2020, will have exercised federal and state regulatory processes and the U.S. supply chain, setting a potential baseline for future offshore wind deployments. Once the projects are operational, DOE requires that each project collect a significant amount of data over the first 5 years of operations, including turbine, structure, and integrated wind plant system engineering, performance, environmental monitoring, operations, and cost data to validate the design and operation in a field environment. These data will be used to validate and de-risk the innovative technology—novel substructures, wind plant controls, O&M strategies, and so on—and its performance, confirming that implementation of these technologies on a commercial scale will lead to cost reductions. As these projects will be some of the first offshore wind projects installed in the United States, the lessons learned during project development, fabrication, construction, and operations will be documented and disseminated to benefit the broader U.S. offshore wind community.

The demonstration projects can also provide value in validating advanced design tools. Advanced design tools allow for researchers and engineers to accelerate innovative concepts from an idea to commercial-scale deployment. DOE intends to use the data collected by the Offshore Wind Advanced Technology Demonstration Projects to support model validation efforts, de-risking the tools and developing confidence in the models. This confidence reduces design uncertainty and margins, allowing for additional creativity and innovation that can lead to significant reductions in offshore wind costs.

Action 1.2.2: Advance Partnerships to Address Unique U.S. Offshore Challenges

DOE will encourage collaboration among the offshore wind community, leveraging interdisciplinary, intersector cooperation to rapidly advance U.S. offshore wind energy. A consortium that crosscuts the domestic offshore wind community operating under a joint industry project could potentially jumpstart the nation's industry through the systems approach to addressing the key U.S.-specific technological challenges. Such a consortium would leverage previous DOE and global industry investments, including the Carbon Trust's Offshore Wind Accelerator, DOE's Atmosphere to Electrons initiative, and DOE's Offshore Wind Advanced Technology Demonstration Projects. Integrated technology advancement could focus on interdependent technical areas, including advanced substructure technology, installation technology, O&M technology, development of design standards, and wake interaction technology. The consortium would oversee a portfolio of R&D projects to best address these interdependent challenges and use the experience gained to develop, de-risk, and commercially implement the most promising advancements on an accelerated timeframe.

Action 1.2.3: Improve Reliability of Offshore Wind Systems

Because of the harsh environments in which offshore wind facilities are located, the ability to perform both scheduled and unscheduled maintenance is a major challenge. As a result, availability for offshore wind plants is lower than for land-based facilities, and O&M costs can make up 20% of total LCOE for offshore wind facilities. An unplanned failure of a major component, such as a gearbox in an offshore wind turbine, can involve mobilizing an expensive heavy lift vessel (the same kind used for turbine installation) and necessitate waiting months for a safe weather window in which to conduct marine operations. To improve this situation, DOE intends to invest in technology development to reduce the cost and frequency of such unscheduled visits, leverage unscheduled maintenance for scheduled maintenance, and expand the conditions in which facilities can be safely accessed. Developing prognostic health monitoring and management of major components, for example, could allow operators to identify early signs of failure in a component and run the affected turbine at a reduced intensity to lengthen its life until the next scheduled maintenance window. These investments will increase availability and AEP, and significantly reduce O&M costs.

Action 1.2.4: Develop Offshore Wind Energy Design Standards

DOE, with support from DOI, will continue to work toward the development of structural design standards for the U.S. offshore wind industry, which provide certainty to regulators, developers, and the financial community regarding the quality and safety of turbine and substructure designs. Standards that specifically address the unique conditions of the United States, such as floating technologies and areas prone to hurricanes, will allow for optimized designs, which reduce costs for developers while increasing certainty for financiers and insurers, thus lowering the costs of financing. One potential result of this action would be an updated version of the *AWEA Large Turbine Compliance Guidelines: AWEA Offshore Compliance Recommended Practices (2012); Recommended Practices for Design, Deployment, and Operation of Offshore Wind Turbines in the United States* document adopted as a full design standard [92]. A workshop on structural modeling issues that was held in April 2016, by BOEM and NREL helped kick off this effort by soliciting feedback from industry on how the standards need to be developed. Additional workshops will be considered on a 1- or 2-year interval to continue sharing ideas with industry.

Action Area 1.3: Installation, Operation and Maintenance, and Supply Chain Solutions

The development of a U.S. supply chain dedicated to offshore wind development is inhibited by an insufficient pipeline of projects. The current U.S. offshore wind supply chain is dispersed, relying on adapted fabrication facilities in the Gulf of Mexico and international assets. Larger turbine technologies can result in reduced capital costs, increased production, and reduced OpEx, but also create unique installation challenges requiring purpose-built vessels. O&M infrastructure, especially on the West Coast, is limited in breadth and lacks operational experience. DOE can address some of these issues through the following actions.

