Floating Offshore Wind Manual

Port Requirements, Opportunities, and Impacts

[bw] RESEARCH PARTNERSHIP

Introduction

BW Research prepared this report on behalf of Renewable Northwest to present stakeholders in the port management and development environment with a comprehensive manual on the different opportunities and requirements in the floating offshore wind industry. The research team analyzed various technical reports, case studies, and existing port examples in the offshore wind supply chain across the United States (US) and internationally to understand the potential opportunities and benefits of different activities in this growing industry. Unlike a typical ports assessment, which examines specific ports and makes recommendations for each based on technical requirements and attributes, this report is intended to provide port managers with information about various port-related activities for offshore wind (OSW) so that they can make informed decisions based on their own specialized local needs.

Federal and state governments have developed a suite of new investments and policies to attract suppliers and developers to support offshore wind. On the US West Coast, the need for floating turbines presents an additional layer of complexity since this technology is less mature than fixed-bottom technologies and includes some different supply chain requirements. Floating offshore wind (floating OSW or OFW) is an important piece of the region's energy goals, which presents both an opportunity and a need for a local supply chain and port infrastructure to bolster the industry.

Within the nation's offshore wind goals, the target for floating offshore wind is to generate 15 GW of electricity by 2035, with a large portion coming from the West Coast. To reach this goal the Bureau of Ocean Energy Management (BOEM) announced in 2022 five winners of lease areas off the coast of California to develop an estimated 4.6 GW of offshore wind energy. In 2024, BOEM announced the proposed sale of two further lease areas off the coast of Oregon, potentially providing up to 3.1 GW of electricity. In addition, BOEM anticipates an additional lease sale off the coast of California by early 2028.

In the European Union (EU) and the US East Coast, the offshore wind industry has brought about new and expanded local manufacturing opportunities, robust investments in disadvantaged communities, and other long-term economic benefits. It has also led to the creation of local, high-wage jobs in the EU, and such benefits are also starting to surge in the US East Coast. This report gives more insight into the port needs and economic impacts of a floating offshore wind supply chain as a first step for port managers and communities that want to analyze the potential economic opportunities of this growing industry.

How To Use This Report

This report provides detailed information on various construction and manufacturing activities related to offshore wind to support port managers and directors in determining whether and which activities might be worth pursuing for their communities. Most of the information is based on a port facility of a typical size, representing a midpoint of a range of potential. The following information is included for each type of floating offshore wind port:

- Port Activities: Work done at the facility for each type of port
- Logistics Requirements: Access to rail or truck transportation
- Permitting and Construction Timeline Estimates
- Physical Port Requirements: Area, draft, wharf, depth, width, loading capacity, and storage
- Workforce Effects: Job creation potential, average wages, and occupations
- Equipment Requirements: Types of cargo handled, cranes, utilities, and other needs

This report was authored by Nicole Hughes and Casey MacLean from Renewable Northwest and Phil Jordan, Julian Ugalde, and Sophia Nelson from BW Research.

Renewable Northwest and BW Research would like to thank the interviewees and the reviewers for this project.

Table of Contents

Funding Opportunities

For Offshore Wind Activities

This section provides a high-level overview of some of the policies and investments at the state and federal level aimed towards ports, manufacturers, and developers in the offshore wind industry. This chapter is intended to provide port managers with an initial, but not exhaustive, list of available funding opportunities in this industry to introduce them to existing investments and policies.

Existing and Future Policies

The federal government has led policy and investment efforts to develop a robust offshore wind industry in the US with the Inflation Reduction Act (IRA) of 2022 and the Infrastructure Investment and Jobs Act (IIJA) of 2021, also known as the Bipartisan Infrastructure Law (BIL). State governments and local agencies have also established several programs to develop a local supply chain and capture economic benefits through jobs, taxes, and longstanding economic activities.

