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Offshore Wind Guide

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Wind Energy Technologies Office

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Introduction to the Guide

The WINDExchange Offshore Wind Energy Guide is a foundational resource that introduces the major concepts and topics within offshore wind energy:

- Project anatomy and components
- The project development process (including leasing and permitting)
- Siting of wind turbines and transmission infrastructure
- State and local government involvement in offshore wind energy development
- Tribal considerations and involvement in offshore wind energy development
- Community considerations and priority issues
- Public engagement in decision making and planning
- Economic impacts
- Supply chain, ports, and vessels
- Workforce roles and development activities.

This guide provides information and resources intended to support readers in building a foundation of knowledge about offshore wind energy.

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Introduction to Offshore Wind Energy

What Is Offshore Wind Energy?

Offshore wind energy projects harness offshore wind resources to generate electricity. Wind turbines are installed in large bodies of water, typically the ocean, and convert the renewable offshore wind resource into electricity. This electricity is then transmitted onshore via transmission infrastructure and integrated into the grid to power homes, businesses, schools, and other end uses. These projects can be installed nearshore in shallow waters or farther offshore in deep waters. Different technologies—such as wind turbine components, foundation types, and other infrastructure—are used depending on local conditions like soil type, water depth, wind speed, and the potential for extreme weather conditions.

In March 2021, the Biden-Harris administration established an ambitious domestic goal of deploying 30 gigawatts (GW) of offshore wind energy by 2030.[i] In October 2022, the administration set an additional goal of deploying 15 GW of floating offshore wind energy by 2035 to encourage the development of this resource in deep-water sites like the Pacific Coast and the Gulf of Maine. California, Connecticut, Maine, Maryland, Massachusetts, Louisiana, New Jersey, New York, North Carolina, Oregon, and Virginia also have wind energy targets or goals (as of 2024).

Globally, there are 319 operating offshore wind energy projects, totaling more than 68 GW of capacity (as of 2023); countries with the most offshore wind energy deployed include China, United Kingdom, Germany, the Netherlands, Denmark, and Belgium.[ii] The United States has three fully constructed and operational offshore wind energy projects totaling 174 megawatts [MW], as of October 2024.[iii] These projects are the Block Island Wind Farm, installed off of Rhode Island in 2016; Coastal Virginia Offshore Wind, the first phase of which was installed off of Virginia in 2020; and the South Fork Wind Project, installed off of Rhode Island in 2024. Projects under construction in October 2024 totaled 4,097 MW,[iv] and projects totaling more than 15 GW had been approved for construction by the federal government as of September 2024.[v] See the annually produced Offshore Wind Market Report for information on offshore wind targets, new lease areas, project announcements, and other offshore wind energy activities in the United States and other countries.

Why Offshore Wind Energy?

The advantages of offshore wind extend far beyond it being a clean energy resource. Coastline states and communities are home to a significant portion of the population; about 81% of the U.S. population lives in states adjacent to the coast (including the Great Lakes),[vi] and 40% of the U.S. population lives in coastline counties (i.e., counties adjacent to the ocean or the Great Lakes).[vii] Furthermore, a significant amount of electricity demand—nearly 80%—comes from coastal areas and the Great Lakes.[viii] Offshore wind energy projects have the potential to serve those communities by generating reliable, clean electricity.

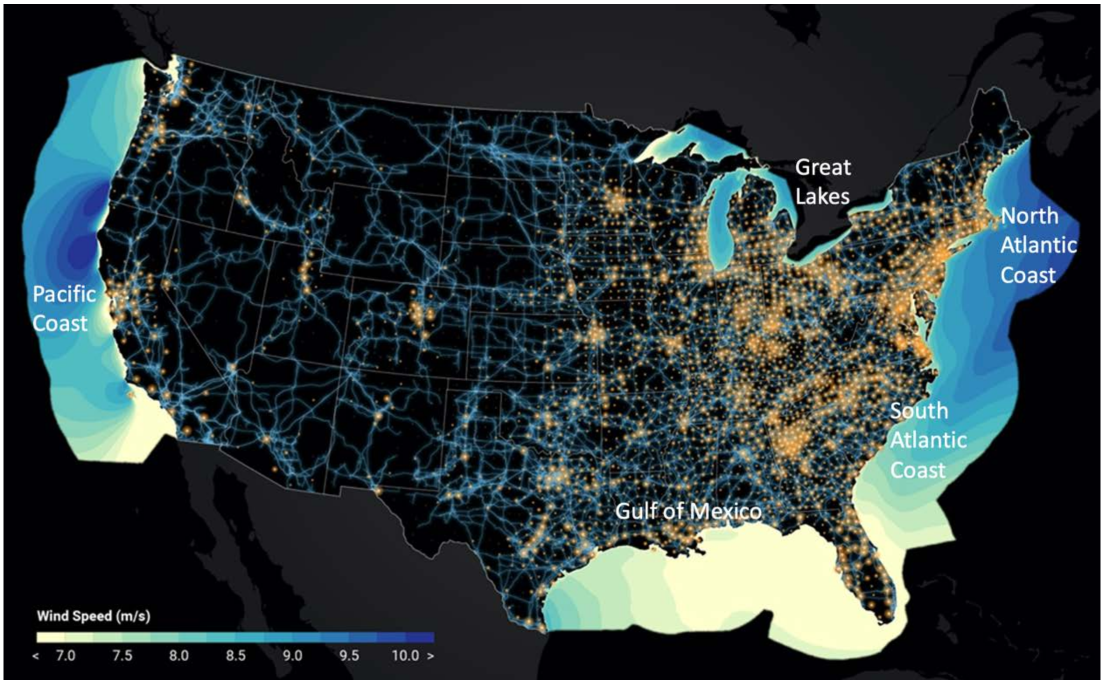

Figure 1. This map of the United States depicts offshore wind speeds and nighttime light emissions, with the latter representing relative differences in electricity demand in different parts of the country. *Figure from Billy Roberts, NREL*

Additionally, offshore wind resources are typically stronger, more abundant, and more consistent than those onshore. The National Renewable Energy Laboratory (NREL) estimates that the technical resource potential for offshore wind energy in the United States is more than 4,200 GW of capacity, or 13,500 terawatt-hours per year of generation, which is about three times the amount of electricity consumed annually in the United States.[ix]

Offshore wind energy projects also generate unique economic opportunities through lease revenues, tax payments, community benefit agreements, job creation, and more. Such activities can benefit states, local communities, and businesses and workforces that provide project support and services. Furthermore, the development of a domestic supply chain for offshore wind energy can revitalize ports and provide additional workforce and business opportunities.[x]

As climate change continues to affect the world, coastal communities are facing impacts such as sea level rise, flooding, and extreme storms. Generating electricity with renewable energy resources like offshore wind can help limit those impacts by reducing the country's greenhouse gas emissions. Offshore wind energy development may also be accompanied by investments in transmission infrastructure upgrades, grid resiliency, coastal resiliency, port and waterfront infrastructure upgrades, marine ecosystem protection, and other priorities that can help coastal communities, and the United States as a whole, adapt to climate change.

Project Anatomy and Component Characteristics

This section explores the specific components of an offshore wind energy project—from wind turbine towers and blades to foundations and substructures. It also explains how an offshore wind turbine connects to onshore infrastructure and the existing electricity grid. Reading this section should provide a clearer understanding of the scale of these projects, the infrastructure needed to support them, and how offshore wind turbines generate electricity.

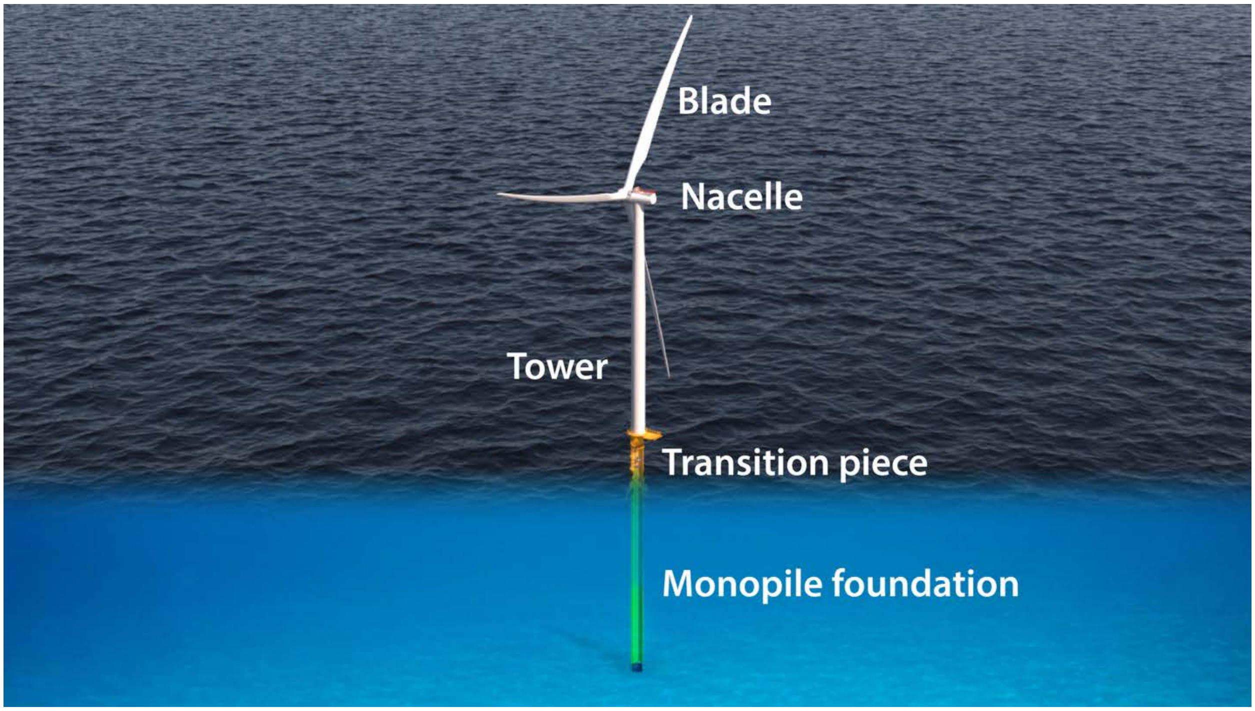

Figure 2. Visualization of the above-water and below-water components of a fixed-bottom offshore wind turbine with a monopile foundation. Blade: most wind turbines have three blades made mostly of fiberglass; blades harness wind energy and cause the rotor to spin. Nacelle: the nacelle converts rotational energy from the rotor into electrical energy; it contains subcomponents like the main bearing and generator. Tower: the tower is a tubular steel structure that supports the nacelle and rotor. Transition piece: the transition piece connects the wind turbine tower to the substructure. Monopile Foundation: this is the most common type of foundation for fixed-bottom turbines; it is a hollow steel tube driven into the seabed. *Image from Josh Bauer, NREL*

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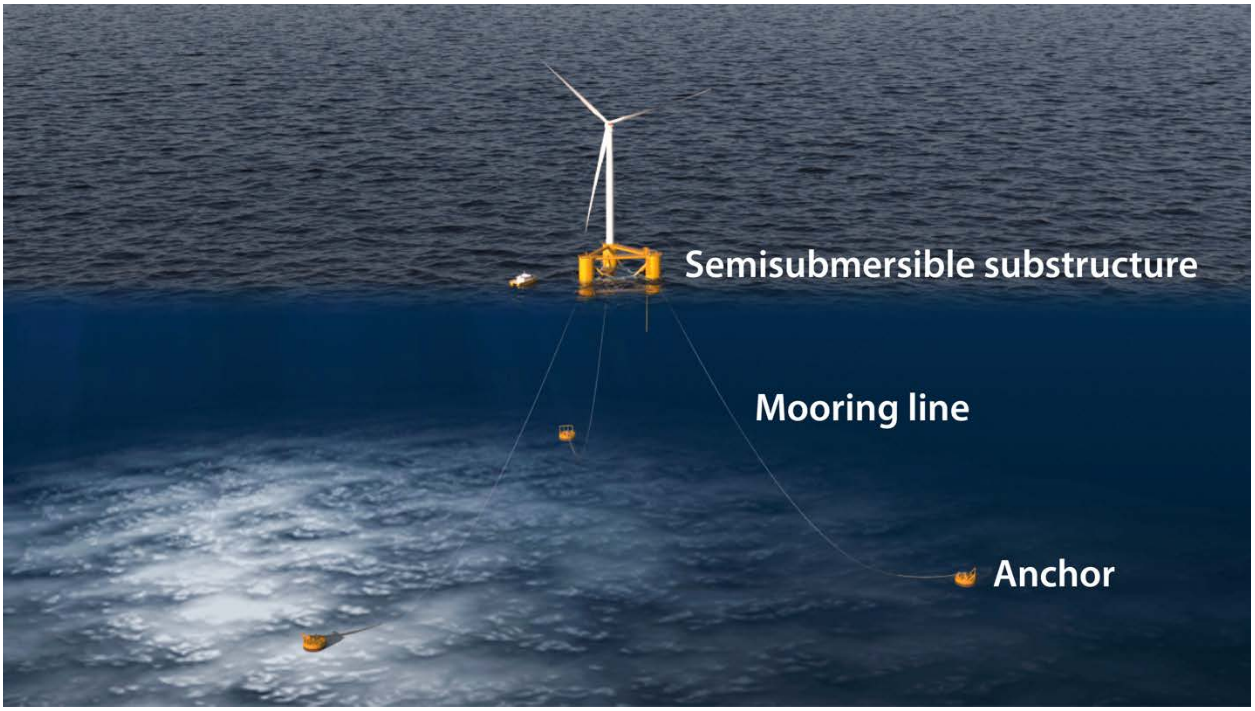

Figure 3. Visualization of the above-water and below-water components of a floating offshore wind turbine with a semisubmersible substructure. Semisubmersible substructure: this is one type of substructure for a floating offshore wind turbine; it keeps the turbine afloat and stable. Mooring line: mooring lines connect the floating turbine's substructure to the seabed; this keeps the turbine stable and secured. Anchor: the anchor is installed within the seabed and keeps the mooring line attached; this is one of several methods for securing mooring systems. *Image from Josh Bauer, NREL*

While the facts and figures introduced throughout this section are accurate snapshots of the offshore wind industry as of 2024, it's important to note that this information is constantly changing with technology and supply chain advancements.

Wind Turbines

Offshore wind turbines capture mechanical energy from the wind to generate electricity. A single offshore turbine can generate up to 15 MW of power at peak output, depending on its size. In 2016, Deepwater Wind built America's first offshore wind project, Block Island Wind Farm, which has five 6-MW turbines with a total installed capacity of 30 MW. Since the Block Island Wind Farm was developed, offshore wind turbines have evolved considerably in both capacity and size. Offshore wind turbines with higher nameplate capacities are already being built and designed; for instance, Vineyard Wind 1, which began construction in 2023, is using 13-MW turbines.[xi]

As nameplate capacities increase, offshore wind turbines also tend to increase in size. Larger wind turbines with higher nameplate capacities are more cost-effective than smaller turbines because fewer turbines are needed to generate a given amount of energy, which can lead to lower overall costs.[xii] As shown in Figure 4, the "hub height"

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for Block Island's 6-MW turbines is 328 feet (ft), but by 2035, the average hub height for offshore wind turbines in the United States is expected to reach 500 ft.[xiii]

An offshore wind turbine's hub height is measured from the water line to the middle of the turbine's rotor; more specifically, hub height is typically measured from the wind turbine foundation's mean lower low-water height, or the average of the lower low-water height of each tidal day observed over the [National Tidal Datum Epoch](). The hub of a wind turbine holds the blades, the blades and hub form the rotor, and the rotor is ultimately connected to the nacelle (described later in this section).

Another way of viewing turbine size is the rotor diameter, or the width of the circle swept by the rotating blades. Rotor diameters have increased over time as larger turbines have been developed; larger rotor diameters allow turbines to sweep more area and produce more electricity, including in areas with lower wind speeds.[xiv] The total height of a turbine is the maximum tip height, or the highest point that a blade tip will reach as the blades rotate. The tip clearance is the lowest point that a blade tip will reach as the blades rotate, measured from the water line. For example, the turbines used in the Vineyard Wind 1 project have a hub height of 358 to 473 ft (109 to 144 meters [m]), a rotor diameter of 538 to 729 ft (164 to 222 m), a total height or maximum tip height of 627 to 837 ft (191 to 255 m), and a tip clearance of 89 to 105 ft (27 to 32 m) (all heights measured from the mean lower low-water height).[xv]

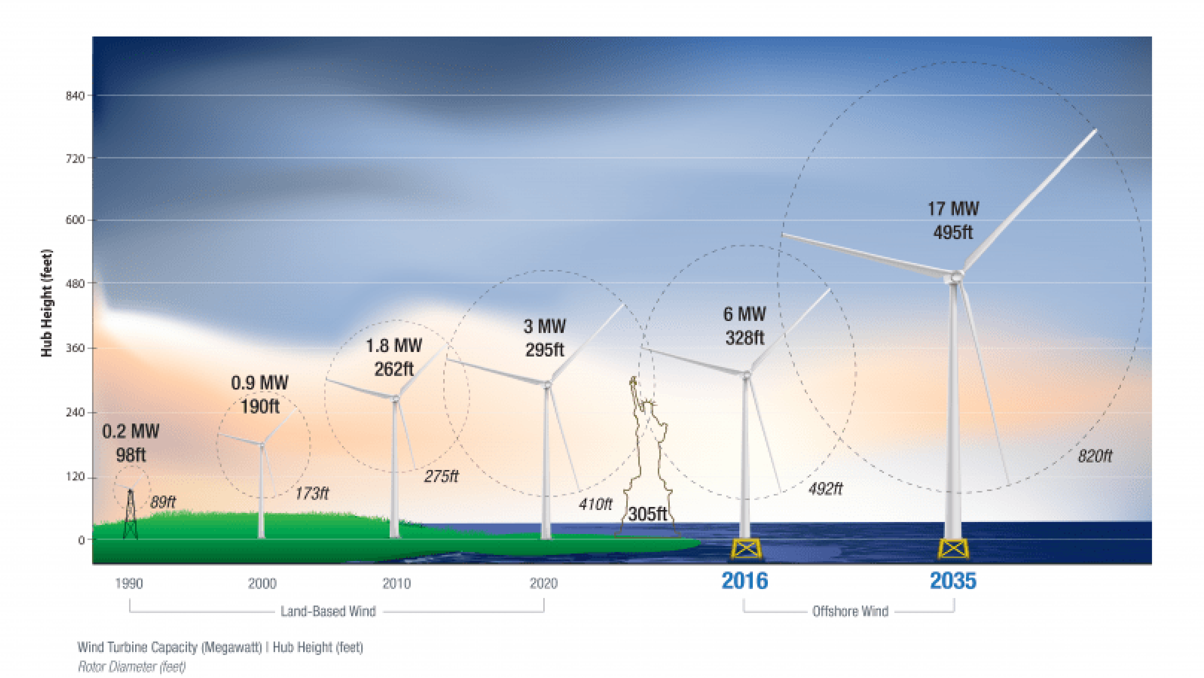

Figure 4. Land-based wind turbines of different heights are shown alongside offshore wind turbines of different heights and the Statue of Liberty for reference. *Figure from U.S. Department of Energy*

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Blades

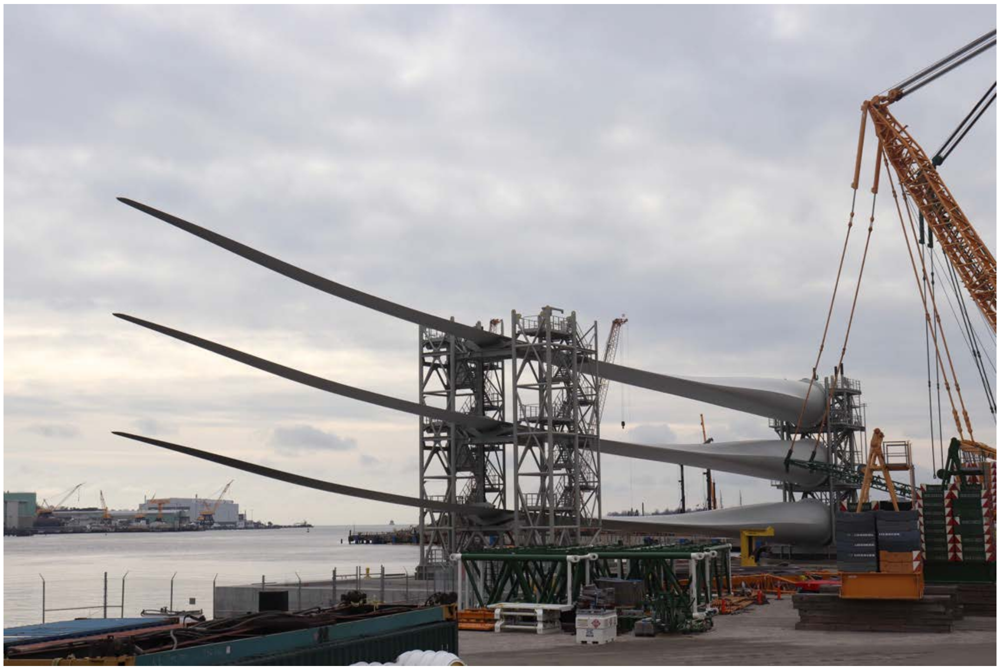

Figure 5. Wind turbine blades for the South Fork Wind project await transportation at State Pier in New London, Connecticut. *Photo from Matilda Kreider, NREL*

Wind turbine blades are made from composite materials designed to be strong, lightweight, and durable so they can efficiently capture energy from wind and transfer it to the rest of the turbine. These blades range in length; the following examples highlight offshore wind turbines that are being deployed or developed as of mid-2024 and their corresponding blade sizes:

- Siemens Gamesa 10.0-193 DD (10 MW): 308-ft blades (94 m)
- GE Renewable Energy Haliade-X (12 MW): 351-ft blades (107 m)
- Vestas V236 (15 MW): 379-ft blades (115.5 m).

While 379-ft-long blades are currently the largest produced in the offshore wind market, there is potential for blades to become longer and heavier. As wind turbines exceed 15 MW, blades could reach a mass of over 60 metric tonnes (t).[xvi]

Given the size and weight of offshore wind turbine blades, they cannot be transported easily over road or rail. Instead, they must be manufactured and assembled at coastal facilities with access to deep channels for vessel transportation.

As blades increase in size, so do rotor diameters. A turbine's rotor diameter, or wingspan, is the width of the circle made by its rotating blades. This is a large distance; a 6-MW offshore wind turbine that has a 328-ft (100-m) hub height might have a rotor diameter of 492 ft (131 m), whereas a 17-MW offshore wind turbine with a hub height of

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495 ft (151 m) might have a rotor diameter of 820 ft (250 m).[xvii] For reference, both these distances are larger than the length of a football field. Larger rotor diameters allow the turbine to capture more wind and therefore produce more electricity.[xviii]

Nacelle

Figure 6. Nacelles for the South Fork Wind project await transportation at State Pier in New London, Connecticut*. Photo from Matilda Kreider, NREL*

The nacelle converts rotational energy from the rotor into electrical energy and houses a series of subcomponents, such as the main bearing and generator, necessary to the function of the overall turbine. Nacelles can weigh up to 600 t.[xix]

Nacelles typically have two configurations: geared or direct drive. Gearless, or direct-drive systems, connect the rotor directly to the generator to produce electricity, whereas geared systems feature a multistage gearbox to convert wind energy into electricity. There are advantages and disadvantages to each type of system. Gearboxes can require more maintenance and repair, which can be difficult to perform in an offshore environment. Direct-drive systems can improve reliability but require expensive rare earth materials. A more detailed explanation of geared and direct-drive systems can be found on the U.S. Department of Energy (DOE)'s website.