Table 4.3. DOE and DOI Actions to Address Installation, Operation and Maintenance, and Supply Chain Solutions

Action	Lead Agency	Deliverable	Impact
1.3.1. Support a Regularly Updated U.S. Supply Chain Inventory	DOE	Open-source database of information detailing U.S. supply chain assets, such as manufacturing capabilities, vessels, and ports	Enhanced understanding of the supply chain baseline and the ability to conduct multifaceted analysis of the existing capabilities and gaps to increase domestic supply
1.3.2. Evaluate Supply Chain Bottlenecks, Costs, Risks, and Future Scenarios	DOE	Assessment of the current U.S. supply chain shortcoming and the impact on offshore wind costs with future supply chain development	Identification of supply chain investment opportunities and quantification of the supply chain infrastructure required to achieve the *Wind Vision* development scenarios and increase the domestic supply of offshore wind components and labor

Action 1.3.1: Support a Regularly Updated U.S. Supply Chain Inventory

DOE has previously supported research that establishes a supply chain baseline in manufacturing [56], vessels [72], and ports [70]. This past research can be leveraged and regularly updated to establish a baseline and capture the dynamic nature of the U.S. supply chain. To continue keeping the data relevant, the data could be put into an open-source tool that would not only catalogue the U.S. supply chain, but allow suppliers and offshore industry members to input capabilities data. The tool would need to be maintained and expanded as industry entities use it and the offshore wind industry grows in the United States. It could be organized by industry sector—manufacturing, vessels, ports, and so on—and leveraged to enable supplementary supply chain analysis. For example, DOE could sponsor a database of Jones-Act-compliant vessels in the United States that could support offshore wind installation, including technical specifications and capabilities. Using this database, further analysis could be performed to document how modifications and retrofitting could enable the vessels to support offshore wind installation activities. With access to a ports and manufacturing database, the installation vessel analysis could also be extended to identify shipyards that have the ability to modify existing vessels or construct new offshore wind installation vessels.

Action 1.3.2: Evaluate Supply Chain Bottlenecks, Costs, Risks, and Future Scenarios

To support offshore wind development in the short and long term, supply chain bottlenecks should be evaluated and assessed. In the short term, vessels that are used to install and maintain turbines are critical. Research to understand the added cost and risk of using current Jones-Act-compliant alternatives, such as European TIVs and U.S.-flagged feeder vessels, or using U.S.-based assets in creative ways, can help determine the business case for a U.S.-flagged TIV. DOE could also convene stakeholders and federal agencies such as the U.S. Department of Transportation's Maritime Administration to discuss mechanisms that could be leveraged to improve the business case for U.S.-flagged TIVs. Additionally, this work could help identify creative and effective solutions in installation sequencing.

Evaluation of the supply chain bottlenecks that inhibit significant long-term deployment is also important. DOE could sponsor research that evaluates the annual offshore wind deployment that is required to meet the *Wind Vision* scenarios from the present day to 2050, and distinguish the supply chain limits as well as where additional investment is needed. These studies could consider critical production volumes of particular components necessary to facilitate investment or LCOE reductions, the impact of various installation and O&M strategies on local content and cost, and ways to leverage the land-based wind supply chain. Research could also explore the benefits associated with more revolutionary installation solutions, such as semisubmersible floating platforms and self-erecting or "float-and-flip" turbines, that eliminate the need for specialized infrastructure by enabling offshore installation by traditional tugs and other readily available, general-purpose vessels.

4.2 Strategic Theme 2: Supporting Effective Stewardship

Stakeholders suggest that DOI optimize the regulatory process to increase certainty for offshore wind developers and stakeholders while continuing to provide effective stewardship of the OCS. To further promote good stewardship of U.S. waters in the context of offshore wind development, DOE and DOI have also acquired significant knowledge concerning the potential impacts of offshore wind development on biological resources and human communities over the past 5 years. Investment in research over the next 5 years regarding the first generation of offshore wind projects can validate that understanding and help focus regulatory efforts on the most important environmental and human-use impacts.

Action Area 2.1: Ensuring Efficiency, Consistency, and Clarity in the Regulatory Process

DOI helps facilitate safe, efficient, and environmentally responsible offshore wind development by continuing to improve consistency and clarity in the regulatory process. To advance this objective and provide more certainty to developers as they progress through the planning, siting, and plan review phases of their projects, DOI will take a number of actions, including reevaluating its SAP requirement and Intergovernmental Task Force structure, considering alternative approaches to performing its COP review and attendant NEPA analyses, and collaborating with relevant agencies to standardize and synchronize review processes where feasible. Many of these actions address postlease issues, reflecting the fact that BOEM has progressed from the planning and leasing stage to the plan-review stage for many of its offshore areas.

For a number of initiatives, DOI has been able to identify and provide reasonable timeframes for critical decision-making milestones. Other initiatives will require additional analysis prior to DOI developing a timeline for completion. However, DOI will undertake all of the following actions during the 5-year scope of this strategy and commit to informing stakeholders about its progress towards completion.

Table 4.4. DOI Actions to Ensure Efficiency, Consistency, and Clarity in the Regulatory Process

