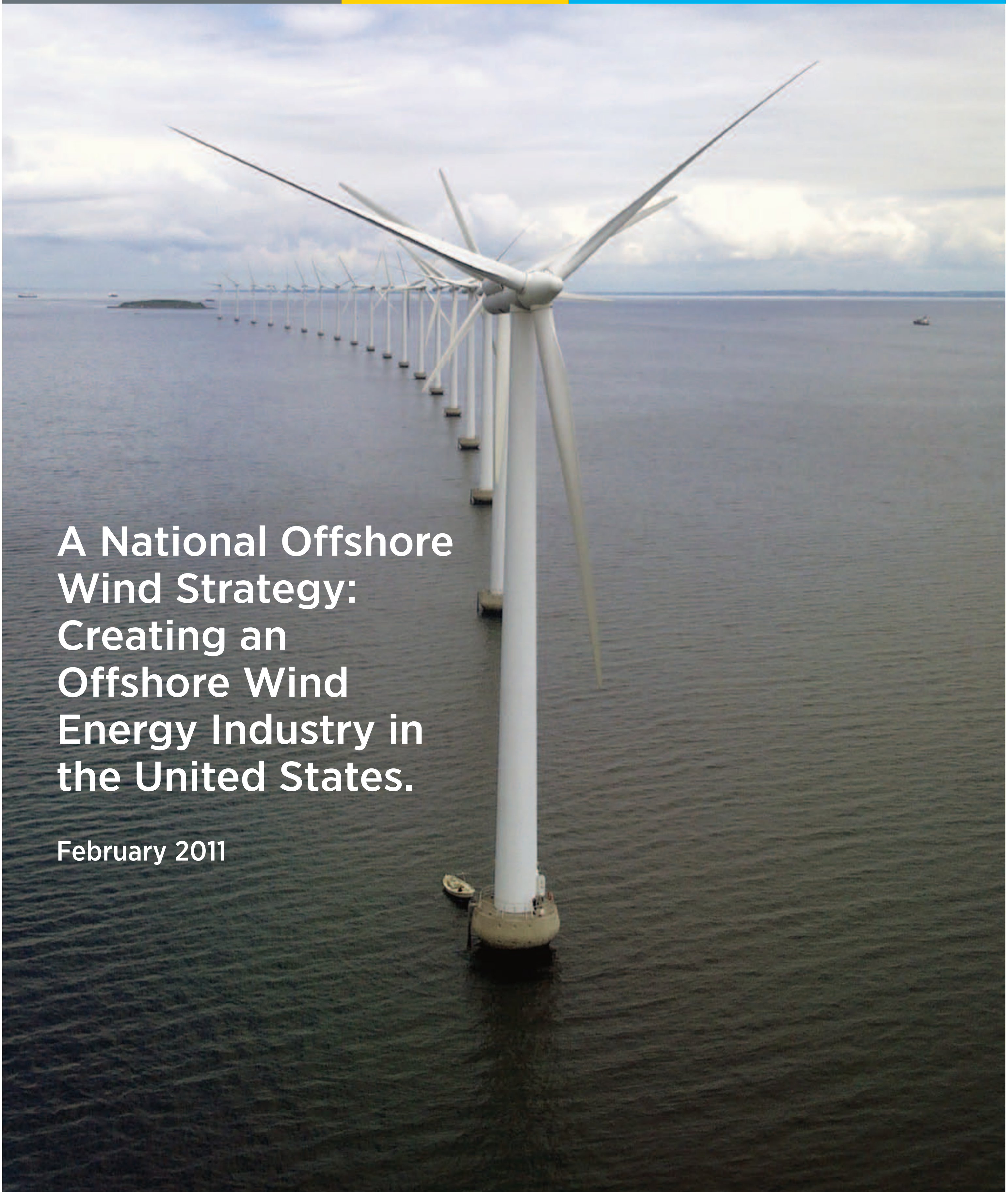
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States.

February 2011

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A National Offshore Wind Strategy

Creating an Offshore Wind Energy Industry in the United States

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Water Power Program

U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement

February 7, 2011

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Executive Summary

A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States was prepared by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Wind and Water Power Program to outline the actions it will pursue to support the development of a world-class offshore wind industry in the United States. This *National Offshore Wind Strategy* will guide DOE as it expands its ongoing efforts through the Offshore Wind Innovation and Demonstration (OSWInD) initiative to promote and accelerate responsible commercial offshore wind development in the U.S. in both federal and state waters.

As the agency with primary jurisdiction over reviewing and approving offshore wind projects in federal waters, the Department of the Interior (DOI) is a crucial partner in implementing this *National Offshore Wind Strategy* and ensuring the creation of a robust and environmentally responsible offshore wind energy industry in the U.S. Over the past two years, DOI has developed a regulatory framework to review proposed offshore wind projects in federal waters and recently launched the Smart from the Start initiative to facilitate siting, leasing, and construction of new projects. This *National Offshore Wind Strategy* incorporates elements of that initiative and illustrates the commitment of DOE and DOI to work together to spur the rapid and responsible development of offshore wind energy.

Key Points

- Offshore wind energy can help the nation reduce its greenhouse gas emissions, diversify its energy supply, provide cost-competitive electricity to key coastal regions, and stimulate revitalization of key sectors of the economy by investing in infrastructure and creating skilled jobs.
- Key challenges to the development and deployment of offshore wind technology include the relatively high cost of energy, technical challenges surrounding installation and grid interconnection, and permitting challenges related to the lack of site data and lack of experience with permitting processes for projects in both federal and state waters.
- Since no wind turbines are installed in U.S. waters, there is a shortage of critical data on the environmental and siting effects of turbines and on the installation, operations, and maintenance of these turbines. This lack of data drives up the costs of financing offshore wind projects to the point where financing charges account for roughly half of the cost of offshore wind energy.
- This *National Offshore Wind Strategy* details the OSWInD initiative, which will guide the national effort to achieve a scenario of 54 gigawatts (GW) of deployed offshore wind generating capacity by 2030, at a cost of energy of $0.07 per kilowatt-hour (kWh), with an interim scenario of 10 GW of capacity deployed by 2020, at a cost of energy of $0.10 / kWh.
- To achieve this scenario, the OSWInD initiative must accomplish two critical objectives: reduce the cost of offshore wind energy and reduce the timeline for deploying offshore wind energy.
- The OSWInD initiative will address these critical objectives through a suite of three focus areas – Technology Development, Market Barrier Removal, and Advanced Technology Demonstration – encompassing seven major activities: innovative turbines, marine systems engineering, computational tools and test data, resource planning, siting and permitting, complementary infrastructure, and advanced technology demonstration projects.

- The OSWInD initiative will help reduce the cost of offshore wind energy through technology development to reduce capital costs; applied research to decrease installation, operations, and maintenance costs; turbine innovation to increase energy capture; and codes and standards development to reduce technical risks and financing costs.
- Working in partnership through the OSWInD initiative and the Smart from the Start initiative, DOE and DOI will help reduce the offshore wind deployment timeline in federal waters through resource planning, siting and permitting engagement, and complementary infrastructure support. The OSWInD initiative will include similar efforts in state waters, including the Great Lakes, with close collaborations between DOE and federal and state agencies with jurisdictional responsibility over those areas. Through implementation of a well coordinated siting strategy, offshore wind energy facilities and associated infrastructure can be deployed in a manner that reduces conflict with other ocean and Great Lakes uses and the management of protected resources and areas. This strategy will be implemented in a manner consistent with the polices and principles of the National Policy for the Stewardship of the Oceans, Our Coasts and Great Lakes (Executive Order # 13547) and its Framework for Coastal and Marine Spatial Planning.
- The OSWInD initiative will ultimately facilitate gigawatt-scale offshore wind power deployment and will augment the more than $90M in funding allocated to offshore wind research and test facilities through the American Reinvestment and Recovery Act of 2009 (ARRA) and Department of Energy appropriated funds for Fiscal Year (FY) 2009 and FY 2010.

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Acronyms and Abbreviations

ACOE	U.S. Army Corps of Engineers
AOWEC	Atlantic Offshore Wind Energy Consortium
ARRA	American Reinvestment and Recovery Act of 2009
AWEA	American Wind Energy Association
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
CMSP	Coastal and Marine Spatial Planning
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COE	Cost of energy
DHS	U.S. Department of Homeland Security
DOC	U.S. Department of Commerce
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EERE	Office of Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
EU	European Union
EWEA	European Wind Energy Association
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FWS	Fish and Wildlife Service
FY	Fiscal Year
GW	Gigawatt
IO&M	Installation, operations, and maintenance
kW	Kilowatt
kWh	Kilowatt-hour
m	Meter
MOU	Memorandum of Understanding
m/s	Meters per second
MW	Megawatt
MWh	Megawatt-hour
NEPA	National Environmental Policy Act of 1969
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NREL	National Renewable Energy Laboratory
OCRM	Office of Ocean and Coastal Resource Management
OCS	Outer Continental Shelf
OE	Office of Electricity Delivery and Energy Reliability
OSWInD	Offshore Wind Innovation and Demonstration Initiative
O&M	Operations and maintenance
RFI	Request for Information
USCG	U.S. Coast Guard

1. Introduction

Offshore wind energy can help the nation reduce its greenhouse gas emissions, diversify its energy supply, provide cost-competitive electricity to key coastal regions, and stimulate revitalization of key sectors of the economy. However, if the nation is to realize these benefits, key challenges to the development and deployment of offshore wind technology must be overcome, including the relatively high cost of energy, technical challenges surrounding installation and grid interconnection, and the permitting challenges governing deployment in both federal and state waters.

In Fiscal Year (FY) 2010, the U.S. Department of Energy instituted the Offshore Wind Innovation and Demonstration (OSWInD) initiative to consolidate and expand its efforts to promote and accelerate responsible commercial offshore wind development in the U.S. *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* is an action document that amplifies and draws conclusions from a companion report, *Large-Scale Offshore Wind Energy for the United States* (W. Musial 2010). The *National Offshore Wind Strategy* will guide DOE's OSWInD initiative to support the development of a world-class offshore wind industry in the United States able to achieve 54 GW of offshore wind deployment at a cost of energy of $0.07 / kWh by the year 2030, with an interim scenario of 10 GW at $0.10 / kWh by 2020.

To realize these scenarios, the OSWInD initiative has developed a strategy to achieve two critical objectives: reduce the cost of offshore wind energy and reduce the timeline for deploying offshore wind energy (see Figure 1 below).

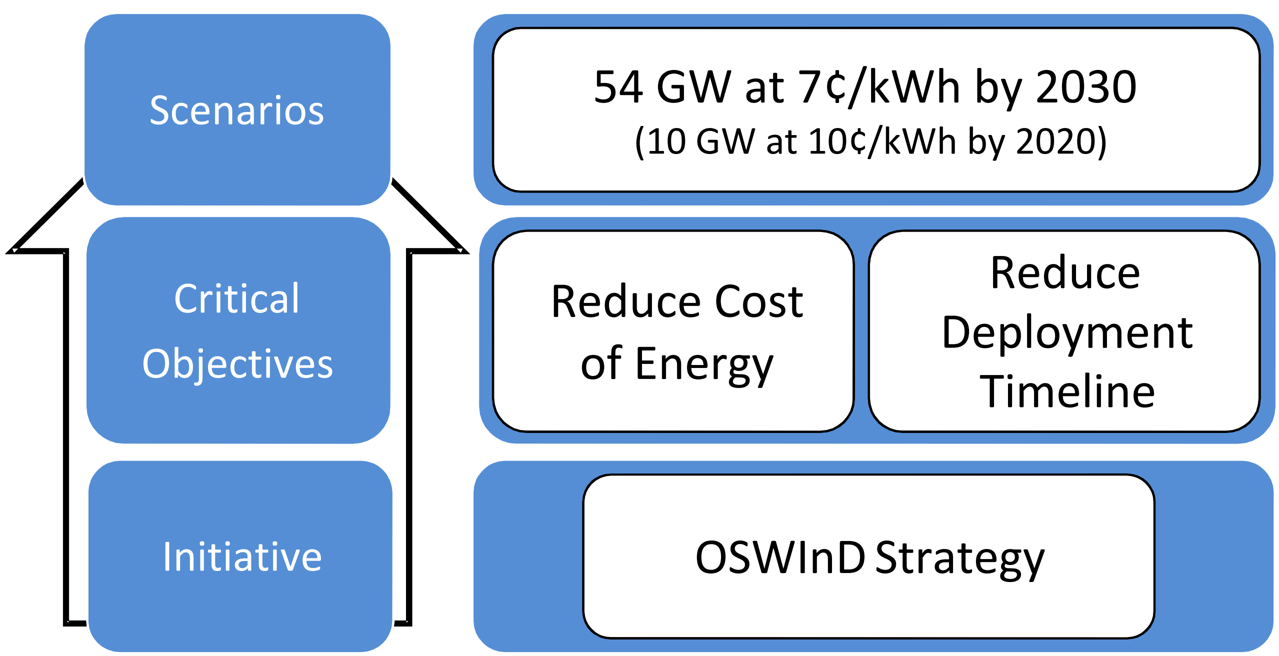

Figure 1. OSWInD initiative deployment scenario and critical objectives

Close collaboration and partnerships among all federal and state agencies with jurisdictional responsibility over federal and state waters will be crucial to the success of the OSWInD initiative. Federal waters in particular – those along the Outer Continental Shelf (OCS)[1] – hold tremendous promise for substantial offshore wind development in the coming years.

The Energy Policy Act of 2005 provided the Department of the Interior's Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) with the authority to issue leases for renewable energy on the OCS. In 2009, BOEMRE released a new regulatory framework to govern the review and approval of proposed offshore wind projects. Building off of this effort, DOI announced in 2010 the Smart from the Start initiative to facilitate environmentally responsible offshore wind development along the Atlantic OCS in the shortest period possible by streamlining the approval process for individual proposed projects, implementing a comprehensive expedited leasing framework that includes identifying wind energy areas along the Atlantic OCS, and moving aggressively on a separate parallel track to process offshore transmission applications.