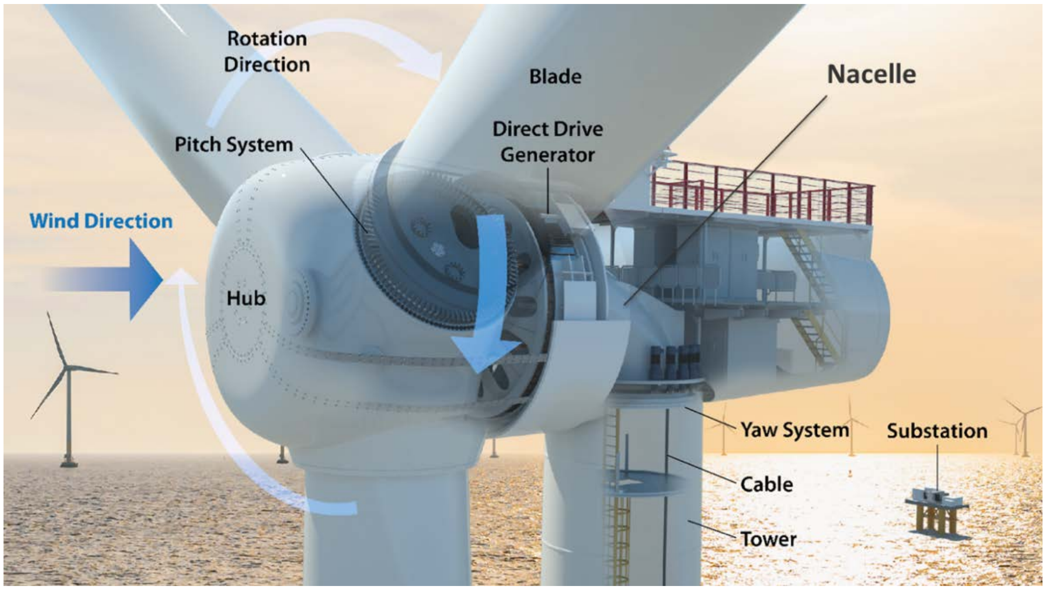

Figure 7. Visualization of some of the external and internal components of an offshore wind turbine. Note: this figure depicts a direct-drive system, which is one of two options for nacelle configurations. *Image from Josh Bauer, NREL*

Tower

Figure 8. Tower components for the South Fork Wind project await transportation at State Pier in New London, Connecticut. *Photo from Matilda Kreider, NREL*

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The tower is a tubular steel structure that supports the nacelle and rotor. Aside from general structural support, the tower also provides storage space for safety, electrical, and control equipment as well as access to the nacelle.

For fixed-bottom offshore wind turbines (i.e., turbines with foundations fixed directly to the seabed), towers can be more than 426.5 ft (130 m) tall, have a base diameter of up to 33 ft (10 m), and weigh about 70 t.[xx] Towers are large structures that are installed in three or more sections and must be connected using flanges (large ring-shaped connecters typically made of steel).

Transition Piece

The transition piece connects the wind turbine substructure and tower. For fixed-bottom turbines, transition pieces are typically more than 98 ft (30 m) tall, have a diameter of at least 28 ft (8.5 m), and weigh about 500 t.[xxi] Transition pieces are made of steel and located at least 66 ft (20 m) above sea level to avoid waves, splashes, and storm surges.[xxii] These components must also have space to house a crew access system and work platform.

Similar to other offshore wind energy project components, the transition piece must be manufactured in a coastal location with a lot of space. Some newer wind turbine designs are integrating the transition piece directly into the substructure to minimize construction time and costs. Without a formal transition piece, a tower can be connected directly to the foundation.[xxiii]

Substructure and Foundation

Offshore wind foundations and substructures are fully or partially submerged below the water line and support the parts of the wind turbine located above the water. There are two main types of offshore wind turbine foundations: fixed bottom and floating. Fixed-bottom offshore wind turbines have foundations that are fixed directly to the seabed and are used in water depths up to about 197 ft (60 m). Floating wind turbines can look the same as fixed-bottom turbines above water but differ in their substructures below water, which are connected to the seabed by mooring lines and an anchor system. Floating offshore wind turbines can be deployed in areas with deeper water (e.g., U.S. Pacific coast and the Great Lakes). While most offshore wind energy projects are currently fixed-bottom, a large potential market exists for floating offshore wind because 80% of global offshore wind resources are in waters deeper than 197 ft (60 m).[xxiv]

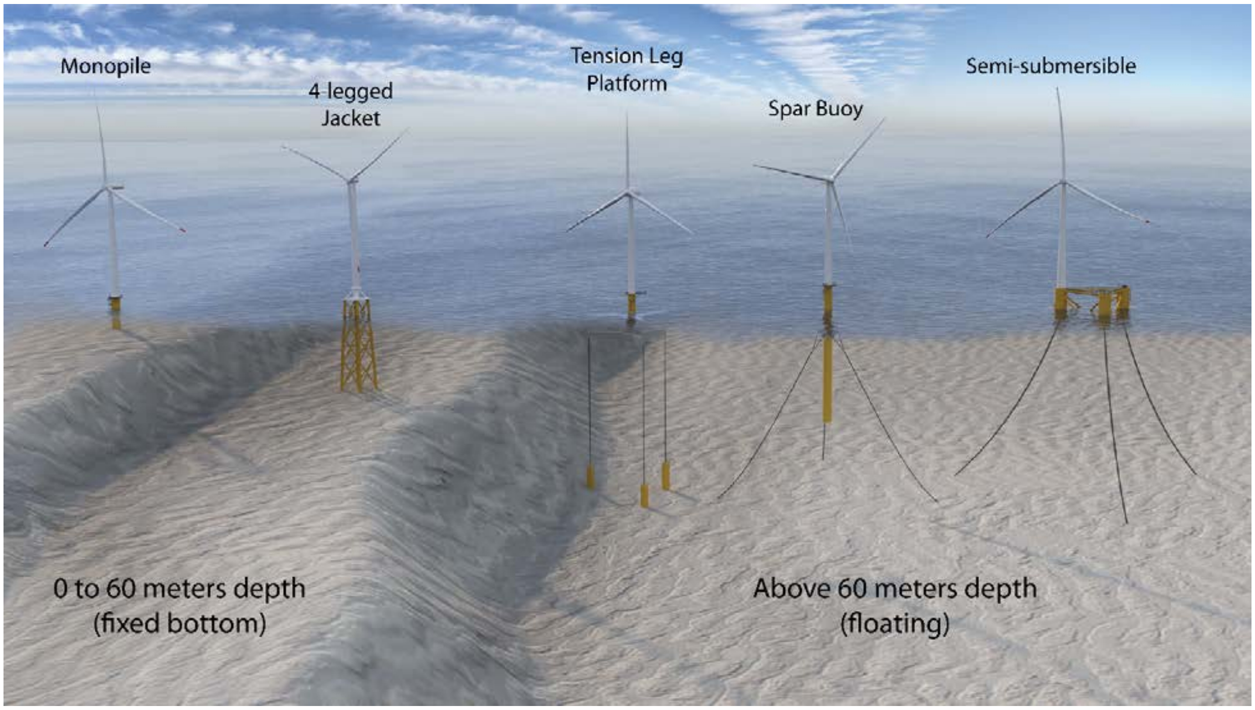

Figure 9. Different turbine substructures and foundations may be used depending on water depth and other factors. *Image from Josh Bauer, NREL*

Fixed-Bottom Foundations

Fixed-bottom offshore wind turbines have several types of foundations; choosing a foundation type depends on the geological conditions and water depths of a particular site. The monopile is the most common foundation type; out of the 68,258 MW of offshore wind energy projects installed around the world through the end of 2023, monopiles represent about 56% of substructures used.[xxv] A monopile foundation is a hollow steel tube driven 100 ft or more into a sand or clay seabed by a large installation vessel. Monopiles are large, heavy structures that can exceed 262 ft (80 m) in height, reach 2,500 t in weight, and have base diameters exceeding 39 ft (12 m).[xxvi] The size of these foundations varies due to water depth and depth of embedment, but they have been planned for use in water depths up to 164 ft (50 m).[xxvii] This threshold could change as larger and heavier monopile foundations are designed to support larger turbines.[xxviii]

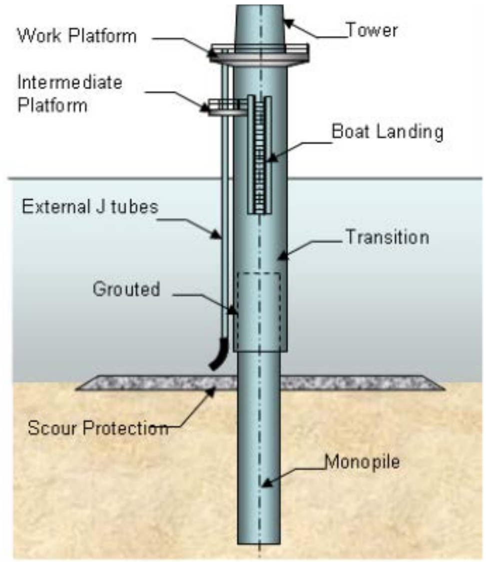

Figure 10. Illustration of a monopile foundation for an offshore wind turbine*. Image from DNV*

The second most common fixed foundation type is the jacket structure, which represents about 13.4% of existing offshore wind substructures deployed globally as of the end of 2023.[xxix] Jackets are four-legged lattice structures also fixed to the seabed, but with watertight suction devices (caissons) or piles. Jackets are most commonly used in water depths around 131 to 197 ft (40 to 60 m); they can be used in water depths up to 197 ft (60 m), a greater water depth than most other fixed foundations.[xxx] Jackets use less material overall than monopiles, can be installed throughout a variety of seabed types (though less well suited for locations with many boulders), and have a higher degree of stiffness, but they are more expensive to manufacture.[xxxi]

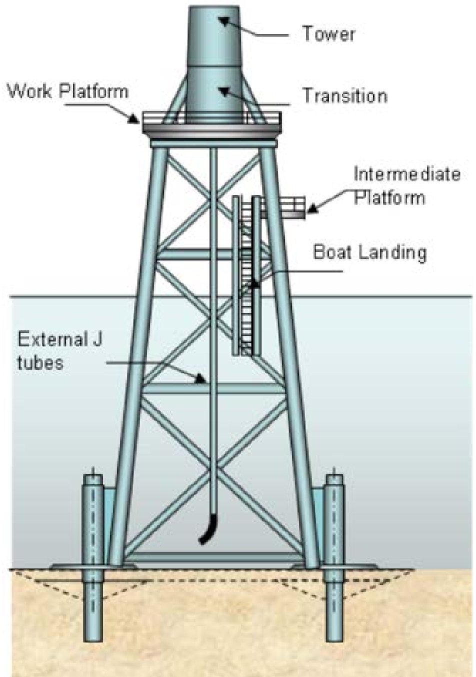

Figure 11. Illustration of a jacket structure for an offshore wind turbine*. Image from DNV*

Tripods are similar to jackets but have three legs and represent about 1.6% of the total existing substructures deployed globally as of the end of 2023.[xxxii] Tripods are most commonly used in water depths around 131 to 160 ft (40 to 50 m), with a maximum water depth of 160 ft (50 m). Tripods are fixed to the seabed with piles or suction caissons and can be installed in a variety of seabed conditions, including locations with many boulders.[xxxiii]

Gravity-base foundations, which make up about 1.3% of substructures deployed globally as of the end of 2023, are heavy concrete or steel structures held in place on the seabed with stones, concrete, sand, or iron ore.[xxxiv] They take more preparation than monopile or jacket foundations because they require a flat and level seabed surface, which may require dredging several meters below the mudline.[xxxv] These heavy structures are built onshore, towed to a project site, sunk using controlled flooding of the structure, and then ballasted (i.e., stabilized) with sand, stones, concrete, or iron ore. They do not need to be embedded in the seafloor and can therefore be used in areas where other fixed-bottom foundation types cannot be used, such as sites with boulders or shallow bedrock.[xxxvi]

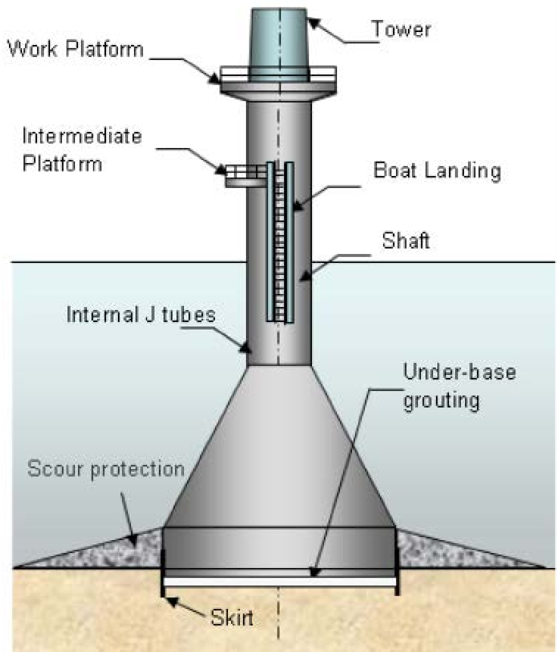

Figure 12. Illustration of a gravity-base foundation for an offshore wind turbine. *Image from DNV*

Each fixed-bottom foundation type comes with unique environmental considerations. Refer to the Siting Considerations section and the Bureau of Ocean Energy Management's (BOEM's) study, *Comparison of Environmental Effects From Different Offshore Wind Turbine Foundations*, for information about the environmental impacts associated with each foundation type.

Floating Substructures

Beyond a water depth of 197 ft (60 m), fixed-bottom foundations become less viable and more expensive to install. As a result, floating platforms present a more viable alternative to fixed-bottom platforms because they can be deployed in deeper waters, which also tend to have stronger wind resources. However, they remain more expensive than fixed-bottom infrastructure because the industry is not yet up to scale. As supply chains and infrastructure develop to support the deployment of floating offshore wind turbines, this technology will likely become more economical. More information on supply chains for floating offshore wind turbines can be found in NREL's report, *The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States.*

There are three leading design types for floating foundations: spars, tension-leg platforms (TLPs), and semisubmersibles. These foundations include components that keep the wind turbine afloat, provide stability to prevent the turbine from overturning, and prevent the turbine from drifting away from the installation location. They differ in how they are stabilized, such as by buoys, ballast (i.e., heavy material placed low in a floating structure), or mooring and anchoring systems; some of the most common substructures are:

- **Spars** comprise a single, large, cylindrical buoy with ballast that supports the overall structure and keeps it upright. These structures typically weigh 800 t and have a diameter of 23 ft (7 m).
- **TLPs** feature a buoyant steel platform held to the seabed by vertically tensioned tethers that provide stability.[xxxvii] TLPs can have up to eight tethers, with diameters ranging from 15 to 59 ft (4.5 to 18 m).[xxxviii]
- **Semisubmersible** substructures have characteristics of both spars and TLPs. They can be made of steel or concrete and comprise two or more partially submerged, buoyant columns held together with braces. The columns are spaced far enough apart to provide stability.

Mooring systems connect the substructures to anchors and include cables that stabilize the overall structure. They limit motion by withstanding horizontal and vertical forces and are secured to the seafloor through various methods. These methods include the use of heavy weights, anchors set below the seabed surface, driven piles resembling monopiles, or watertight suction devices.[xxxix]

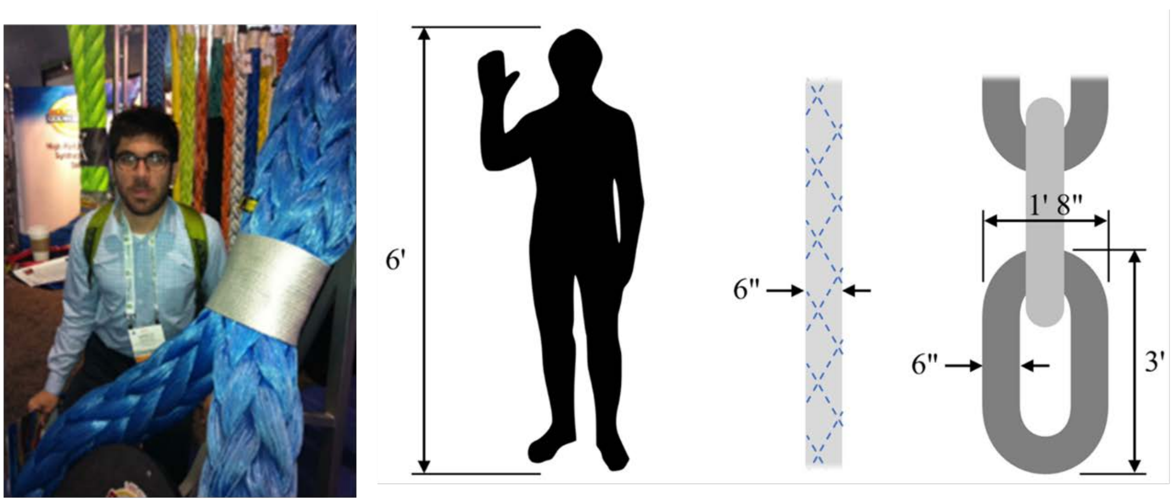

Figure 13. These images depict the size of the mooring ropes and chains in comparison to humans. (left) Rope materials can include polyester, nylon, and polypropylene. (right): A 6-ft-tall outline of a person is compared to representative sections of mooring rope (middle) and a mooring chain link (right). *Photo from Walt Musial, NREL; illustration from Matt Hall, NREL*

The types of mooring systems include:

- **Catenary moorings**, which are heavy steel mooring lines held under low tension. They have the largest footprint but are also the simplest to install. Both spar and semisubmersible foundations use these mooring systems to prevent wind turbines from drifting.[xl]

- **Semitaut moorings**, which have the benefit of significantly reducing the distance between the anchor and the wind turbine without changing the anchor types or substructure design.
- **Taut moorings**, which have the potential to reduce the footprint even further and can provide stability, but require vertical-load anchors and a more complex design. For example, the steel tethers in TLPs provide stability, but require anchors that can withstand the large upward forces created by the floating platform.[xli]

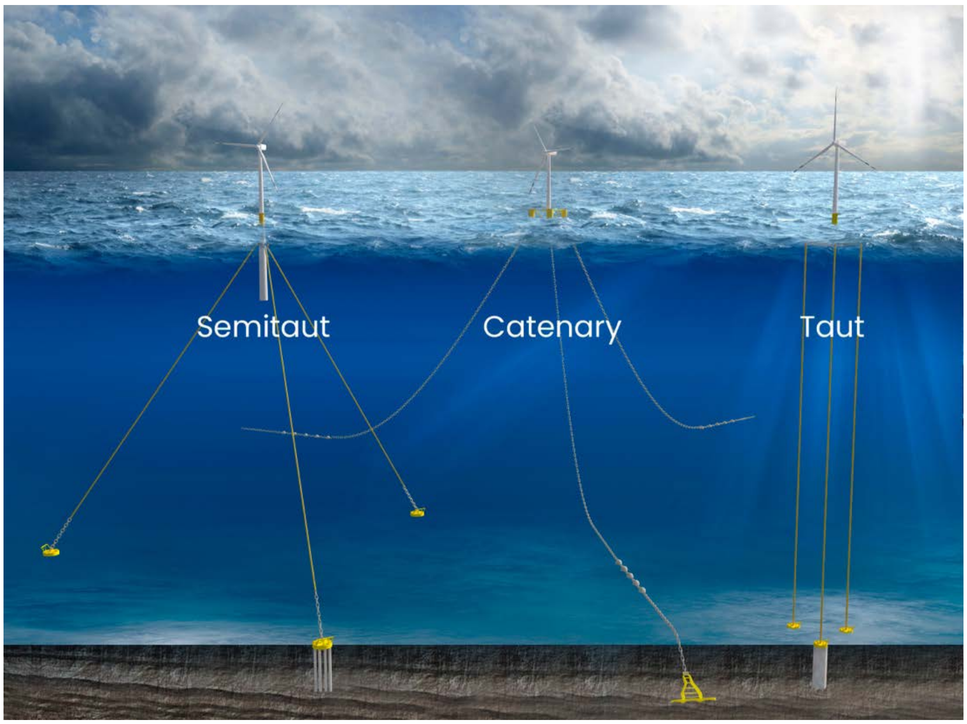

Figure 14. Floating offshore wind turbines can have different types of mooring systems, including semitaut, catenary, and taut. *Image from Josh Bauer, NREL*

Information about environmental effects from floating turbines can be found in a study by BOEM, *Comparison of Environmental Effects From Different Offshore Wind Turbine Foundations*.

Offshore Transmission Infrastructure

Substation

Substations convert electricity generated from wind turbines to a voltage suitable for exporting to the shore. Specifically, substations convert electricity from lower-voltage array cables to one or more higher-voltage export cable(s). The following section describes the differences between these cables.

An offshore wind energy project will usually require between one and three offshore substations.[xlii] The number of substations used is influenced by several factors,

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including the size and layout of the project, distance of the wind turbines from shore, and existing electrical grid infrastructure. Larger wind energy projects with a higher number of turbines generally require more substations to efficiently manage the electricity generated. Layout also matters, as substations may be strategically placed to combine power from different sections of a project. Substations generally increase the voltage of generated power to support efficient transmission to an onshore grid, and longer distances from shore may require more substations to manage voltage levels accordingly.

Figure 15. An offshore substation under construction in the Vineyard Wind 1 project off of Massachusetts. *Photo by Joe DelNero, NREL 90966*

Cables

The types of cables used in an offshore wind energy project depend largely on the foundation; for example, floating wind substructures require dynamic cables that need to accommodate a moving platform and varying tensions in mooring or tension-leg systems.

There are two types of cables in offshore wind projects: array and export. Array cables connect wind turbines to an offshore substation and are usually about 33 kilovolts (kV). Higher-voltage array cables (66 kV) are emerging with larger floating wind projects that require longer cables with higher voltages.[xliii] Export cables connect offshore substations to onshore substations and are similar to array cables but much larger. Export cables can accommodate higher voltages, ranging from 230 to 525 kV.[xliv] The farther offshore a project is built, the longer its export cable needs to be.

Exposed cables are vulnerable to trawling, vessel anchors, and impacts from storms, so it is important to protect this infrastructure. A cable burial risk assessment considers various geophysical (i.e., hard sediments, steep slopes) and co-use (e.g., commercial vessel activity, cultural sites) considerations to inform the depth and type of cable protection.[xlv]

Burying cables is the primary way to protect them and is typically done through trenching, which uses mechanical methods to bury a cable beneath the seabed. In places where burial may be difficult, physical protection (i.e., rocks, concrete mattresses, or half-shell pipes) can cover exposed cable. This kind of protection is common in areas with shallow bedrock or where cables have become exposed due to localized scouring, a process by which water movement erodes and removes sediment or soil from the seabed. After burying cables or applying protection, annual or biannual cable surveys must be conducted to ensure that cables maintain their proper placement.

Dynamic cables that are suspended in the water are used for floating offshore wind turbines because they can accommodate a moving platform and varying tensions depending on the mooring system. These cables connect the floating structure to the main export cable that is buried in the seabed.

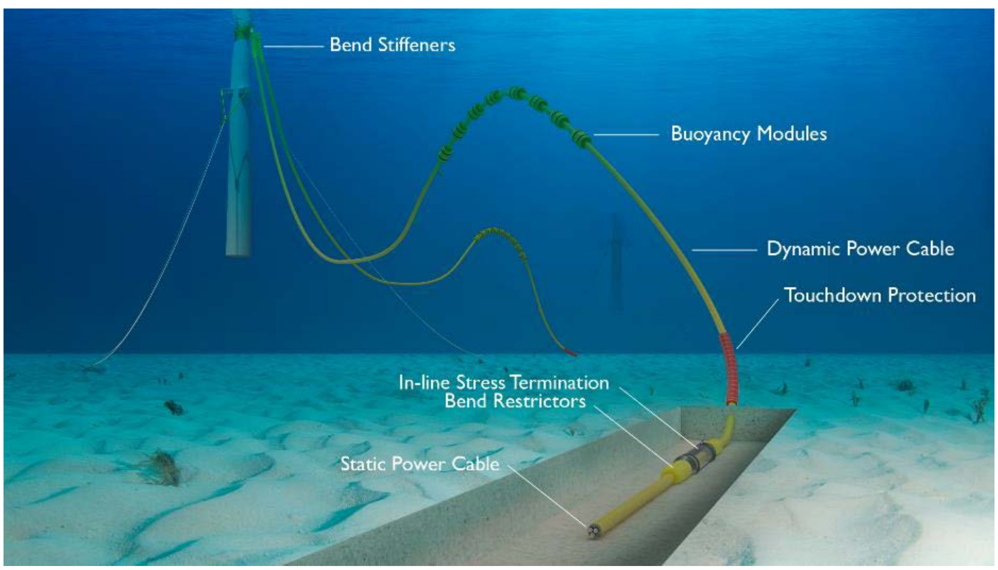

Figure 16. Dynamic cables are used for floating offshore wind turbines to connect the floating structure to the main export cable, which is buried or protected on the seafloor. With fixed-bottom offshore wind turbines, no dynamic cables are necessary. *Image from Josh Bauer, NREL*

Onshore Transmission Infrastructure

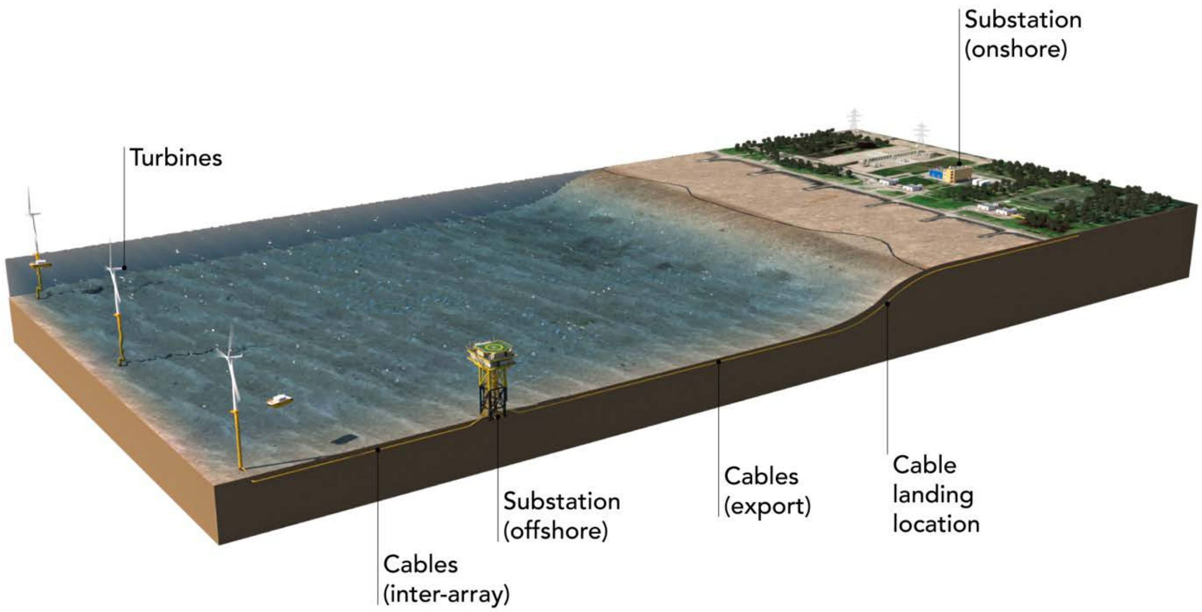

Figure 17. The key infrastructure involved in transmitting power from offshore wind turbines to the onshore grid. Note: this is a simplified visualization that does not depict realistic scale or distances. *Image from Josh Bauer, NREL*

Cable Landing

Landfall is the point at which export cables reach the shore before they are connected to an onshore substation. There are a few ways cables are connected from the seabed to the shoreline. Horizontal directional drilling is a trenchless form of landfall that involves drilling a borehole beneath the seabed from the shoreline to an offshore connection point.[xlvi] Trenching or open-cut methods are another way to make landfall. Trenching involves digging a trench or trench-like depression in the seabed from the shoreline to the offshore connection point. Regardless of installation method, landfall sites are typically reinstated so they can continue to be used. For example, recreational beaches can be used again once installation is complete.