Action	Lead Agency	Deliverable	Impact
2.1.1. Reassess, and Potentially Modify, the SAP Requirements for Meteorological Buoys	DOI	In early 2017, communicate decision on path forward for initiation of potential regulatory changes and/or implementation of process changes for reviewing proposals to install meteorological buoys during the site assessment terms of commercial leases	Less costly and more efficient meteorological buoy deployment to inform commercial wind proposals in offshore wind lease areas
2.1.2. Increase Certainty in Plan-Review Processes	DOI	Decision on one or more plan-review process improvements, and external communication of decision	Greater certainty in timing and requirements for lessees during the plan-review process and reduced costs associated with unanticipated delays
2.1.3. Evaluate a "Design Envelope" Approach for Construction and Operations Plan Environmental Impact Statements	DOI	By July 1, 2017, decision on the implementation of "design envelope" approach; if adopted, revised COP guidelines and potential workshop	Greater flexibility for lessees to make final design decisions later in the process and take advantage of emerging technological improvements
2.1.4. Revisit the Structure of Intergovernmental Task Forces	DOI	Document describing Task Force evaluation and path forward for BOEM's Task Force utilization	Efficient intergovernmental coordination that considers input from any and all potentially affected states
2.1.5. Enhance Interagency Coordination Around Offshore Wind Development	DOI	Structured and recurrent federal interagency coordination on offshore wind projects; if adopted, implementation of one or more options considered to standardize agency offshore wind project review processes	Increased governmental coordination of offshore wind projects and improved project review processes
2.1.6. Provide a Regulatory Roadmap	DOI	By July 1, 2017, publish regulatory roadmap on BOEM's website that provides requirements associated with OCS offshore wind projects	Clarification of steps and approvals necessary to develop an OCS wind facility, increased understanding, and regulatory certainty for developers and stakeholders
2.1.7. Consider Modifying Decommissioning Financial Assurance Requirement	DOI	Decision on whether to allow developers to phase in required decommissioning financial assurance; if adopted, publication of proposed regulatory changes in the Federal Register	Reduced up-front financial burdens on lessees, if change adopted

Action	Lead Agency	Deliverable	Impact
2.1.8. Develop U.S. Offshore Wind Energy Safety Guidelines	DOI	Health, safety, and environmental management guidelines for offshore wind construction, installation, and operations activities	Greater certainty and guidance for developers for safe construction, installation, and operations activities
2.1.9. Assess Path Forward for Potential Next Round of Atlantic Planning and Leasing	DOI	Stakeholder meetings in summer or fall of 2017 to gather input on the next round of Atlantic planning and leasing; subsequently, decision on path forward for potential future Atlantic planning and leasing	Shared vision and coordination on the next round of planning and leasing, greater certainty for industry, and opportunity for specific feedback from stakeholder community resulting in more informed decision-making
2.1.10. Continue Work Towards Establishment of International Offshore Wind Regulators Forum	DOI	Meetings and conversations with other offshore wind regulators, in an effort to establish an offshore wind regulators forum	Facilitate sharing of best practices, which could lead to the adoption of more efficient regulatory models
2.1.11. Convene an Offshore Wind Stakeholders Group	DOI	In 2017, convene inaugural meeting of the Offshore Wind Stakeholders Group; determine appropriate meeting frequency and hold said meetings	Ensure transparent and productive dialogue about the challenges and opportunities in the regulatory realm

Action 2.1.1: Reassess, and Potentially Modify, the SAP Requirement for Meteorological Buoys

Stakeholders have expressed concern that BOEM's requirement to submit a SAP and associated data to support installation of a meteorological buoy in a specific lease area is unnecessarily onerous given the scale of these facilities. In response to these comments, BOEM will re-evaluate its current regulatory requirements and its SAP review procedures, and subsequently determine the appropriate path forward on this issue in early 2017. BOEM may, at that time, decide to initiate the rulemaking process to consider eliminating or minimizing some or all of the applicable regulatory requirements for SAPs that propose installation and operation of meteorological buoys. Alternatively, at that time, BOEM may decide to retain the current regulatory requirements, but identify and implement process changes to lessen the burden on developers. If BOEM determines that it would be appropriate to lessen any requirements, then it will implement the change(s) through the appropriate process and update its *Guidelines for Information Requirements for a Renewable Energy Site Assessment Plan (SAP)* [93], as necessary. This could result in less costly and more efficient meteorological buoy deployment to inform commercial wind proposals in offshore wind lease areas.

Action 2.1.2: Increase Certainty in Plan Review Processes

Stakeholder feedback suggests that BOEM's plan review process needs to be more transparent, predictable, and expeditious to reduce scheduling uncertainty and financial risk. As a result, BOEM will consider different approaches to improve and streamline this process. Approaches that BOEM will consider include: 1) setting timelines for BOEM's NEPA review process pursuant to 40 CFR 1501.8; 2) establishing informal agreements with lessees (e.g., developing memoranda of agreements on a project-by-project basis that include timelines for critical milestones); and 3) providing a target review period for plans once they are determined to be complete and sufficient (e.g., establish a target review period of 18 months for complete and sufficient COPs). In addition to complying with the requirements associated with FAST-41, BOEM will implement one or more methods to improve its plan review process and communicate that decision to the offshore wind stakeholder community. This effort will provide lessees with greater certainty as they move forward with their project proposals.

Action 2.1.3: Evaluate a "Design Envelope" Approach for Construction and Operations Plan Environmental Impact Statements

Industry suggests that it may not be effective for BOEM to require lessees to provide certain project details when submitting COPs, as developers may not be prepared to confirm those project design elements at that stage. In an effort to address this concern, BOEM will investigate the "design envelope" concept for conducting an Environmental Impact Statement to support its COP decision-making. This investigation will include, but not be limited to, discussions with its European regulatory counterparts, for whom this practice is more commonplace. This approach would allow a lessee to describe its project within a range of agreed-to parameters, and would permit BOEM to analyze the range of impacts associated with those parameters. BOEM will communicate its decision regarding the use of the design envelope approach by July 1, 2017. If BOEM adopts this concept, it will revise its *Guidelines for Information Requirements for a Renewable Energy Construction and Operations Plan (COP)* [94], as necessary, and may hold a workshop to explain the implementation of this approach for lessees and other stakeholders. If implemented, this methodology would provide lessees with the flexibility to defer certain project design decisions until after a COP is approved as well as take advantage of technological improvements that occur during the course of project development.