DOI's offshore wind efforts mirror its innovative strategy for facilitating onshore renewable energy development, which has resulted in the approval of 12 commercial-scale renewable energy projects (solar, wind, and geothermal) on federal lands. Once built, these projects will produce almost 4,000 megawatts (MW) of energy, enough to power over 1.2 million homes and create thousands of construction and operational jobs. Going forward, DOI is using landscape-level planning to identify federal lands that may be particularly suitable for renewable development. The Smart from the Start initiative for offshore wind will use approaches similar to DOI's onshore renewable energy development efforts. The Smart from the Start initiative and DOE's OSWInD initiative are complementary efforts that will help reduce the offshore wind deployment timeline in the nation's waters.

The efforts to facilitate gigawatt-scale offshore wind deployment described in this *National Offshore Wind Strategy* will augment the more than $90M that DOE has allocated to offshore wind research and test facilities through the American Reinvestment and Recovery Act of 2009 (ARRA) and FY 2009 and FY 2010 appropriated funds. In FY 2010, DOE's offshore wind energy activities included the development of large-scale wind turbine component test facilities, supported by approximately $70M in ARRA funds; innovative floating turbine platform research, supported by approximately $8M in ARRA funds; publication of the report *Large–Scale Offshore Wind Power in the United States, Assessment of Opportunities and Barriers* (W. Musial 2010); and several ongoing projects to characterize offshore wind resources, assess the possible environmental impacts of offshore wind, and develop offshore wind energy curricula to train the future workforce. These projects are discussed in more depth in Section 5.4 of this document.

In FY 2011, the OSWInD initiative will expand its ongoing efforts into a suite of seven major activities, administered through three focus areas, targeted at the critical objectives of reducing the cost of offshore wind energy and reducing the timeline for deploying offshore wind systems. The three focus areas are Technology Development, Market Barrier Removal, and Advanced Technology Demonstration.

[1] The OCS consists of submerged lands, subsoil, and seabed starting 3-9 nautical miles from shore (depending on the state) and extending approximately 200 nautical miles outward.

The seven major activities are innovative turbines, marine systems engineering, computational tools and test data, resource planning, siting and permitting, complementary infrastructure, and advanced technology demonstration projects.

Section 2 of this document discusses the rationale for a national offshore wind initiative. Section 3 summarizes the key technical and market barriers to the creation of a world-class U.S. offshore wind industry and lays out the assumptions and conclusions that influenced DOE's decision-making for the *National Offshore Wind Strategy*. Section 4 introduces the proposed strategy of the OSWInD initiative and Section 5 lays out the proposed structure of the OSWInD initiative in more detail.

2. Rationale for a National Offshore Wind Program

Increasing the use of renewable energy for electricity generation is crucial to mitigate the risks of climate change and to shift the nation to a long-term, low-carbon economy. In his 2011 State of the Union Address, President Barack Obama called for 80% of the nation's electricity to be generated from clean energy sources, including wind, by the year 2035 (White House 2011). In the North American Leaders' Declaration of Climate Change and Clean Energy, the Obama Administration supported the global goal of reducing carbon dioxide (CO_2) emissions by 50% by 2030 and 80% by 2050 (White House 2009). Because offshore wind power generates electricity without emitting CO_2, gigawatt-scale offshore wind deployment could contribute significantly to a national climate change mitigation strategy. Previously, a scenario analyzed in the EERE report *20% Wind Energy by 2030* found that the United States could generate 20% of its electricity from wind energy by 2030, with offshore wind providing 54 GW of capacity (Department of Energy 2008). This analysis clearly shows the potential for wind energy, and offshore wind in particular, to address the daunting challenge of reducing CO_2 emissions in a rapid and cost-effective manner.

2.1 Resource Size

The energy-generating potential of offshore wind is immense due to the lengthy U.S. coastline and the quality of the resource found there (offshore winds blow stronger and more uniformly than on land, resulting in greater potential generation). Offshore wind resource data for the Great Lakes, U.S. coastal waters, and the OCS indicate that for annual average wind speeds above 7 meters per second (m/s), the total gross resource of the United States is 4,150 GW, or approximately four times the generating capacity of the current U.S. electric power system (M. Schwartz 2010). Of this capacity, 1,070 GW are in water less than 30 meters (m) deep, 630 GW are in water between 30 m and 60 m deep, and 2,450 GW are in water deeper than 60 m (see Figure 2). More than 66% of the nation's offshore wind resource is in wind class 6 or higher. The scale of this theoretical capacity implies that under reasonable economic scenarios, offshore wind can contribute to the nation's energy mix at significant levels.

Table 1. Offshore wind potential for areas up to 50 nautical miles from shore with average wind speeds 7 m/s or greater at 90-m elevation (W. Musial 2010)

Region	0–30 m depth	30–60 m depth	>60 m depth	Total
New England	100.2	136.2	250.4	486.8
Mid-Atlantic	298.1	179.1	92.5	569.7
South Atlantic Bight	134.1	48.8	7.7	190.7
California	4.4	10.5	573	587.8
Pacific Northwest	15.1	21.3	305.3	341.7
Great Lakes	176.7	106.4	459.4	742.5
Gulf of Mexico	340.3	120.1	133.3	593.7
Hawaii	2.3	5.5	629.6	637.4
Total	**1,071.2 GW**	**628.0 GW**	**2,451.1 GW**	**4,150.3 GW**

Currently, the majority of offshore wind projects are in the European Union (EU), where utility-scale planning for offshore wind has at least a 10-year history. Shallow water technology is proven in Europe, with 39 projects constructed and more than 2,000 MW of capacity installed, although this market is heavily subsidized. The EU and European Wind Energy Association (EWEA) have established aggressive targets to install 40 GW of offshore wind by 2020 and 150 GW by 2030. In the United States, roughly 5 GW of offshore wind capacity have been proposed in federal and state waters (W. Musial 2010).

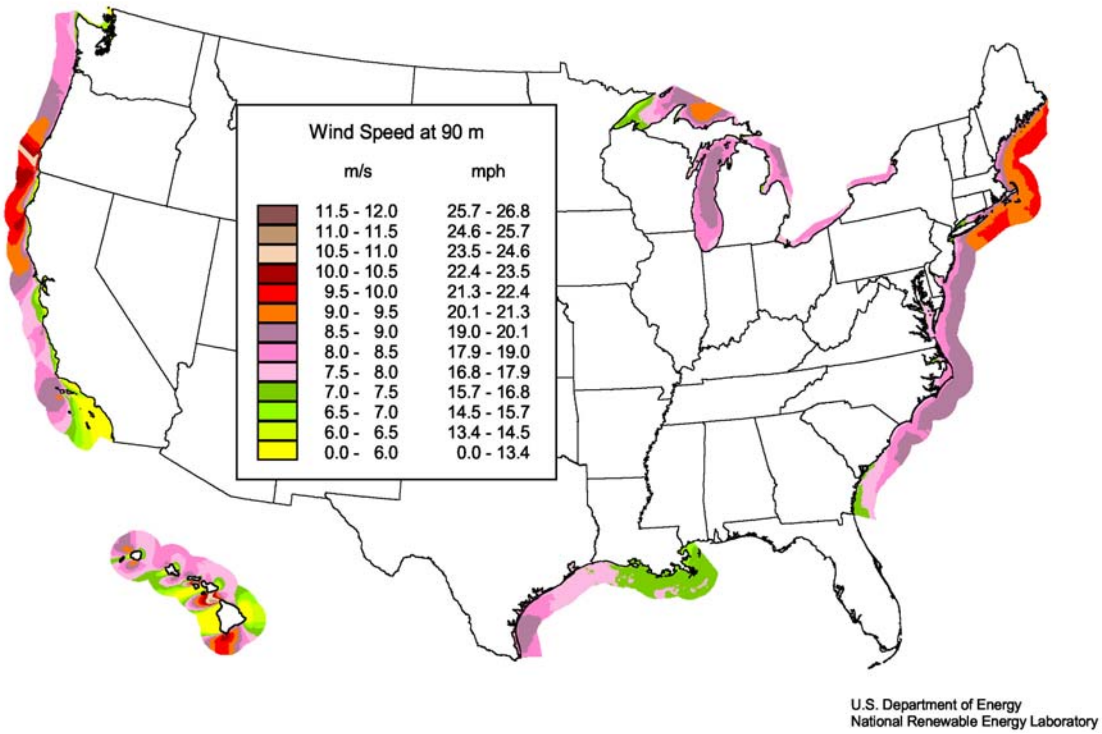

Figure 2. U.S. offshore wind speed estimates at 90-m height

2.2 Benefits of Offshore Wind Deployment

On average, one gigawatt of installed offshore wind power capacity can generate 3.4 million megawatt-hours (MWh) of electricity annually. Generating the same amount of electricity with fossil fuels would consume 1.7 million tons of coal or 27.6 billion cubic feet of natural gas and would emit 2.7 million tons of carbon dioxide equivalent (CO_2e) annually (S. Dolan 2010). Because offshore winds generally blow more strongly and consistently than onshore winds, offshore wind turbines operate at higher capacity factors[2] than wind turbines installed on land. In addition, daily offshore wind speed profiles tend to correspond well to periods of high electricity demand by coastal cities, such that the strongest winds (and thus highest potential energy generation) correspond to the periods of greatest electricity demand (W. Musial 2010).

High electricity costs in coastal regions, more energetic wind regimes offshore, and close proximity of offshore wind resources to major electricity demand centers could allow offshore wind to compete relatively quickly with fossil fuel-based electricity generation in many coastal areas. The 28 coastal and Great Lakes states in the continental United States use 78% of the nation's electricity (Department of

[2] A measure of the productivity of a power plant, calculated as actual energy produced by a plant over a given period divided by the amount of energy that the plant would produce when generating at maximum capacity during that period.

Energy 2008) while facing higher retail electricity rates than their inland neighbors (Figure 3). Mid-Atlantic and Northeastern coastal states in particular face a dual problem: high electricity costs and dependence on high-carbon, price-volatile supplies of fossil fuel for generation. In states without substantial land-based renewable resources, offshore wind deployment will be critical to meet their renewable energy standards or goals. In states with high electricity rates, offshore wind energy may quickly become cost-competitive. Finally, the proximity of offshore wind resources to major electrical load centers minimizes the need to build new transmission capacity to serve those centers.

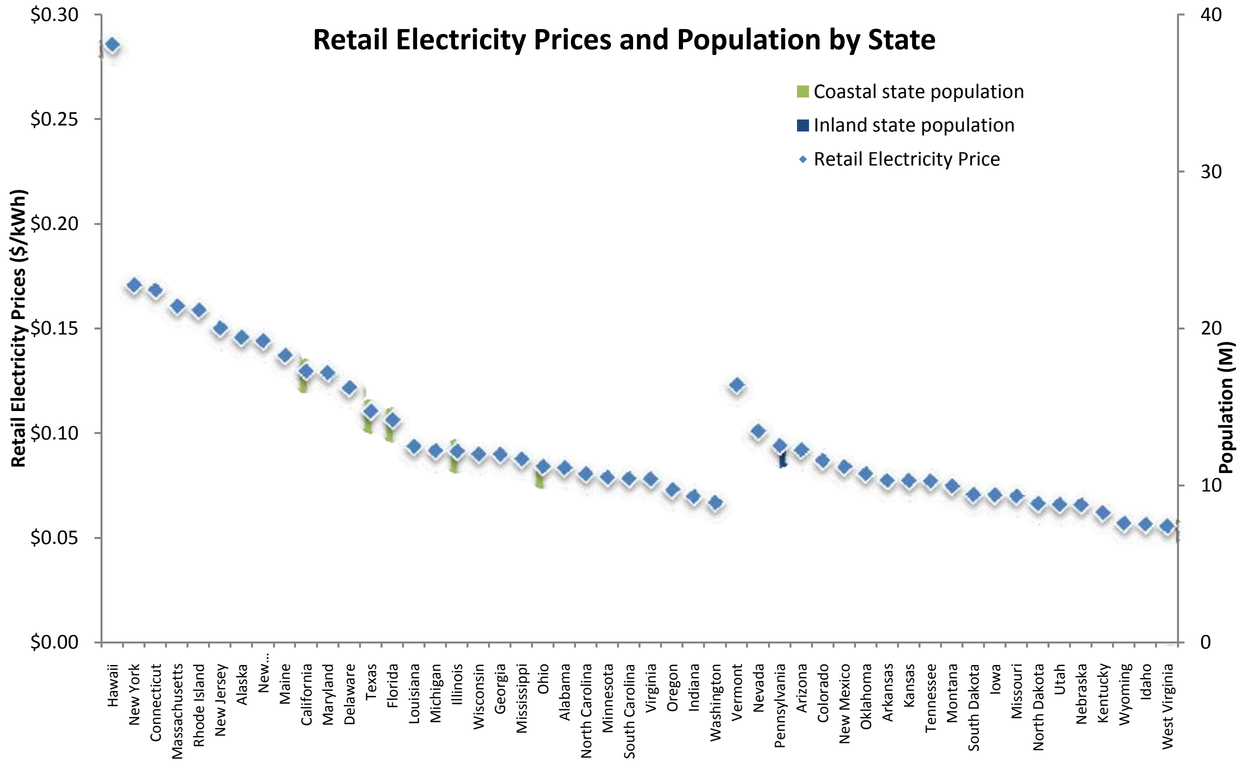

Figure 3. Coastal versus inland state retail electric rates. Source: DOE-EIA

Deployment of wind energy along U.S. coasts would also trigger direct and indirect economic benefits. According to NREL analysis and extrapolation of European studies, offshore wind would create approximately 20.7 direct jobs per annual megawatt installed in U.S. waters (W. Musial 2010). Installing 54 GW of offshore wind capacity in U.S. waters would create more than 43,000 permanent operations and maintenance (O&M) jobs and would require more than 1.1 million job-years to manufacture and install the turbines (W. Musial 2010). Many of these jobs would be located in economically depressed ports and shipyards, which could be revitalized as fabrication and staging areas for the manufacture, installation, and maintenance of offshore wind turbines.