Onshore Substation

Onshore substations convert electricity carried by the export cable to an appropriate voltage for the existing power grid. They occupy an area of about 6 to 9 acres and can include several buildings that contain equipment to measure electricity exported to the grid.[xlvii]

Challenges of Grid Connection

The current electrical grid will need to be upgraded to handle the larger influx of power created by offshore wind turbines. Insufficient grid capacity to integrate offshore wind could lead to curtailments, wherein energy market operators reduce the power output of individual generators to avoid overloading the transmission infrastructure.[xlviii] While curtailment could avert more severe issues on the grid, it can impact energy prices, driving them higher in some locations and lower in others.[xlix]

Transmission infrastructure is often built or upgraded to accommodate the interconnection of individual projects. This can include onsite battery storage that could reduce curtailment.[l] In addition, some regional transmission planning processes identify projects that reduce costs or increase reliability across larger areas, or projects that bring lower-cost wind energy from locations where wind resources are most abundant to where the energy is needed most.[li] These larger regional projects can support the integration of future wind energy, including offshore wind energy.

One option being explored by some transmission decision makers is the idea of an ocean-based grid in which multiple offshore wind energy projects are connected; this coordinated planning approach could reduce the costs, time, and permitting required to connect a new project to the onshore grid and reduce the environmental and community impacts of cable construction.[lii]

Ports and Vessels

Figure 18. At a port in Denmark, blades are loaded onto a vessel to be transported to an offshore wind energy project site. *Photo from Siemens AG 27843*

The offshore wind energy industry will continue to grow over the next decade, and ports and manufacturing facilities will need to be designed to accommodate larger wind turbine components that cannot be transported over road or rail. Offshore wind ports have essential characteristics, which usually include a staging area where vessels are loaded, considerable depth for vessels coming in and out, and air draft that offers enough vertical clearance for vessels and cargo. Additionally, they are typically located close to the project to minimize cost, transit time, and worker fatigue.

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The success of the offshore wind energy industry depends on large investments in the nation's port infrastructure. Refer to the Supply Chain, Ports, and Vessels section of this guide for further information on the current state of the offshore wind port and vessel infrastructure in the United States as well as a discussion of supply chain development and capacity.

Creating an Offshore Wind Energy Project

Developing offshore wind energy projects involves coordination between a wide variety of stakeholders and processes such as leasing, permitting, and financing that can take years or even decades to complete. In this section, we focus on [the Bureau of Ocean Energy Management's leasing process] for projects in federal waters (which begin 3 miles from shore in most states) and the activities that developers are responsible for, such as project financing. Other key processes like the development of offshore wind energy projects in state waters, states' procurement of energy, and the role of local governments in developing onshore infrastructure are discussed in the State and Local Involvement section.

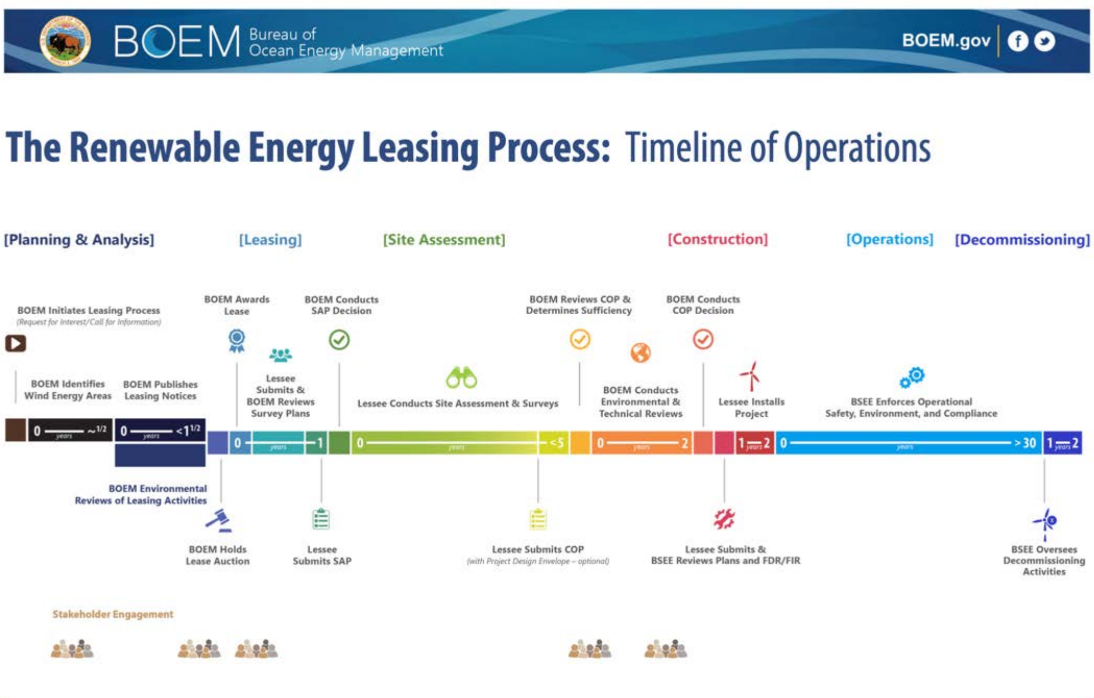

Figure 19. Timeline of BOEM's renewable energy leasing process. *Figure from BOEM*

BOEM Leasing Process

[The Bureau of Ocean Energy Management (BOEM)] resides within the U.S. Department of the Interior and is the government agency responsible for authorizing the development of offshore energy projects located on the Outer Continental Shelf, including oil and gas and renewable energy such as offshore wind energy. BOEM's process for offshore wind energy takes place in four phases: planning and analysis, leasing, site assessment, and construction and operations. Opportunities to engage in BOEM's processes are highlighted throughout this section, and additional information about how to engage can be found in the Engagement section of this guide.

Planning and Analysis

The planning and analysis phase often begins with states or territories requesting that BOEM establish an Intergovernmental Renewable Energy Task Force for their state, territory, or region.[liii] Task forces may include representation from federal, state, local, and Tribal governments and are intended to collect and share information in consideration of potential offshore renewable energy activities. As of mid-2024, BOEM had established both individual state and multistate task forces along the Atlantic, Gulf of Mexico, and Pacific coasts. An example of a multistate task force is the Gulf of Maine Intergovernmental Renewable Energy Task Force, which includes Maine, New Hampshire, and Massachusetts.[liv]

During the planning and analysis phase, BOEM "seeks to identify suitable areas for wind energy leasing consideration through collaborative, consultative, and analytical processes that engage stakeholders, Tribes, and State and Federal government agencies."[lv] This phase involves activities such as identifying wind energy areas, soliciting input through public comment periods and public meetings,[lvi] conducting environmental assessments and reviews, and consulting with Tribes, governments at different levels, and ocean users.

As an initial step, BOEM publishes a Call for Information and Nominations to gauge competitive interest in areas where commercial offshore wind leasing could take place, as well as request comments from interested and affected parties regarding site conditions, resources, and other uses of those areas. If competitive interest does not exist, BOEM may choose to not grant leases in that area or to negotiate a lease with a sole interested developer rather than holding a lease auction. If competitive interest exists, BOEM may proceed with the area identification process for a potential lease auction in the second phase.

Area identification is a two-step process that considers multiple competing uses and environmental concerns that may be associated with a proposed area's potential for commercial wind energy development. First, BOEM publishes draft wind energy areas for public comment, which is not a regulatory requirement but contributes to a more transparent and inclusive process. Second, BOEM reviews comments received on the draft wind energy areas before publishing final wind energy areas and a Notice to Prepare an Environmental Assessment under the National Environmental Policy Act (NEPA).[lvii] The objective of the Environmental Assessment is to estimate the nature,

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severity, and duration of impacts that might occur from site assessment and site characterization activities, and to compare the impacts of the various alternatives for a proposed offshore wind energy lease sale. BOEM requests public comments on both the Notice to Prepare and the draft Environmental Assessment as part of this process.

Outside of this process, offshore wind energy developers may also submit an unsolicited lease request, which lets BOEM know that there is interest from developers in a certain area. For example, two developers submitted unsolicited lease requests to BOEM in 2022 for proposed offshore wind energy projects off the coast of Washington.[lviii]

Leasing

The leasing phase results in the issuance of a commercial wind energy lease either through a competitive or noncompetitive process. If competitive interest does not exist, BOEM may choose to not grant leases in that area or negotiate a lease with a sole interested developer. If competitive interest exists, BOEM will hold a lease auction in which developers compete for a lease through bidding.

In the first step of the competitive process, BOEM publishes a Proposed Sale Notice for public comment that contains information about potential lease areas in a wind energy area available for leasing; certain lease provisions and conditions; auction details; criteria for evaluating competing bids; and procedures for lease award, appeals, and lease execution. BOEM reviews and considers the comments received on the Proposed Sale Notice before publishing the Final Sale Notice, which contains descriptions of the lease areas available for bidding by developers and the auction date.

Figure 20. One turbine in the Block Island Wind Farm*. Photo from Dennis Schroeder, NREL 40450*

BOEM holds offshore wind lease sales through auctions that occur over a series of rounds, where the asking price generally increases in each round. The initial bid amount is set by BOEM based on the expected level of interest and economics of the area. During the auction, BOEM posts information on its website for the public, including the price and number of bidders on each lease area after each round concludes. Ultimately, the auction ends when there is only one bidder on each lease area (i.e., the bidder who was willing to pay the most for the lease area). The actual cash bid paid in an auction depends on any bidding credits awarded before the lease sale to a developer. BOEM's auctions have lasted anywhere from a few hours to several days depending on the number of lease areas and bidders and the level of interest.

BOEM can include provisions in a lease to enforce certain requirements and/or encourage developers to take certain actions. For example, some leases have stipulations requiring developers to make every reasonable effort to:

- Enter into project labor agreements.
- Submit a statement of goals for domestic supply chain development.
- Develop plans to engage with Tribes, fisheries, and agencies.
- Report on the engagement they have done with communities, stakeholders, and Tribes that may be impacted by their activities in the lease area to BOEM.

Bidding credits are another way to incentivize certain actions or investments within the lease sale process. If a bidder meets specific requirements before the lease sale, a bidding credit may be added to the component of their bid to meet the asking price. For example, the 2023 Gulf of Mexico lease sale included a credit for bidders who committed to contributing monetarily to workforce training programs and supply chain development, as well as a credit for bidders who committed to contributing funds to a fisheries compensatory mitigation fund.[lix] BOEM has a limit of 25% of the asking price for bidding credits to ensure fair return from BOEM's lease auctions.

A commercial lease does not give the developer or lessee the right to begin constructing offshore wind energy projects; rather, the lease grants the right to conduct site assessment activities and develop plans, which must be approved by BOEM.

Additional information about BOEM's leasing studies, administrative documents and information, and up-to-date information on existing leases can be found on BOEM's website.

Site Assessment

During the site assessment phase, a lessee or developer conducts studies and surveys to characterize the site and assess its wind resource. Conducting site characterization studies allows developers to understand key aspects of the site that may impact project development decisions; for example, developers may conduct surveys using vessels to map the seafloor and identify sensitive habitats and archaeological sites that may need to be avoided or protected. Key aspects of site characterization include avian surveys; geophysical, geotechnical, and geohazard surveys; archaeological and historical property surveys; fisheries surveys; benthic habitat surveys; and marine mammal and sea turtle surveys. All of these activities help developers optimize their project design (e.g., wind turbine location, spacing) and minimize negative impacts to the environment, marine species, or cultural resources. More information about BOEM's guidelines and recommendations for site characterization studies can be found on BOEM's website.

During the site assessment phase, a lessee will collect meteorological and oceanographic data, typically using meteorological buoys or towers. With advancements in lidar technology, it is now more likely that buoys will be used for this purpose than towers. The lessee may also provide BOEM with information about the technology that will be deployed to conduct site assessment activities and how potential impacts to the marine environment and wildlife will be minimized.

More information about the considerations that factor into project siting can be found in the Siting Considerations section.

Construction and Operations

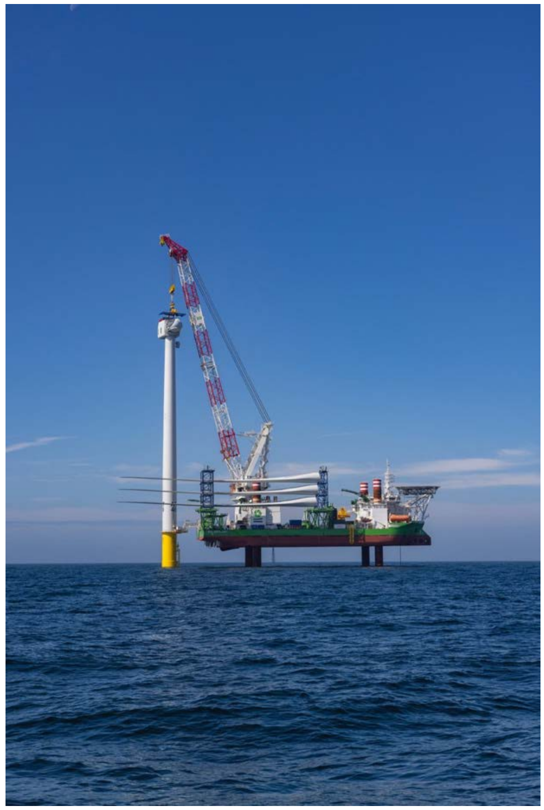

Figure 21. An offshore wind turbine is installed in 2023 as part of the Vineyard Wind 1 project off of Massachusetts. *Photo from Joe DelNero, NREL 90946*

Before construction can begin, the lessee or developer must develop a Construction and Operations Plan (COP) that provides detailed information about how the lessee will construct and operate the offshore wind energy project. The COP is informed by the results of the site assessment and characterization activities conducted in the previous site assessment phase. COPs may vary in terms of their content and organization, but some activities that may be reported in the plan include:

- Assessing acoustics
- Conducting geotechnical surveys
- Investigating geoelectric and magnetic fields
- Studying impacts to marine species, marine ecosystems, birds, bats, and onshore ecosystems
- Evaluating visual impacts
- Assessing impacts to fisheries and the fishing industry
- Analyzing economic and workforce impacts
- Investigating marine archaeological and cultural resources.[lx]

Additionally, the COP may contain project-specific information, such as the design of each structure involved in the project, safety and environmental protection features or measures, and operating procedures and systems during normal conditions and in the case of accidents or emergencies.[lxi] A full list of items to be included in the COP can be found in BOEM's guidance document, *Information Guidelines for a Renewable Energy Construction and Operations Plan (COP)*, and many of these items are available to be viewed by the public on BOEM's website.

BOEM conducts environmental and technical reviews of the COP, including an Environmental Impact Statement under NEPA, and BOEM and the Bureau of Safety and Environmental Enforcement (BSEE) conduct consultations with Tribes, states, and federal agencies to ensure obligations are met. BOEM consults with Tribes, conducts meetings with potentially affected ocean users and stakeholders, and has public comment periods during its NEPA review of the COP to inform its eventual decision about the COP. To receive the necessary certifications, identify mitigation measures, and adopt conservation recommendations for a project, regulations require BOEM to consult with Tribes and other state and federal agencies under a variety of laws, including the National Historic Preservation Act, Endangered Species Act, and Coastal Zone Management Act. The directives and statutes governing these consultations delegate a range of authorities to the entities responsible for overseeing the individual processes. All of these consultation processes inform BOEM's decision making, and some can impose nondiscretionary requirements to mitigate (i.e., avoid, minimize, or compensate for) potential effects of activities authorized by BOEM.

Following these reviews and consultations, BOEM publishes a Record of Decision in which it can approve, approve with modification, or disapprove the COP. BOEM's publication of the Final Environmental Impact Statement and Record of Decision on a COP initiates the next phase in constructing an offshore wind energy project. Environmental monitoring, information collection, and analysis continue throughout the construction phase and inform the process.

The operations phase of an offshore wind energy project is expected to last 25 years or more. As part of the COP, the lessee must submit conceptual decommissioning plans and file financial assurance for decommissioning, meaning there is a financial guarantee that the developer will remove the infrastructure at the end of its service life. Prior to the end of the lease term, the lessee must submit a decommissioning application with more detailed plans to BSEE. BOEM and BSEE require that all project components be removed to 15 ft below the mudline, and that decommissioning must be complete within 2 years following the lease termination.[lxii] More information on BOEM's decommissioning regulations can be found in BOEM's study, *Supporting National Environmental Policy Act Documentation for Offshore Wind Energy Development Related to Decommissioning Offshore Wind Facilities*.

Bureau of Safety and Environmental Enforcement

Like BOEM, BSEE is an agency within the U.S. Department of the Interior. In January 2023, regulations governing workplace safety and environmental compliance for offshore renewable energy activities were transferred from BOEM to BSEE.[lxiii] BSEE oversees enforcement of safety and environmental requirements for facility design, fabrication, installation, operation, and decommissioning of renewable energy projects on the Outer Continental Shelf. BSEE is involved in analyzing materials submitted by lessees, such as COPs, decommissioning cost estimates, and decommissioning plans.[lxiv]

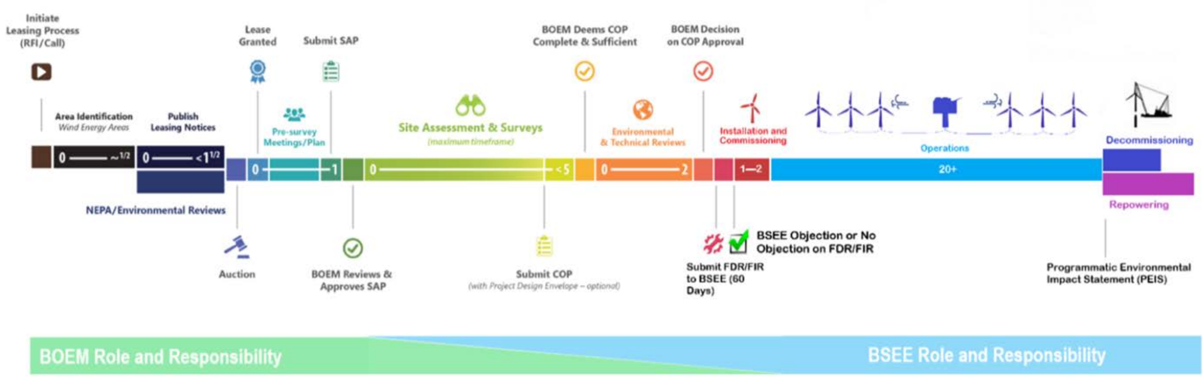

Figure 22. This timeline of renewable energy leasing, construction, operations, and decommissioning demonstrates BOEM and BSEE's respective responsibilities. *Figure from BSEE*

Developer Processes and Decision Making

Project Planning

Offshore wind energy developers may spend years assessing sites, markets, and technologies before entering the leasing phase for an offshore wind energy project. This includes making important decisions such as determining the most feasible ways to develop the lease area, how large the project should be, what other companies (e.g., utilities, other developers) the company could partner with to develop the project, and how to finance the project. Early planning phases also involve activities such as surveying and monitoring sites, conducting economic research on the viability of a project, engaging with other stakeholders like BOEM and state governments, evaluating power markets, and assessing supply chain and workforce needs and capabilities in a given region. These activities help developers evaluate the viability of a potential project and prepare for the efforts, coordination, and investments needed to make the project successful.

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In the early stages of planning a project, developers may engage with the public and specific stakeholder groups about project decisions. More information about engaging with developers can be found in the Engagement section of this guide.

Financing

Developing offshore wind energy projects is complex, capital-intensive, and risky, as developers must bear the cost of competing for leases, conducting site assessment and surveying activities, competing for state offtake agreements, and obtaining permits before they reach the stages of constructing, operating, maintaining, and eventually decommissioning their projects.[lxv] Developers may also play a significant role in developing the supply chain and workforce necessary to support project development, which can involve costs related to actions like investing in port facilities and establishing workforce programs. Another consideration is the costs associated with community engagement and impact mitigation, such as employing Tribal and community liaisons, compensating impacted communities, and forming community benefit agreements.

On top of these costs, developers must also confront the risky nature of offshore wind energy development.[lxvi] Long development timelines, potential delays related to permitting and interconnection, changing supply chain costs, and inflation are just some of the dynamics that introduce risk into offshore wind energy development. Additionally, risks associated with the construction and operations and maintenance of offshore wind energy projects include weather delays, vessel availability, and technology nonperformance or failure.

With these costs and risks to consider, project financing is a significant part of the process of creating an offshore wind energy project. Some of the primary financing sources or models[lxvii] present in the offshore wind industry are:

- **Internal sources of financing**, in which developers may use their own profits or other internal sources of revenue to finance some aspects of project development
- **External sources of financing**: because of the high initial costs of developing an offshore wind energy project, developers typically must seek out external financing, including:
  - **Debt sources of financing**, such as bank loans, tax equity financing, and bonds
  - **Project finance**, a special financing mechanism for large-scale investments, through which developers take on debt at the project level rather than the company level
- **Joint venture**, in which two or more entities enter a business arrangement to jointly develop an offshore wind energy project.

Joint ventures are common both in the U.S. offshore wind energy market and globally, which is why offshore wind energy projects often have more than one company's name attached to them. Joint ventures allow companies to share responsibilities (such as providing capital and developing project designs), share resources such as staff and expertise, and share risks.[lxviii] Developers that are developing multiple projects may not have the same partners for each one, and they may choose to pursue joint ventures for some of their projects and not for others.

Tax equity financing allows developers to recoup some of the capital costs of their project once it is operational; this can be done through tax credits such as the federal investment tax credit. The Inflation Reduction Act of 2022 extended offshore wind energy's eligibility for the investment tax credit of 30% for at least 10 years; attaining the 30% tax credit level requires paying a prevailing wage and meeting registered apprenticeship requirements.[lxix] Additionally, developers can receive bonus credits of 10 percentage points each if they meet domestic content thresholds (i.e., a certain amount of manufacturing activities and steel production taking place within the United States) or if they locate onshore grid interconnection facilities in energy communities (e.g., former coal communities or communities with a certain unemployment rate and fossil fuel employment rate).[lxx] The Inflation Reduction Act also includes per-watt manufacturing credits for the domestic manufacturing of components like wind turbine blades and offshore wind vessels. More information on the impact of the Inflation Reduction Act on the offshore wind industry can be found in NREL's *Offshore Wind Market Report: 2024 Edition*.