Action 2.1.4: Revisit the Structure of Intergovernmental Task Forces

In acknowledgement of comments received in response to the RFF, BOEM will re-evaluate its current approach to establishing its Intergovernmental Task Forces to ensure effective coordination with all interested and potentially affected states throughout BOEM's planning, leasing, and plan review processes. After completing its evaluation, BOEM will provide a document on its website that describes the outcome of this evaluation and its path forward. BOEM may continue to carry out the current process of setting up Task Forces on a state-by-state basis, or may implement a different methodology that it believes will be more effective. Either way, BOEM will ensure that all potentially affected states are consulted about offshore wind activities off their coasts in a manner that avoids potential delays to BOEM's planning and leasing processes.

Action 2.1.5: Enhance Interagency Coordination Around Offshore Wind Development

BOEM is not the only federal agency with a role in permitting offshore wind farms. Rather, there is a complex regulatory roadmap that each developer must traverse. The efforts under Action 2.1.6 will provide greater clarity to elucidating that path, but hurdles will still remain. Specifically, industry has highlighted the importance of governmental coordination given the multitude of agencies with a role in offshore wind permitting. BOEM will evaluate options to standardize and synchronize review processes across agencies, and will research successful examples implemented by other federal agencies, as well as its European counterparts. As a component of this effort, BOEM is leading the Offshore Wind Permitting Subgroup under the White House Interagency Working Group on Offshore Wind to identify ways to streamline and improve interagency coordination associated with the SAP review process. Lessons learned may be incorporated into the review processes for other plans. Given the multitude of agencies with a role in permitting offshore wind projects, efficient and effective governmental coordination will be critical to avoiding detrimental and costly delays in the permitting process.

Action 2.1.6: Provide a Regulatory Roadmap

Given the number of governmental permits and authorizations required for the realization of an offshore wind project, BOEM will develop a regulatory roadmap that outlines the requirements of BOEM and other agencies that industry must follow when developing offshore wind projects. BOEM will coordinate with other federal agencies to ensure that the document is thorough and informed, and make it available to the developers and the public via its website and other appropriate means by July 1, 2017. Such a roadmap will help the regulated community by clarifying the steps and approvals necessary to develop an OCS wind facility.

Action 2.1.7: Consider Modifying Decommissioning Financial Assurance Requirements

In response to the RFF, industry professionals described the potential difficulties associated with providing decommissioning financial assurance prior to receiving project income. BOEM will consider modifying its regulations to allow developers to phase in their required decommissioning financial assurance. BOEM will need to weigh the potential benefits of doing so against the financial risk that the government may incur as a result. If BOEM determines that modifying its regulations to accommodate this approach would be appropriate, the resulting regulatory amendment may alleviate a substantial financial burden that developers face prior to receiving operating income from their projects.

Action 2.1.8: Develop U.S. Offshore Wind Energy Safety Guidelines

DOI will develop health, safety, and environmental management guidelines for offshore wind construction and operation activities. These guidelines will combine applicable information from the U.S. offshore oil and gas sector, as well as lessons learned and best management practices from the international experience with offshore wind to help ensure that construction and operation activities are conducted in a safe and environmentally sound manner.

Action 2.1.9: Assess Path Forward for Potential Next Round of Atlantic Planning and Leasing

BOEM has received informal inquiries from stakeholders relating to the next steps for planning and leasing in the North and Mid-Atlantic regions, and a number of RFF comments recommended steps that BOEM could take to better inform its planning and leasing processes moving forward. In order to help BOEM determine the appropriate time for an additional round of planning and leasing offshore all or certain Atlantic states, and ensure that any such efforts are as informed as possible, BOEM will convene public meetings to gather stakeholder input on this issue in the summer or fall of 2017. After determining the appropriate path forward and the timing of next steps, BOEM will communicate that decision to the offshore wind stakeholder community via its website and any other appropriate means. This decision-making process will help to provide certainty to industry about BOEM's longer-term plans for facilitating Atlantic offshore wind development, and will help ensure that BOEM implements lessons learned from its first tranche of Atlantic planning and leasing.

Action 2.1.10: Continue Work Towards Establishment of International Offshore Wind Regulators Forum

One consistent area of informal feedback has been the importance of interfacing with regulators from other countries to learn best practices. As discussed at the White House Summit on Offshore Wind in September 2015, DOI has begun discussions with offshore wind regulators in various European countries about the best ways for the United States to learn from their experiences. BOEM recently executed a memorandum of understanding with the Embassy of Denmark to share knowledge, data, best practices, and capitalize on their decades of experience in offshore wind development. In this vein, DOI aims to establish a multilateral group to discuss ways to responsibly facilitate offshore wind development in the United States and around the globe. The group will present a unique opportunity for sharing lessons learned, discussing regulatory approaches and best practices, and exchanging scientific and environmental information.

Action 2.1.11: Convene an Offshore Wind Stakeholders Group

As referenced above, DOI's practices are and will continue to be informed by the experiences of countries that have spent years regulating offshore wind farms. For example, several of those countries, including the United Kingdom, have created opportunities for high-level conversations between government officials and industry leaders. In an effort to encourage and continue open dialogue about the challenges of and opportunities for offshore wind deployment in the United States, DOI will convene, on a regular basis, stakeholders to discuss regulatory and strategic issues to ensure clear communication between industry, other stakeholders, and regulators.