3. Key Challenges Facing Offshore Wind Deployment

The major challenges facing deployment of offshore wind power in U.S. waters include the high costs of offshore wind facilities; the technical challenges and lack of current infrastructure to support the fabrication, installation, interconnection, operations and maintenance of these systems; and the permitting challenges related to the lack of site data and lack of experience with new or developing permitting processes for projects in federal and state waters.

3.1 High Capital Costs and Cost of Energy

Offshore wind installations have higher capital costs than land-based installations per unit of generating capacity, largely because of turbine upgrades required for operation at sea and increased costs related to turbine foundations, balance-of-system infrastructure, interconnection, and installation. In addition, one-time costs are incurred with the development of the infrastructure to support the offshore industry, such as vessels for turbine installation, port and harbor upgrades, manufacturing facilities, and workforce training programs. NREL estimates a current baseline of installed capital costs for offshore wind at $4,250 per kilowatt (kW) based on energy market surveys (W. Musial 2010). The estimated life-cycle costs for a typical offshore wind project are shown in Figure 4 below. Several important offshore technology issues require research and development to achieve competitive market pricing in the long term. These issues include reducing installed capital costs, improving reliability, and increasing energy capture. In the longer term, innovative, comparatively inexpensive foundation designs will be required to harness the massive wind resource located in water more than 60 m in depth.

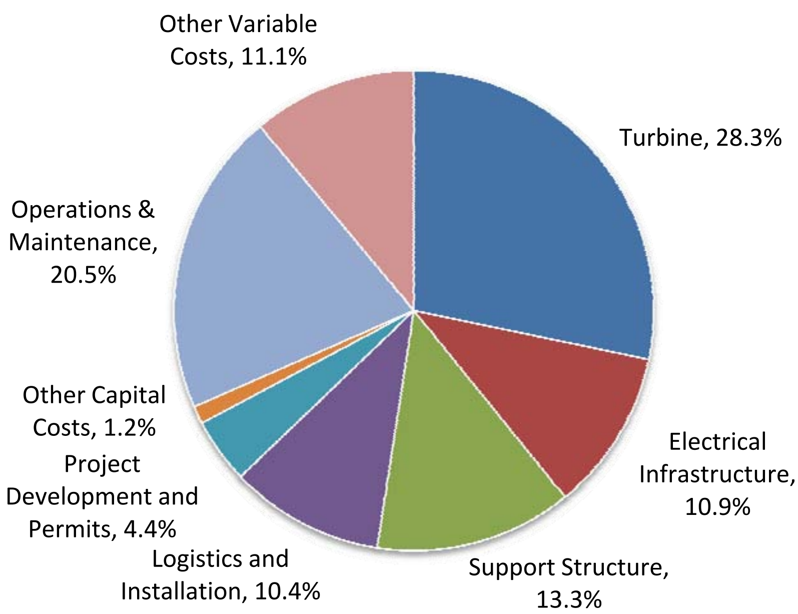

Figure 4. Estimated life-cycle cost breakdown for a typical offshore wind project (W. Musial 2010).

In addition to elevated capital costs, offshore wind energy currently has a higher cost of energy[3] than comparable technologies. As discussed throughout this *National Offshore Wind Strategy*, a critical objective of the OSWInD initiative is to lower the cost of offshore wind energy. This cost of energy can be broadly calculated as the sum of all up-front annualized capital equipment costs and operations and maintenance costs over the life of the project, divided by the total energy output of the project. Cost of energy is thus calculated as a unit of currency per unit of energy (typically $/MWh or ¢/kWh). The cost of energy can be lowered by reducing the capital costs, financing costs, or operations and maintenance costs of a project, or by increasing the amount of energy generated by the project over its operational life. Increased energy generation will result from larger, more efficient, more reliable turbines with access to the best wind resource possible. A substantial reduction in costs and increase in energy capture will have a dramatic effect on lowering the cost of energy. Finally, projects in U.S. waters that demonstrate and validate offshore wind technologies can help reduce the cost of financing future projects by reducing the perceived risk of offshore wind systems on the part of investors.

Offshore Wind Cost of Energy Calculations

The general formula for calculating the cost of offshore wind energy can be represented as:

$$COE = \frac{(DRF \times ICC) + O\&M + LRC + Fees}{AEP}$$

COE = cost of energy
DRF = discount rate factor
ICC = installed capital costs
O&M = operations & maintenance costs
LRC = levelized replacement costs
AEP = annual energy production
Fees = annual insurance, warrantees, etc.

$$DRF = \frac{d}{1 - 1/(1+d)^N} \times \frac{(1 - T \times PVDEP)}{1 - T}$$

d = discount rate
N = analysis period
T = marginal income tax rate
PVDEP = present value of depreciation

Current cost of energy projections must be cut by more than 50% to enable the offshore wind deployment scenario envisioned in this *National Offshore Wind Strategy*. DOE will work with all necessary parties to improve all components of offshore wind project development, capital expenditures, and operational processes, to reduce capital costs, reduce operations and maintenance costs, and improve energy production.

- *Turbine Capital Cost*: reducing capital and installation costs of all turbine components;
- *Balance of System Capital Cost*: reducing capital and installation costs of foundation structures, cabling, substations and other non-turbine components;

[3] This cost of energy calculation represents the bus-bar cost of offshore wind energy delivered to the terrestrial transmission system and does not include possible additional interconnection costs related to imbalance/integration charges, firming charges, or transmission upgrades needed for interconnection.

- *Operations, Maintenance and Replacement Cost*: reducing scheduled maintenance, improving reliability, and reducing replacement costs for components such as gearboxes, generators and blades;
- *Capacity Factor*: improving overall system performance through improved siting, energy capture, reliability, and availability;
- *Transmission & Grid Integration Cost*: incorporating low-cost transmission configurations and wind integration into power management systems;
- *Start-up and Permitting Cost*: reducing delays caused by permit approval times; and
- *Cost of Capital*: reducing financial risks and lowering insurance and warranty premiums as a result of stable and predictable energy output and life-cycle operational time through the use of demonstrated, validated technologies.

3.2 Technical and Infrastructure Challenges

Significant challenges to offshore wind power deployment related to resource characterization, grid interconnection and operation, and infrastructure will need to be overcome. The offshore wind resource is not well characterized. This significantly increases uncertainty related to potential project power production and turbine and array design considerations, which in turn increase financing costs. The implications for adding large amounts of offshore wind generation to the power system need to be better understood to ensure reliable integration and to evaluate the need for additional grid infrastructure such as an offshore transmission backbone. Finally, with current technology, cost-effective installation of offshore wind turbines requires specialized vessels, purpose-built portside infrastructure, robust undersea electricity transmission lines, and grid interconnections. These vessels and this infrastructure do not currently exist in the U.S. Although foreign-flagged turbine installation and maintenance vessels exist, legislation such as the Jones Act limits the ability of these vessels to operate in U.S. waters.

3.3 Permitting Challenges

As a nascent industry in the United States, offshore wind projects face new and untested permitting processes, which contribute to the uncertainty and risk faced by potential project developers and financiers, in turn potentially impacting investment in both offshore wind power projects and development of the supply chain and other supporting infrastructure. Estimates for project approvals on the OCS vary based on the amount and quality of data collected for the project, environmental studies, site characterization, and diligence of the developer. For the Great Lakes, where eight states and the Canadian province of Ontario claim jurisdiction, numerous competing activities and the lack of an overarching regulatory framework create a unique set of permitting challenges.

Numerous state and federal entities have authority over siting, permitting, and installation of offshore wind facilities. Table 2 below, adapted from Appendix A of *Large-Scale Offshore Wind Power in the United States* (W. Musial 2010), lists the key statutes and responsible agencies involved in the permitting of offshore wind power projects. DOI, through the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), serves as the lead agency in permitting offshore wind energy on the OCS. The U.S. Army Corps of Engineers (USACE), which is responsible for permitting any potential obstruction or alteration of U.S. navigable waters, currently serves as the lead federal agency in permitting offshore wind in state waters, including the Great Lakes. Several federal entities also have mandates to review and/or approve certain aspects of offshore wind projects, such as the Environmental Protection Agency (EPA), Fish and Wildlife Service (FWS), National Park Service (NPS), Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), NOAA's National Marine Fisheries Service (NMFS), Federal Aviation Administration (FAA), Department of Defense (DoD), U.S. Coast Guard (USCG), and the Federal Energy Regulatory Commission (FERC). Numerous state, local, and tribal government entities, as well as other stakeholders, must also be consulted in the permitting process. The mandates of these various entities include managing protected species, managing commercial and recreational fisheries, protecting marine and coastal habitats, and designation and protection of marine areas with special significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or aesthetic qualities.

Agencies must consider a range of environmental and cultural resources, protected areas, and competing uses when permitting the installation of offshore wind power projects. Some of the key environmental resources of concern are bird and bat species, marine mammals, pelagic and benthic species and habitats, and water quality. Historic preservation sites, such as notable shipwrecks or coastal structures, and tribal resources, such as burial grounds or other ocean areas with cultural or religious significance, must also be considered in the siting process. Certain ocean areas are protected or restricted from development, including NOAA's National Marine Sanctuaries, coastal National Parks and National Wildlife Refuges, DoD limited access areas, or designated ship navigation lanes. Finally, wind project siting must consider competing uses of the ocean space, including ship navigation, commercial fishing, DoD training and operations, and other activities.

Coordinated and concurrent project review processes can lead to efficiency gains in the permitting of offshore wind projects. In some cases, these opportunities for increased efficiency are already recognized and can be quickly adopted. In other cases, collaboration is needed to identify the potential efficiencies to be gained through coordinated and concurrent project review. Adoption of such process efficiencies, including implementation of the National Ocean Policy and coastal and marine spatial planning, can help protect natural resources, protected areas, and competing uses when permitting offshore wind energy facilities in the nation's ocean and Great Lakes waters. Additionally, the development and use of best management practices can provide valuable tools for mitigating the impacts of offshore wind projects on wildlife and ecosystems.

Table 2. Key statutes and agencies involved in offshore wind permitting[4]

Statute	Key Agencies	Description
National Environmental Policy Act of 1969 (NEPA)	All federal agencies	Requires federal agencies to consider the potential environmental impacts of proposed federal actions. For any major federal action that is likely to result in significant environmental impacts, agencies must prepare an Environmental Impact Statement (EIS).

[4] States often have similar statutes and regulatory requirements as those listed here, such as state environmental policy acts and state endangered species acts, as well as rules governing power generation.

Endangered Species Act of 1973	FWS; NOAA NMFS	Requires federal agencies to consult with the FWS and NOAA NMFS to ensure that proposed Federal actions are not likely to jeopardize the continued existence of any species listed at the federal level as endangered or threatened, or result in the destruction or adverse modification of critical habitat.
Marine Mammal Protection Act of 1972	FWS; NOAA NMFS	Prohibits, with certain exceptions, the take of marine mammals in U.S. waters by U.S. citizens on the high seas, and importation of marine mammals and marine mammal products into the U.S.
Magnuson-Stevens Fishery Conservation and Management Act	NOAA NMFS	Requires federal agencies to consult with the NMFS on proposed federal actions that may adversely affect essential fish habitats necessary for spawning, breeding, feeding, or growth to maturity of federally managed fisheries.
Marine Protection, Research, and Sanctuaries Act of 1972	EPA; USACE; NOAA	Prohibits the dumping of certain materials without a permit from the EPA. For ocean dumping of dredged material, the USACE is given permitting authority.
National Marine Sanctuaries Act	NOAA	Prohibits the destruction, loss of, or injury to any sanctuary resource managed under the law or permit.
Coastal Zone Management Act of 1972	NOAA Office of Ocean and Coastal Resource Management (OCRM)	Specifies that coastal states may protect coastal resources and manage coastal development.
National Historic Preservation Act of 1966	NPS; Advisory Council on Historic Preservation; State or Tribal Historic Preservation Officer	Requires each federal agency to consult with the Advisory Council on Historic Preservation and the State or Tribal Historic Preservation Officer before allowing a federally licensed activity to proceed in an area where cultural or historic resources might be located.
Federal Aviation Act of 1958	FAA	Requires that, when construction, alteration, establishment, or expansion of a structure is proposed, adequate public notice be given to the FAA as necessary to promote safety in air commerce and the efficient use and preservation of the navigable airspace.
Federal Power Act	FERC; BOEMRE	Establishes BOEMRE as the lead authority to regulate offshore wind in federal waters. (Note that under the Federal Power Act, per an MOU between DOI and FERC, FERC has the lead role in regulating offshore kinetic energy, such as wave energy devices.)
Ports and Waterways Safety Act	USCG	Authorizes the USCG to implement measures for controlling or supervising vessel traffic or for protecting navigation and the marine environment.
Rivers and Harbors Act of 1899	USACE	Delegates to the USACE the authority to review and regulate certain structures and work that are located in or that affect navigable waters of the United States, including submarine cable systems.
Outer Continental Lands Act of 1953	DOI	Granted the Department of the Interior with the authority to lease submerged lands on the Outer Continental Shelf. The Energy Policy Act of 2005 amended this act to give DOI the authority to lease renewable energy, including offshore wind, on the OCS.
Clean Water Act	EPA, USCG	Prohibits the discharge of oil or hazardous substances into waters or adjoining shorelines which may affect natural resources belonging to the United States.
Clean Air Act	EPA, BOEMRE	Prohibits federal agencies from providing financial assistance or issuing approval for activities that do not conform to approved plans for achieving National Ambient Air Quality Standards. Requires the EPA (or authorized state agencies) to issue a permit before the construction of, or major modification to, any major stationary source of air pollution.