In some cases, developers may restructure their project financing or adjust their plans for the project because of changes in costs, risks, or other issues that arise during project development. Developers may even decide not to go forward with a project that is no longer financially viable, though this is uncommon.

Links to Relevant Resources

BOEM: Information Guidelines for a Renewable Energy Construction and Operations Plan (COP)

BOEM: National Environmental Policy Act and Offshore Renewable Energy

BOEM: What Is The Environmental Impact Statement (EIS) Process?

BOEM: Guidelines for Information Requirements for a Renewable Energy Site Assessment Plan (SAP)

BOEM: Strengthening the Intergovernmental Renewable Energy Task Forces

BOEM: Wind Energy Commercial Leasing Process

Siting of Turbines and Transmission Infrastructure

Siting offshore wind energy projects involves assessing a variety of factors to find a location that will support a successful project. Ideally, a site will have a strong wind resource and allow developers to maximize energy production and project benefits while also minimizing project costs and any potential adverse impacts to communities, existing industries, and the environment as much as possible. This section introduces some of the considerations that accompany offshore wind energy siting, including wind resource, distance from shore, interactions with existing ocean users, transmission and interconnection, seabed composition, depth, and environmental factors. Please see the Creating an Offshore Wind Energy Project and State and Local Involvement sections for more information about siting and permitting processes conducted by BOEM, state agencies, local governments, and others.

Wind Resource

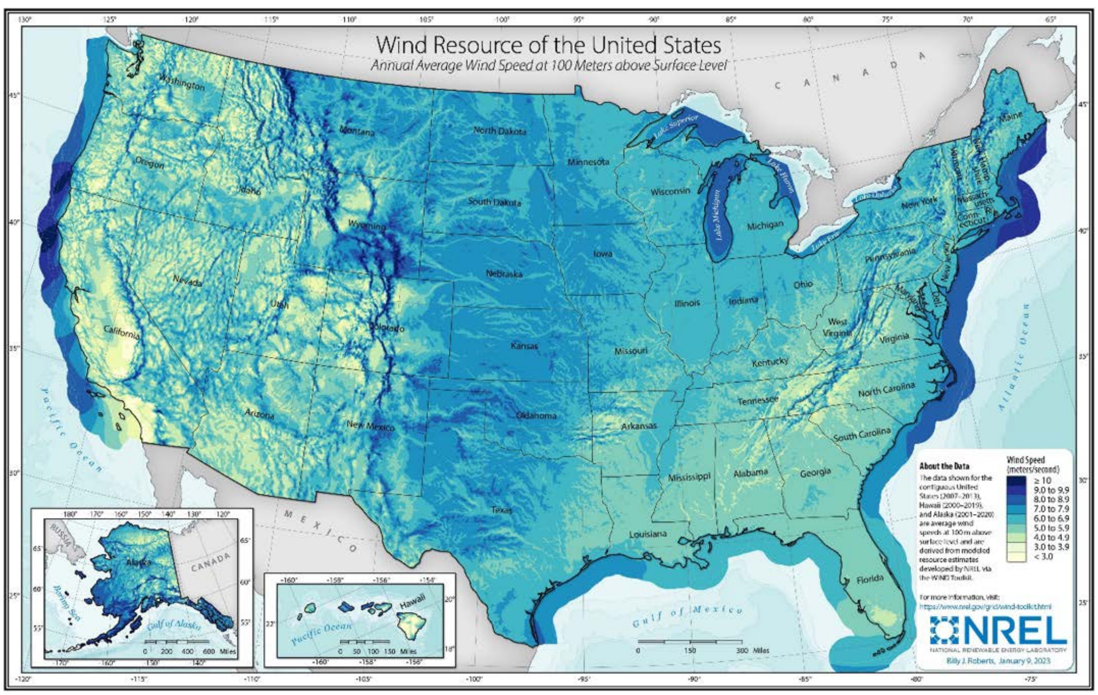

Figure 23. Map of wind resource throughout the United States, which shows annual average wind speed at 100 meters above surface level. *Figure from Billy Roberts, NREL*

The wind resource is the amount of available and usable wind energy in a specific area measured over a certain time period. It is defined according to a few characteristics: wind speed probability, prevailing wind direction, diurnal (daily) and seasonal variations, and wind shear, or the change in wind speed and direction up and across different altitudes. At its maximum estimate, the contiguous United States (i.e., lower 48 states

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and the District of Columbia) has about 4,300 GW of offshore wind technical potential, which is a measure of achievable energy generation given system performance, topographic, environmental, and land-use constraints.[lxxi] This is more than three times the nation's annual electricity use.[lxxii]

Offshore wind is typically stronger and more consistent than on land, though it can vary geographically. In the United States, areas with average wind speeds greater than about 7 meters per second are considered viable for offshore wind energy development.[lxxiii]

Wind resource assessments measure the technical potential of an area and occur before the siting, construction, and operation of a wind energy project. A project developer will typically conduct these assessments to better inform wind turbine placement and construction. On a broader scale, states and the U.S. Department of Energy's Wind Energy Technologies Office support several wind resource assessment initiatives, such as NREL's wind resource maps and the Wind Forecast Improvement Project being carried out by a number of national laboratories and other research institutions. For more information on wind resource assessment and characterization, see DOE's website.

Wind resource is usually measured at the turbine hub height to reflect conditions across the area swept by the rotor. While wind resource measurements can be taken on onshore and offshore meteorological towers equipped with anemometers and wind vanes, these methods do not always produce results that reflect the wind resource at the exact location of wind turbine placement. Buoy-based wind speed measurements have the potential for increased accuracy because these mobile systems can be deployed to capture location-specific wind resource characteristics. Anemometers are commonly mounted on buoys to collect wind speed and direction data at different timescales, typically every 10 minutes or hour.[lxxiv] More recently, buoys have been equipped with lidar, a technology that uses laser beams to measure wind speeds at different heights and produces some of the most reliable and accurate estimates for offshore wind speeds.

Distance From Shore

To determine an offshore wind energy project's distance from shore, developers must balance a range of considerations, such as economic factors, minimization of visual impacts and impacts to other ocean users (e.g., fishers, shipping industry), and the challenges of using longer cables. To add to this complexity, a project's distance from shore also determines jurisdictional authority, which subjects a project to different regulatory processes.

Offshore wind projects can be sited in state or federal waters; state waters usually extend to 3 nautical miles (about 3.5 statute miles) offshore, although in Texas and on

Florida's western coast, the states have jurisdiction out to 9 nautical miles (about 10.3 statute miles) offshore.[lxxv] Project siting in state waters is managed by state agencies like the Louisiana Department of Natural Resources, whereas project siting in federal waters is managed by BOEM.

State waters are home to the country's first offshore wind energy project, the Block Island Wind Farm, which is located approximately 3 statute miles off the southeastern coast of Block Island in Rhode Island state waters. Future offshore wind energy projects in the Great Lakes region will fall under state jurisdiction, and projects in other regions like the Gulf Coast may be sited in state waters as well.[lxxvi] Refer to the State and Local Involvement section for more information on offshore wind development in state waters and the roles that state governments play.

Although the first offshore wind project in the Unites States is in state waters, most offshore wind projects are expected to be deployed in federal waters starting at about 15 to 20 miles from shore, but this could expand beyond 20 miles.[lxxvii] For example, Vineyard Wind 1 and the Coastal Virginia Offshore Wind projects are both sited in federal waters, 15 miles and 27 miles offshore, respectively. Still, some project-related infrastructure, like export cables, will pass through state waters and be subject to state jurisdiction.

Offshore wind energy projects that are sited further offshore minimize the visual impacts of wind turbines on coastal communities, reduce potential conflicts with other coastal uses, and benefit from the higher average offshore wind speeds generally observed with greater distances from shore. At the same time, increased distances drive up the cost for transmission infrastructure, project installation, and operations and maintenance due to longer transportation times to the project site. A visual depiction of an offshore wind turbine at different distances from shore can be found in the Community Considerations section.

Interactions With Existing Ocean Users

Determining the areas where other types of ocean use or competitive interest are already present is an important part of the planning and analysis activities for offshore wind energy development. Depending on the location, it may be necessary to consider maritime traffic routes, fishing activity, recreation, cultural and historical heritage sites, marine protected areas, and military areas. The National Oceanic and Atmospheric Administration (NOAA) and BOEM maintain a collaborative Marine Cadastre database with more than 300 map data layers that contain information about the interests listed earlier as well as other ocean boundaries, uses, and restrictions. Spatial modeling with NOAA's National Centers for Coastal Ocean Science helps BOEM model and identify suitable areas for wind energy development that minimize potential conflicts and reduce the environmental footprint of offshore wind energy activities in the ocean ecosystem. Tribal fishing, treaty, and subsistence rights are also major considerations in wind energy project planning and are further discussed in the Tribal Considerations and Involvement section.

For example, in the South Atlantic region, U.S. Department of Defense restrictions make up the largest area of competitive co-use. Nearly 70,000 square kilometers in size, this area is off limits to wind energy development because of military restrictions such as submarine transit routes and danger zones.[lxxviii] Other military-related concerns in this area include radar system interference and reflections from rotating blades.[lxxix]

Co-use considerations can also include future developments, such as planned shipping fairways. Relative use indices, which determine the value and use of existing traffic and fishing lanes, can be useful resources when assessing areas of overlap and narrowing final areas for offshore wind energy project development.[lxxx]

More information about ocean co-use and offshore wind energy can be found in the Community Considerations section of this guide.

Transmission and Interconnection

Figure 24. Upgraded grid infrastructure on Block Island, Rhode Island, after the construction of the Block Island Wind Farm. *Photo from Dennis Schroeder, NREL 40394*

Energy generated by offshore wind turbines is transferred onshore and connected to the grid through transmission infrastructure that includes array cables, export cables, offshore and onshore substations, and cable landing areas (refer to the Project Anatomy and Component Characteristics section for more information about individual

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transmission components). Transmission infrastructure planning happens at multiple scales, ranging from local project-specific interconnection into the grid to interregional planning for long-distance transmission lines. These planning processes depend on collaboration among a variety of actors, including state and federal government, community organizations, regional transmission planning organizations, electric utilities, and the private sector.

The laying and burial of array, interarray, and export cables requires careful route planning that depends on the depth and type of seabed, as well as the experience and risk tolerance of those burying the cables. The construction and connection of all these components are preceded by extensive surveys that consider site-specific factors such as water depth, waves, current, and sediment type.[lxxxi] For example, sediment surveys can ensure that below-ground cables are sited in areas with stable, environmentally safe sediment. Other siting considerations for cables include areas of existing use (e.g., commercial vessel activity, fishing activity) and geological seabed factors (e.g., slope, sediment mobility charts). Different cable burial methods can address different siting considerations; for example, using a jet plow to create a trench for cable burial may release less sediment than a method that drills directly into the seabed.[lxxxii]

When laying a cable, project developers must also consider state and federal permitting because cables pass through both state and federal waters before making landfall and continuing underground to onshore substations. Federal regulations require 15 feet of cable burial depth below shipping channels, whereas states may have different guidelines. For example, New Jersey has a minimum burial depth of 5 feet, and New York does not have a specific cable burial depth requirement.[lxxxiii]

Onshore transmission infrastructure includes the cable landing area, onshore export cable, and onshore substations, which convert power from the wind turbines to a voltage suitable for longer-distance transmission. The planning processes for onshore transmission infrastructure include assessing onshore grid capacity and existing land-use considerations. In addition, project developers may need to acquire lease agreements and easements from local municipalities for construction processes under public rights of way, such as roads.[lxxxiv] Developers may also need to acquire various state-specific environmental permits for onshore transmission construction, such as upland waterfront development, coastal wetlands, and water quality permits.

Figure 25. Construction occurs in the parking lot at Covell's Beach in Barnstable, Massachusetts, the location where cables from the Vineyard Wind 1 project come onshore. Following the completion of construction, this trench was covered, leaving no lasting visual impact or impact on use of the area. *Photo from Robin Lubbock, [WBUR](#)*

Figure 26. The parking lot at Covell's Beach in Barnstable, Massachusetts, in May 2024, after construction of the underground cable for the Vineyard Wind 1 project was completed and the area was restored to previous conditions. *Photo from Mary Ann Labue*

Communities in the pathway of onshore transmission systems may experience temporary construction noise, road closures, and traffic when export cables are buried under the shoreline and roads and when an onshore substation is built. In some cases, these impacts may be avoided, minimized, or mitigated; for example, construction may be scheduled outside of summer months to avoid impacts to recreation and tourism, and roads may be upgraded following cable construction. Additionally, horizontal directional drilling may be used instead of creating an open trench. Refer to the State and Local Involvement section for more information on local participation in cable landing and substation development.

For more information on offshore wind energy transmission planning and community impacts, refer to:

- Offshore Wind Energy (OWE) Transmission (Sea Grant Offshore Wind Energy webpage)
- Making Offshore Wind Transmission Work for Communities (Regional Plan Association webpage)

- Atlantic Offshore Wind Transmission Study (National Renewable Energy Laboratory webpage)
- Offshore Wind Transmission Federal Planning and Support (U.S. Department of Energy webpage).

Seabed Type

Seabed composition varies and depends on location. The seabed can be rocky, sandy, muddy, clayey, or a combination. Seabed type is important to offshore wind energy development because it influences turbine location, the types of foundations that can be used, and installation methods for cables. Refer to the Project Anatomy and Component Characteristics section for more information on foundations and suitability for different seabed types.

Surveys and other scientific studies can help determine seabed composition and characteristics. For example, geotechnical and geophysical surveys may help determine seabed stability, and an Environmental Impact Assessment can detect the presence of sensitive habitats, marine ecosystems, and protected species.

Depth

Water depth is the main determining factor for whether fixed or floating substructures are used. For depths up to 60 m, the most common substructures are fixed bottom. Beyond 60 m in depth, it becomes more cost-effective to use floating substructures. Depth depends on location and generally increases with distance from shore. The Pacific Coast is an exception, as the continental shelf in this region is steep and rapidly drops off to create deeper waters closer to shore.

In the United States, many of the first offshore wind energy projects will be sited in shallower waters along the East Coast and employ fixed-bottom substructures. However, about 70% of the country's offshore wind potential is in waters too deep for fixed foundations.[lxxxv] The Great Lakes, for instance, have about 415 GW in potential floating wind capacity.[lxxxvi] Together, California, Oregon, and Washington have 297 GW of floating wind technical potential.[lxxxvii] The Gulf of Mexico contains more potential for floating wind than both of these regions combined, with 867 GW of technical potential.

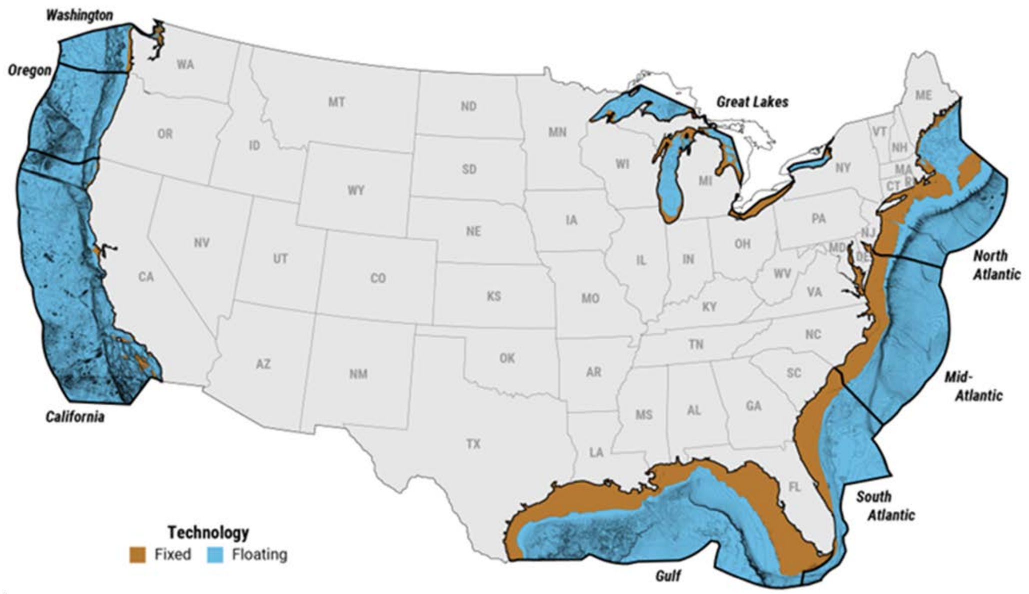

Figure 27. Map of waters where fixed-bottom offshore wind technology and floating offshore wind technology could be deployed in the United States depending on water depth. An ocean depth of 60 m is a common delineator for using fixed or floating offshore wind technology. *Figure from Billy Roberts, NREL*

While floating offshore wind turbines can be installed in deep waters, the costs and complexities associated with such projects increase as water depth increases. As supply chains advance and reduce project costs, deploying floating offshore wind projects at greater depths may become more economical.

Environmental Considerations

Environmental considerations for offshore wind energy projects include potential impacts to wildlife above and below the water and their habitats during the leasing, site investigation, construction, operations, and decommissioning phases. These considerations vary depending on factors like the location, time of year, activity, type of foundation, cable location and installation method, and onshore cable landing location, and are also component-specific.

Offshore wind energy development can affect the marine, nearshore, and coastal environments in a variety of ways throughout project planning, construction, operations, and decommissioning. The installation and removal of foundations, anchors, and cables can temporarily or permanently disrupt sediment structure and displace species living on or near the seafloor due to habitat alteration or loss. Offshore wind energy projects may also attract species to an area; for example, the installation of foundations and scour protection (rocks or other material that protect erosion around coastal structures) can produce new types of habitats that cause some species to move to new locations and others to be attracted to or attached to the foundation.[lxxxviii] Decommissioning or removal of infrastructure can similarly disrupt ecosystems and habitats that develop around these structures. Other impacts of installation and decommissioning include temporary disturbances related to water quality, such as sediment plumes (i.e., plumes of sediment stirred up from the seabed and suspended in the water), as well as noise from installing fixed-bottom foundations.[lxxxix]

Minimizing the Impact of Offshore Wind on Marine Species

NOAA Fisheries helps avoid and minimize impacts to protected species and their habitats throughout the life cycle of offshore wind energy projects. There is no evidence at this point that draws a correlation between noise from acoustic surveys and whale mortality,[xc] but federal agencies including NOAA Fisheries continue to closely monitor this issue as part of their responsibilities under the Marine Mammal Protection Act.[xci] It is also important to note that the sound sources used in these surveys are generally considered high resolution and low impact and are very different from seismic air guns used in oil and gas surveys or tactical military sonar. They produce much smaller impact zones because, in general, they have lower noise, higher frequency, and narrower beam width. The area within which these sounds might disturb a marine mammal's behavior is orders of magnitude smaller than the impact areas for seismic airguns or military sonar. Any marine mammal exposure to sound from these surveys would be at significantly lower levels and shorter duration, which is associated with less severe impacts to marine mammals.

Currently, the greatest threats to whales are vessel strikes and entanglement in fishing material.[xcii] This is especially true as climate change drives prey of marine species closer to shore and into parts of the ocean where human activity is higher.[xciii] Whale migration patterns are an important siting consideration for planned offshore wind energy project transit routes to avoid potential strikes with vessels.

For more information on environmental impacts of offshore wind energy, refer to the Fisheries section and the Marine Life and Ecosystems section. Additional resources include:

- U.S. Offshore Wind Synthesis of Environmental Effects Research
- *Overview of the Effects of Offshore Wind Farms on Fisheries and Aquaculture* (European Commission report)
- Offshore Wind Facts: Habitats and Species
- Fisheries and Offshore Wind Interactions: Synthesis of Science (NOAA technical memorandum)
- Offshore Wind Energy: Protecting Marine Life (NOAA Fisheries webpage)
- Frequent Questions—Offshore Wind and Whales (NOAA Fisheries webpage)
- New Jersey Department of Environmental Protection Statement on East Coast Whale Mortalities
- NOAA interactive map showing locations of 2016–2024 Humpback Whale Unusual Mortality Event Along the Atlantic Coast

- An Ocean of Information (Marine Cadastre, a cooperative effort between BOEM, NOAA, and regional/state partners that provides access to data and tools related to the ocean and ocean-based industries).

Environmental Reviews and Monitoring

Before holding a lease sale, BOEM conducts an Environmental Assessment. Environmental Assessments analyze the environmental effects and the potential significance of the effects of proposed activities associated with the lease sale, including site characterization activities (e.g., biological, geological, and geotechnical surveys) and site assessment activities (e.g., using buoys to understand weather and ocean dynamics at a potential project site). Later in the development process, after receiving a Construction and Operations Plan from a developer, BOEM conducts a formal assessment of the potential effects of constructing, operating, and decommissioning the proposed project, as required by NEPA. If appropriate, an Environmental Impact Statement will be prepared. The formal process for an EIS includes opportunities for input from Tribes, stakeholders, and the public. Other required environmental reviews include consultation under the Endangered Species Act, National Historic Preservation Act, the Magnuson-Stevens Fishery Conservation and Management Act, and Coastal Zone Management Act.

Other federal agencies may serve as cooperating agencies with BOEM to provide expertise during EIS preparation and to support the analysis of impacts as required under additional authorities. This may include, for example, an offshore wind developer applying to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service for incidental take authorization under the Marine Mammal Protection Act, allowing the unintentional take of a small number of marine mammals during project construction. In addition, developers apply to the U.S. Army Corps of Engineers for any permits requested under Section 10 of the Rivers and Harbors Act or Section 404 of the Clean Water Act.

Offshore wind projects must also consider state marine conservation areas and National Marine Sanctuaries in project siting and development. These areas have special national, state, or Tribal significance and can be very large. While BOEM cannot authorize offshore wind projects within designated National Marine Sanctuaries, they can be built adjacent to them, so siting in these areas may require unique consideration and community engagement efforts.

Most states also have their own environmental review standards, such as the California Environmental Policy Act, New York State Environmental Quality Review Act, or Connecticut Environmental Policy Act. These may be especially pertinent for projects sited in state waters.

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Collectively, these reviews identify mitigation measures to avoid or minimize project impacts and disclose or address impacts that cannot be effectively mitigated.

The project developer must also complete a series of preconstruction assessments, which may include surveys to establish baseline conditions at the project site. The lessee's assessments provide information and analyses that facilitate BOEM's work and inform the development of effective mitigation measures to mitigate environmental impacts. Some examples of surveys include:

- Acoustic geographical surveys, which analyze seabed disturbance and identify shallow hazards to avoid in foundation placement
- Video and photographic surveys, which capture changes to habitats at broader spatial scales
- Biological samples, which assess species composition from seabed sediment.

Compliance with environmental law and policy also includes environmental monitoring requirements. This monitoring tracks compliance as well as changes in data collected from surveys throughout a project's lifetime. Environmental monitoring, surveying, and assessing are important parts of siting an offshore wind energy project because they can identify and avoid sensitive or critical habitats that may be adversely impacted by offshore wind development and identify areas where construction should not occur (i.e., areas where sediment may be contaminated or areas with unexploded munitions from military activity).

State and Local Involvement

State and local governments play several different roles in offshore wind energy development. First, states may consult and collaborate with the federal government when projects are being sited in federal waters, and states control siting for projects in state waters. Second, state governments have a key role in shaping offshore wind energy deployment through solicitation and power procurement processes, as states are typically the customers for the power produced by offshore wind energy projects. Third, state and local governments oversee transmission infrastructure siting in coordination with the federal government, including siting subsea cables and cable landfall sites. Finally, state and local governments can be involved in the development of ports and oversee port activities.

Figure 28. Transmission infrastructure on Block Island, Rhode Island. The island saw transmission infrastructure upgrades as part of the Block Island Wind Farm project. *Photo from Dennis Schroeder, NREL 40487*

State Involvement in Project Siting and Development in Federal Waters

The majority of commercial-scale offshore wind energy projects will be sited in federal waters, meaning that state and local governments play a lesser role than the federal government and project developers in project siting. However, state governments will likely be consulted in decision making about projects in federal waters by the federal government and project developers, as states' support for or opposition to decisions can be influential for project outcomes. States may also become involved in offshore wind energy planning with BOEM and developers long before leases are awarded, such as joining or requesting the creation of a BOEM Intergovernmental Renewable Energy Task Force, which is a forum through which states, Tribes, and local governments can coordinate planning, exchange information, and provide feedback to BOEM.