Action Area 2.2: Managing Key Environmental and Human-Use Concerns

DOE and DOI can contribute to the successful coexistence between offshore wind and other resources and users through investment in science to understand the impacts of development and identify how these impacts might be appropriately mitigated. This science is the foundation of DOI's environmental review and regulatory process. Although significant research has already been conducted on these subjects, the next 5 years present an opportunity for DOE and DOI to conduct research at first-generation offshore wind projects to better understand how offshore wind affects biological resources and human communities and uses.

Action 2.2.1: Collect Environmental Impact Data and Support Testing of Monitoring and Mitigation Technologies at First-Generation Projects

The near-term development of offshore wind facilities in the United States provides an excellent opportunity to reduce environmental uncertainty for future projects. Research at DOE's demonstration projects in addition to other first- and second-generation offshore wind developments will help reduce uncertainty regarding the environmental impacts of offshore wind. Over the next 5 years, DOE will partner with wind developers and federal agencies to conduct research at first-generation projects that will drive innovation in monitoring technologies and test the effectiveness of mitigation tools. This action will include participation in BOEM's RODEO efforts to measure environmental stressors, such as construction noise, as well as separate research efforts to measure the biological response of organisms to offshore wind energy.

Action 2.2.2: Synthesize Environmental Impact Data and Develop Predictive Models

To supplement the action to collect reliable data and develop mitigation technologies, DOE will support retrospective analyses of impact-producing factors and environmental impacts from observations and lessons learned using the demonstration projects as case studies. After multiple projects have been developed, DOE will support meta-analyses of initial data across projects, with an aim to identify environmental risks that were previously of concern, but may be retired due to lack of impacts and areas for additional research. Using data from first-generation wind projects, DOE plans to support the development of risk models that predict impacts, taking behavior, exposure, and hazard into account. The intent of this work is to replace monitoring with modeling, where feasible, by creating and validating tools that allow developers and regulators to accurately predict impacts and aid in recommending appropriate mitigation.

Action 2.2.3: Evaluate and Support Mitigation of Unique Impacts of Offshore Wind on Coastal Radar Systems and Other Federal Missions

DOE pursues approaches to mitigate wind turbine radar interference under a memorandum of understanding with the U.S. Department of Defense, Federal Aviation Administration, NOAA, and the *Federal Interagency Wind Turbine Radar Interference Mitigation Strategy* developed by these agencies [95]. Offshore wind may pose unique impacts to coastal radar systems given the differences in propagation of radar signals over the ocean versus land. One mitigation approach will be to improve modeling and simulation tools to aid in the siting and evaluation of planned offshore wind facilities. In doing so, the interagency team plans to integrate various simulation parameters into their existing tools that coincide with the offshore wind environment.

In addition, DOE plans to conduct studies to evaluate the potential impacts of currently planned offshore wind facilities on ground-based coastal air surveillance radar to evaluate the vulnerability of these air surveillance radars to offshore wind turbines. These studies will further identify which mitigation measures that are either existing or under development may be appropriate to address those vulnerabilities. For example, the interagency team is collaborating to develop concepts to improve the wind turbine interference mitigation capabilities of existing radars through signal-processing software upgrades and minor hardware modifications. DOE is partnering with the Massachusetts Institute of Technology's Lincoln Laboratory on a study that looks at the feasibility of advanced signal-processing techniques for existing National Airspace System radars, and plans to apply these techniques to coastal radars where possible. Where these initial efforts reveal a need for mitigation specific to offshore wind development, DOE will pursue further R&D with its interagency partners.

Table 4.5. DOE and DOI Actions to Manage Key Environmental and Human-Use Concerns

Action	Lead Agency	Deliverable	Impact
2.2.1. Collect Environmental Impact Data and Support Testing of Monitoring and Mitigation Technologies at First-Generation Projects	DOE	Field data of the environmental impacts from offshore wind energy in U.S. waters and field testing of monitoring and mitigation technologies	More informed understanding of the relative impact of offshore wind development in the United States to increase regulatory certainty and minimize environmental compliance costs
2.2.2. Synthesize Environmental Impact Data and Develop Predictive Models	DOE	More accurate and informed predictive models of potential impacts from offshore wind energy installations on sensitive species	Improved basis for implementation of effective and prudent monitoring and mitigation measures, and a decrease in environmental impacts
2.2.3. Evaluate and Support Mitigation of Unique Impacts of Offshore Wind on Coastal Radar Systems and Other Federal Missions	DOE	Incorporation of offshore wind-specific parameters to improve radar modeling and simulation tools and studies of potential mitigation options	Improved radar interference modeling and simulation tools, mitigation technologies, and reduced conflict between wind development and radar missions
2.2.4. Support Social Science to Understand the Drivers of Opposition and Acceptance of Offshore Wind Farms	DOE	Increased understanding of the drivers of acceptance and opposition of offshore wind facilities	Identify and encourage development practices that are most likely to create acceptance and support for offshore wind projects
2.2.5. Aggregate and Disseminate Environmental Impact Information	DOE	Greater dissemination of the results of environmental and human-use impact research	Improved understanding by regulators and stakeholders of highest priority issues; decreased impact by offshore wind, reduced uncertainty in monitoring and mitigation measures, and shorter and less-expensive project deployment timelines