DOE's OSWInD initiative will operate in the context of developing offshore energy collaborations and a changing ocean policy and energy regulatory landscape that presents unique opportunities to work with federal and state partners. With respect to federal waters, DOE and DOI will continue to work closely to implement their respective complementary offshore wind initiatives: OSWInD and Smart from the Start.

DOI's Smart from the Start initiative is a strategy to facilitate offshore wind development along the Atlantic OCS. Elements of the initiative include:

1. Streamlining the approval process for individual proposed projects and eliminating unnecessary regulatory requirements.
2. Implementing a comprehensive, expedited leasing framework for offshore wind development by identifying wind energy areas along the Atlantic OCS that appear most suitable for offshore wind energy development because of fewer user conflicts and resource issues, organizing an interagency process to gather information from key agencies regarding the environmental and geophysical attributes and other uses of these wind energy areas, and assembling that data in a publicly available format to help assess the feasibility and risks associated with any potential development in the identified areas.
3. Moving aggressively on a separate but parallel track to process any applications to build offshore transmission lines, such as potential regional 'backbone' lines that would serve multiple future offshore wind projects along the Atlantic OCS.

The Smart from the Start initiative builds off of DOI's efforts of the past two years to develop an efficient and responsible permitting process. Following the issuance in 2009 of the new regulatory framework governing offshore wind development, BOEMRE actively engaged state-based task forces, comprising federal, state, and tribal governments, to collect data and share knowledge about potential development areas along the Atlantic OCS. DOI also signed an MOU with 11 coastal states to establish the Atlantic Offshore Wind Energy Consortium (AOWEC), which pledged to identify ways to facilitate the development of offshore wind energy. AOWEC action plans are being incorporated into the Smart from the Start initiative and, with the OSWInD initiative, represent a robust collective strategy to support this important renewable energy resource.

These collective efforts are taking place within the broader context of the new National Ocean Policy for the United States, which emphasizes the importance of coastal and marine spatial planning and early and frequent collaboration among stakeholders. In July 2010, President Obama created a new National Ocean Council chartered to implement the National Ocean Policy and the recommendations of the Interagency Ocean Policy Task Force, including the development of coastal and marine spatial plans at the regional level. DOE and DOI are active participants in the new National Ocean Council, and the OSWInD and Smart from the Start initiatives will coordinate closely with this effort.

4. OSWInD Strategy

As discussed in Section 2, a common set of challenges confront the initial U.S. deployment of offshore wind energy and its long-term growth into a major industry and significant contributor to the nation's energy and economic needs. DOE, as a non-regulatory agency, is in a unique position to provide national leadership through collaborative partnerships with other federal agencies, the states, academia, and industry. This section of the *National Offshore Wind Strategy* details a plan to accelerate offshore wind deployment in the United States through targeted technical research and development, partnerships to remove market barriers, and implementation of pioneering demonstration projects. Through such an initiative, DOE can capitalize on its unique position to help eliminate uncertainty, mitigate risks, and facilitate the use of the first installed offshore turbines as testbeds for research and development.

The OSWInD strategy considers two critical objectives in overcoming the challenges to offshore wind energy deployment: reducing the cost of energy through technology development to ensure competitiveness with other electrical generation sources, and reducing deployment timelines and uncertainties limiting U.S. offshore wind project development. To meet these objectives, the OSWInD initiative will undertake a set of seven major activities: Computational Tools and Test Data, Innovative Turbines, Marine Systems Engineering, Siting and Permitting, Complementary Infrastructure, Resource Planning, and Demonstration Projects. These activities, which are further specified into research areas, details, and stages, are administered through three focus areas: Technology Development, Market Barrier Removal, and Advanced Technology Demonstration. Section 5 of this report contains an in-depth discussion of the initiative by activity and research area.

Offshore Wind Critical Objectives

- Reduce the cost of energy through technology development to ensure competitiveness with other electrical generation sources.
- Reduce deployment timelines and uncertainties limiting U.S. offshore wind project development.

4.1 Reducing Cost of Offshore Wind Energy

A world-class research and development effort is needed to integrate the resources and expertise of the country in a coordinated investment and information exchange to propel the United States to the leading edge of offshore wind technology. In the short-term, the Technology Development focus area will concentrate primarily on risk reduction to facilitate the initial deployment of offshore wind projects in U.S. waters. Over the long term, the Technology Development focus area will have a primary goal of developing new technologies that lower the cost of energy, sustain the growth of the industry, and make offshore wind cost-competitive without subsidies.

Facilitating deployment of the initial projects in the United States is a top priority in the short term because these installations will provide experience, generate performance data, and highlight unforeseen issues, all of which will help inform and prioritize the OSWInD initiative's longer-term technology research and development effort. Design codes, standards development, and performance models are some of the specific technology development activities that will both lay the foundation of a long-term research and development program and reduce risk for developers, regulators, designers, and financiers involved in the first offshore wind installations. Special consideration of technical improvements needed to adapt primarily European technologies to the U.S. offshore environment will also be a priority.

OSWInD's long-term research and development strategy will focus primarily on hardware development to reduce the life-cycle costs of offshore wind energy systems and to expand access to the most promising wind resource areas. More than half of the estimated life-cycle cost of an offshore wind turbine farm is determined by the foundation, electrical infrastructure, installation and logistics, and operations and maintenance costs.

Table 3. Potential Path to Reduce Cost of Offshore Wind Energy in Class 6 Wind ($2009 USD) (NREL 2010)[5]

Component	2010	2020	2030	2010 - Land
Installed Capital Cost ($/kW)	$ 4,259	$ 2,900	$ 2,600	$ 2,120
Discount Rate Factor (DRF)[6]	20%	14%	8%	12%
Turbine Rating (MW)	3.6	8.0	10.0	1.5
Rotor Diameter (m)	107	156	175	77
Annual Energy Production / Turbine (MWh)	12,276	31,040	39,381	4684
Capacity Factor	39%	44%	45%	36%
Array Losses	10%	7%	7%	15%
Availability	95%	97%	97%	98%
Rotor Coefficient of Power	0.45	0.49	0.49	.47
Drivetrain Efficiency	0.9	0.95	0.95	0.9
Rated Windspeed (m/s)	12.03	12.03	12.03	10.97
Average Wind Speed at Hub Heights (m/s)	8.8	9.09	9.17	7.75
Wind Shear	0.1	0.1	0.1	.143
Hub Height (m)	80	110	120	80
Cost of Energy ($/kWh)	**0.27**	**0.10**	**0.07**	**0.09**
Cost of Energy ($/kWh) at constant 7% DR	**0.12**	**0.08**	**0.07**	**0.08**

DOE has outlined a potential path for reducing the cost of offshore wind energy at the scale envisioned in this report. Under this scenario, detailed in Table 3 above and based on a cost of energy analysis approach developed by NREL (J. Cohen 2008), the cost of offshore wind energy can be reduced from $0.27 per kWh in 2010 to $0.07 per kWh in 2030 by addressing three critical factors. First, cost of energy

[5] All values are preliminary and subject to change. Values are expressed in constant 2009 dollars.
[6] The Discount Rate Factor calculation is based on a significant financial risk premium for U.S. offshore wind technology in 2010; this financial risk premium is assumed to decrease over time.

can be reduced by increasing system efficiency and decreasing capital costs through the development of larger systems, innovative components and fully integrated system designs. Under this scenario, installed capital cost will decline by 39% from $4,259/kW to $2,600/kW, average turbine rating will increase from 3.6 MW to 10.0 MW, and turbine capacity factor will improve from 39% to 45%. Second, overall costs can be reduced by decreasing operational and replacement costs. Operating costs for offshore turbines must be continually reduced to compete with land-based systems, and fully loaded replacement cost, including the cost of marine transport and component replacement costs, will need to be reduced through higher reliability and innovative, low-maintenance designs. Finally, the financing components of the cost of offshore wind energy, roughly half of the modeled cost of offshore wind energy in U.S. markets, can be reduced by reducing project risk. Under this scenario, the discount rate factor will decline from a current estimate of 20% to a target level of 8% by reducing perceived risks to investors. DOE will help reduce these perceived risks by developing validated turbine performance models that accurately predict project output, by participating in the development of design codes and standards that help ensure turbine reliability and survivability, and by partnering in demonstrations of offshore wind technologies in U.S. waters to reduce perceptions of technology risk. Predictable and timely regulatory and permitting approvals will also help reduce financing costs, as will stable and predictable installation and construction costs, system performance, and maintenance and replacement requirements.

Successful implementation of this ambitious national research and development initiative will require collaboration with federal and state agencies, universities, international organizations, non-governmental organizations, the European offshore wind industry, and the U.S. offshore oil and gas industry. Identifying shared research priorities will be critical to maximizing investment with minimal overlap. Access to shared resources, especially test facilities, will be integral to developing the next generation of large offshore wind turbines. As a final step, field testing could be conducted near-shore, and then offshore, to provide platforms for testing pre-commercial turbines before full deployment and for collecting performance data to benefit the entire industry and lead to improved reliability.

4.2 Reducing Deployment Timelines

Currently, offshore wind development in the United States is in its infancy. Projects are proceeding through regulatory permit processes for the first time. Much of the critical environmental baseline data from which to build environmental impact assessments has not been collected. The balance of risks and benefits of offshore wind energy development with respect to critical environmental and cultural resources, protected areas, and competing uses is not well understood; offshore wind resources in some areas are poorly characterized; and essential transmission, supply chain, installation and maintenance infrastructure do not yet exist. Without collaboration among key agencies and stakeholders to develop and implement high-quality and efficient permitting processes that proactively avoid and mitigate conflicts with other ocean uses, project development risks will continue to be unmanageable and cost of energy will increase.

The OSWInD initiative will address these challenges through three primary activities:

- *Energy Resource Planning*, which will address wind resource characterization and facility design conditions.
- *Siting and Permitting*, which will address policy and economic analysis, regulatory processes, environmental risks, public acceptance, conflicting uses, potential interference with radar and other electronic equipment used in marine operations, and risk management.
- *Complementary Infrastructure*, which will address domestic manufacturing and supply chain development, transmission and interconnection planning, and specialized vessels and other installation, operations and maintenance technology.

As discussed above, DOI's complementary Smart from the Start initiative will directly address the siting and permitting aspects of offshore wind development in federal waters. The initiative is aimed at addressing concerns raised about the potential timelines facing individual offshore wind projects through upfront planning to identify wind energy areas that appear best for development because of fewer user and resource conflicts, gathering available data on resources and uses of those wind energy areas, and then making that data available to the public to facilitate effective evaluation of individual projects within identified wind energy areas.

Importantly, the Smart from the Start initiative will include proposed environmental reviews under NEPA that substantially shorten the initial projected timelines for individual offshore wind projects. Specifically, the impacts of leasing and performing site assessment activities within identified wind energy areas will be subject to an environmental assessment under NEPA. The proposed construction and operation plans for individual projects would then be subject to an environmental impact statement. Each review will be conducted under aggressive schedules with dedicated staff and high-level engagement. Earlier estimates of a 7- to 10-year permitting timeline for each project were based on the assumption that multiple, typically lengthy environmental impact statements would be required. Instead, this strategy will ensure robust environmental review at the appropriate points in the process and not subject each proposed project to multiple and duplicative environmental reviews. Coupled with other efficiencies in the review process, including enhanced interagency coordination, the Smart from the Start initiative has the potential to shorten initial timeline estimates by more than half.

For the OSWInD and Smart from the Start initiatives to be successful, close collaboration among key federal and state agencies, as well as other stakeholders, will be crucial. Each proposed offshore wind project is subject to a myriad of federal, state, and other requirements. DOE and DOI are working closely to identify and overcome some of the permitting challenges that are likely to arise because of those multiple requirements while maintaining the integrity of the review processes and the values they protect. Additionally, the DOE and DOI initiatives, as well as related agreements with NOAA, share the goal of improving the amount of available data on external conditions (e.g., ocean uses and resources as well as meteorological and geophysical conditions) that influence design requirements, energy production, and economic viability. One of the key components of the Smart from the Start initiative is the creation of a senior-level interagency working group tasked with gathering available resource and user data on wind energy areas along the Atlantic OCS, making that data publicly available, and identifying crucial data gaps that should be filled through collaborative research efforts. The OSWInD initiative will similarly facilitate collaboration between key agencies and research organizations to establish a national data network for characterizing the wind resource and other factors such as wave action and seabed mechanics. These factors are not well documented but must be better understood for accurate marine spatial planning, establishing prioritized offshore wind areas, and financial due diligence.

DOE is uniquely positioned to play a catalytic role in addressing market barriers by bringing depth of knowledge of the technology and the industry, technical and financial resources, and a positive history of working across agencies and stakeholders, which will help in identifying administrative efficiencies to overcome regulatory barriers. Similarly, as the primary agency with jurisdiction over proposed offshore wind projects in federal waters, DOI can convene agencies and stakeholders to share information, identify challenges, and find solutions. The OSWInD and Smart from the Start initiatives will engage federal and state regulators, resource management agencies, and outside stakeholders to drive collective action toward creating an offshore wind industry. This engagement will include the establishment of additional formal working arrangements such as memoranda of understanding with key agencies, as well as interagency working groups. For example, DOE and DOI entered into an MOU on the future development of commercial offshore renewable energy projects on the OCS (see DOE/DOI MOU and Action Plan text box), which formalizes the close working relationship between the two agencies and their shared goal of supporting commercial offshore renewable energy projects. DOE is also working with ACOE to develop permitting processes for offshore wind energy in the Great Lakes under the auspices of the White House Council on Environmental Quality. DOI has entered into an MOU with 11 coastal states to establish the Atlantic Offshore Wind Energy Consortium (AOWEC), which will identify ways to facilitate the development of Atlantic offshore wind energy. AOWEC action plans are being incorporated into the Smart from the Start initiative and will identify means to reduce deployment timelines and support the development of the offshore wind industry.