Under the federal Coastal Zone Management Act of 1972, states that have an approved Coastal Zone Management Plan have the authority to review certain federal projects to ensure they are consistent with state coastal management policies and standards.[xciv] This process, called federal consistency review, applies to most projects that are located in or are expected to affect a state coastal zone and that receive federal funds, require federal permits, are a direct action of a federal agency, or "are part of Outer Continental Shelf plans for exploration, development, and production."[xcv] This means that in some cases, aspects of offshore wind energy projects will undergo federal consistency review. Areas within federal waters where there are federal activities that have foreseeable effects on a state's coastal uses or resources can be determined to be a geographic location description under the Coastal Zone Management Act; states can determine what kind of activities (e.g., offshore wind energy development) within a geographic location description are automatically subject to federal consistency review.[xcvi] Thirty-four coastal states and territories participate in the National Coastal Zone Management Program, including all of the coastal states in the country's offshore wind energy regions (i.e., Atlantic Coast, Pacific Coast, Gulf of Mexico, and Great Lakes).[xcvii]

States may form advisory committees or working groups to discuss different topics in offshore wind energy development, such as workforce and fisheries, and to ensure that stakeholders and experts within the state have avenues to engage and inform the state government about issues and impacts of concern. For example, New Jersey has an Environmental Resources Offshore Wind Working Group with representatives from the fishing industry, maritime industry, universities, and conservation organizations, among others.[xcviii] In another example, the Massachusetts Executive Office of Energy and Environmental Affairs and the Massachusetts Clean Energy Center administer a Habitat Working Group that brings together experts (e.g., environmental nonprofits, research institutions, federal and state agencies, developers) to give feedback and discuss impacts from offshore wind energy.[xcix]

State Involvement in Project Siting and Development in State Waters

Figure 29. Turbines in the Block Island Wind Farm in Rhode Island state waters. *Photo from Dennis Schroeder, NREL 40460*

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When projects are sited in state waters, like the Block Island Wind Farm, the state government has control over the siting process. State waters extend to 3 nautical miles offshore in most states; in Texas and the Gulf Coast of Florida, state waters extend to 9 nautical miles. The state of Louisiana signed agreements in 2023 for two offshore wind energy projects (Cajun Wind and Diamond Offshore Wind) in state waters.[c] In the Great Lakes, any siting of offshore wind energy projects will be controlled by the states in the region because the Great Lakes are state waters. Additionally, demonstration projects may be sited in state waters, such as the University of Maine's New England Aqua Ventus I project; demonstration projects are smaller offshore wind energy projects that are used to test new technologies or address technical challenges.[ci]

Local Involvement in Project Siting and Development

It is unlikely that a local government would have control over the siting process for a project, as state waters begin at the shore. However, local governments may be consulted by developers, state governments, and the federal government as part of siting processes for projects in federal or state waters. Local governments have a more significant role in siting onshore infrastructure, such as substations and cable landing sites, which is discussed later in this section.

State Solicitation and Procurement Processes

In most cases, states have authority to buy the energy generated by offshore wind energy projects. When developed in federal waters, offshore wind energy projects are not required to sell their power to the state nearest the project site. Instead, developers pursue the power sale options they consider most favorable or beneficial for their projects, which is typically done through state procurement processes in which developers compete. Generally, this means developers will sell power from their projects to states where there is a high anticipated value of offshore wind energy and/or where they can negotiate favorable agreements. Long-term sale and purchase agreements for power are often called "offtake agreements."

To guide their future efforts to procure offshore wind energy, states may set short- and long-term procurement targets or goals. These targets also help inform developers that a given state and/or utility may be a future customer for the power generated by their offshore wind energy projects. Such targets are typically set through state laws or executive orders. Up-to-date information on state procurement targets and offtake agreements can be found in NREL's annual offshore wind market reports. The process through which a state selects offshore wind energy projects to procure energy from is typically called a competitive solicitation, as developers must compete to have their projects selected by the state. Solicitations generally occur between the leasing stage and the construction and operations stage of BOEM's leasing process, meaning that projects already hold leases but have not yet been built. States typically use one of two procurement instruments to conduct these energy solicitations: power purchase agreements or offshore renewable energy certificates (ORECs).

Power purchase agreements are long-term agreements between a utility and offshore wind developer for the purchase of power from projects of a specific size. States that use power purchase agreements typically require that their utilities sign these contracts with the developers that the state has chosen via the competitive process to purchase power. ORECs, on the other hand, are the environmental attributes that are attached to the production of offshore wind energy. Utilities need ORECs to demonstrate they comply with their obligations to purchase a certain proportion of their power from offshore wind as part of states' renewable portfolio standards. In a procurement process, states will offer the winning bidder (i.e., the project developer) a long-term purchase option in which utilities buy the ORECs from the project (usually via an intermediary) while the power will be sold into the wholesale market. The result of both procurement processes is that offshore wind energy project owners have long-term stable purchasers for the power they produce, and ratepayers have stable, predictable electricity prices.[cii]

Solicitations are an important opportunity for states to exert some control over the offshore wind development process through the requirements they have in place for developers and the projects they ultimately select. Obtaining offtake agreements is critical for the success of projects, so developers may need to adjust their plans or seek offtake options with another state if they do not win a solicitation. States can use the solicitation process to incentivize or require efforts related to workforce and supply chain development, community benefits, stakeholder engagement, environmental protection, and other priority topics in the state. For example, in New York's third competitive solicitation in 2022, the state required developers to submit plans related to workforce development, supply chain investment, mitigation of impacts to fisheries, and stakeholder engagement, as well as to highlight in their proposals how disadvantaged communities would benefit from the planned offshore wind energy activities.[ciii]

State and Local Involvement in Siting Transmission Infrastructure

The siting of transmission infrastructure such as subsea cables is overseen by a combination of federal, state, and local governments, as cables will typically pass through federal and state waters before making landfall in communities on the coast and continuing underground to onshore substations.

States may have a variety of roles in offshore wind energy transmission planning, such as conducting studies on transmission options and impacts, coordinating the development of infrastructure, and approving cable routes through state waters. The state agency with authority over siting decisions about cables in state waters will vary depending on the state. States may also be involved in regional transmission

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coordination with other states, as the power from offshore wind energy projects will feed into electrical grids spanning multiple states in many cases.

Figure 30. Covell's Beach in Barnstable, Massachusetts, is the location of the cable landing site for the Vineyard Wind 1 project. This photo was taken in May 2024, following completion of the cable installation and restoration of the beach and parking lot. *Photo from Mary Ann Labue*

Local governments typically have the authority to approve the siting of cable landing sites (i.e., places where cables come onshore) within their jurisdiction, giving them the ability to shape how their community is impacted by onshore transmission infrastructure. Though cable landfall will occur underground, and cables typically travel underground until they reach onshore substations, local governments may still consider construction impacts and the visual impacts of substations.[civ]

Additionally, local governments may coordinate with offshore wind energy developers and state governments to plan cable routes and landing sites that minimize local impacts. The part of a local government with authority to approve cable landing siting will vary depending on the community, but in many cases, it can be a planning or zoning board, conservation commission, or town or city council.

The technical aspects of cables and other transmission infrastructure are covered in greater detail in the Project Anatomy and Component Characteristics section and Siting of Turbines and Transmission Infrastructure section of this guide, and the potential economic impacts of transmission infrastructure are introduced in the Economic Impacts section. More information about local processes for siting transmission infrastructure can be found in the Regional Plan Association's report, [Making Offshore Wind Transmission Work for Communities](#).

State and Local Involvement in Developing Ports and Supply Chain Infrastructure

Figure 31. Components for the South Fork Wind project await transportation at State Pier in New London, Connecticut. State Pier was redeveloped to have offshore wind marshaling capabilities through a partnership between the state government and the South Fork Wind project developers. *Photo from Matilda Kreider, NREL*

State and local governments typically have a significant role in the development of port facilities, factories, and other supply chain infrastructure used by the offshore wind energy industry. This can involve constructing new facilities or redeveloping existing facilities. Most ports in the United States are governed by port authorities, which are typically connected to either the state or local government in the port's area. Thus, most offshore wind energy port projects are publicly funded and under the purview of state or local government; in some cases, port projects may also receive private funding from stakeholders like offshore wind energy developers who will use the port to develop their projects. In some cases, private companies may own and operate port facilities, but transforming a port for use with offshore wind energy would still require state and local permits and approvals. More information on these topics can be found in the Supply Chain, Ports, and Vessels section.

Tribal Considerations and Involvement

Figure 32. Panelists at a session on Indigenous perspectives on offshore wind energy at DOE's 2024 Tribal Clean Energy Summit. From left to right: Mark Severy (DOE Grid Deployment Office), Linnea Jackson (Hoopa Valley Tribe), Glenn Ellis Jr. (Makah Tribe), Michael Gerace (Yurok Tribe). *Photo from DOE Office of Indian Energy*

The interests of Tribal nations and Indigenous communities present unique economic, political, and cultural considerations with respect to offshore wind energy development. Although many Tribes have stated their strong support for renewable energy development and deployment generally, many have also raised questions and concerns about the potential impacts offshore wind energy development could have on diverse Tribal resources, including treaty rights, traditional food sources, usual and accustomed fishing areas, coastal ecosystems, wildlife, and sacred sites, among other concerns that can vary by Tribe.

This section introduces some of the key challenges and opportunities concerning offshore wind energy development on or near Tribal lands. It is important to emphasize that every Tribe is a distinct entity, with a unique history and set of cultural beliefs and practices. All parties must avoid generalizing one Tribe or an Indigenous person's thoughts and opinions about offshore wind energy to other Tribes and Indigenous peoples. Generalizing or co-opting (i.e., using to further another group's purposes) Indigenous people's narratives about wind energy can diminish or sideline their voices in decision-making processes.[cv] This guide therefore does not offer a definitive view of how offshore wind energy should be considered with respect to Tribes. It does, however, provide insight on ways to center Indigenous voices and priorities, with an

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emphasis on place-based approaches to engagement and collaboration with Tribes when considering offshore wind energy development in specific contexts.

Tribal Sovereignty

American Indian and Alaska Native Tribal nations are sovereign governments, meaning they have a government-to-government relationship with the United States recognized under the U.S. Constitution, treaties, statutes, executive orders, and court decisions. The federal government has trust and treaty responsibility to Tribal nations, and Tribal sovereignty has important implications for planning and developing wind energy facilities on or near Tribal waters, coasts, and sacred or culturally significant sites. Federal law, supported by federal court decisions and executive directives, requires that federal agencies meaningfully consult about infrastructure projects that may impact Tribal lands and peoples. To meet this requirement, BOEM, which is responsible for wind energy development in federal waters, engages in consultation with Tribes and publishes an annual Tribal consultation report. Additionally, individual states may have government-to-government relationships with Tribes. In some cases, specific policies may require additional federal consultation processes, such as consultation obligations to Alaska Native corporations, though these never replace or diminish the government-to-government relationship and consultation requirements existing between the United States and Tribal nations.[cvi] For information on specific policies affecting Tribal jurisdiction and consultation requirements, see the Policies at the Federal Level section.

In addition to the legal definition and implications of Tribal sovereignty, Indigenous communities may also refer to sovereignty as a concept with broad historical and political significance that can influence perspectives on how lands and waters should be managed, including in the development of an offshore wind energy project. According to Indigenous histories and knowledge, many Tribes have been caring for their lands and waters, and all the forms of life they contain, since time immemorial. Continuing stewardship of lands and waters is an important way Tribes maintain their cultural identities and express their nationhood, including through harvesting “first foods” (Indigenous traditional foods), holding ceremonies in sacred sites, and protecting biodiversity. Strong cultural ties may also be felt by Indigenous communities that do not belong to a federally recognized Tribe, and it is important that the priorities and perspectives of these groups are included in decision making about offshore wind energy development. For a list of federally recognized Tribes, see the Bureau of Indian Affairs directory of Tribes.

Respecting Indigenous Coastal Resources and Practices

The coasts and oceans are home to a diverse range of Tribal resources, from traditional foods to sacred sites, that must be considered during offshore wind energy planning and deployment. Indigenous communities are also valuable partners in mitigating the

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environmental impacts of development. Through thousands of years of stewarding these places, Tribes have developed a wealth of intergenerational knowledge and sustainability practices (sometimes called Indigenous Knowledge or Traditional Ecological Knowledge) to manage and protect coastal environments.

Fishing and Food Resources

Along every coast in the United States, Indigenous peoples have been fishing and harvesting food from the seas and shores for millennia. For some federally recognized Tribes, fishing, hunting, and gathering rights are protected in treaties. The techniques for managing and sustainably harvesting traditional "first foods" have been passed down in Tribes for countless generations, and they continue to be an important part of cultural identity, community health, and essential nutrition. In this way, these first foods often allow Tribes to maintain "food sovereignty," or the "ability of communities to determine the quantity and quality of the food that they consume by controlling how their food is produced and distributed."[cvii] Along the coastlines of the Pacific Northwest and Alaska, for example, salmon are a central pillar of both Indigenous diets and Tribal identities. One Indigenous resident of Nugashak watershed in Alaska described the relationship of the Yup'ik and Dena'ina peoples to salmon this way:

> "When you listen to the stories and take a steam, even in the middle of winter, people talk about salmon. It is in our stories; it is in our art. It is who we are; it defines us."[cviii]

Understanding and mitigating any harmful impacts of offshore wind energy development on the availability of first foods is tremendously important to the health and well-being of Tribal communities. Transitioning to certain renewable energy sources can help protect traditional food sources, as the impacts of climate change on ocean warming, acidification, and ecological disruption by invasive species pose a very serious threat to many first food sources.[cix] However, in the past, other types of large-scale infrastructure projects have limited access to important harvest areas or caused critical damage to first food sources. Dam facilities in the Pacific Northwest, for example, have dramatically weakened salmon populations fished by the many Tribes in the Klamath, Columbia, and Snake River basins.[cx] [cxi]

Mitigating potential impacts from offshore wind energy installations will require robust communication and collaboration between government agencies, developers, and Tribes. Area assessments can map the potential effects of offshore wind energy infrastructure on marine life, habitats, and harvesting access. Cooperative efforts between Tribes, developers, and the federal government to integrate Indigenous Knowledge into planning processes can help to ensure that new infrastructure does not compromise Indigenous food resources.

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Biodiversity and Other-Than-Human Kin

Although coastal and marine life are key sources of first foods for many Tribes, the plants and animals in these areas also have inherent cultural and spiritual importance for Indigenous peoples. Globally, the lands and waters managed by Indigenous peoples contain 80% of the planet's biodiversity.[cxii] The species that Indigenous peoples steward can be central to Tribal identities and knowledge, often carrying special meaning in both creation stories and personal life histories.[cxiii] Whales and salmon are among the many animals that may have special meaning for Tribes in coastal regions. For many Indigenous people, caring for plants and animals is often part of reciprocal, kinship relationships: other-than-human life can be considered "relatives" who provide food, medicine, spiritual meaning, and intergenerational connections to the land.[cxiv] [cxv] [cxvi]

Given these connections, protecting local ecosystems from any negative impacts associated with offshore wind energy is key to respecting Indigenous beliefs and practices. In addition to conducting environmental assessments and monitoring, offshore wind energy developers can prioritize cooperative stewardship with Indigenous communities, ensuring that management of traditional lands remains with Indigenous peoples. Impact mitigation plans can also include partnerships with Tribes to use Indigenous Knowledge.[cxvii] In addition to protecting culturally significant ecosystems, these measures can help make offshore wind energy development sustainable in the long term.

Sacred Sites

Figure 33. The Block Island Wind Farm as seen from Block Island, Rhode Island. This project is sited about 3 miles from Block Island; most offshore wind projects will be sited farther from shore and thus be less visible from shore, but there can still be impacts on landscapes and viewsheds with significance to Indigenous peoples. *Photo from Dennis Schroeder, NREL 40474*

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For some Indigenous peoples, coastal areas are home to sacred places that require specific efforts to avoid negative impacts from offshore wind energy infrastructure. Sacred sites—which include landscapes where ancestors are buried, ceremonies are held, or key cultural stories or events have taken place—are unique in that they cannot be moved or replaced.[cxviii] [cxix] The religious significance of a sacred site is inseparable from the geography and attributes of the landscape itself, making such areas particularly vulnerable to the impacts of infrastructure development. Because the place-based nature of Indigenous religious practices is unfamiliar to most Western religious framings, some Tribal members also worry that their spiritual connections to sacred sites may be dismissed or deprioritized in deference to other siting factors.[cxx] Even the process of advocating for the protection of sacred sites comes with risk, as disclosing the location of a sacred place may leave it exposed to co-optation or misuse.[cxxi]

In addition to specific coastal landscapes, sacred sites can include areas with viewsheds (i.e., the view from a specific location or point) that have cultural and spiritual significance and may be impacted by wind energy development. Some Tribes refer to sacred sites as sacred places in recognition that they are not always confined to a specific geographic boundary. For example, Wampanoag tradition holds that the landforms of the Nantucket Sound have special cultural significance, including as areas where ancestors lived, leading to concerns about construction impacts and potential visual obstruction from wind turbines and other infrastructure planned for offshore wind energy projects in the area.[cxxii] [cxxiii] Additional information on sacred sites is included in the Bureau of Indian Affairs' *Best Practices Guide for Federal Agencies Regarding Tribal and Native Hawaiian Sacred Sites*.

Policies at the Federal Level

There are several key federal policies that include requirements for protecting Tribal resources and consultation with Tribal governments during the offshore wind energy development process (note that these policies predominantly apply only to federally recognized Tribes, though some may allow for seeking input from other Indigenous communities.) At the broadest level, court decisions have determined that the United States has a trust responsibility to Tribes, meaning that the federal government has a moral and fiduciary obligation to protect Tribal lands, resources, and treaty rights.[cxxiv] To meet this trust responsibility, specific statutes require that federal agencies consult with Tribes during the development of large infrastructure projects like offshore wind plants. The two most notable consultation requirements for offshore wind energy development are in the National Historic Preservation Act (NHPA) and NEPA.

NHPA, which was enacted to protect historic property, mandates Tribal consultation on "undertakings" (i.e., infrastructure projects) that come under the jurisdiction of a federal agency, including projects receiving federal funding or permitting.[cxxv] The Tribal consultation provision comes specifically from Section 106 of the NHPA, which requires agencies to consider the impact of their undertakings on "property of traditional religious and cultural importance to an Indian [T]ribe."[cxxvi] The Advisory Council on Historic Preservation, which is the agency that consults Tribes and administers regulations under NHPA, has noted that Indigenous Knowledge should be considered when applying Section 106.[cxxvii] Similarly, NEPA, an environmental protection law, requires that infrastructure projects subject to review incorporate potential cultural impacts in their assessments. Under the act, federal agencies must also consult Tribes early in the review process "when their involvement is reasonably foreseeable."[cxxviii]

NHPA and NEPA currently offer the most robust federal provisions for protecting Tribal resources in offshore wind energy development, though they have been subject to ongoing critique. Some Tribes and legal scholars have expressed concern that NEPA and NHPA consultation processes begin too late in the permitting process,[cxxix] do not adequately protect cultural resources at the landscape level,[cxxx] and leave gaps in federal accountability to Tribes.[cxxxi] Additionally, because NHPA and NEPA do not apply to Tribes that are not federally recognized, they may leave the priorities of some Indigenous peoples unaddressed. In partial response to these concerns, the Advisory Council on Historic Preservation has released recommendations and best practices for earlier coordination with Tribes on infrastructure projects.[cxxxii]

Actions by federal agencies like BOEM have also sought to strengthen coordination with Tribes in the deployment of offshore wind energy. For example, in addition to other consultation efforts, BOEM requires that companies leasing offshore wind energy sites submit Native American Tribal Communications Plans "to ensure early and active information sharing, focus discussion on potential issues, and collaboratively identify solutions" with Tribes.[cxxxiii] Recent offshore wind leasing stipulations have also required companies to release regular progress reports that identify how communication with Tribes has informed their offshore wind energy project plans.[cxxxiv] The U.S. Department of the Interior and the U.S. Department of Agriculture have also issued a joint secretarial order stating that federal lands and waters should be managed "in a manner that seeks to protect the treaty, religious, subsistence, and cultural interests of federally recognized Tribes including the Native Hawaiian Community," including through collaborative management of public lands and waters.[cxxxv]

Under Executive Order 13175, which was issued in 2000, federal agencies are required to "establish procedures for meaningful consultation and coordination with [T]ribal officials in the development of federal policies that have [T]ribal implications."[cxxxvi] President Biden has issued several memoranda to establish "uniform minimum standards" for Tribal consultation across all agencies, and agencies are encouraged to build on these standards in accordance with their unique, agency-specific missions and issues.[cxxxvii] Though many federal agencies may be involved in Tribal consultation related to offshore wind energy, BOEM's consultation activities may be of particular

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interest; BOEM's Tribal consultation guidance and policy documents, which include annual reports on Tribal consultation activities, provide further information.

Offices in the White House have issued guidance on integrating Indigenous Knowledge into the stewardship of ocean resources as part of the Ocean Climate Action Plan.[cxxxviii] This includes reference to partnering with Tribes to increase scientific research and knowledge on offshore wind energy's potential impacts to coastal and ocean resources.

Social Impacts and Workforce

Offshore wind energy has the potential to create significant economic development and workforce growth. For these and other social benefits to come to Native communities, it is important to consider how offshore wind can avoid the mistakes of past energy development and better support community priorities.

Recognizing the Painful Legacies of Energy Industries in Native Communities

To ensure Native communities can share in the benefits of a growing offshore wind energy industry, it is important to recognize how other energy industries have sometimes excluded or negatively impacted Indigenous peoples. The social and health consequences of nuclear energy,[cxxxix] [cxl] hydropower infrastructure,[cxli] and fossil fuel energy generation[cxlii] have often been serious for those living on affected Tribal lands, even as energy generation and mining have sometimes provided important sources of revenue and jobs.[cxliii] In addition to ecological disruptions that have damaged culturally significant landscapes, energy-related industries have been associated with increased cancer and birth defect rates as well as other chronic illnesses on Tribal land.[cxliv] These painful legacies may lead Native communities to distrust claims about economic opportunities related to offshore wind energy development. As vice chairman of the Yurok Tribe in 2023, Frankie Myers summarized this sort of skepticism around offshore wind energy development in California:

> "When the offshore wind industry tells us about all the great opportunities their projects will provide Native people, we've heard it before […]. California [T]ribes are worried that these corporations will come in, profit off of our resources and leave our communities poorer for it."[cxlv]

By offering a clean energy alternative to industries and energy sources that have severely hurt Native communities, offshore wind energy could produce significant health, safety, and climate benefits for Tribes. Realizing that potential will require robust efforts to prioritize Native leadership and partnership while avoiding replicating any past environmental, economic, and social harms.

In California, for example, the Yurok Tribe has begun developing strategies to prevent one of the most painful experiences associated with some other forms of energy development: sex trafficking and cases of Missing and Murdered Indigenous People.

Testimonies from Indigenous peoples, as well as studies conducted by the National Congress of American Indians and the U.S. Bureau of Justice Statistics, indicate that the influx of workers into “man camps” (temporary housing areas for workers for the duration of oil, gas, or mining projects) can drastically increase violence against Indigenous peoples, especially women, girls, and two-spirit individuals.[cxlvi] In one study on areas experiencing an oil boom, the rate of violent victimization was found to increase by 70%, which can have devastating effects on local Native communities, especially in areas split between Tribal and state jurisdiction.[cxlvii]

In June 2023, the Yurok Tribal Court issued a memo highlighting the importance of proactive strategies for protecting Indigenous peoples both on and off Tribal lands during offshore wind energy development. These strategies include provisions in community benefit agreements (covered in the following section), ongoing monitoring and background checks, and continuous planning and engagement with Tribal leaders and community members.[cxlviii] The Yurok Tribe has also partnered with Cal Poly Humboldt and College of the Redwood to develop training and education initiatives to support a local offshore wind energy workforce along California’s northern coast, creating more opportunities for Tribal members to work on wind energy projects happening in their communities.[cxlix] Financial and procedural support for Tribe-led solutions like these can help prevent development-related harm.