Action	Lead Agency	Deliverable	Impact
2.2.6. Improve Communication of BOEM's Offshore Wind Energy Studies and Research with All Stakeholders	DOI	Implementation of appropriate outreach measures to increase stakeholder awareness of the studies' processes and results, including opportunities for industry and other stakeholder input	Increased transparency of the studies' processes, greater stakeholder accessibility and usability of BOEM's environmental studies data, and a more informed stakeholder base
2.2.7. Provide Guidance to Clarify Information Needs and Data Collection Requirements	DOI	Updated preconstruction survey guidelines, where necessary; postconstruction guidelines developed with input from industry, resource and regulatory agencies, and other stakeholders; and, if appropriate, information on how design parameters (e.g., turbine height) relate to environmental and socioeconomic resource impacts to inform future COP submission	Clearer resource agency data collection requirements and establishment of a feedback loop for guideline development, so that developers have certainty when navigating the regulatory and environmental compliance processes
2.2.8. More Comprehensive Baseline Data Collection to Support Regional Spatial Planning	**DOI**	Updated marine wildlife and habitat baseline data (collected through BOEM's environmental studies program) to support regional marine planning, NEPA processes, and predictive modeling	More comprehensive regional baseline data to better inform stakeholder knowledge as well as planning and development decisions

Action 2.2.4: Support Social Science to Understand the Drivers of Opposition and Acceptance of Offshore Wind Farms

Public acceptance of particular offshore wind facilities and development will be needed to support significant deployment in the United States. A rich collection of literature on the impacts of land-based wind facilities on communities exists throughout the world and explores the drivers of acceptance and opposition to development in those communities; however, more needs to be done both in the U.S. context as well as on offshore wind. DOE's Lawrence Berkeley National Laboratory is conducting the first national baseline assessment that looks at these factors around the nation with respect to land-based facilities. Under this action, DOE plans to conduct similar studies for the first offshore projects in development. For example, it will track community responses to these projects longitudinally, from development through operations, to determine the factors that make a project more or less acceptable to affected communities, and begin to suggest development practices that are most likely to create acceptance of and support for offshore wind in locations around the country.

Action 2.2.5: Aggregate and Disseminate Environmental Impact Information

DOE plans to work with federal agencies, the offshore wind industry, and other stakeholders to ensure that environmental and wildlife market barrier research results gathered throughout the world are aggregated, synthesized, and shared so that regulators, industry members, and other stakeholders have access to information and analysis on the state of the current scientific understanding. DOE aims to continue combining information gathering and sharing efforts, including the continued support of the Tethys[32] database, to house information on environmental research and make it easily accessible. DOE, in conjunction with DOI, will also continue to support and commit leadership to the international Working Together to Resolve Environmental Effects of Wind Energy (WREN)[33] initiative and associated activities, including a webinar series, participation in conferences, engagement with European counterparts, and biannual state-of-the-science analyses that present the current state of knowledge regarding wind-wildlife monitoring techniques, impacts, and mitigation strategies.

Action 2.2.6: Improve Communication of BOEM's Offshore Wind Energy Studies and Research with All Stakeholders

To better align BOEM efforts with project requirements and other information needs of the offshore wind industry, BOEM will create more productive opportunities for input from all stakeholders, including industry, early in the studies development process. Implementation of this action includes restructuring BOEM's outreach tools to inform and update stakeholders on the status of ongoing studies as well as the results of completed studies. Specific outreach tools that BOEM will include, but are not limited to, the following: incorporating relevant studies information on applicable web pages (e.g., individual state activities pages); producing an annual year-in-review report; conducting stakeholder webinars to share the results of completed studies and the status of ongoing studies; and holding in-person information transfer meetings with stakeholders every 2 years. BOEM will also collaborate with DOE on WREN to conduct additional outreach activities.

Action 2.2.7: Provide Guidance to Clarify Information Needs and Data Collection Requirements

As early as 2013, BOEM began publishing guidance for industry related to the collection of preconstruction or baseline data. Now that the guidance has been in use for a few years, BOEM will update it by incorporating lessons learned, new technology, and recent research/studies. In addition, BOEM will solicit industry input to determine specific topics of interest for new guidance documents (e.g., lighting requirements and assessing visual impact concerns).

Providing guidance on postconstruction monitoring will facilitate coordination between the offshore wind industry and related stakeholders. Communicating the data collection requirements of the federal resource and regulatory agencies involved will provide greater transparency and consistency in BOEM's plan-approval processes. Guideline development will focus on resources and activities that enable consistency across projects, as opposed to project- or site-specific requirements that will need to be determined through project-specific consultations.

BOEM will also conduct analyses to identify which parameters related to design envelopes (as described in Action Area 2.1: Ensuring Efficiency, Consistency, and Clarity in the Regulatory Process) are pertinent to the level of significance of resource impacts. This approach will help to clarify the information requirements for COP submission, with the overall goal of improving efficiency in the environmental review process.

Action 2.2.8: More Comprehensive Baseline Data Collection to Support Regional Spatial Planning

The preparation of NEPA documents and consultations under various regulations require information about the environment that often extends beyond the footprint of an offshore wind project. Through regional planning efforts, significant amounts of data are now available both through the compilation of existing data and the gathering of new information. These data are shared across federal, state, and tribal governments, and are available to the public through regional data portals. BOEM will help to ensure the best-available science is used in decision-making through continued collection of regional baseline data and updating of predictive models for OCS wildlife. All data collection efforts will continue to be shared and provided through existing data portals.