Safety, domestic economic benefits, cost-effective installation and operations, and practical grid integration processes depend on development of large-scale local,

DOE/DOI MOU and Action Plan

On June 29, 2010, the Department of the Interior and the Department of Energy signed a new Memorandum of Understanding that will strengthen the working relationship between the two agencies on the future development of commercial offshore renewable energy projects on the OCS. Under the Action Plan developed as part of the MOU, the DOE Wind Program and DOI's Bureau of Ocean Energy Management and Regulatory Enforcement (BOEMRE) committed to improved exchange of data on offshore wind resources and technologies, engaging stakeholders on critical barriers, and collaborating on research projects to achieve objectives in five areas, including:

- Developing attainable deployment goals for offshore wind on the OCS
- Reducing siting and permitting timelines for project developers
- Improving resource assessment capabilities
- Developing technical standards for the U.S. offshore wind industry
- Reducing public acceptance risk through information exchange and public engagement

Successful implementation of the MOU and the Action Plan will be critical to reducing the deployment barriers identified in this *National Offshore Wind Strategy*.

regional and national infrastructure components dedicated to meeting the requirements of the offshore industry. The OSWInD initiative plans research activities with states, federal agencies, and industry to develop optimized, integrated strategies for meeting these needs and funding technical development.

4.3 Program Performance Metrics & Analysis

DOE will conduct cost-benefit analyses to help define ongoing program activities and metrics and to provide a context for decision-making. Analysis-based metrics for cost of energy and other factors are critical for reporting progress toward technical objectives and judging the feasibility of new technologies. Analysis activities include a coherent system of metrics to track program impact, analysis of the costs of deployment barriers that will help characterize program performance, and support for the development of analysis tools to assist DOE in prioritizing major program research and deployment elements. DOE will develop and track these metrics to inform decision-making regarding support for technology development and to assess the long-range impact of its investment.

Cost of energy modeling examines microeconomic cost and supply (e.g., operations and maintenance, installation, turbine subcomponents) as well as macroeconomic effects (e.g., commodity prices, exchange rates, public policy). These activities require substantive knowledge and evaluation tools, some of which remain to be developed. The analysis areas include national energy penetration models such as ReEDs, NEMS, and Markal. These efforts support national-scale initiatives to quantify carbon reductions and enhance high-penetration renewable energy scenario modeling. They also integrate offshore wind projections with ongoing job models, such as NREL's Jobs and Economic Development Impact (JEDI) model, that are already underway and include market and policy analysis on offshore wind projects, both in the U.S. and Europe, as appropriate.

5. OSWInD Implementation

This section details how each of the focus areas, activities, and research areas will be implemented as the OSWInD initiative matures.

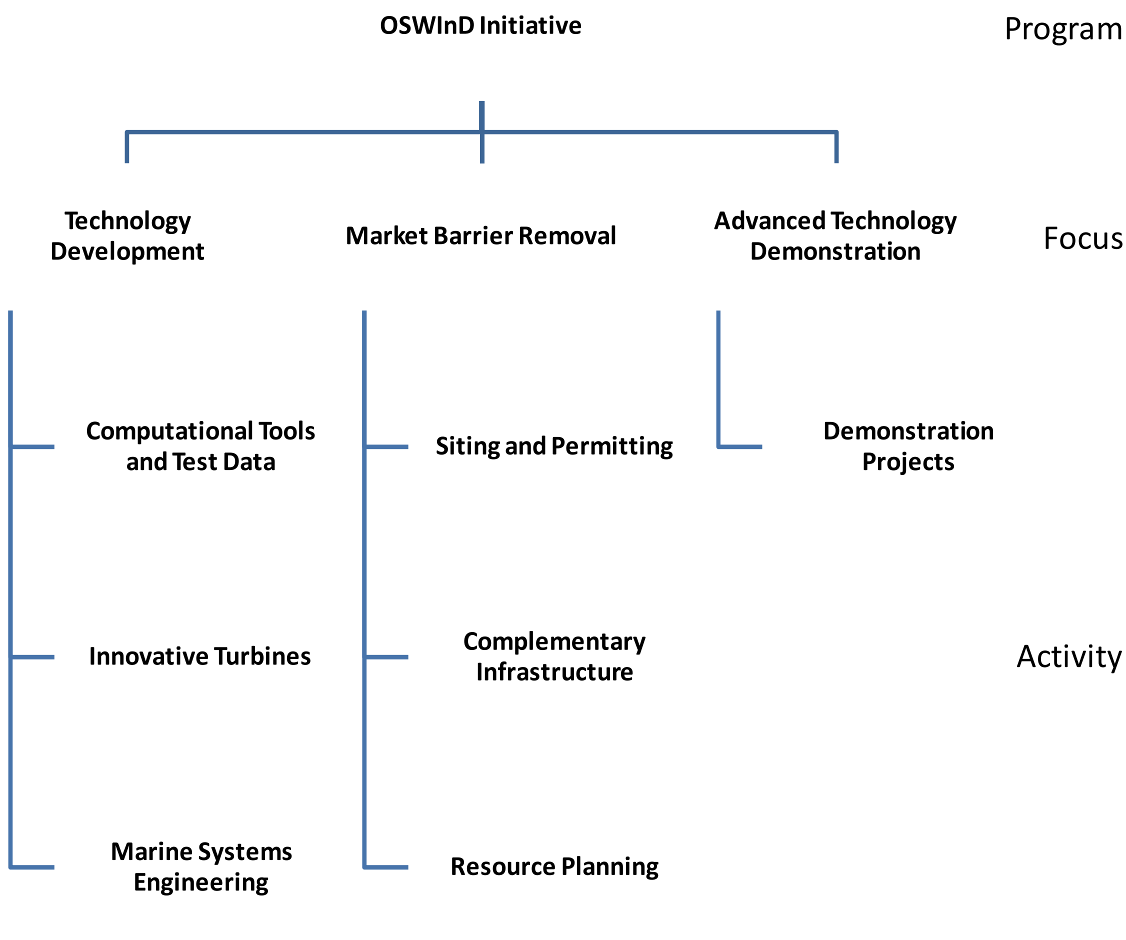

Figure 5. Structure of OSWInD focus areas and activities

5.1 Technology Development

The research efforts in Focus Area 1: Technology Development will help overcome technological barriers to the deployment scenario of 54 GW of offshore wind by 2030. Specific activities will focus on improvements to models, design tools, components, turbines, and balance-of-system components that will lead to a lower cost of energy, reduction in technological risk, and increased access to wind resources. Activities are highly integrated such that results in one area will be used as inputs to another area, and may ultimately be guided by a system-level optimization methodology. The Technology Development focus area is broadly categorized into three main activities: (1.1) Computational Tools and Test Data, (1.2) Innovative Turbines, and (1.3) Marine Systems Engineering.

Activity 1.1: Computational Tools and Test Data

Current offshore wind turbine technology is largely derived from land-based designs that have been conservatively modified for offshore use. A new generation of modeling and design tools is required that specifically addresses unique wind turbine technology requirements, including installation and operations in an extremely harsh ocean environment. Developing and assessing innovative technology begins with the computational design tools, standards, and testing methods that lay the foundation for safer, more reliable, cost-effective, and higher-performing offshore wind turbines. Computational design tools provide a baseline analysis and development capability for industry, help create and develop new intellectual property in offshore wind, and help provide educational tools for training the next generation of engineers and scientists in offshore wind technology.

Computational design tools require continuous updates and modification to reflect the best analysis methods and scientific models available. This information must be obtained from parallel research and development activities that improve our fundamental understanding of the underlying physics and phenomenology involved. High-performance computing efforts will lead to a better understanding of these fundamental processes, addressing performance barriers with innovations derived from an improved understanding of the atmospheric processes affecting wind farm performance, characterization of the dynamic interactions between turbines operating in large multiple arrays and complex terrains, and advanced optimization methodologies producing the lowest cost of energy options through modeling of integrated system designs.

Design tools and codes must be validated to ensure acceptance by designers and manufacturers, and to help in attracting capital investment. Field testing capabilities and facilities will provide the validated data to support the continued improvement of both design tools and standards, leading to reduced financial and regulatory risks and increased confidence in the long-term viability of offshore wind plants.

Research Area 1.1.1: Performance Modeling and Validation

Fundamental challenges affecting the wind industry include array under-performance, higher-than-expected dynamic loads, premature hardware failures, the need to optimize wind plant performance, and the need to assess potential adverse environmental effects produced through interactions between wind turbines and the atmospheric boundary layer. Validated design tools and codes are essential in developing innovative technology, planning projects, and minimizing the perceived risk of offshore wind energy development. When assessing the economic feasibility of a project, designers, developers and financiers rely on models that predict the amount of energy a wind project will produce over its lifetime to establish financial viability and develop operations strategies.

The deployment of offshore (and land-based) multi-megawatt turbines in multiple-array wind farms requires a new generation of modeling capability to assess individual turbine performance within the array as well as the overall wind plant performance. One immediate goal of OSWInD will be to incorporate offshore capabilities and requirements to design tools developed for land-based turbine systems, and to make these tools freely available to industry and academia. In addition to improving the capability of desktop computer performance modeling tools, high-performance computing and atmospheric science research and development are critically needed to advance our understanding of the *in situ* operating environments of large multiple-array wind farms and to help assess any potential impacts of large wind farms on micro- and macro-climatic conditions. Special formulations of computational fluid dynamics and finite element analysis tools that couple atmospheric inflow, multi-turbine rotor aerodynamics, the air/sea interface, and turbine dynamic response are required to provide high-fidelity data and simulations that can be used in assessing existing technology and guiding future innovation of technology optimized for offshore deployment.

Research Area 1.1.2: Design Tools and Standards

The development of new, accurate computer models is necessary to aid in the development of optimized offshore wind turbine designs. DOE will support development of computational tools needed to address structural design, control systems, aerodynamics, energy production, certification and verification issues, multiple turbine array effects, multiple array impacts on a regional basis, resource characterization, and meteorological and oceanographic phenomena. These tools will address the unique extreme environments in the United States, including hurricanes and ice conditions, to allow deployment of offshore wind in all regions of the country.

Advanced design tools must reliably predict the behavior of complex ocean environment conditions and permit the rigorous assessment and development of innovative turbine concepts, components, and foundations. In addition, new enhancements and capabilities are required to evaluate the fixed and floating platform designs necessary to deploy in transitional and deep water sites to access high-value offshore wind resources critically important to reaching national renewable energy goals.

A robust set of technical design, performance, and safety standards must be developed for the benefit of designers, developers, regulatory agencies and the industry at large to reduce risk and increase reliability. Partnerships with international and national standards-writing entities will result in access to existing guidelines and standards, which can serve as a baseline for national efforts. Standards development is an ongoing iterative process under which testing and operating experiences highlight new issues requiring further research and standards development. Development of such standards will lead to increased reliability, lowered risk, and lower cost of capital. DOE will work with BOEMRE and other agencies to provide technical consultation and coordinated research to address knowledge gaps in the current framework for technical approval of offshore wind power facilities.

Research Area 1.1.3: Field Testing

The most effective way to establish offshore wind turbine design requirements and confirm performance is through measurements made on actual wind turbines and components, both on land and in the water. It will be necessary to instrument and measure multiple turbines to capture regional and technology design differences. DOE and its national laboratories will partner with university research centers and industry in planning a long-term national operational data-gathering program.

Field-test data from multiple diverse test sites is essential for computer model validation and to support innovation. This field-test data should include grid interconnection and research instrumentation. Additionally, it is important to collaborate with industry to establish a national or international database of shared operating experience, which can lead to industry-wide understanding of the shortcomings of existing designs in order to direct and inform future research and development toward activities resulting in the highest possible positive impact on reliability and costs.

Table 4. Technology Development Activity 1.1: Computational Tools and Test Data

Research Area		Detail	Deliverable	Impact
1.1.1 Performance Modeling and Validation	1	Develop wind turbine & array performance models	Computational models that reliably predict individual turbine and array performance in large offshore farms	Reliable power production predictions reduce project performance risk, lower cost of capital, and increase energy capture
	2	Validate performance models with field test data	Validation of above model with field test data	Reliable power production predictions reduce project performance risk, lower cost of capital and increase energy capture
	3	Develop methodologies and computational tools to optimize next-generation offshore wind turbines, arrays, and O&M strategies at a system level	Concepts, methods and computational tools to assess impacts of proposed subsystem improvements	Enables optimized designs which ultimately lead to lowest cost of energy
1.1.2 Design Tools and Standards	1	Partner with European labs to access existing databases	Existing research and operational data from European offshore wind installations	Test data from European installations provides baseline for design tool development
	2	Develop U.S. standards for offshore wind. Harmonize with international standards	Robust suite of design and operation standards for U.S. offshore wind industry	Standards lead to increased reliability, lowered cost, and lower cost of capital
	3	Coupled dynamic computational model development	Validated model to evaluate dynamic response on the coupled wind turbine and support structure to wind and wave loading	Allows development of floating platforms and optimization of full turbine systems
	4	Develop and validate loading models for extreme environments (hurricanes, ice, etc.)	Validated model that accurately predicts wind turbine loads under extreme environmental conditions	Essential capability to enable deployment in Southeast and Great Lakes and inform standards development
	5	Advanced design tools for complex subsurface structures	Computational model that reliably predicts behavior of complex subsurface structures	New capability permits rigorous assessment of innovative structures
1.1.3 Field Testing	1	Implement data gathering campaign and gather test data from multiple field test sites (fixed, floating, regional)	Field test data from diverse sites	Field testing is essential for model validation and to support innovation and technological risk reduction
	2	Provide grid interconnection and research instrumentation for field test sites	Field test equipment operational at sites identified in above task	Field testing is essential for model validation and to support innovation and technological risk reduction

Activity 1.2: Innovative Turbines

To lower overall project cost of energy, innovative integrated turbine configurations, encompassing rotor, drivetrain, tower, controls, and foundations, are needed to reduce system weight relative to rated capacity, simplify installation processes, dramatically reduce maintenance requirements, improve reliability, increase energy capture, and derive benefits from economies of scale in general. DOE will form partnerships with research consortia, including industry, to identify, model, and eventually demonstrate candidate system configurations with high potential to impact cost of energy.