Community Benefits and Workforce Development

Figure 34. Intertribal Networks Training at the Flatirons Campus of the National Renewable Energy Laboratory in Colorado. *Photo from Devonie Oleson, NREL*

The potential benefits of offshore wind energy projects go far beyond reducing carbon emissions. Mechanisms like community benefit agreements or Tribal benefit agreements, which are voluntarily used by developers to provide additional benefits to groups impacted by a project, can channel funding and capacity to initiatives of specific

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importance to Indigenous communities. These mechanisms can include community health, environmental protections, coastal resiliency, housing and other infrastructure, energy bill credits, food sovereignty, educational programs, and economic development. Because nongovernmental organizations can be parties to these types of agreements, they are a useful option for providing benefits to dispersed Native communities or Tribes that are not federally recognized. These community benefit or Tribal benefit mechanisms can also work to mitigate potential negative impacts from offshore wind energy construction and operations, like concerns about the safety of local Indigenous residents.[cl]

In 2023, the Santa Ynez Band of Chumash Indians signed a community benefit agreement with Floventis Energy, the developer of a small proposed floating offshore wind energy project off the coast of California.[cli] The agreement includes collaborative planning (e.g., working closely with the Tribe on environmental reviews), Tribal workforce development, the establishment of a research institute led by the Tribe, and naming rights for the offshore wind energy project. In 2024, the Wampanoag Tribe and Vineyard Offshore (the developers of Vineyard Wind 1) signed a Tribal Benefit Agreement that created the Mashpee Wampanoag Tribe Offshore Wind Community Fund. The fund will "support various initiatives including scholarships, wastewater projects, language reclamation, workforce training, and importantly, Tribal capacity to engage with offshore wind projects."[clii]

The offshore wind energy industry can also provide value to local Tribal communities and economies through apprenticeship and worker training programs, including through Tribal colleges and universities.[cliii] In some cases, requirements within processes like leasing and procurement can ensure that Tribal community members are included and/or prioritized in training and job opportunities in the offshore wind energy industry. Employers may also support employment- and education-related services, like childcare and transportation, to alleviate some of the barriers to accessing workforce opportunities.[cliv]

Considerations for Engaging With Tribes

The best experts on Tribal priorities are Tribes themselves. Strong engagement and collaboration with Tribes and Indigenous communities are indispensable for making offshore wind energy work for those communities. While contexts will vary widely, the following recommendations provide some action items for companies and organizations that would like to begin building relationships with Tribes.

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Figure 35. Attendees at a session on strategic clean energy planning at DOE's 2024 Tribal Clean Energy Summit. *Photo from DOE Office of Indian Energy*

Start Early

Consulting Tribes after a plan for offshore wind energy development has already been finalized may lead to a lack of trust and sense of frustration. A Tribe may need to mobilize multiple elements of their government to engage with developers, and a Tribe may not be able to engage during certain times of year due to practices and ceremonies. Therefore, good-faith engagement starts early in the development process and provides more time for Tribes and developers to share knowledge, address key concerns, co-design benefits, and adapt plans to respect Tribal resources.

Conduct Background Research

Before starting engagement, consider researching the Indigenous history (and present context) of the proposed project area. This process includes learning about Tribes' preferred terms and names, legal territories, treaty agreements, and traditional homelands in the area. Specifically researching Tribes' histories with energy development can also be important. It is not necessary to become an "expert"; consider aiming to reach a level of understanding that supports a respectful partnership. Some useful resources for conducting background research include Native Land Digital (a mapping resource) and FIRST STEPS: A Resource for Engaging Communities in STEM.

Avoid Making Assumptions

Many misconceptions about Tribes and Indigenous peoples persist in non-Native culture. When unsure about Tribal norms, terms, practices, values, or beliefs—or when the only information available comes from an outside source—it is important to consider politely asking Tribal members. When doing so, ask open-ended questions and avoid leading questions (e.g., "Is it true that…"). Accepting corrections without becoming defensive and leaving space for open-ended feedback are also established best practices.

Honor Cultural Norms and Traditions

Once knowledge about cultural norms and traditions has been shared, it is important to consider how to treat that knowledge respectfully. This may entail setting aside time and space for cultural practices (e.g., prayer or personal introductions) during meetings and events, considering how different cultural values may affect communication goals (e.g., being efficient vs. building connections), and being careful not to co-opt Native practices or viewpoints. Sometimes, knowledge about Indigenous practices and beliefs is not meant to be shared with non-Native people; respecting these boundaries is also an important part of honoring cultural traditions. For example, do not assume that it is appropriate to take photos or share traditions publicly.

Allow Time and Access to Resources for Informed Decisions

Tribes may need to know detailed plans to be able to respond and evaluate how a project could impact sacred sites, traditional foods, or other Tribal resources. Tribal review and evaluation may involve elders and various experts within the Tribe, and Tribes may need to coordinate amongst themselves.

Value Feedback

Engaging with Tribes and Native communities purely to satisfy a requirement—rather than engaging with the intention of genuinely soliciting and incorporating feedback—can erode trust. Meaningful engagement and collaboration are more likely when there is a focus on valuing Tribal rights, Indigenous knowledge, and the priorities of Native communities. Consider reflecting this approach in how decisions are made and who is included in decision-making processes.

Respect Sovereignty

As covered in the Tribal Sovereignty section, Tribes' sovereignty requires formal government-to-government relationships and legal agreements, and the concept of sovereignty may also be expressed in Indigenous peoples' relationships with lands, waters, and wildlife. It can be beneficial to bring in experts in Federal Indian Law to advise on the nuances of Tribal sovereignty. Recognizing Tribal sovereignty (and not conflating it with concepts of state or local jurisdiction) is a key component of engaging with Tribes.

Look for Opportunities to Partner

Many Tribal governments are already active in providing basic services that are needed to support new industries, including housing, development, education, and childcare. Increasingly, Tribes are also launching their own energy and economic development projects by investing their own capital or leveraging access to tax credits and Tribal loan programs. Recognize the potential for Tribes to be equity partners and work with them, rather than around them, to help ensure mutual benefit.

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Community Considerations

As with any major infrastructure development, offshore wind energy projects have the potential to introduce new social, economic, and cultural influences or dynamics into a community. For example, offshore wind energy development may bring new residents, tourists, investment, and jobs, and it may change the ways that areas of land or ocean have historically been used. Some of these changes may be temporary, such as an influx of workers into the community during project construction, whereas others may be more permanent, such as the redevelopment of an existing port into an offshore wind port or displacement of traditional economic activity that had previously occurred at the port.

Although many of these changes are likely to have positive impacts, some members of communities may face challenges. Different communities or community members may experience impacts differently; for example, a new offshore wind energy manufacturing facility may provide jobs to some members of the community while causing concerns about traffic and pollution for others. Community members may also have different risk perceptions about impacts from offshore wind energy, which can affect how they view and respond to changes in their community; this can be exacerbated by the uncertainty of offshore wind energy's impacts as a new industry in the United States.[clv]

"Community" often serves as a catchall and can be an unclear term. For the purposes of this guide, we use the term to capture groups impacted in any way by an offshore wind energy project. Communities may be characterized by their occupation, interest, proximity to offshore wind energy infrastructure, or other shared characteristics that influence how they interact with offshore wind energy developments. For information that is specific to Tribes and Indigenous community members, refer to the Tribal Considerations and Involvement section.

Figure 36. A group of people stand on the stretch of beach on Block Island where cables from the Block Island Wind Farm come onshore below the ground. Photo from Dennis Schroeder, NREL 40399

In this section, we outline some of the potential effects that offshore wind energy may have on communities in the following topic areas: fisheries, marine life and ecosystems, ocean uses, tourism, viewshed/visual impacts, property values, onshore infrastructure, and workforce. Additionally, we introduce some of the approaches that may be used to mitigate impacts. Each community may experience different effects from offshore wind energy development, including ones that may not be addressed here. The issues and impacts introduced in this section were chosen because they are frequently discussed in public engagement channels like meetings and working groups and by stakeholders like BOEM, state and local governments, Tribes, universities, and industry groups that are working to identify and address impacts from offshore wind energy. Additionally, these impacts have been identified by BOEM and other agencies through regulatory processes such as NEPA review. The Engagement section of this guide provides information about how to engage in offshore wind decision-making processes about these topics and other community concerns.

Fisheries

Offshore wind energy infrastructure, including wind turbines, subsea cables, and mooring lines, has the potential to disrupt or alter fishing activities carried out by commercial, recreational, and Tribal fishers. Some concerns that fishers have are that offshore wind energy development could limit access to traditional fishing areas, disrupt existing transit lanes, cause entanglements with gear or various marine species,

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increase vessel traffic, disrupt navigation systems, and/or disturb the marine environment in a way that changes the distribution or abundance of commercially important species.

Understanding the potential impacts—both positive and negative—of offshore wind energy on fishers and the marine environment they depend on is complex and ongoing work. Although a great deal of research on the topic has been and continues to be conducted, there is still some uncertainty about how offshore wind energy development impacts fisheries. Impacts to fish populations from offshore wind energy can vary based on species, location, phase in the project's lifetime (e.g., construction, operations), type of offshore wind technology in the area (e.g., fixed bottom, floating), other ocean uses in the area, and other factors. Though a great deal of knowledge has come from Europe, where there is more offshore wind energy deployed, it will require increased offshore wind energy deployment in the United States to better understand impacts specific to U.S. fisheries. Local knowledge about fisheries and fishing practices in a given area of the ocean can play a key role in understanding and addressing the impacts of offshore wind energy.

Fishers themselves may be affected differently depending on factors like their location, the type of offshore wind energy technology in the area, the species they harvest, and the types of fishing gear or methods they use. For example, fishers using mobile gear like trawls and dredges may have to change their operations significantly to avoid interacting with wind turbine cables and mooring lines.[clvi] Impacts may also vary by the type of fisher, such as commercial, recreational, or subsistence. For example, a study found that the Block Island Wind Farm created some challenges for commercial fishers but increased the amount of recreational fishing in the area, due in part to the project acting as an artificial reef that attracted populations of certain target fish species.[clvii]

At the federal level, BOEM evaluates impacts on the marine environment and economic resources as part of its offshore wind energy leasing process and engages continuously with fishers and fishing industry groups to address impacts. Other federal agencies like NOAA and DOE also conduct research on the environmental and socioeconomic impacts of offshore wind energy, as do state governments, universities, and other institutions and organizations. For example, the Responsible Offshore Development Alliance, an alliance of more than 200 fishing industry organizations and fishing companies, works to minimize conflicts between offshore developments and fishing, ensure fishermen's knowledge and input are included in research and decision making, and collaborate with regulatory agencies, developers, and research institutions. These advisory organizations and agencies help inform the decisions that BOEM and developers ultimately make.

For additional information on offshore wind energy and fisheries, visit:

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- Fisheries and Offshore Wind Interactions: Synthesis of Science (NOAA technical memorandum)
- Offshore Wind Energy: Fishing Community Impacts (NOAA Fisheries webpage)
- Fishing and Offshore Renewable Energy (BOEM webpage)
- What Is the Research Saying? (Sea Grant webpage)
- U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER).

Marine Life and Ecosystems

Potential impacts to marine life and ecosystems are key considerations for offshore wind energy development. Ecosystem dynamics are complex and evolving, particularly with the impacts of climate change, and the ocean is affected by a variety of industrial activities. For these reasons and others, it can be challenging to track the effects of offshore wind energy.

While the U.S. is still in early stages of offshore wind energy development, there is a lot of expertise and knowledge to gain from Europe, where research on offshore wind energy's environmental impacts has been conducted for several decades. European research has found that offshore wind energy development can introduce a diverse array of changes to the seafloor ecosystem, including temporary negative disturbance during construction and changes to local habitat characteristics during project operations, which may impact biodiversity and species occurrence by attracting or driving away species.[clviii]

Knowledge of impacts specific to the United States is continuously evolving as the U.S. increases its deployment of offshore wind energy. There is substantial ongoing research from federal and state agencies, universities, and other research institutions to understand how different marine species may be impacted by offshore wind energy development. For example, electromagnetic fields (EMFs) from cables and other electrical infrastructure have been the focus of a number of past and current studies. Although subsea cables are sources of low frequency electromagnetic fields, these EMFs dissipate rapidly from the source and are mitigated through cable shielding and burial.[clix] Studies indicate that some animals have demonstrated behavioral responses when in close proximity to subsea cables, whereas other animals do not demonstrate behavioral responses.[clx] Studies have not determined that a species or population has been negatively affected by electromagnetic fields,[clxi] and continued research will further refine our understanding of the effects of EMFs on wildlife.

Some other areas that have received scientific study and assessment include:

- Underwater noise and vibrations.
- Vessel collisions/strikes.
- Disturbance to the benthic environment (i.e., the ecological zone on or near the seafloor) from foundation and cable installation.

- Effects on fish ecology from the introduction of new structures.
- Risk to marine life from floating cable systems and marine debris.
- Bird and bat interactions with offshore wind energy projects.[clxii]

Minimizing the Impact of Offshore Wind on Marine Species

NOAA Fisheries helps avoid and minimize impacts to protected species and their habitats throughout the life cycle of offshore wind energy projects. There is no evidence at this point of a correlation between noise from surveys and whale mortality,[clxiii] but federal agencies, including NOAA Fisheries, continue to monitor this issue closely as part of their responsibilities under the Marine Mammal Protection Act.[clxiv] It is also important to note that the sound sources used in these surveys are generally considered high resolution and low impact and are very different from seismic airguns used in oil and gas surveys or tactical military sonar. They produce much smaller impact zones because, in general, they have lower noise, higher frequency, and narrower beam width. The area within which these sounds might disturb a marine mammal's behavior is orders of magnitude smaller than the impact areas for seismic airguns or military sonar. Any marine mammal exposure to sound from these surveys would be at significantly lower levels and shorter duration, which is associated with less severe impacts to marine mammals.

Currently, the greatest threats to whales are vessel strikes and entanglement in fishing material.[clxv] This is especially true as climate change drives prey of marine species closer to shore and into parts of the ocean where human activity is higher.[clxvi] Whale migration patterns are an important siting consideration for planned offshore wind energy project transit routes to avoid potential strikes with vessels.

More information on marine ecosystem and marine life considerations in offshore wind energy project siting can be found in the Siting of Turbines and Transmission Infrastructure section of this guide. For additional information, visit:

- U.S. Offshore Wind Synthesis of Environmental Effects Research
- *Overview of the Effects of Offshore Wind Farms on Fisheries and Aquaculture* (European Commission report)
- Offshore Wind Facts: Habitats and Species
- Offshore Wind Energy: Protecting Marine Life (NOAA Fisheries webpage)
- Frequent Questions—Offshore Wind and Whales (NOAA Fisheries webpage)
- New Jersey Department of Environmental Protection Statement on East Coast Whale Mortalities
- NOAA interactive map showing locations of 2016–2024 Humpback Whale Unusual Mortality Event Along the Atlantic Coast

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- An Ocean of Information (Marine Cadastre, a cooperative effort between BOEM, NOAA, and regional/state partners that provides access to data and tools related to the ocean and ocean-based industries).

Ocean Uses

Figure 37. A group of people take a boat tour to view the Block Island Wind Farm. *Photo from Dennis Schroeder, NREL 40453*

Ocean users can include commercial fishers, the maritime industry (e.g., shipping, cruise ships), subsistence fishers, ocean recreationists (e.g., boaters, recreational fishers), ocean-based tourism companies, and the military. These stakeholders are likely to have different ideas and priorities related to ocean use. Balancing diverse sets of economic, environmental, social, and cultural interests and priorities can be difficult, but it is an important part of ensuring that offshore wind energy development is equitable and can coexist with existing ocean uses.

There are several ways in which industries and organizations can engage a diverse set of stakeholders, and initiatives throughout the United States provide examples of such collaboration. For example, BOEM engages members of the maritime industry for input on ways to minimize disruption from offshore wind energy.[clxvii] Similarly, the Offshore Energy Facilitation Task Team,[clxviii] led by the U.S. Coast Guard and BSEE, has hosted events such as industry listening sessions to better understand the concerns of maritime stakeholders when it comes to offshore wind energy development.[clxix] In another example, DOE, the Department of Defense, the Department of Homeland Security, the Federal Aviation Administration, NOAA, and BOEM are engaged in an interagency effort to study and mitigate the impacts of wind farms on radar systems through the Wind Turbine Radar Interference Mitigation Working Group.[clxx]

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Tourism

The tourism and recreation industries are important economic drivers, employers, and sources of cultural significance for many coastal communities, leading to some concerns about how offshore wind energy development may impact these industries. Some stakeholders are concerned that offshore wind projects may reduce the attractiveness of a place and thus decrease the number of visitors.[clxxi] Additionally, there may be concerns that ocean-based tourism and recreation activities like boating and fishing will be impacted by reduced or altered access to the sites where offshore wind energy projects are located.

While the aesthetic appeal of landscapes is important to tourists, studies have found that only a small fraction express disapproval of wind turbines in the places they visit. In fact, wind turbines can serve as places of interest for tourists, leading to increases in tourism in coastal or island communities near offshore wind energy projects.[clxxii] [clxxiii] When information centers are available to provide visitors with educational opportunities related to offshore wind energy, interest can be higher.[clxxiv] Tourists that express disapproval for offshore wind projects tend to be recurrent visitors or recreationists who may have a stronger attachment to a particular place than infrequent visitors.[clxxv]

A literature review about offshore wind energy and tourism from 2015 to 2019 found that impacts vary according to local context, but potential negative impacts are largely avoidable. Negative impacts on the tourism industry can be mitigated with thorough engagement from tourism and recreation stakeholders early in project siting and reliable, transparent information sharing.[clxxvi] While a large body of evidence[clxxvii] suggests that offshore wind energy projects do not have a significant negative impact on tourists or recreational users, a variety of research, engagement, and planning activities are underway to better understand the relationships between offshore wind energy and ocean-based/coastal tourism industries. For more information, visit:

- Beyond the Beach: Tradeoffs in Tourism and Recreation at the First Offshore Wind Farm in the United States
- Offshore Renewable Energy and Tourism (European Marine Spatial Planning Platform)
- The Potential of Offshore Wind Energy Tourism in Ocean City, New Jersey
- *Atlantic Offshore Wind Energy Development: Values and Implications for Recreation and Tourism*.

Viewshed/Visual Impacts

People's connections to the environment, ocean, and/or a specific coastal location can influence how they perceive and respond to offshore wind energy development. For individuals who strongly identify with a landscape and its physical and symbolic

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elements, an offshore wind energy project may disrupt their "sense of place."[clxxviii] One of the primary concerns related to this idea is that offshore wind energy infrastructure may negatively impact the viewshed, which is the geographical area that is visible from a specific location or viewing point (e.g., beach, coastal property). The impacts of offshore wind energy on a viewshed are not universally perceived as negative, as some residents and visitors may find offshore wind turbines visually appealing and/or feel that they fit in with the landscape.[clxxix]

Visual impacts depend on factors like the size of the wind turbines, where the project is sited, weather, time of day, and where the viewer is located. Utility-scale offshore wind energy projects are typically sited around 15–20 miles from shore, but because of their height and safety lighting requirements, the turbines can sometimes be seen from shore. Some offshore wind energy projects, like the Block Island Wind Farm, may be sited in proximity to islands and thus be more visible to island residents and visitors. Additionally, those traveling by boat may pass by offshore wind turbines more closely and thus experience greater visual impacts than they would from shore.

3 Miles from Shore | 10 Miles from Shore | 15 Miles from Shore | 20 Miles from Shore

Figure 38. This visualization depicts a view of an offshore wind turbine from shore at 3, 10, 15, and 20 miles away. These visuals are based on the GE Haliade-X 14-MW turbine, which has a total height of 853 ft or 260 m. Note: visual impacts can vary depending on factors like turbine size, distance from the turbine, time of day, and weather. *Images from Josh Bauer, NREL*

Property Values

Some coastal homeowners may be concerned about the potential impact of offshore wind energy development on their property value, especially as it relates to ocean views in coastal communities. Studies from various countries, including Australia, Canada, Denmark, the United Kingdom, and the United States, have generally shown no significant decrease in property values near wind plants, both offshore and onshore.[clxxx] While the current body of evidence suggests that offshore wind energy projects do not adversely affect property values, this issue is likely to be the subject of ongoing research as U.S. deployment increases.

Onshore Infrastructure

Although the footprint of an offshore wind energy project is mostly at sea, there is also onshore infrastructure to consider, most of which falls into two categories: grid infrastructure (e.g., cable landing sites) and supply chain infrastructure (e.g., ports, manufacturing facilities). Onshore infrastructure can have visual, economic, cultural, and environmental impacts that differ from the impacts of the offshore wind energy project itself.

Offshore wind components must be produced and assembled at ports along the coast or navigable waterways and then transported to project sites at sea. Thus, it is necessary for the industry to build new port facilities and/or redevelop existing port facilities to support offshore wind energy development. Port development is a massive investment that can provide significant benefits to the community and region hosting the port, including tax revenues, job creation, workforce and business development, increased economic impacts (e.g., increased business at local restaurants and stores), and additional benefits in the form of a community benefit agreement or fund.[clxxxi]

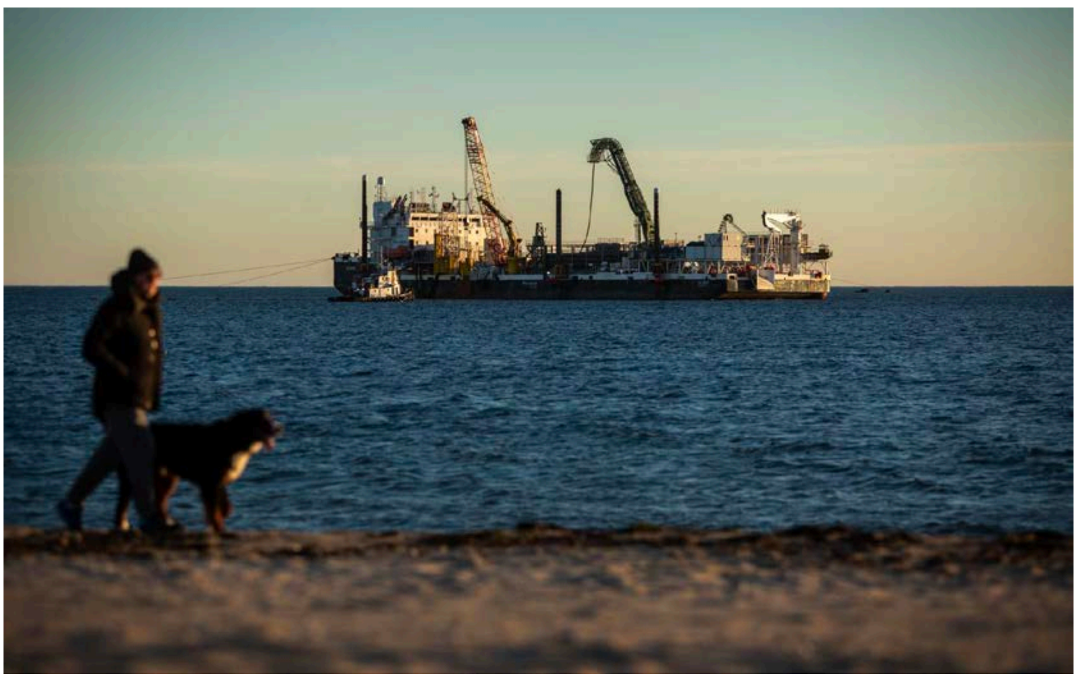

Figure 39. A cable-laying vessel lays subsea cables for the Vineyard Wind 1 project, seen from Covell's Beach in Barnstable, Massachusetts. *Photo from Robin Lubbock, WBUR*

However, there is also the potential for some negative impacts, such as displacement of existing workers or businesses at the port or increased emissions from industrial activity and vessels that harm local air quality. Ports can also affect local water quality; for example, runoff may carry pollutants that prohibit communities from enjoying the recreational value of the water. Light and noise pollution are also possible, as ports may have industrial activity and traffic at all hours of the day. Many communities living near ports are considered disadvantaged and/or environmental justice communities, making them especially vulnerable to these potential negative impacts.[clxxxii]

Developers and port operators can help mitigate potential negative economic, environmental, and health impacts through actions like prioritizing local and/or diverse hiring, workforce development, and contracting; creating community benefit packages (e.g., community benefit agreements, community benefit funds) for port communities; using shore power for vessels (i.e., allowing vessels to connect to onshore electric power rather than burning fuel at the port), electrifying port operations, and engaging with community members about port project decision making. Additional information about the local impacts of offshore wind ports can be found in the Supply Chain, Ports, and Vessels section of this guide, as well as in NREL's report, *A Supply Chain Road Map for Offshore Wind Energy in the United States.*

Grid infrastructure development is necessary to connect power produced offshore to the onshore grid. Cables transporting power to shore are buried beneath the seafloor and beach to offer the highest level of cable protection and prevent disruption to marine and coastal activities. When export cables make landfall, communities will experience short-term construction activity as the cable is buried underground. After construction, and in some cases during it, coastal communities will retain access to beaches and not experience any visual impacts from cable landings. As the export cable is connected to an onshore substation, communities may experience elevated traffic, noise, and roadway closures; for example, roads may be temporarily closed to lay the cable.

More information about the planning aspects of onshore grid infrastructure can be found in the State and Local Involvement section, and information about the economic impacts of grid infrastructure can be found in the Economic Impacts section.

Workforce

Offshore wind energy development and, relatedly, the development of a domestic offshore wind energy supply chain, have the potential to create tens of thousands of good-paying, skilled jobs, both in coastal communities and in regions of the country that are farther from the coast.[clxxxiii] Depending on the community, there may be jobs at offshore wind projects (e.g., wind turbine installation, operations and maintenance), at port facilities (e.g., staging, marshaling, and assembling components), at manufacturing facilities (e.g., manufacturing components), and in office settings (e.g., project planning, research, public affairs). These jobs can range from short to long term or permanent.