4.3 Strategic Theme 3: Increasing Understanding of the Benefits and Costs of Offshore Wind

To increase understanding of offshore wind and aid policymakers and stakeholders in making decisions about policies and projects, DOE can invest in rigorous assessment of grid integration challenges associated with offshore wind as well as quantify the electricity system impacts, and social and environmental benefits and costs of its development. DOI is committed to re-evaluating its operating fee mechanism to improve certainty for developers while continuing to ensure fair return to the nation from offshore wind development on the OCS. DOE can also support communication of offshore wind costs and benefits to key audiences, to enable more informed decision-making around offshore wind policies and projects, increase policymaker and public understanding and confidence of the potential effects of offshore wind in the energy system, and help improve the market outlook for offshore wind.

Action Area 3.1: Offshore Wind Electricity Delivery and Grid Integration

The interconnection and integration of offshore wind energy bear significant similarities to land-based wind, allowing the independent system operators, regional transmission operators, utilities, regulators, state legislators, and other stakeholders to more readily incorporate offshore wind energy into the energy mix. However, key challenges and advantages specific to offshore wind energy merit further study. These include examining the benefits and impacts of integrating significant quantities of offshore wind into congested load centers as well as the effects of offshore wind-specific transmission and other electrical infrastructure on the power system.

Table 4.6. DOE Actions to Address Offshore Wind Electricity Delivery and Grid Integration

Action	Lead Agency	Deliverable	Impact
3.1.1. Analyze Optimized Offshore Wind Grid Architectures	DOE	Better understanding of optimal system architectures for aggregation and delivery of electricity from U.S. offshore wind projects	Potential for reduced capital costs associated with cabling and increased potential buildout associated with access to offshore transmission infrastructure
3.1.2. Analyze State and Regional Offshore Wind Integration Strategies	DOE	Better understanding of the impacts of interconnection and integration at the state and regional levels	Electricity system plans and policies that effectively account for offshore wind integration; increased utility and policymaker confidence in the ability to integrate offshore wind

Action 3.1.1: Analyze Optimized Offshore Wind Grid Architectures

Offshore wind projects under development all currently propose individual radial connections to shore. Developing offshore transmission "backbones" and connection points could enable offshore wind development by reducing the costs of interconnection and alleviating transmission congestion on land and in transmission-constrained coastal states. The use of high-voltage direct-current transmission could also provide benefits. For example, this type of transmission can be controlled more easily than high-voltage alternating-current transmission to reduce onshore congestion. New research to evaluate the impacts of transmission expansion for offshore wind could include valuation of improved system reliability, reduced transmission congestion, and related operational effects, such as short-term reliability and flexibility from high-voltage direct-current transmission and offshore wind backbone infrastructure.

Action 3.1.2: Analyze State and Regional Offshore Wind Integration Strategies

DOE plans to conduct studies to assess state and regional interconnection and integration of offshore wind energy that would build on work started in 2011. These studies assist decision-makers, including independent system operators and utilities, to evaluate grid integration aspects for future offshore wind development scenarios and plan for the associated requirements needed including transmission expansion, resource adequacy, and other consequences for the power system. Additional studies would allow these audiences to evaluate imminent infrastructure needs as well as guide new private and public investments capable of lowering the cost of offshore wind energy through optimal siting and delivery. These studies may also become increasingly important in the context of broader renewables integration by showing offshore wind's ability to integrate with other renewables, such as solar photovoltaics and land-based wind, which present their own unique benefits and challenges. Specific information provided in these studies would also be instrumental in identifying the full suite of electricity system benefits and costs associated with offshore wind.

Action Area 3.2: Quantifying and Communicating the Benefits and Costs of Offshore Wind

As noted in Section 2.7, offshore wind offers a number of economic, environmental, and social benefits that can contribute to a long-term, low-carbon electricity future.

Table 4.7. DOE and DOI Actions to Quantify and Communicate the Benefits and Costs of Offshore Wind

Action	Lead Agency	Deliverable	Impact
3.2.1. Quantify Offshore Wind Social and Environmental Benefits and Costs	DOE	Tools that evaluate site-specific and state/regional GHGs and other environmental and economic benefits of offshore wind	Better informed consideration of offshore wind-specific policies and projects and increased policymaker, utility, and stakeholder confidence in offshore wind
3.2.2. Quantify Offshore Wind Electricity Market Benefits and Costs	DOE	Studies and tools quantifying the impacts of offshore wind on electricity system costs, including analysis on aspects such as capacity value and site-specific LCOE information	Better informed consideration of offshore wind-specific policies and projects and increased policymaker, utility, and stakeholder confidence in offshore wind
3.2.3. Communicate the Benefits and Costs of Offshore Wind	DOE	Communications products and stakeholder engagement that put offshore wind costs, benefits, and impacts in the right context for policymakers and stakeholders	Improved decision-making around offshore wind policies and projects; increased policymaker, utility, and stakeholder confidence in offshore wind
3.2.4. Reconsider Operating Fee Structure to Provide More Certainty to Developers during PPA Negotiations	DOI	Identification and evaluation of alternative operating fee structures for BOEM's consideration to implement, through rulemaking	Improved certainty around the BOEM operating fee to inform PPA negotiations, if adopted

It also carries with it impacts and costs. As a result, DOE can assist to rigorously quantify and effectively communicate these benefits and costs to support effective decision-making on offshore wind and broader energy policy issues, offshore wind PPAs, and in the project siting and regulatory process, as well as build understanding and confidence in offshore wind technology among key decision-makers to support its advancement. DOI can reassess its operating fee mechanism to give greater certainty to developers in PPA negotiations while ensuring a fair return from offshore wind development to the nation.