Research Area 1.2.1: New Turbine Concepts

It is generally recognized that, in order to generate cost-competitive electricity, larger turbines are needed to overcome the added cost of foundations and other non-turbine capital costs associated with offshore wind turbines. A concept study of a large, efficient, and cost-effective turbine system will highlight the research and development areas that will be required to realize a system of that size. This will help direct research and development of advanced components, especially rotors, which will be required to achieve the turbine design requirements. Concepts that achieve major weight reduction will also help enable future floating foundation designs.

Research Area 1.2.2: Advanced Drive Concepts

Innovative turbine drivetrains that have the potential for lower cost of energy, improved reliability, reduced weight, and increased energy capture must be developed to enable cost-effective, next-generation turbines. DOE will support pre-prototype studies modeling the integration of superconducting generators, transverse flux topologies, and other enabling technologies into advanced turbine drivetrains. DOE-supported drivetrain test facilities and, eventually, an offshore test bed will lower the risk for industry to develop these next-generation drive concepts.

Research Area 1.2.3: Controls and Power Electronics

Due to their increased size and cost, offshore turbines offer new possibilities in controls and power electronics sophistication not economically feasible in smaller systems. Research and development leading to advances in condition monitoring systems, control algorithms, blade control strategies, and power conditioning can increase turbine energy production, capacity factor, and component lifetime.

A condition-based monitoring system, consisting of a comprehensive suite of sensors and robust algorithms that detect impending problems before they occur, would improve availability and reliability, lower operating costs, and improve energy capture. These benefits are especially valuable for relatively remote and inaccessible offshore turbines. This comprehensive suite of sensors and algorithms can also be combined into control systems that increase hurricane survivability, reduce operational loads, and provide sufficient damping for floating platforms.

Table 5. Technology Development Activity 1.2: Innovative Turbines

Research Area		Detail	Deliverable	Impact
1.2.1 New Turbine Concepts	1	Large, cost -effective turbine concept studies	Turbine concepts with full cost analysis, demonstrated engineering feasibility, and tradeoffs for hardware development.	Larger machines are needed to lower balance of station costs that dominate offshore project economics
	2	Advanced rotor development	New materials, manufacturing methods and design concepts to enable next-generation rotor development	Innovations in materials, manufacturing and design lead to load and weight reduction enabling higher energy capture and larger machines
1.2.2 Advanced Drive Concepts	1	Evaluate and develop innovative turbine drivetrains with potential for lower cost of energy	Innovative turbine drivetrains demonstrated to improve reliability, lower cost, reduce weight, and increase energy capture	Innovations in the market that increase reliability, lower costs, and increase energy capture
	2	Develop reliability framework and O&M Priorities	Ongoing reliability characterization and analysis reporting	Database that gathers/provides information targeted at improving reliability and asset management
1.2.3 Controls and Power Electronics	1	Evaluate and develop condition-based monitoring systems for offshore systems	A comprehensive suite of sensors and robust algorithms that detect impending problems before they occur	Improved availability and reliability with lower operating costs and improved energy capture
	2	Evaluate and develop advanced control systems for offshore wind turbines	Control systems that increase hurricane survivability, reduce operational loads, and provide sufficient damping for floating platforms	Increase survivability, increase energy capture and enable successful operation of floating platforms

Activity 1.3: Marine Systems Engineering

A DOE-sponsored design effort for U.S.-engineered support structures, anchors, and moorings will lead to identification of significant cost-saving opportunities for wind power plants utilizing either fixed-bottom or floating substructures in shallow- or deep-water installations. Engineering trade-off analyses will be followed by detailed design studies and prototype testing. The development of grid architecture and hardware will be integrated with innovative foundations and turbine concepts into a system-level optimization methodology to produce an optimized next-generation offshore wind turbine technology platform adaptable to regional differences. Such efforts would draw upon the knowledge and expertise of the nation’s marine engineering industry.

Research Area 1.3.1: Support Structures

DOE will support development of innovative shallow, transitional-depth, and deepwater substructure designs that lower capital and installation costs and expand access to available wind resources. Advanced computational design tools for rigorously analyzing and reliably predicting the behavior of these complex subsurface structures will enable focused and cost-effective technology development through design trade-off studies, dramatically decreasing the technology adoption timeline. Innovative anchors and mooring approaches for these advanced substructure designs will further reduce cost and risk. Advanced control systems will help reduce loads on foundations and enable the development of floating systems, which will require stability control and load minimization. Foundation designs, in tandem with installation strategies, will optimize the time, cost, and complexity of the construction process, which is susceptible to weather, availability of specialized equipment, and variability of seabed conditions.

Research Area 1.3.2: Balance of System

The design of the wind turbine array grid, including inter-turbine connection schemes, substation designs, and longer connections to the main electrical grid, will need to be optimized to make offshore wind projects economically viable. DOE will support design studies for high-voltage direct current transmission, superconducting transmission, and other advanced transmission technologies. Concepts and hardware that allow for load balancing, short-term forecasting of wind farm production, and other power grid services will also help make offshore wind more economical and improve offshore wind energy integration with the existing electrical grid infrastructure. Reliability of offshore substations is also of vital importance, especially as projects grow in size and are installed further from shore.

Table 6. Technology Development Activity 1.3: Marine Systems Engineering

Research Area		Detail	Deliverable	Impact
1.3.1 Support Structures	1	Evaluate and develop low cost offshore support structures for a variety of water depths and offshore conditions including floating platforms.	Innovative shallow, transitional and deepwater support structure designs that lower capital and installation costs	Demonstrated and validated innovative support structures that lower cost and expand access to resources
	2	Evaluate and develop innovative anchors and moorings for floating offshore systems in coordination with water program to reduce cost and risk	Innovative anchor and mooring designs for floating offshore systems that lower cost and risk	Lower cost of energy, increased reliability, and improved investor confidence
1.3.2 Balance of System	1	Offshore grid hardware and integration studies	Grid architecture and hardware design concepts	Improved array efficiency, feed in to system level optimization
	2	Evaluate and develop grid hardware	New hardware solutions developed based on above designs	Enables larger and more efficient and reliable electrical grids leading to lower COE and O&M costs

5.2 Market Barrier Removal

The research efforts in Focus Area 2: Market Barrier Removal will aid in increasing the efficiency of the current deployment timeline. The Market Barrier Removal focus area is categorized into three main activities: (2.1) Siting and Permitting, (2.2) Complementary Infrastructure, and (2.3) Energy Resource Planning.

Activity 2.1: Siting and Permitting

To meet the OSWInD initiative's goals for offshore wind deployment, permitting and siting timelines and costs need to be minimized; key market, socioeconomic, and environmental risks need to be better understood and mitigated; and strategies to build public acceptance of the technology need to be applied to regions with near-term deployment goals. Concerted federal investment and engagement—coordinated within and across agencies and in close partnership with states, non-governmental organizations, tribes and other stakeholders—will be required to enable both the short- and long-term success of a vibrant offshore wind industry in the United States.

Although DOE has no legal authority in the siting or regulation of offshore wind installations, the OSWInD initiative can make a significant impact in planning, siting, and permitting processes by partnering with federal, state, and local agencies that regulate and manage offshore wind projects in state and federal waters. DOE will help jumpstart the nascent offshore wind industry by supporting research and analysis to better understand regulatory uncertainties and to identify, reduce, and mitigate key environmental and social science risks. DOE will also produce and disseminate critically needed objective information to enable informed decision making by stakeholders. In addition, DOE will collaborate with environmental stakeholders to help identify high-priority areas for protection, existing data gaps, and the best manner by which to efficiently incorporate natural resource considerations into the permitting and siting process.

DOI's Smart from the Start initiative is similarly aimed at decreasing regulatory uncertainty by clarifying how the DOI's offshore renewable energy regulatory framework will be implemented and by convening key agencies to share data on areas identified for potential development and to collaborate on individual projects as they are proposed. The interagency data-gathering and data-sharing provisions, in particular, will help ensure that stakeholders are able to make informed judgments and decisions about potential projects rather than relying on uncertain projections and estimates.

The efforts of the OSWInD and Smart from the Start initiatives in this area will be targeted at overcoming common barriers currently facing offshore investment and deployment, such as lack of available ocean resource and use data and complicated and untested permitting processes. DOE will prioritize efforts that leverage its investment with initiatives funded by other federal agencies, state and local governments, and the private sector, including utilities. The activities supporting implementation of the DOE/DOI MOU Action Plan referenced above will be critical in these initiatives, as will ongoing collaborative efforts in the Great Lakes with the Council on Environmental Quality and ACOE and the work of the National Ocean Council as it implements the National Ocean Policy and coastal and marine spatial planning.

Research Area 2.1.1: Market Analysis and Public Acceptance

Development of a utility-scale offshore wind project requires capital investment of hundreds of millions, even billions, of dollars. As experience from land-based wind and European offshore wind development has shown, policy options and financial mechanisms can have major impacts on the viability of projects. Credible, objective analysis to inform stakeholders and compare options has often been lacking. In the absence of sophisticated and broadly accepted methods of analyzing the costs and benefits associated with developing offshore wind projects in the U.S., there is likely to be a wide variety of contradictory data and interpretations of the public value and financial viability of offshore wind.

Under the Market Analysis and Public Acceptance research area, DOE will support the development of standardized methods, models and guidelines for the development of credible information on and tools for the evaluation of the costs and benefits of offshore wind, including relevant externalities compared to conventional electric generation sources competing with offshore wind energy. DOE will support the quantification of relevant positive and negative externalities, such as environmental and socioeconomic impacts, in cost of energy calculations, and will support objective analysis of policy and regulatory options related to offshore wind to enable informed decision-making on relevant questions related to specific projects, the offshore wind industry, and national energy policy.

Public acceptance of offshore wind will also be crucial to both the deployment of specific projects and the long-term success of the industry. The development of offshore wind could pose risks to competing uses of the ocean space, such as fishing, navigation, tourism, and military operations. Affected communities, tribes, and organizations will also have concerns that will need to be addressed. Many of these issues will be site-specific, but many will have common themes that can be addressed collectively. DOE and DOI will work together, along with other federal and state partners and key stakeholders, to identify and better understand the potential socioeconomic impacts of offshore wind energy and the concerns of key stakeholders and communities. Identification of gaps in understanding will be followed by targeted research to develop risk mitigation measures and communication strategies to build public acceptance of offshore wind. Increased public acceptance of offshore wind will also be driven by inclusive siting and permitting processes that consider community equities and produce outcomes that show incorporation of public sentiment.

Research Area 2.1.2: Regulatory Processes

Planning an offshore project requires consideration of hundreds of important environmental and conflicting-use factors, as well as compliance with a multitude of regulations enforced by agencies with varying levels of jurisdictional authority. This complexity, compounded by the general lack of robust data on ocean resources, can result in lengthy permitting processes, particularly in the absence of effective interagency collaboration to identify and resolve issues that arise with any given project. Moreover, the regulatory processes are currently relatively untested, increasing uncertainty and risk for investors.

DOE will work closely with other federal agencies to identify means of enhancing efficiency in permitting processes through concurrent and coordinated review for projects in both federal and state waters. DOE will also support efficiency in permitting through the support and development of mechanisms such as standardized protocols for baseline planning surveys and monitoring programs and the development of adaptive management strategies.

DOI's complementary Smart from the Start initiative will directly address the siting and permitting aspects of offshore wind development in federal waters. The Smart from the Start initiative includes the early identification of wind energy areas that appear particularly well-suited for potential development because of fewer user and resource conflicts, followed by the implementation of a review process for proposed projects in those wind energy areas that is streamlined and efficient while promoting thorough public review and analysis of potential impacts. AOWEC action plans discussed above include: (1) implementing state-based pilot projects to harmonize state and federal permitting processes to facilitate data-sharing and ensure coordination; (2) continuing to review the new regulatory framework for OCS renewable energy projects, particularly as individual projects are proposed and then reviewed under the new regulations, to identify any potential regulatory reforms or statutory amendments that would reduce permitting timelines while still allowing robust environmental review; (3) developing best management practices for siting offshore renewable energy facilities and for developing projects that minimize potential impacts; and (4) ensuring frequent communication and collaboration between federal agencies and the states, particularly with respect to research, data acquisition, and planning.

The development of offshore wind facilities can be based on a siting process that proactively avoids and mitigates conflicts with other ocean uses and resources. Rather than taking a first-come, first-served approach to siting offshore wind projects, which can miss efficiencies in required baseline data collection, environmental review, and other permitting requirements, a properly designed and proactive approach to siting and permitting may have the potential to significantly accelerate responsible installation of projects while mitigating impacts on critical ocean resources, areas, and competing uses. Both the OSWInD initiative and the Smart from the Start initiative are aimed at ensuring this proactive approach.

Research Area 2.1.3: Environmental Risks

Hundreds of environmental studies have been conducted in Europe in conjunction with offshore wind development. Although the United States can leverage lessons learned from these studies, few studies have been done in U.S. waters. Consequently, major data gaps exist that can delay and add significant risk to the installation of offshore facilities for both project developers and regulators. Filling these gaps requires upfront investments in long-term, expensive research that—while of substantial benefit to the entire industry—falls largely to the first generation of individual project developers.