Beyond direct jobs in the offshore wind energy industry, there may be indirect jobs working with contractors that support the industry and induced jobs that stem from the industry's activities, such as jobs at restaurants or other businesses near offshore wind

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energy facilities. Communities may also see new or increased opportunities for local workforce development, such as education, training, and labor union apprenticeships.

Those who are not seeking employment in the offshore wind energy industry may still experience impacts from a growing workforce. For example, an influx of temporary or permanent workers into a community may stimulate the local economy through dollars spent at local businesses, occupation of rentals and other housing stock, and an increased tax base. On the other hand, pressure may be put on local resources, such as on housing and schools, and there may be negative social impacts from an influx of temporary workers.

More information on the offshore wind energy workforce, including training and job types, is provided in NREL's *Offshore Wind Energy Workforce Assessment* as well as in the Workforce section of this guide.

Mitigation of Offshore Wind Energy Impacts

When potential or existing negative impacts are identified by communities, offshore wind energy decision makers may take different approaches to mitigate or address these impacts. These approaches may differ depending on the type of impact, the geographic scale, the impacted community, the process through which the impact was identified, and the mitigation measures the decision makers have at their disposal.

Avoiding impacts is one approach that can be used when possible; examples include changing where wind turbines are sited to avoid impacting a sensitive habitat or choosing not to develop a port facility in a community that is vulnerable to environmental health impacts.

Minimizing impacts is another approach that may be used when entirely avoiding an impact is not possible; examples include changing wind turbine arrays so that fishing boats can still use some of their typical routes or using low-emission technologies at a port facility to reduce pollutant emissions.

Mitigating impacts is an approach that may be used for impacts that are unavoidable or in cases where impacts have been minimized but still occur; one of the most common forms this takes is compensatory mitigation. Examples include setting aside an area of the ocean for protection to offset negative environmental impacts, creating a fisheries compensation fund to make up for lost fishing revenues, or providing a community benefit agreement to a community that hosts a port facility.

Efforts to mitigate impacts may also take place on different levels or geographic scales, usually in accordance with the level at which the impacts occur. For example, the Fisheries Mitigation Project, a collaborative effort between 11 East Coast states to set up a compensation fund for fishers impacted by offshore wind energy development, is occurring at the regional level because fisheries transcend state borders. Additionally, a regional fund may allow the states involved to do more mitigation than they could have done on their own.[clxxxiv] On the other side of the spectrum, a community benefit agreement that aims to mitigate impacts of a port facility or cable landing is typically at the local level because the impacts of such infrastructure are concentrated in a specific host community.

Throughout the offshore wind energy development process, stakeholders like BOEM, state governments, and developers will identify potential impacts and mitigation strategies that may be used to address these impacts. The NEPA review process, including Environmental Assessments and Environmental Impact Statements, can be used to inform the mitigation strategies. Additionally, developers account for impacts and describe mitigation efforts as part of their Construction and Operations Plan in BOEM's leasing process and as part of their competition for offtake agreements in many state procurement processes.

Offshore wind energy projects in the United States and other countries have also provided lessons for how impacts from offshore wind energy development can be mitigated. For example, the developers of the Vineyard Wind 1 project in Massachusetts consulted with fishers and considered fishing interests early on to address concerns about disruptions to fishing lanes for lobstermen and trawlers. This effort resulted in Vineyard Wind 1 developers reducing the planned project footprint by 20%.[clxxxv] The developers also changed the layout of wind turbines within the Vineyard Wind 1 project to allow for easier transit to Martha's Vineyard.

For more information about how to engage with offshore wind energy developers and decision makers about mitigating potential impacts, see the Engagement section. For more information on compensation for impacts, see the Economic Impacts section.

Engagement

Conducting successful public engagement strategies as part of offshore wind energy decision making can be challenging, as offshore wind energy projects have a long planning horizon and involve a wide array of stakeholders. But engaging with the public is a central requirement of decision-making and development processes, and establishing trust, supporting the meaningful exchange of ideas, and incorporating public feedback in decisions can help ensure offshore wind energy projects are both successful and equitable. Public engagement opportunities vary based on factors like who is leading the engagement, the type of engagement, project location, and stage of the process. The following sections introduce the major opportunities for public engagement in federal, state, and local processes and with developers, though there may be additional opportunities for a given project or context that are not reflected here.

Figure 40. *Photo from Werner Slocum, NREL 82946*

Engaging on the Federal Level

Within the multiyear leasing process for an offshore wind energy project in federal waters, BOEM conducts outreach to Tribes, all potentially impacted parties, and the public to provide multiple opportunities for engagement. There are public comment periods to solicit comments on the Call for Information and Nominations, draft wind energy areas, and the Environmental Assessment for the site assessment and site characterization activities that result from a lease being issued. There is also a public comment period when BOEM publishes a Proposed Sale Notice. Finally, there are multiple public comment periods and public meetings held during BOEM's preparation of an Environmental Impact Statement and Record of Decision on the lessee's Construction and Operations Plan (COP). Public comment periods are typically held for a period of 30–60 days, during which time members of the public can submit written comments and/or testify at public hearings. More information on public participation in the federal leasing process can be found in the Offshore Wind Public Participation Guide.

Public comment periods are opportunities for the public to provide formal written comments on proposed actions that are published in the Federal Register.[clxxxvi] Public comment periods are typically held for 30–60 days, meaning the public has a deadline for when they must submit their comments. Comments become part of the official public record, so the public can read the comments submitted in previous comment periods. Additionally, BOEM may provide summaries and responses to comments received on a particular action; for example, in 2023, BOEM published its response to comments on its Final Sale Notice for the Gulf of Mexico Lease Sale.

Public meetings are opportunities for the public to discuss issues, share and receive information, provide input and feedback to BOEM, and learn more about BOEM's processes and decision making.[clxxxvii] BOEM holds public meetings at various points in its leasing process as needed. Comments and questions received by BOEM during public meetings become part of the public record, and recordings and transcripts of public meetings are typically published on BOEM's website; for example, all information related to the public meetings for the Revolution Wind project can be found on BOEM's website.

In addition to public comment periods and meetings, BOEM may organize convenings or working groups focused on certain topics or regions. For example, the agency has organized New York and New Jersey offshore wind environmental justice forums,[clxxxviii] an offshore wind and maritime industry knowledge exchange,[clxxxix] and a series of Gulf of Mexico fisheries workshops[cxc]; although focused on certain stakeholders, these events have been open for the public to join. Working groups can provide opportunities for more in-depth discussion and exchanges between different stakeholders, and they may meet regularly over a period to allow for longer-term discussions. Members of the public are also welcome to listen in and ask questions during meetings of BOEM Intergovernmental Renewable Energy Task Forces, which are discussed in the next section.

Once a lease has been awarded and project development activities are underway, members of the public may also review documents made public by BOEM, including COPs, workforce and economic impacts reports, environmental impact studies, and other studies and plans produced by developers. Keeping up to date on developers' plans and activities through BOEM's online documents is key to staying informed about where offshore wind energy projects are headed and the impacts they may have. For example, BOEM's webpage for the Revolution Wind project shows recent updates and hosts a site assessment plan, COP, Environmental Impact Statements, and other important documents for the project; BOEM's website has similar pages for each project that is involved in the federal leasing process. Checking BOEM's newsroom for press releases and notes to stakeholders and following BOEM on social media are two other ways to stay informed.

Other federal entities, such as NOAA and the U.S. Department of Energy, may also seek public engagement in their offshore wind energy activities. These activities may take various forms, such as environmental studies and surveys, studies on community impacts from offshore wind energy, and informational events.

Engaging on the State Level

State governments engage the public in various ways throughout their offshore wind energy activities. Although state engagement processes may vary, some of the typical opportunities to engage include attending public meetings and submitting public comments during state energy procurement processes, joining state-level working groups on different aspects of offshore wind energy, and providing comments on plans for onshore infrastructure like ports. In some cases, states may seek input from specific stakeholders like members of the fishing industry, but in many cases, engagement opportunities are open to the public.

For example, in New York, the solicitation process begins with gathering stakeholder input by meeting with offshore wind energy technical working groups, hosting public meetings, and requesting public comments on a draft solicitation.[cxci] New York's technical working groups are organized around topics such as jobs, maritime commerce, the environment, and fisheries and use workshops from local stakeholder groups to directly make recommendations to the state about offshore wind energy decisions.[cxcii]

BOEM Intergovernmental Renewable Energy Task Forces are forums for states, Tribes, and local governments to engage with BOEM about offshore wind energy development; the task forces are typically requested by states and facilitated by BOEM. States may appoint key stakeholders to be members of the task force, and BOEM often strives to gain participation from members of the public and specific stakeholder groups. Task force meetings are open to the public, presenting an opportunity to engage regularly with state and federal decision makers.

For offshore wind energy projects sited in state waters (i.e., from shore to 3 nautical miles offshore in most states), state governments have authority over the siting and leasing processes and will seek public input for these decisions. Similar to the BOEM leasing process, state-led offshore wind energy development processes include public meetings and opportunities for public comment.

Engaging on the Local Level

Figure 41. *Photo from Joe DelNero, NREL 83836*

Local decision-making processes focused on onshore infrastructure such as cable landing sites and port facilities offer members of the community opportunities to directly engage with their local government and learn about development activities that may affect them. Depending on the community, local government may mean a county or municipal government, and there may be different committees or commissions leading decision-making and engagement processes related to offshore wind energy, such as conservation commissions, port committees, or planning and zoning boards.

Local decision-making processes can differ across communities but typically include public meetings that allow community members to offer their opinions and ask questions about the decisions being considered by their local government. Local governments may also organize informational meetings to help community members learn about offshore wind energy. For example, the city of Rehoboth Beach, Delaware, hosted a special meeting about offshore wind energy in 2022 with presentations about topics such as the federal leasing process, the state government's role in community impacts research, and proposed offshore wind energy projects in the region.[cxciii]

In addition to local government, other stakeholders may provide opportunities to engage about topics related to offshore wind energy. Depending on the community and state, these stakeholders may include universities, nongovernmental organizations, economic development organizations, research institutions (e.g., Sea Grant), port authorities or operators, and industry groups. For example, local chambers of commerce may host events about opportunities to join the offshore wind energy industry, and port authorities or operators may hold public meetings about planned offshore wind port development. Working groups are another opportunity to engage with local or regional stakeholders, such as the Environmental Business Council of New England's Offshore Wind Working Group, which addresses topics ranging from supply chain and ports to environmental impacts.[cxciv]

Local governments may be consulted in federal or state siting processes and may in turn seek input from their constituents, and they may make some decisions about onshore infrastructure. However, local governments do not ultimately make siting or permitting decisions about offshore wind energy projects. Thus, community members interested in being involved in the development and regulatory processes for these projects should engage with the state and federal processes described in previous sections.

Engaging With Developers

Offshore wind energy developers may seek to engage the public in various aspects of their project development process to gain feedback on project decisions, form relationships with local stakeholders, and inform the public about local impacts and opportunities related to the project. While developers may conduct some engagement before being awarded a lease area, they will typically increase their engagement efforts once they have been awarded a lease area and are ramping up their project development activities.

Opportunities to engage with developers can take many forms, including open houses, community meetings, hiring events, business expos, information sessions, presentations at local government meetings or to community-based organizations, booths at community events, and questionnaires or surveys. Developers may aim to engage the general public through some efforts like online public meetings, while using other, more focused efforts to connect directly to specific communities, such as an open house for the local business community or an in-person meeting in a town that is hosting a cable landing site.

Developers typically employ community engagement representatives, often called community liaisons, to lead their engagement efforts in a particular area or community. Fisheries representatives, often called marine affairs managers or fisheries liaisons, are another key developer role with a focus on communicating with the local fishing community, minimizing project impacts to fisheries, and developing mitigation and compensation efforts. Developers also often employ Tribal liaisons who work on building and maintaining relationships with Tribal governments and community members and ensuring there is two-way communication between Tribes and the developer about project decisions. Finally, developers also often have employees who focus on workforce and business development; community members interested in joining the offshore wind energy industry may engage with these employees at open houses, hiring events, training sessions, and other events focused on local hiring and contracting.

Tribal Consultation

Under federal law, federal agencies are required to meaningfully consult with federally recognized Tribal nations about infrastructure projects that may impact Tribal lands, trust resources, and Tribal communities. BOEM engages in government-to-government Tribal consultation and other informal engagement with Tribes as part of its offshore wind energy leasing process, and state governments may also conduct consultation processes with Tribes. For more information about Tribal consultation and best practices for engagement, see the Tribal Considerations and Involvement section of this guide.

Economic Impacts

The deployment of offshore wind energy involves massive infrastructure investments and developing a new domestic industry and supply chain, with significant economic impacts at the international, national, state, and local levels. This section introduces some of the economic impacts that may come from the offshore wind energy industry, including lease revenues, tax revenues for onshore infrastructure, community benefit mechanisms, and workforce and supply chain impacts.

Figure 42. The Block Island Wind Farm off of Rhode Island. The community of New Shoreham on Block Island has a community benefit agreement with the developers of the Block Island Wind Farm. *Photo from Gary Norton, DOE 41182*

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Lease Revenues, Rents, and Operating Fees

As part of the leasing process for offshore wind energy projects on the Outer Continental Shelf, BOEM holds lease sale auctions in which developers bid for rights to develop offshore wind projects in designated lease areas. BOEM receives billions of dollars in lease sale revenues, rents, and operating fees through this process. The agency has projected that its annual revenues from offshore wind energy will range from $170 to $823 million during the Fiscal Year 2024 to Fiscal Year 2028 period.[cxcv] Currently, federal law requires that these funds go to the U.S. Treasury, but some in Congress have proposed legislation that would share revenues with states and communities near lease areas.[cxcvi,cxcvii]

Lease area auction prices have trended upward over time, though prices can fluctuate depending on factors like the region, technology being deployed, project costs, energy demand, wholesale power prices, inflation, and the number of bidders interested in a particular lease auction. For example, bids totaled $3.8 million for the first leases auctioned off the coast of Massachusetts in 2013, but bids totaled only $300,000 in the 2015 auction for lease areas off of Massachusetts.[cxcviii] In the first California lease auction held in late 2022, the bids totaled $757.1 million; the five winning bids were between $130 and $173.8 million each, or approximately $1,600–$2,500 per acre.[cxcix] The New York Bight lease auction held in early 2022 was the highest-grossing competitive energy lease sale in history, with bids totaling $4.37 billion; the six winning bids were between $285 million and $1.1 billion each, or approximately $6,600-$10,700 per acre.[cc] Comparatively, the Gulf of Mexico lease auction held in 2023 drew fewer bids than some other lease auctions and the one winning bid was $5.6 million, or approximately $55 per acre.[cci] More information on past lease auctions can be found on BOEM's website and in DOE and NREL's annually updated offshore wind market reports.

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Onshore Infrastructure: Tax Revenues and Tax Agreements

Figure 43. This area of beach on Block Island is where cables come onshore from the Block Island Wind Farm. The cables are buried underground. *Photo from Dennis Schroeder, NREL 40486*

To build onshore infrastructure like cable landings, developers generally must acquire lease agreements and easements from the local or state governments that have jurisdiction over land-use decisions at that site. Developers will typically then pay property taxes to the local government in return for their use of the site. Additionally, sales taxes on materials and equipment purchased locally during project construction can generate additional tax revenues for communities and states where purchases occur. Both property and sales taxes can make significant long-term economic impacts in host communities. More information on tax revenues can be found in the Land-Based Wind Energy Economic Development Guide; although this resource focuses on land-based wind energy, some elements are applicable to the land-based infrastructure involved in offshore wind energy.

In some cases, developers and local governments may negotiate tax agreements such as Payments-in-Lieu-of-Taxes (PILOT payments), in which the tax burden for wind energy developers is changed by the local jurisdiction in return for financial payments or investments. Thus, rather than receiving property taxes from developers for use of a site, local governments will receive an agreed-upon alternative form of financial benefit. Even though in some cases the local government may receive less money in a tax agreement than they would have in property taxes, tax agreements can attract investment from developers and give local governments more flexibility in how they can use the funds than they might have with property taxes. Additionally, tax agreements can ensure governments receive steady payments from developers, regardless of fluctuations in land value or changes in local or state tax policies.[ccii]

For example, the town of Brookhaven, New York, provided $87.4 million in sales tax breaks and property tax breaks over 25 years to Ørsted and Eversource for developing an underground cable and other onshore grid infrastructure for their offshore wind energy project, Sunrise Wind.[cciii] The town also provided $2.6 million in tax breaks over 10 years for creating an operations center for Sunrise Wind in the town. In return, Sunrise Wind will pay the town, county, and several school districts a total of $169.9 million over 25 years, with $28 million of this total being part of the tax agreement and the remainder being separate payments to host communities.[cciv] The host community agreement signed between the town of Brookhaven and Sunrise Wind is one example of community benefits from offshore wind energy, which are discussed in the next section.

Community Benefit Mechanisms

Community benefit mechanisms like community benefit agreements and funds provide additional financial and/or nonfinancial benefits for communities impacted by their projects. The provision of community benefits is becoming increasingly common for offshore wind energy development, often in the form of a host community agreement between a developer and a coastal or island community impacted by offshore wind energy infrastructure like a cable landing or port. Some examples of communities with community benefit mechanisms in place related to offshore wind energy infrastructure include Salem, Massachusetts; the Mashpee Wampanoag Tribe; New Shoreham, Rhode Island; and East Hampton, New York. Details on these and other community benefit mechanisms for U.S. offshore wind projects and ports can be found in the Wind Energy Community Benefits Database.

There is a wide range of benefits that communities can receive, as well as a range of mechanisms used by developers to provide those benefits. Community benefits may be financial, such as direct payments to local governments, investment in local programs or priorities, and the creation of community benefit funds. They may also include nonfinancial benefits that reflect community values or priorities, such as environmental protection, coastal resiliency, or local economic and workforce development. Examples include expanding internet access for local residents, prioritizing local hiring and job creation, hiring a fisheries liaison, and reducing the local environmental impacts of the supply chain (e.g., using low-emission vessel technologies at a port).

Community benefits can help make offshore wind energy deployment more equitable, particularly when agreements are reached through fair and representative decision-making processes.[ccv] Because communities have limited decision-making power during offshore wind energy siting processes, community benefits processes can be opportunities for communities to meaningfully engage with developers about their concerns and ways to mitigate them.

Community benefits are not currently required by the federal government or by most state or local governments in the United States. However, some states have issued support or guidance for providing community benefits, and BOEM has encouraged their use in offshore wind energy development through bid credits in lease auctions.[ccvi] If a bidder meets specific requirements before the lease sale (in this case, forming a community benefit agreement), then these credits can be added to the cash component of their bid to increase its value.

More information on community benefit mechanisms, including case studies, can be found in the Wind Energy Community Benefits Guide. A comprehensive database of community benefit data for U.S. offshore wind projects and ports can be found in the Wind Energy Community Benefits Database.

Economic Impacts of Supply Chain and Workforce Activities

Offshore wind supply chain and workforce activities create a variety of economic impacts from the local to the international level, such as investments in port and manufacturing facilities, job creation, and increased economic activity in communities hosting supply chain infrastructure. An estimated $10 billion has been invested in the U.S. offshore wind supply chain since 2021, with $2.1 billion in domestic supply chain investments announced in 2023 alone.[ccvii] An interactive map showing some of the major investments in U.S. manufacturing, ports, vessels, workforce development, and research can be found on American Clean Power's website. The U.S. Department of Energy's Building America's Clean Energy Future map highlights offshore wind industry investments stemming from the Inflation Reduction Act and the Bipartisan Infrastructure Law.

Economic impacts may be direct, such as investment in a new manufacturing facility or the purchase of materials, or they may be indirect, such as increased business for a contractor working with the manufacturing facility. There are also induced impacts, which stem from increased spending in an area by those employed or otherwise involved in the industry; for example, workers building an offshore wind energy project may spend money at local restaurants and other businesses. These examples show that investments in the offshore wind energy supply chain and workforce development can have local and regional economic impacts beyond the industry itself.

More information about the offshore wind supply chain can be found in the Supply Chain, Ports, and Vessels section, and details on the offshore wind energy workforce can be found in the Workforce section. More information about the economic impacts of offshore wind supply chain and workforce development in a specific state or city may be provided by state governments, local governments, economic development organizations, or research institutions in areas of interest.

Supply Chain, Ports, and Vessels

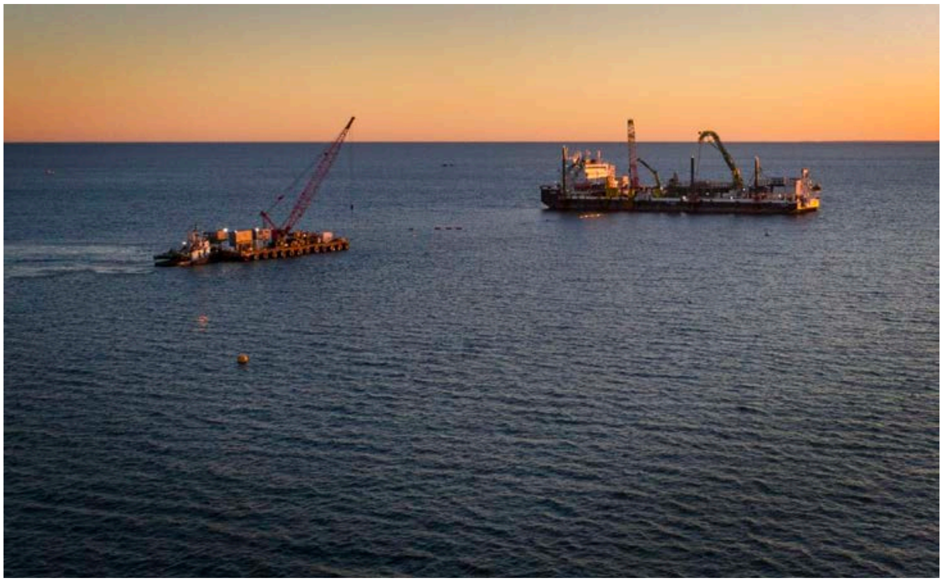

Figure 44. Vessels involved in construction for the Vineyard Wind 1 project, seen from Covell's Beach in Barnstable, Massachusetts. *Photo from Robin Lubbock, WBUR*

While the offshore wind energy industry can use some existing supply chain facilities and practices from other industries, the unique characteristics and technical challenges of offshore wind turbines make it necessary to develop an offshore wind energy supply chain in the United States, separate from the land-based wind energy supply chain. Although many components can be sourced from offshore wind supply chains in Europe and/or Asia, the existing capacity from these supply chains cannot accommodate upcoming U.S. demand. Additionally, it is preferable to have a domestic supply chain that supports American manufacturing and jobs and reduces the risk of global supply chain disruptions. A pipeline of planned offshore wind energy projects encourages investment in a domestic supply chain by ensuring there will be future need for domestic ports, vessels, and manufacturing capabilities.

This section introduces the key aspects and considerations involved in developing an offshore wind supply chain, including port development, vessels, domestic and local content, the supporting supply chain, regional differences, and the local impacts of supply chain infrastructure.

Offshore Wind Ports and Manufacturing Facilities

Offshore wind turbines are very large, which means that some major components such as substructures, towers, blades, and nacelles cannot be transported to the coast by truck or rail. Instead, these components are manufactured and assembled at portside facilities along the coast or navigable waterways like large rivers. Once they are produced, large components are transported by a vessel directly to the project site for

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construction or to a portside location for staging and/or storage. Smaller components (e.g., subassemblies, subcomponents) that can be transported by truck or rail may be manufactured at facilities that are located away from the coast.

In addition to supporting manufacturing facilities, ports will also be needed to support marshaling and staging and integration activities, as well as operations, maintenance, and decommissioning activities.

Figure 45. Components for the South Fork Wind project sit at State Pier, an offshore wind marshaling terminal in New London, Connecticut, awaiting transportation to the project site off of Long Island, New York. *Photo from Matilda Kreider, NREL*

Types of Ports

There are several different types of ports that may be involved in offshore wind energy development:

- **Marshaling ports** are used for fixed-bottom wind turbines to stage components like blades and towers until they are loaded onto vessels and transported to the project site.
- **Staging and integration ports** are used for floating installations to stage components like blades and towers until wind turbines are assembled portside and towed to the project site.
- **Manufacturing/fabrication ports** are ports with manufacturing facilities where components are produced and/or assembled before being transported by a vessel directly to the project site or to marshaling or staging and integration ports for staging and/or storage.

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- **Operations and maintenance ports** support activities throughout an offshore wind energy project's lifetime, such as transporting workers and materials to and from the project site and conducting maintenance and upgrades.