Action 3.2.1: Quantify Offshore Wind Social and Environmental Benefits and Costs

Offshore wind provides a number of environmental and social benefits not explicitly valued in electricity prices. These benefits include avoided emissions of greenhouse gases and other air pollutants, with associated environmental and health benefits, reductions in electricity sector water use, and significant economic development and employment impacts. DOE aims to build off the *Wind Vision* and other work to rigorously quantify these benefits for various deployment scenarios and ideally for a variety of relevant spatial and temporal scales. DOE also plans to ensure that the tools used to conduct such analyses are readily available and easily usable (where possible) by the broader offshore wind community to enable them to conduct more tailored analysis of projects and policies. These analyses and provision of the tools used to conduct them will provide a baseline to educate stakeholders, inform policymakers, and provide for more informed evaluation and decision-making around offshore wind and broader energy policy and supply questions.

Action 3.2.2: Quantify Offshore Wind Electricity Market Benefits and Costs

Offshore wind has a number of electricity system benefits and costs aside from direct LCOE effects that policymakers and utilities should consider in making decisions about the future energy system. DOE plans to develop information for coastal regions and states to provide policymakers, utilities, and system operators with vital data to inform policy and project-level decisions about offshore wind. This includes the value of offshore wind's potential contribution to resource adequacy and system reliability, as well as its capacity value. DOE also aims to provide analysis and tools for analyzing the regional energy system cost and price impacts of various offshore wind development scenarios to explore the value of potential price suppression, transmission congestion relief, and other system costs and benefits and how they flow through to ratepayers.

A key component of these analyses will include extending DOE's site-specific LCOE-LACE analysis, presented in Section 2.6. This capability allows for consideration of a wide range of variables, such as grid access points, site-specific hourly wind resource profiles, bathymetry, and turbine availability and array losses, and projected future cost curves for offshore wind. These analyses will enable policymakers, utilities, and ratepayers alike to better evaluate offshore wind development at the policy and project-specific levels in a more accurate and sophisticated context that goes beyond LCOE or a project's power purchase price.

Action 3.2.3: Communicate the Benefits and Costs of Offshore Wind

DOE will provide accurate, objective information about the costs and benefits of offshore wind that can help policymakers, stakeholders, and the public make effective decisions about the technologies that are right for their states and communities. These groups often lack detailed knowledge of the social and environmental costs and benefits of electricity generation. As a result, decisions are sometimes made regarding electricity supply without a clear understanding of the actual impacts and benefits of the various options. At the policy level, these decisions can have a significant impact on the potential project pipeline. At the level of individual projects, they can affect the siting and permitting process and the ability to obtain a PPA and financing. Even when there is little scientific information demonstrating significant impacts, negative stakeholder perceptions can ultimately lead to conflict and project abandonment.

Quantification of these costs and benefits as discussed earlier is necessary, but not enough to enable effective decision-making. The results of these analyses also need to be set into the proper context—putting local environmental impacts alongside benefits like GHG emissions reductions and job creation, and the costs and benefits of offshore wind in the light of broader energy supply choices—and translated into useful and actionable information for key audiences. This information then needs to be delivered in the right venues and media. DOE's WINDExchange program and wind Regional Resource Centers provide a useful model for this kind of communication, in which DOE and its national laboratories can serve as sources for detailed analysis and collaborate with regional and local partners to translate this information into the right forms and present it at the right forums to advance offshore wind development.

Action 3.2.4: Reconsider Operating Fee Structure to Provide More Certainty to Developers during PPA Negotiations

BOEM has received suggestions to alter its existing operating fee payment formula. Developers suggest that certain adjustments to the calculation would enhance price stability and reduce uncertainty in the high-cost offshore operating environment. For example, rather than BOEM estimating the wholesale market value of projected electric power production using the current wholesale power price, developers would prefer to use the price of electricity set forth in a PPA (i.e., contract price) or other legal contract.

Changes to current regulations would be required for any operating fee payment proposal that does not use a wholesale power price index (30 CFR 585.506). The regulations allow for minor adjustments (i.e., to reflect documented variations by state or within a region and recent market conditions), but do not address contract prices. BOEM acknowledges that its current operating fee formula has limitations, and will begin a thorough review of the operating fee payment and its individual components. If BOEM determines that revising the formula may be appropriate, then it will move forward with considering implementing the change through the rulemaking process.

Notes

32. *Tethys* is a knowledge management system that actively gathers, organizes, and disseminates information on the environmental effects of marine and wind energy development.

33. *WREN* was established by the International Energy Agency's Wind Committee in October 2012 to address environmental issues associated with commercial development of land-based and offshore wind energy projects. As the operating agent for WREN, the United States leads this effort with support from the Pacific Northwest National Laboratory, National Renewable Energy Laboratory, and the U.S. Department of Energy's Wind Energy Technologies Office.

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