DOE, along with other federal agencies, will institute a nationally coordinated effort to gather, analyze, and make public environmental data in order to better inform stakeholders and decision-makers on the extent of potential environmental impacts of offshore development. This effort will avoid compelling individual developers to shoulder the high costs of more broadly applicable research and will build the common knowledge base. The work will include collaborations such as the offshore interagency working group organized by the Department of the Interior under the Smart from the Start initiative to coordinate identification of gaps and priority risks, analysis of European studies to identify data and conclusions applicable to the U.S., aggregation and dissemination of existing environmental data through publicly available databases, collection of baseline data to fill key gaps, site-specific efforts such as before-after control-impact studies of relevant marine ecology in key geographic areas, development of tools and technologies for cost-effective pre- and post-construction environmental monitoring and mitigation, assessment of the environmental impacts of new foundation and balance-of-plant technologies, and development of broadly acceptable integrated environmental risk assessment and decision-making strategies.

Over time, these investments will reduce perception of environmental and statutory risks to the regulatory and resource management agencies, reduce requirements for baseline environmental data gathering, monitoring, and mitigation requirements to be borne by individual project developers, and increase community acceptance.

Research Area 2.1.4: Impact on Marine Operations

It is possible that under certain conditions, offshore wind turbine arrays may cause electromagnetic or acoustic interference with specific electronic navigation, detection, or communication equipment. This potential for interference presents a serious concern for many stakeholders, including operators of commercial, recreational, and fishing vessels, the Department of Defense (DoD) and the Department of Homeland Security (DHS).

While many potential electromagnetic interference issues will be similar to those associated with land-based wind systems, there are also circumstances unique to offshore facilities that may potentially affect equipment such as land-based radar, airborne radar, Automatic Identification Systems (AIS), Global Positioning Systems (GPS), shipboard radios, Sound Navigation & Ranging (SONAR) and Coastal Ocean Dynamics Applications Radar (CODAR). Therefore, additional research is needed to effectively assess any potential operational impacts, characterize the technical challenges and develop mitigation options.

Assessments of potential electromagnetic or acoustic challenges presented by offshore wind energy facilities to sea surface, subsurface and airborne electronic systems must include engagement with key stakeholders to proactively identify the full range of concerns, characterize potential impacts to operations, identify known requirements and options for mitigation, and establish research and policy needs.

Both DOE and DOI are members of the sub-interagency policy committee on radar. This committee is chaired by the National Security Council and involves representatives from the DoD, DHS, FAA, NOAA, and the Director of National Intelligence. The committee focuses on identifying and resolving conflicting priorities regarding interaction between wind turbines and radar systems. Interaction with these key partners will effectively characterize the technical challenges of radar/turbine interaction and develop mitigation options.

Activities of the OSWInD initiative will complement, and will be defined by, the collaborative framework established for investigation of potential impacts on electronic equipment and marine operations. This framework includes:

- Joint assessment studies to inform research needs.
- Roadmaps that prioritize research and development activities of individual agencies and identify opportunities for joint research projects between agencies.
- Funds for research and development of wind turbine mitigation technologies that can be implemented by the wind industry.
- Validation of new technologies that can allow development of the nation's wind resources without jeopardizing national security missions.

A goal of this approach is to dramatically reduce the need for project-by-project technical assistance through broadly accepted technology mitigation measures. These efforts will be informed by the experience and investigations carried out in conjunction with the European offshore wind industry, such as tests integrating supplemental radar systems and modifications to radar processing software.

Table 7. Market Barrier Removal Activity 2.1: Siting and Permitting

Research Area		Sub-task	Deliverable	Impact
2.1.1 Market Analysis & Policy	1	Ongoing policy and market analysis	Annual market data report and analysis of emergent policy and economic questions	Reduced information barriers to investment, better decisions by policy makers and other stakeholders
	2	Offshore costs & benefits analysis	Standard methodologies for project costs and benefits evaluation, including quantification of externalities and COE analysis of non-technology barriers and costs	Allow apples-to-apples comparison of offshore wind with competing generation technologies to enable informed decision making
	3	Economic and public acceptance risk reduction	Studies to improve understanding of and mitigation options for key socioeconomic and public acceptance risks. Targeted engagement of key stakeholders through publications, electronic media, workshops, etc	Reduced study costs to developers, improve quality and availability of environmental and socioeconomic data required for effective permitting, reduced risks to investors and regulators, improved public acceptance of offshore wind
2.1.2 Regulatory Processes	1	Efficient regulatory processes	Recommendations to increase efficiency of federal and state project authorization processes and shorten timelines, standardized protocols for environmental monitoring and mitigation, adaptive management strategies	Decreased timeline and risks associated with siting and permitting to both developers and regulators
	2	Proactive planning and siting	Using coastal and marine spatial planning principles to identify wind energy areas in federal waters for near-term, GW-scale deployment, and supporting similar advanced siting efforts in state waters. Improved broad-scale environmental and ocean use data. Plan for potential research leases	Accelerated deployment in priority regions, reduced environmental study costs to developers, improved quality and availability of environmental and socioeconomic data required for effective permitting, reduced long-term risks to investors and regulators

2.1.3 Environmental Risks	1	Data aggregation and dissemination	Instituting interagency working groups and other formal working relationships to share and disseminate available ocean resource and user data and to identify data gaps. Develop offshore wind environmental knowledge management system	Maximize leverage of European experience; enable objective, data-based review and decision-making
	2	Environmental study technologies and methods	Assessments, technology development, and validation of novel environmental study technologies and methods	Reduced environmental study costs and risks to developers and regulators
	3	Site-specific environmental studies	Studies to address key environmental issues facing specific projects in development	Overcome regulatory hurdles faced by specific projects. Reduce regulatory burden for projects facing similar questions
	4	Broad-scale environmental studies	Studies to address priority broad-scale environmental data gaps, offshore wind risk evaluation framework	Reduced regulatory and environmental uncertainty for developers, regulators and other stakeholders; improve quality and availability of environmental and socioeconomic data required for effective permitting; risk framework will help prioritize areas for investment and separate perceived from real risks.
2.1.4 Impact on Marine Operations	1	Assessment of potential interference with electronic equipment	Baseline study of the potential impact of offshore wind facilities on navigation, detection or communication equipment used in marine operations	Determination of research needs, operational procedures, mitigation techniques and policy requirements to protect mission equities of key stakeholders

Activity 2.2: Complementary Infrastructure

Research efforts will address infrastructure challenges that, if not adequately resolved on a national level, pose significant restrictions to offshore wind market growth and deployment. Priority will be given to efforts leveraging DOE investment with initiatives funded by other federal agencies, state and local governments, and the private sector, including utilities.

Research Area 2.2.1: Manufacturing and Supply Chain Development

The supply chain is defined as the system of manufacture and/or procurement of components, subcomponents and materials that compose the assembled turbine and completed offshore facility. Domestic infrastructure is critical to the practicality and financial viability of individual offshore projects. Domestic manufacturing and the growth of U.S.-based suppliers is also key to asserting global technical leadership and realizing the full economic benefit of the offshore wind industry. Domestic manufacture of offshore turbines, tower structures, and balance-of-plant components offers advantages in transportation and transactional costs during installation and operational periods.

In addition to offering financial incentives such as loan guarantees, DOE will provide technical support to companies seeking to supply offshore turbines and components and to economic development agencies seeking to establish manufacturing facilities in their regions. The goal for this effort is to coordinate, facilitate, and leverage research activities at national laboratories, universities, and other agencies, such as the Department of Commerce (DOC), to facilitate U.S.-based manufacture, assembly, transport, operation, and maintenance of offshore wind turbine systems and components. Such support includes studies on optimized integrated manufacturing and installation strategies, research and development on manufacturing processes for components such as blades, and analyses of critical material supply and demand factors that will face the offshore wind industry as it grows.

Research Area 2.2.2: Transmission Planning and Interconnect Strategy

Offshore projects are being planned in close proximity to major urban load centers, requiring interconnection with some of the country's major electricity service providers. Grid interconnection studies are required to ensure that the impacts of large concentrations of offshore wind generation facilities on these transmission networks are properly understood and can be effectively integrated into the day-to-day power management strategies of the utilities, and to identify system upgrades needed for reliable interconnection. Studies will also assess the value to utilities of offshore wind energy versus energy from other sources or regions, and the potential value to the East Coast distribution grid of an extended offshore electric delivery network.

The OSWInD initiative will collaborate with DOE's Office of Electricity Delivery and Energy Reliability (OE) to develop a long-range DOE approach that characterizes and addresses the needs for transmission planning and interconnection strategies specific to offshore wind energy. These strategies will leverage the experience of existing offshore electric transmission projects. Near-term research will support OE-led, interconnect-wide transmission planning and address related long-range industry needs and utility challenges. Potential near-term research topics include technology and industry characterization, initial integration analyses, collaborative utility assessment studies, and advanced technology evaluation (including of a potential offshore transmission 'backbone').

Research Area 2.2.3: Optimized Infrastructure and Operations

Offshore wind provides an opportunity for revitalization of U.S. ports and heavy industry facilities. Due to the large scale of offshore wind turbine components, towers and foundation structures, it is generally advantageous to limit or eliminate overland transport from assembly and installation scenarios in order to maximize process efficiency and minimize logistics time and costs. In addition, European experience has clearly indicated that it will be necessary to create a purpose-built installation, operations, and maintenance (IO&M) infrastructure for offshore wind, including specialized vessels and port facilities. To assist industry and regional port facilities in making informed decisions regarding design requirements for IO&M infrastructure, DOE will participate in collaborative studies of infrastructure needs and capabilities for the benefit of all national regions.

A significant portion of the cost differential between land-based and offshore wind energy systems lies in transport and installation requirements. European experience indicates that specialized wind system installation vessels, rather than adapted oil and gas vessels, will be required for cost-effective, highvolume installation. DOE will support development of integrated manufacturing, transport, installation, and maintenance strategies leading to specialized vessels, safety systems, and tooling.

Operations and maintenance analysis and planning at the onset of the design and development of offshore wind projects can contribute significantly to reductions in the cost of energy by optimizing system reliability and availability. Through maintainability analysis that considers projected component reliability and periods of access limitations, this effort can support accurate energy production estimates as well as provide targeted reliability goals at a component and vessel fleet level. These efforts will include establishment of operations databases and development of advanced O&M strategies based on data analysis targeted at improving asset management.

Table 8. Market Barrier Removal Activity 2.2: Complementary Infrastructure

Research Area		Sub-task	Deliverable	Impact
2.2.1 Domestic Manufacturing and Supply Chain Development	1	National manufacturing infrastructure assessment and development strategy	Quantify existing and long term manufacturing needs and supplier opportunities as well as critical path to effective growth	Enhanced likelihood of efficient buildup of national scale infrastructure to meet industry needs.
	2	Manufacturing improvement techniques	Quantify existing and potential component needs and supplier opportunities. Identify technical pathway for market entry of large offshore components	Manufacturing strategy targeted at the build-out of a robust supply chain
2.2.2 Transmission Planning & Interconnect Strategies	1	National offshore grid interconnection study	Baseline assessment of projected scale of offshore wind industry, deployment scenarios, technology and power characteristics, and integration strategies	Will enable utilities and interconnect-wide planning collaboratives to make more informed decisions regarding offshore wind integratjon and operations
	2	Collaborative utility integration studies	Case studies and joint analysis carried out with utilities having large-scale offshore wind development proposed in their service areas	Activities will address integration concerns and technical challenges identified by partner organizations
	3	Advanced technology assessments	Identify potential advanced marine grid and interface hardware designs such as HVDC offshore "backbone", marinized substations, advanced undersea cable concepts, and optimized inter-array grids	Technical analysis will result in advancements that lower costs, increase reliability, reduce risks and/or facilitate acceptance.
2.2.3 Optimized Infrastructure and Operations	1	Optimized IO&M strategies	Analysis and models to identify the most practical means of reducing cost of energy through IO&M techniques and supporting infrastructure while ensuring safety	Required for effective decision making by industry

	2	Optimized vessels, facilities & technology for IO&M	Identify needs, solutions, costs and timeframes for development. Provide technical and financial support	Enhance efficient buildup of national scale infrastructure to meet industry needs.
	3	Develop reliability framework and O&M priorities	Ongoing reliability characterization and analysis reporting.	Database that gathers/provides information targeted at improving reliability and asset management

Activity 2.3: Energy Resource Planning

Accurate field data, mapping, and databases are essential for assessing potential offshore wind project sites and establishing zones of prioritized activity. Although many agencies, universities and other organizations have programs nominally addressing offshore wind resource data needs, there has been no national-scale coordination to integrate these efforts in order to meet an agreed-upon set of data needs for the offshore industry. Through this OSWInD initiative activity, DOE will facilitate a nationally coordinated effort to collect and disseminate data for use in planning individual projects and carrying out critical marine spatial planning activities in support of responsible offshore wind development. For federal waters in particular, the OSWInD initiative and the Smart from the Start initiative will work in tandem to gather and share crucial data to support responsible siting of proposed offshore wind projects. Both of these initiatives will in turn inform larger efforts, such as the National Ocean Council's coastal and marine spatial planning work, to plan responsibly for a myriad of ocean and Great Lakes uses.

DOE-NOAA Collaboration on Wind Resource Characterization

DOE and NOAA are working collaboratively to improve the understanding of meteorological phenomena that affect wind resources and other renewable energy technologies. Better information on meteorological processes and improved modeling of the variability of the wind, sun, water, and other resources will ultimately increase the country's ability to predictably and reliably integrate renewable energy into the electrical grid. The collaborative effort has yielded a jointly-led wind forecasting initiative to help better predict the short-term changes in wind that cause challenging ramps in power production from wind plants. Building upon their already successful collaboration, DOE and NOAA signed an MOU on January 24, 2011, to formalize this partnership and expand their efforts in the terrestrial and offshore renewable energy technologies arena.