Multiple activities may take place at one port if it has enough space and meets necessary specifications; for example, a large port could have both a manufacturing facility and a staging area. However, it is unlikely that one port could support all of the project development and operations for an offshore wind energy project, let alone for multiple projects, so it will be necessary to develop a coordinated network of ports to support offshore wind energy activities in the United States. Each region will likely need its own port infrastructure, and the number of ports that are needed will depend on factors like the pace of project development, the type and number of vessels being used to survey, install, operate, and maintain offshore wind energy projects in the region, and the extent of domestic manufacturing capabilities.

In regions that will have floating offshore wind turbines, such as the Pacific Coast and Gulf of Maine, ports will have to be designed differently than those in regions with fixed-bottom turbines, like the Atlantic Coast. Ports that support manufacturing and staging of floating offshore wind projects typically need to be larger and have more laydown area because of the logistics of storing, assembling, and maneuvering multiple floating platforms and wind turbine systems around the port site; additionally, staging and integration ports are expected to require deeper waters and no obstructions (e.g., bridges, power lines), because floating wind turbines are constructed at the port and then towed out to sea rather than constructed at sea.[ccviii]

Existing port facilities may be modified to meet the industry's needs in many cases. Modifications can include dredging to increase the depth and width of navigation channels, redesigning terminal configurations, upgrading quayside infrastructure, increasing bearing capacity, constructing manufacturing facilities, and deconstructing existing infrastructure that will no longer be used. In other cases, new ports will be constructed specifically for the offshore wind energy industry, as in the case of the New Jersey Wind Port. Planning, permitting, and constructing new port sites can take many years or even decades depending on where the port is located, whether a new port authority will need to be established, and the design requirements for the specific site. Financing, permitting, planning, construction, and stakeholder engagement activities for new manufacturing facilities located at these ports could take at least an additional 3–5 years.

NREL's report, *A Supply Chain Road Map for Offshore Wind Energy in the United States,* provides more details on port development, such as port needs (e.g., space, proximity to project sites) and how the industry can build out the necessary port infrastructure. Additionally, NREL's report, *The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States,* provides insights into port infrastructure needs specific to floating offshore wind projects. Some additional resources to consider include:

- *Building a National Network of Offshore Wind Ports: A $36B Plan for Domestic Clean Energy Infrastructure* (2023 report from Oceantic Network)
- "Marshaling ports required to meet US policy targets for offshore wind power" (2022 journal article in *Energy Policy*).

Vessels

All phases of offshore wind energy development, from preconstruction surveys to construction to operations to decommissioning, require the use of vessels. Project development and operations will rely on at least 25 types of vessels per project; the number and category of vessels used depends largely on environmental conditions, distance between the project site and port, project size, and other factors.[ccix] Service operation vessels and crew transfer vessels are used across the lifetime of the project in both construction and operations and maintenance. Highly specialized construction vessels, such as wind turbine installation vessels, are needed to install turbines for fixed-bottom projects, whereas anchor-handling tug supply vessels are used to tow and install fully assembled floating wind turbines. Other key vessels are heavy-lift vessels, which are mainly used to install foundations and have traditionally been used in the offshore oil and gas industry; feeder barges, which are used to transport components from ports to project sites; and cable-laying vessels, which lay miles of array cables between the wind turbines and offshore substation and tens of miles of export cables from the offshore substation to the onshore substation. More information about vessel types can be found in American Clean Power's publication, Offshore Wind Vessel Needs.

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Figure 46. This visualization depicts a wind turbine installation vessel installing a turbine. *Image from Josh Bauer, NREL*

Figure 47. This visualization depicts a cable-laying vessel, which would be used to install transmission cables for offshore wind energy projects. *Image from Josh Bauer, NREL*

Obtaining or building the necessary vessels is critical to offshore wind energy development, and there are several key considerations that shape how the industry is approaching this challenge. The primary consideration is the need to comply with federal law—namely, the Jones Act, which requires that cargo traveling between American coastwise points (e.g., ports) must be transported by vessels that were built in the United States, owned by Americans, and carry a majority American crew.[ccx] Under this law, an American offshore wind turbine is considered a coastwise point because it is permanently affixed to the seabed. Complying with the Jones Act means that no foreign vessels can transport offshore wind turbine components between U.S. offshore wind ports and project sites, which presents a unique challenge for the industry because most existing wind turbine installation vessels are foreign.

There are a number of approaches being considered and taken to comply with the Jones Act while advancing the offshore wind energy industry in the United States. Currently, one of the most common approaches is using American-built barges or other vessels to transport components from the port to the project site, where foreign wind turbine installation vessels can install the components. Another approach is to build these vessels in the United States to reduce reliance on foreign vessels. Both of these approaches are being used by the offshore wind energy industry, and both have advantages and drawbacks in terms of cost, business case for vessel owners, timing, and support for domestic supply chain activities like shipbuilding. Across the lifetime of an offshore wind energy project, most of the vessels used will be American and will be crewed by American mariners. According to industry predictions, 82% of all marine crew man-hours related to services for and work on offshore wind energy will employ American mariners over the lifetime of a typical project.[ccxi] NREL's report, *A Supply Chain Road Map for Offshore Wind Energy in the United States*, provides more details on vessel needs and challenges.

Vessels that support renewable energy installations such as offshore wind energy are subject to U.S. Coast Guard inspection and oversight.[ccxii] Additionally, the Coast Guard has a statutory responsibility to ensure the safety and environmental protection of U.S. ports and waterways, under the Ports and Waterways Safety Act of 1972.[ccxiii] Thus, the Coast Guard is likely to be an important stakeholder in some decisions about the development and operation of offshore wind energy ports and vessels.

Domestic Content, Local Content, and the Supporting Supply Chain

Federal domestic content incentives encourage the use of domestically sourced materials and/or components (i.e., steel, iron, or manufactured products that are produced in the United States) by offshore wind energy project developers and other stakeholders. As part of the Inflation Reduction Act, developers can receive a bonus investment tax credit of 10 percentage points if they meet domestic content thresholds.[ccxiv]

To qualify for the credit, all manufacturing processes for structural steel and iron for a project must occur in the United States.[ccxv] Initial guidance from the U.S. Treasury has determined that structural steel includes jackets and towers for offshore wind turbines.[ccxvi] For other manufactured products, a certain percentage of the value of manufactured products and components must originate in the United States; beginning in 2023, the requirement is 20% of the value, but this scales up to 55% after 2027. Initial U.S. Treasury guidance has determined that manufactured products include flanges, wind turbines, transition pieces, monopiles, interarray cables, offshore substations, and export cables.[ccxvii] Additionally, BOEM has offered bidding credits within its offshore wind lease sale auctions for developers that commit to developing a domestic supply chain; more information on this can be found in the Creating an Offshore Wind Energy Project section.

Local content differs from domestic content in that it refers to supply chain activity that takes place in the areas or regions near offshore wind energy infrastructure. Local content does not have a strict definition, both in terms of what it includes (e.g., local workforce, location of manufacturing facilities) and in terms of what geographic area would be considered “local” for a given offshore wind energy project. As a result, various stakeholders may have different guidelines for what would be considered “local content.” Federal and state governments may include local content requirements and incentives in their respective leasing and power procurement processes; for example, the New Jersey Board of Public Utilities included local content benefits in the cost-benefit analysis that it uses in its competitive auction of ORECs.[ccxviii] More information about the local impacts of supply chain activities can be found later in this section.

Shipbuilding facilities and manufacturing facilities for smaller components may be in regions that are not on the coast or near offshore wind energy leasing areas. By manufacturing smaller components, referred to as subcomponents (e.g., bolts, gears) or subassemblies (e.g., pitch systems for blades), farther away from offshore wind energy leasing areas, the industry can leverage the existing manufacturing capabilities in regions like the Midwest and the South. Many offshore wind vessels are also likely to be built in states across the country, with a number of shipbuilding investments announced in states like Louisiana, Florida, and Wisconsin.[ccxix] These capabilities can lessen some of the pressure on coastal states to develop new manufacturing facilities and provide benefits, such as increased economic activity and jobs, to these more distant regions.

An interactive map showing some of the major investments in U.S. manufacturing, ports, vessels, workforce development, and research can be found on American Clean Power’s website. The U.S. Department of Energy’s Building America's Clean Energy Future map highlights offshore wind industry investments stemming from the Inflation Reduction Act and the Bipartisan Infrastructure Law.

Local Impacts of Supply Chain Infrastructure

The development of supply chain infrastructure like offshore wind energy ports, manufacturing facilities, and operations and maintenance facilities can have a variety of impacts on the communities that host infrastructure.

U.S. Department of Energy. 2024. "Offshore Wind Energy Guide" Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office: WINDExchange. https://windexchange.energy.gov/offshore-wind-energy-guide.

In many cases, the most prominent will be economic and workforce impacts, such as job creation, local investment, and increased tax revenues. These impacts may be direct (e.g., creation of a new manufacturing facility), indirect (e.g., increased business for a contractor working with the manufacturing facility), or induced (e.g., increased money spent at local restaurants by employees of the facility). While some economic impacts will affect entire states or regions, there may be significant localized impacts for those living near supply chain infrastructure, such as local investment, revitalization of infrastructure that draws in increased business, and prioritized local hiring and job training. For those living close to ports—populations that tend to be economically disadvantaged and highly impacted by environmental justice burdens like air and noise pollution—such local economic activities could deliver significant benefits; prioritizing equity and community input in port decision making can help ensure that port communities are impacted positively.[ccxx]

Figure 48. Buildings in the city of New London, Connecticut, can be seen behind wind turbine blades and a crane at State Pier. The blades are awaiting transportation to the South Fork Wind project site. *Photo from Matilda Kreider, NREL*

As with other industries involving manufacturing and the use of heavy machinery and vessels, the offshore wind energy industry may create environmental health impacts in some cases. Community members living close to or downwind of manufacturing

U.S. Department of Energy. 2024. "Offshore Wind Energy Guide" Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office: WINDExchange. https://windexchange.energy.gov/offshore-wind-energy-guide.

facilities or port facilities may experience negative impacts from increased industrial activity and/or vessel activity, including emissions that can be detrimental to air quality and public health.[ccxxi] Many communities living near ports are considered disadvantaged and/or environmental justice communities, making them especially vulnerable to these potential negative impacts. Similarly, workers at offshore wind energy ports may be exposed to emissions while at work. Sustained exposure to air pollution can contribute to long-term health problems, such as increased cancer risk, respiratory illness, and premature mortality.[ccxxii] Exposure to water, light, and noise pollution are also serious concerns.

Developers and port operators can help mitigate potential negative environmental and health impacts through actions like using shore power for vessels (i.e., allowing vessels to connect to onshore electric power rather than burning fuel at the port) or using electric vehicles and equipment at ports where possible. For example, the developers of the South Brooklyn Marine Terminal offshore wind port in Brooklyn, New York, have committed to making the port a low-emission facility,[ccxxiii] and the operators of Salem Offshore Wind Terminal in Salem, Massachusetts, have committed to incorporating electrification and shore power technologies at the port, with a goal of 100% port electrification by 2040.[ccxxiv] Port communities can be especially vulnerable to climate impacts such as sea level rise and flooding,[ccxxv] so there is potential for offshore wind energy port redevelopment projects to incorporate port and waterfront infrastructure upgrades that may help with coastal resiliency and climate adaptation. Additionally, generating electricity using renewable energy sources like offshore wind energy rather than fossil fuels (e.g., coal, natural gas) can help reduce air pollution and mitigate climate change.

There may also be social and cultural impacts associated with supply chain infrastructure, such as an influx of new workers and businesses or changes made to the way a port or waterfront area has traditionally been used. It is likely that communities will experience a range of impacts that could be perceived as negative, positive, or neutral. For example, communities may notice increased pressure on resources like housing while also enjoying the benefits of local population growth, such as a larger tax base and increased cultural diversity. Similarly, changes to how a waterfront area was traditionally used can have negative impacts, like displacing existing businesses, while also ushering in new investment and workforce and business opportunities in a growing industry.

Local impacts of supply chain infrastructure will vary from place to place and within communities, making it important for community members and leaders to engage with port authorities and other decision makers to better understand potential impacts. More information on the local impacts of supply chain infrastructure and the equity considerations involved in siting port facilities can be found in NREL's report, *A Supply Chain Road Map for Offshore Wind Energy in the United States.* Additionally, NREL's report, *The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States* addresses some of the Tribal impacts of port development on the West Coast and includes equity analysis for the communities surrounding proposed offshore wind energy port sites.

Workforce

Figure 49. Maintenance is performed on a turbine at the Lillgrund Offshore Wind Farm off the coast of Sweden. Photo from Siemens AG 27853

The offshore wind energy industry requires a large, skilled workforce in various roles throughout the offshore wind deployment stages, from development and manufacturing to construction and operations. It is estimated that the offshore wind energy industry will employ an average of 15,000 to 58,000 full-time workers every year from 2024 to 2030, depending on the amount of domestic content (i.e., domestic production of steel, iron, or manufactured products) used by the industry.[ccxxvi] Developing this workforce requires coordinated efforts between stakeholders such as educational institutions, state and local governments, labor organizations, local workforce and economic development organizations, offshore wind energy developers, original equipment manufacturers, and port operators.

Regions and communities where industry activities are taking place may see impacts such as job creation, workforce training program development, and social and economic impacts brought about by the influx of new workers into an area. The development of port and manufacturing facilities will also have a significant impact on the communities that surround them and could contribute to substantial economic growth in those areas. Prioritizing hiring and training for the local workforce offers an opportunity to simultaneously meet workforce needs while ensuring communities most impacted by offshore wind energy deployments are benefiting economically.

This section introduces the job types involved in the offshore wind energy industry, education and training efforts, labor agreements, workforce policies and incentives, and the local impacts of offshore wind energy workforce activities.

Occupations and Roles in the Offshore Wind Energy Industry

There are many different roles that are directly or indirectly involved in the offshore wind energy industry. Throughout an offshore wind energy project's lifetime, the workforce that is needed will vary in terms of job types, numbers, and locations. NREL's *U.S. Offshore Wind Workforce Assessment* provides more details on the responsibilities, education and training requirements, workforce development gaps and opportunities, and demand for specific job types. In more general terms, jobs in the offshore wind energy industry fall into the following five categories:

- **Manufacturing and supply chain:** a range of engineering and factory-level roles involved in multiple tiers of manufacturing and supplier processes for the purpose of fabricating and assembling offshore wind energy project components. This category is expected to provide the largest source of employment in the industry. Example roles:
    - Manufacturing engineer
    - Design engineer
    - Plant manager
    - Manufacturing associate/operator
    - Quality assurance/quality control specialist
    - Skilled tradesperson (e.g., welder, electrician).
- **Development:** mostly professional roles associated with offshore wind energy project development activities that occur prior to construction, such as site assessment, plant design, permitting, financing, and project management. Example roles:
    - Environmental scientist
    - Regulatory/permitting coordinator
    - Financial analyst
    - Public relations/stakeholder specialist
    - Engineer.
- **Ports and staging:** roles located at port facilities mainly involved in supporting offshore wind energy project construction and installation. Example roles:
    - Laborer
    - Longshoreman

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  - Crane operator
  - Port manager.
- **Maritime construction:** roles on vessels operating at sea to construct and install offshore wind energy projects. Example roles:
  - Pile driver
  - Wind turbine technician
  - Vessel captain or crew member
  - Crane operator
  - Health, safety, and environmental officer.
- **Operations and maintenance:** roles involved in operating and maintaining an offshore wind energy project throughout its lifetime. Example roles:
  - Marine crew
  - Wind turbine technician
  - Marine services technician
  - Operations engineer.

Education and Training

Careers in the offshore wind energy industry require varying types of education and training depending on the nature of the role and the part of the industry they are in. For example, roles like environmental scientist or engineer may require advanced degrees, whereas some roles in manufacturing or construction might have less stringent degree requirements but require training and certifications. Workers coming from other occupations and adjacent industries may have transferable skills and certifications that help them transition into the offshore wind industry.[ccxxvii] Details on the requirements for specific positions can be found in NREL's *U.S. Offshore Wind Workforce Assessment*; this section instead focuses on education and training activities more generally.

Stakeholders such as labor unions; community colleges and universities; trade schools; community organizations; state, Tribal, and local governments; and offshore wind energy developers play important roles in developing an offshore wind workforce through education and training. Key workforce development activities include developing offshore wind curriculum and training programs based on the skills needed in the industry, offering apprenticeship programs, training and hiring a local and/or diverse workforce, hosting job fairs and recruitment events, and coordinating or collaborating with other stakeholders to maximize their impact and ensure that workforce opportunities and job requirements are widely known. For example, Sunrise Wind (an offshore wind energy developer) partnered with a local community college and several labor unions in 2022 to establish a National Offshore Wind Training Center on Long Island.[ccxxviii] For more information on workforce development and collaborations, see NREL's Offshore Wind Energy Workforce Development Best Practices Resource.

U.S. Department of Energy. 2024. "Offshore Wind Energy Guide" Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office: WINDExchange. https://windexchange.energy.gov/offshore-wind-energy-guide.

High-quality training is critical for the offshore wind energy industry for many reasons, including that many job roles require specialized knowledge and that training can help alleviate risks to worker safety. For more specialized roles, experienced workers can be brought in from other industries and receive training from labor unions or educational institutions to prepare them to work on offshore wind energy. The offshore wind energy industry carries the typical risks that are associated with working in construction, manufacturing, or ports, such as falls, electrical shocks, crushing injuries, exposure to toxic substances, and burns, but there are also additional risks that come with working at sea.[ccxxix] For more information on roles, responsibilities, and key actions related to safety training for workers who build and operate offshore wind energy projects at sea, see NREL's [Offshore Wind Energy Workforce Safety Standards and Training Resource.]

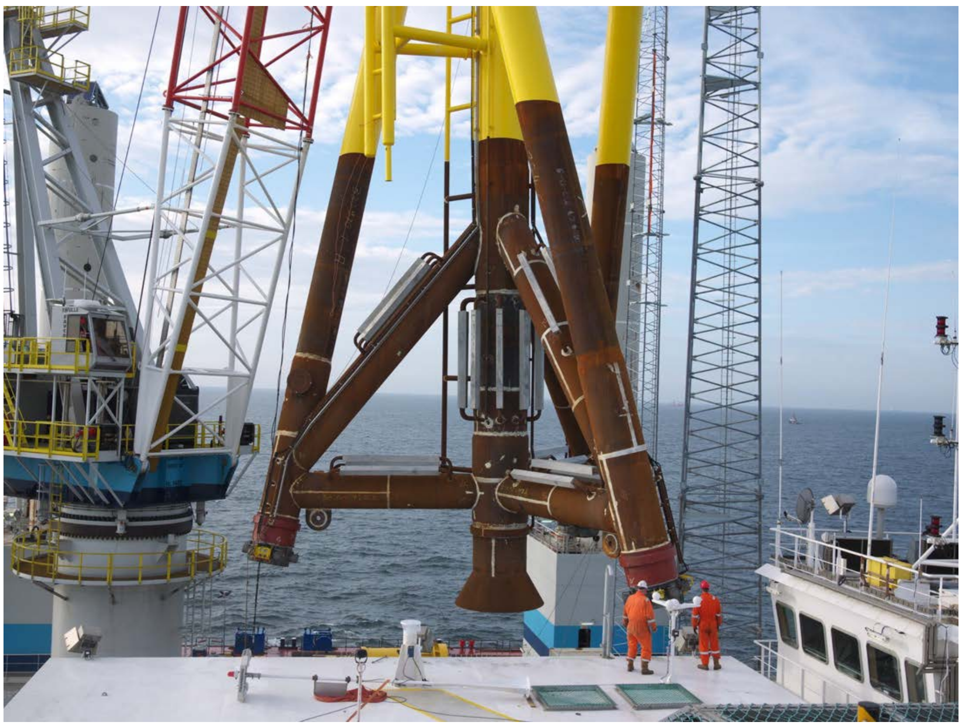

Figure 50. Workers on a vessel installing an offshore wind turbine foundation at a project site off the coast of the United Kingdom*. Photo from Zachary J. Finucane, Keystone Engineering 27999*

Labor Agreements

Offshore wind energy project developers, port developers or operators, and labor unions may sign project labor agreements, which are collective bargaining agreements that determine employment terms for a project prior to the start of work. Project labor agreements can help ensure that workers receive a prevailing wage (i.e., a wage that is based on the local cost of living) and a safe working environment; they can also help ensure that local workers have prioritized access to job opportunities. These agreements also help project developers ensure that they will have a steady, skilled workforce to work on their project, which helps keep projects on track. Offshore wind port projects and transmission projects may also have project labor agreements in place for activities like constructing ports, working at ports, and constructing transmission infrastructure. A list of 16 offshore wind and labor activities occurring as of 2022, including project labor agreements, appears in Table 3 in NREL's *U.S. Offshore Wind Workforce Assessment*.

For some projects receiving federal funds, project labor agreements are required under a White House executive order.[ccxxx] Additionally, in several of its lease auctions, BOEM has included a lease stipulation requiring lessees to make "every reasonable effort" to enter into a project labor agreement for the construction stage of any project proposed for the lease area.[ccxxxi,ccxxxii,ccxxxiii]

Workforce Policies and Incentives

Federal, state, and local governments can influence hiring, workforce development, and other workforce activities in the offshore wind energy industry through policy and incentives. For example, BOEM can offer incentives in the leasing process that encourage developers to take certain workforce actions. For its 2022 Pacific Wind Lease Sale, BOEM offered a bidding credit that allowed offshore wind energy developers to increase the value of their bid by committing to investing in workforce training programs.[ccxxxiv]

Tax incentives are another mechanism that the federal government can use to encourage certain worker benefits or workforce development activities. For example, the Inflation Reduction Act includes a 6% investment tax credit for offshore wind projects beginning construction before January 2026, but the tax credit increases to 30% for renewable energy developers that pay prevailing wages and meet registered apprenticeship requirements.[ccxxxv]

State governments may require offshore wind energy developers to meet certain workforce requirements as part of the state solicitation process to procure energy from an offshore wind energy project. For example, New York, New Jersey, Rhode Island, Maine, and Maryland all have some variation of a project labor agreement or prevailing wage standard as part of their procurement processes.[ccxxxvi] In another example, in its third offshore wind solicitation in 2022, New York required offshore wind energy developers to create supply chain investment plans and New York workforce and jobs plans describing the workforce efforts they plan to perform in the state.[ccxxxvii]

U.S. Department of Energy. 2024. "Offshore Wind Energy Guide" Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office: WINDExchange. https://windexchange.energy.gov/offshore-wind-energy-guide.

Figure 51. Engineers work in the nacelle of an offshore wind turbine at the Lillgrund Offshore Wind Farm in Sweden in 2008. *Photo from Siemens AG*

States and economic development organizations are also actively engaged in ensuring their workforce has a role in offshore wind energy development. Such initiatives or actions aimed at increasing the likelihood of hiring from nearby communities include providing grants for new training programs and institutions, developing testing facilities, developing and revitalizing ports, incentivizing the development of manufacturing facilities, developing transmission infrastructure, performing workforce analysis, coordinating with other governments and organizations, and prioritizing diversity and energy justice.

Governments can encourage certain workforce activities through the siting and development of onshore infrastructure like ports and cable landings. For example, when developing a port project or other supply chain facility, local or state government agencies may establish hiring or contracting goals (e.g., local hiring goals, goals for contracting with minority- and women-owned businesses) or require certain workforce provisions (e.g., prevailing wage) as part of the approvals for a port project. Local governments may also negotiate with developers to have workforce provisions included during the process of approving a cable landing site.

For more information on workforce policies, incentives, and actions, see NREL's Offshore Wind Energy Workforce Development Best Practices Resource.

Local Impacts of Workforce Activities

Communities that host infrastructure like factories and ports and/or are in proximity to offshore wind energy projects may notice impacts from workforce activities, such as new workforce and economic opportunities and an influx of new residents.

Job creation and new education and training opportunities can be highly beneficial for local communities, especially for residents who are interested in joining the offshore wind energy industry. Local educational institutions and labor unions may expand or develop new training and apprenticeship programs, creating new workforce opportunities in the community. Similarly, new opportunities may arise for local business owners to receive support and develop new capabilities to help them enter the offshore wind energy industry. Employers like offshore wind energy port authorities or project developers may prioritize local hiring and contracting and/or diverse hiring and contracting, both of which can help ensure that opportunities are equitable and benefits flow to local communities.

An influx of new residents (both temporary and permanent) from workforce activities may affect communities in different ways. For example, positive impacts might include new customers and revenues for local businesses, new students in local schools, and additional tax revenues. There may be some challenges along with these impacts, such as added pressure on resources that are already limited (e.g., schools, housing). To help communities adjust to these changes, coordination and communication between employers (i.e., offshore wind energy developers, port operators), state and local governments, and community organizations will be important. More information on these topics can be found in the Supply Chain, Ports, and Vessels section and the Community Considerations section of this guide.

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