Most meteorological, wave, and seabed data used in assessing potential offshore wind sites are based on extrapolations of data from on-shore sites, buoys, or limited surveys. Such projections have not been validated for accuracy. Few wind data have been gathered at actual offshore sites due to the cost and lack of practical instrumentation. Similarly, few data exist on seabed conditions, which are required to design foundations and plan trenching for transmission cables. These data are critical in assessing the costs, energy production, design requirements and overall economic viability of projects.

DOE will collaborate with DOI, NOAA, ACOE, USG, DoD and other key agencies to establish common databases, ensure that available data are utilized, support new measurement initiatives and fund development of advanced instrumentation technology.

Research Area 2.3.1: Energy Resource Characterization

DOE's efforts with DOI and NOAA establish a collaborative framework for defining the highest priority research areas related to the characterization of wind resources. This collaborative framework consists of the following key resource characterization planning activities:

- Engage industry experts and formation of an interagency working group to ensure that a broad range of stakeholders and potential program assets are engaged.
- Prepare a data requirements document identifying exactly what data, collected and compiled to specified protocols, is needed by the offshore wind industry;
- Complete a gap analysis to determine the relevance of existing data, the best sources of data in the future, required modeling and extrapolation software and recommendations for advanced technology development.
- Initiate a long-range implementation plan that acts as a roadmap for the OSWInD initiative and its national partners to coordinate and support specific resource characterization activities.

These planning activities will inform research efforts such as resource characterization for the Outer Continental Shelf and Great Lakes, mesoscale atmospheric modeling to predict long-range weather trends; analysis of extreme events such as hurricanes, assessment and refinement of advanced instrumentation and methodologies, and joint efforts to establish of GIS databases and methods.

Research Area 2.3.2: Facility Design Conditions

To support reliable and safe offshore wind plant design and to provide data for emerging marine spatial planning activities, a long-term, concerted effort to collect and disseminate critical field information beyond wind characteristics is needed. This data provides the basis for technical requirements governing structural design and establish operating parameters for turbines, towers, balance-of-plant structures, and transmission cables. Applying these requirements to facility design will affect determinations of practicality, reliability and economic viability. For instance, information on water depth, currents, seabed migration, and wave action will be used to study mechanical and structural loading on potential turbine configurations and to assess impacts of external site-specific conditions, in terms of both survival during extreme loading and long-term fatigue damage and degradation. Other quantifiable factors of the design environment include growth of marine organisms, tidal forces, salinity, and icing, as well as the geotechnical characteristics of the sea or lake bottom.

To make this design and planning information available, DOE will lead a gap analysis that identifies critical non-wind data and assesses the best means of collection. DOE will also facilitate the planning needed to establish a national network that provides data and support for the required research and development. These activities will leverage the existing knowledge base of ocean engineering established by the offshore oil and gas industry.

Table 9. Market Barrier Removal Activity 2.3: Resource Planning

Research Area		Sub-task	Deliverable	Impact
2.3.1 Resource Characterization (Wind)	1	Data gaps analysis	Planning report assessing national status and future needs with respect to meeting pre-determined industry and stakeholder data requirements	Enables effective long-range interagency planning and coordination
	2	National resource database plan	Plan to establish network of instrumentation, databases and protocols to meet pre-determined data requirements	Enables effective ongoing characterization of offshore resource and design conditions, including local and regional variations
	3	Refined mesoscale modeling & mapping	Reliable OCS and Great lakes mesoscale models and user tools	Models that provide the information necessary to support technology, siting, and economic decisions
	4	Advanced meteorological instrumentation, tools and Methodologies	Evaluation and validation of advanced and applicable technologies (i.e. SODAR, LIDAR, etc.) and related modeling tools	Identification of cost-effective siting tools validated to the satisfaction of structural designers and financial institutions
2.3.2 Facility Design Conditions	1	Data gaps analysis	Report identifying critical non-wind data for turbine, foundation and balance of plant design such as water depth, currents, seabed mechanics, wave action, and ice loading, recommend means to collect data for national and regional use	Required to develop a national database of local and regional design conditions
	2	National offshore planning database	Interagency and multi-organization plan to establish national network to collect and make critical data available	Information feeds into development of priority offshore wind areas and reduction of deployment timelines

5.3 Advanced Technology Demonstration

The OSWInD initiative will undertake Advanced Technology Demonstration projects to impact the speed and scale of offshore wind development. The primary goal of this activity will be to support the installation of offshore wind turbines in U.S. waters in the most rapid and responsible manner possible. Successful deployment of advanced technology demonstration projects will help make offshore wind cost-competitive with other generation through reduction of uncertainties and refinement of technology. By providing funding, technical assistance and government coordination to accelerate deployment of these demonstration projects, DOE can help mitigate risks and facilitate the development of the domestic offshore wind industry.

Specific objectives of the program include establishing a network of installations providing performance validation data; familiarizing the public with offshore wind installations; and testing and refining infrastructure for offshore wind plant construction, operations, and maintenance.

To carry out the demonstration program, DOE will form cost-sharing partnerships with broad consortia, chosen through a competitive process, to support the development of individual offshore wind power projects. Such consortia are likely to include offshore wind power project developers, research institutions, electric utilities, equipment manufacturers, marine engineering and construction specialists, and state and local governments. Through these partnerships, DOE will fund technical research, engineering, and planning activities that enhance timely project deployment and result in documented and publically disseminated technical experience and data.

Examples of potential demonstration projects include, but are not limited to:

- Several offshore wind systems that make up the initial phase of a larger commercial project.
- A large grid-connected demonstration project (~100 MW) that has the capacity to install and test multiple systems from multiple manufacturers.
- A smaller grid-connected demonstration project or research center that will address specific technical challenges and/or regional conditions.

Use of DOE funds will include, but is not limited to:

- Innovative engineering activities, such as for foundations and electrical systems, facility infrastructure, and installation systems and methods.
- Facilitating field testing through the use of instrumented towers, turbines, and foundation structures within a project to gather performance or research and development data.
- Addressing research gaps related to the marine environment and stakeholder factors including resource assessment, environmental and socio-economic research, and efficiency in permitting, planning and siting processes.

DOE will seek to partner in demonstration projects that are diversified by geographical region, water depths, and innovative technologies. Consideration will be given to regions or states in which either wind research or commercial leases already have been proposed or have commenced, those in which federal or state agencies have issued public Requests for Information, and/or those where initial environmental studies have been commenced or completed. Other key criteria that DOE will consider when evaluating potential partnerships will include cost share; strength of collaborative partnerships; demonstrated technical expertise; progress to date toward project deployment, particularly in siting and permitting; justification for how DOE funds would accelerate realization of project goals; explanation of how the project success would advance the national knowledge base on offshore wind; ability of the project to support innovative research; support from state and local communities; and feasibility of proposed deployment timeline.

5.4 Current DOE Offshore Wind Activities

DOE is currently engaged in several ongoing offshore wind activities and has invested a total of $93.4 million through the American Reinvestment and Recovery Act of 2009 (Recovery Act), FY09 appropriations, and FY10 appropriations into offshore-related activities within the Wind Program. Current offshore wind activities support all three focus areas of the OSWInD initiative: technology development, market barrier removal, and advanced technology demonstration projects.

Major activities in support of the technology development focus include the large drivetrain testing facility at Clemson University; the large blade test facility at Massachusetts Clean Energy Center; and research conducted at the University of Maine, the University of Delaware, and the University of Toledo. The large drivetrain and large blade test centers provide national infrastructure for full-scale tests of key turbine components. The facilities will enable testing of drivetrains with capacities as large as 15 MW, and blades up to 90m in length. These facilities are important national investments, as there are currently no facilities in the United States capable of testing the large drivetrains and blades predicted for offshore wind technology deployments. Research conducted by the universities will result in the validation of coupled aeroelastic/hydrodynamic models for floating wind turbine platform deployments; modeling work on two-bladed, downwind floating turbine concepts; feedback to technology developers on corrosion protection and gearbox reliability; and materials innovation using composites for tower and blade structures.

Ongoing market barrier removal activities include the DOE/NOAA partnership on effective deployment, operation and maintenance of weather-dependent and oceanic renewable energy technologies; environmental research at the University of Maine and Michigan State University; projects addressing marketplace acceptance at the University of Delaware, Sustainable Energy Advantage LLC, the Great Lakes Commission, Princeton Energy Resources International, LLC, and the South Carolina Energy Office; and workforce development work at the University of Massachusetts, University of Maine, University of Toledo, and University of Delaware. DOE also supports the development of Rhode Island's Special Area Management Plan, which will create a use plan for various activities in the state's offshore waters, including renewable energy development. The environmental research is investigating avian, bat, and marine animal interactions for both the great lakes and the Atlantic seaboard. The market acceptance research is investigating solutions to current barriers for offshore wind deployment. The workforce development activities will result in new curricula specific to offshore wind energy at the community college, university undergraduate, and university graduate levels. Finally, in collaboration with BOEMRE and NOAA, DOE funds numerous projects to evaluate and mitigate the environmental effects of offshore renewable energy, and to develop protocols for environmental baseline data collection.

Through the Recovery Act, DOE is funding the University of Maine to carry out proof-of-concept testing on a 100 kW wind turbine mounted on a floating deep water platform in the Gulf of Maine. The University will select the turbine and foundation configuration from eleven initial design concepts that will be evaluated through scale model testing in a wave tank facility. The proof-of-concept turbine will be instrumented to gather empirical data for validation of current aero-elastic/hydrodynamic models that will be applied in developing much larger floating platforms for multi-megawatt scale turbines

In addition to supporting the activities mentioned above, DOE maintains a core competency of technical experts by supporting specific research activities within the DOE national laboratory complex. These experts support key activities in multiple disciplines essential to furthering the national wind energy development agenda. Finally, DOE is actively engaged in interagency collaborations through activities associated with the DOI-DOE MOU, the Center on Environmental Quality, and the National Ocean Council, along with other collaborations attempting to address the myriad of regulatory and permitting issues facing offshore wind deployment.

5.5 Current DOI Offshore Wind Activities

For the past two years, the Department of the Interior has been actively engaged in facilitating the commercial-scale development of offshore wind, particularly along the Atlantic OCS. In April 2009, President Barack Obama and Interior Secretary Ken Salazar announced the final regulatory framework for renewable energy development on the OCS. These new regulations establish the process BOEMRE will use for granting leases, easements, and rights-of-way for offshore renewable energy development activities, such as the siting and construction of wind generation facilities on the OCS.

The new regulations encourage collaboration among stakeholders, particularly federal, state, and tribal governments, by allowing BOEMRE to use intergovernmental, state-based task forces in carrying out its responsibilities for authorizing OCS renewable energy activities. These task forces facilitate communication between BOEMRE and state, local, tribal, and federal stakeholders concerning commercial renewable energy leasing and development on the OCS and have served as a forum to collect data about existing resources and uses present along the Atlantic OCS.

Task forces have been established (or are in the process of being established) in Delaware, Florida, Maryland, Maine, Massachusetts, New Jersey, New York, North Carolina, Rhode Island, South Carolina, and Virginia. These task forces include a broad range of state and tribal officials as well as representatives from across the federal government, including BOEMRE, FWS, NPS, Bureau of Indian Affairs, DOE, NOAA, DOT, ACOE, FAA, EPA, USCG, DHS, and DoD.

BOEMRE has used the information collected through the task force processes to issue notices (Requests for Information, or RFIs) inviting all interested and affected parties to comment and provide information on areas preliminarily identified as particularly feasible for potential offshore wind development. RFIs are regulatory notices that allow BOEMRE to request feedback on an OCS area and its suitability for potential development and to determine whether competitive interest exists for a particular OCS area (the Outer Continental Shelf Lands Act requires that BOEMRE issue leases for offshore wind development competitively, unless BOEMRE determines that no competitive interest exists). To date, RFIs have been issued for certain areas off Delaware, Maryland, and Massachusetts, and are being developed for other areas off additional states along the Atlantic coast.

DOI's Smart from the Start initiative and the effort to identify wind energy areas that appear most feasible for development will build on the task force-based effort by using the data collected so far on potential resource and user conflicts, collecting any additional available data to inform the evaluation of potential lease issuance and site assessment activities, and identifying any data gaps that should be filled through collaborative research efforts.

In addition to these efforts, in 2009 BOEMRE issued “Interim Policy leases” that allow for site assessment activities to be performed off the coasts of New Jersey and Delaware. These leases were issued pursuant to an Interim Policy in place prior to the finalization of the new regulations governing renewable energy leasing on the OCS. Under these leases, several companies are authorized to construct meteorological towers and/or buoys that will collect wind resource and other related data to support future proposed projects.

On April 28, 2010, Secretary Salazar signed a Record of Decision authorizing the issuance of a lease to Cape Wind Associates, LLC, paving the way for BOEMRE to issue a commercial lease to the company in October 2010. Should BOEMRE approve Cape Wind Associates’ proposed construction and operation plan, the Cape Wind energy project would be the first wind farm on the OCS, and its approximately 130 planned wind turbines could generate enough power to meet 75 percent of the electricity demand for Cape Cod, Martha’s Vineyard and Nantucket Island combined.

Finally, BOEMRE’s Office of Offshore Renewable Energy Programs (OREP) is actively engaged in conducting research to assess the potential environmental impacts of renewable energy development on OCS resources. These efforts include determining and evaluating the potential effects OCS activities may have on natural, historical, and human resources and the appropriate monitoring and mitigating of those potential effects. OREP’s Environmental Studies Program conducts research across the spectrum of physical, biological and socioeconomic environments.

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DOE/GO-102011 2988 • February 2011

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