At the state level, agencies prioritize creating a supply chain able to comply with the needs of the offshore wind industry, focusing on infrastructure, manufacturing capabilities, domestic production, benefits to local communities, and good-quality jobs. For example, Massachusetts, Rhode Island, and Connecticut signed a regional collaboration agreement to seek multi-state proposals in offshore wind. New York is investing $700 million in supply chain infrastructure exclusively for offshore wind. Programs and investments like these become increasingly important as states set ambitious offshore wind plans, such as Oregon's goal of 3 GW of floating offshore wind by 2030. Since floating offshore wind turbines require onshore fabrication and assembly due to their size, unlike fixed-bottom turbines, investments into port infrastructure and different port activities are key in the US West Coast, which will develop exclusively around floating technology, given the deeper waters.

Some examples of existing policies:

- **IRA Advanced Manufacturing Production Tax Credit**
  Tax credit for US companies manufacturing or selling clean energy equipment domestically. In wind energy, the final credit amount is determined by the component type and the rated capacity of the turbine in watts. This focuses on the turbine's tier 1 components (blades, nacelles, towers), platforms, critical minerals, and vessels. Floating technology is given heavier tax incentives, as floating platforms receive double the dollar amount per watt of rated capacity compared to fixed-bottom platforms. The program started on December 31, 2022, and ends on December 31, 2032. The tax credits are:

Blades	$0.02 per watt of rated capacity
Nacelles	$0.05 per watt of rated capacity
Towers	$0.03 per watt of rated capacity
Fixed-bottom platforms	$0.02 per watt of rated capacity
Floating platforms	$0.04 per watt of rated capacity
Critical mineral production	10% of the cost of production
Vessels	10% of the vessel's sale price

For example, a nacelle manufacturer for 15 MW turbines will receive a tax credit of $750,000 per turbine ($0.05 x 15,000,000 watts).

- **Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) and the Wind Energy Technologies Office (WETO), Offshore Wind National and Regional Research and Development**
  This program spans a range of offshore wind components, focusing on innovation and technology advancement. Floating offshore wind is central to the program, as several grants available prioritize floating platforms, manufacturing of floating-specific components, and efficient deployment of floating turbines. EERE will award close to $49 million, split into individual awards ranging between $200,000 and $5 million.

- **Department of Transportation Maritime Administration, Port Infrastructure Development Program (PIDP)**
  This program aims to enhance the dependability, efficiency, and safety of cargo movement through ports. It grants funds to various port infrastructure upgrades, including those that lower port-related greenhouse gas emissions and encourage the implementation of clean energy, including facilities supporting floating offshore wind. To be granted over five years, from 2022 to 2026, $2.25 billion was allocated for the PIDP program under the Bipartisan Infrastructure Law, of which $450 million was made available in fiscal year 2024 (FY24). The PIDP received an additional $50 million via the FY24 Appropriations Act. In total, $500 million is available to be dispersed through discretionary grant awards in the third year of the PIDP.

- **Department of Transportation, Infrastructure for Rebuilding America (INFRA) Grant Program**
  The competitive INFRA grant program provides funding for multimodal freight and roadway projects with national or regional significance over five years. From the BIL, approximately $2.7 billion of the $8 billion allocated for INFRA was available through early 2024. Grant recipients may receive funding for transportation infrastructure projects that indirectly support floating offshore wind, such as port or highway renovations that facilitate the transportation of oversized wind turbine components. The Humboldt Bay Harbor in California received $427 million in early 2024 for new offshore wind infrastructure.

- **Washington Department of Commerce, Energy Programs in Communities (EPIC)**
  This program, developed by the WA Department of Commerce, offers funding for the planning, designing, and constructing of clean energy projects in the state. This is particularly relevant for offshore wind projects that leverage private and federal funding. Further grants are available for clean energy projects in tribal or disadvantaged communities. About $117 million is available for grants through the program, which started in early 2024.

- **Oregon Port Revolving Fund**
  Although not specifically focused on clean energy, this program focuses on improving Oregon's port infrastructure to boost economic activities. The state's offshore wind industry can be one of the main benefactors of such programs, as port infrastructure is central to its growth. This program provides

loans of up to $3 million for planning and constructing port facilities and infrastructure. This program comes from Business Oregon.

The examples presented above are a small portion of the incentives available nationwide and at the state level. Developing these programs and incentives are key to guaranteeing long-term stability for the local offshore wind industry. States like New York have prioritized in-state manufacturing and made funding opportunities available to attract manufacturers and investors.

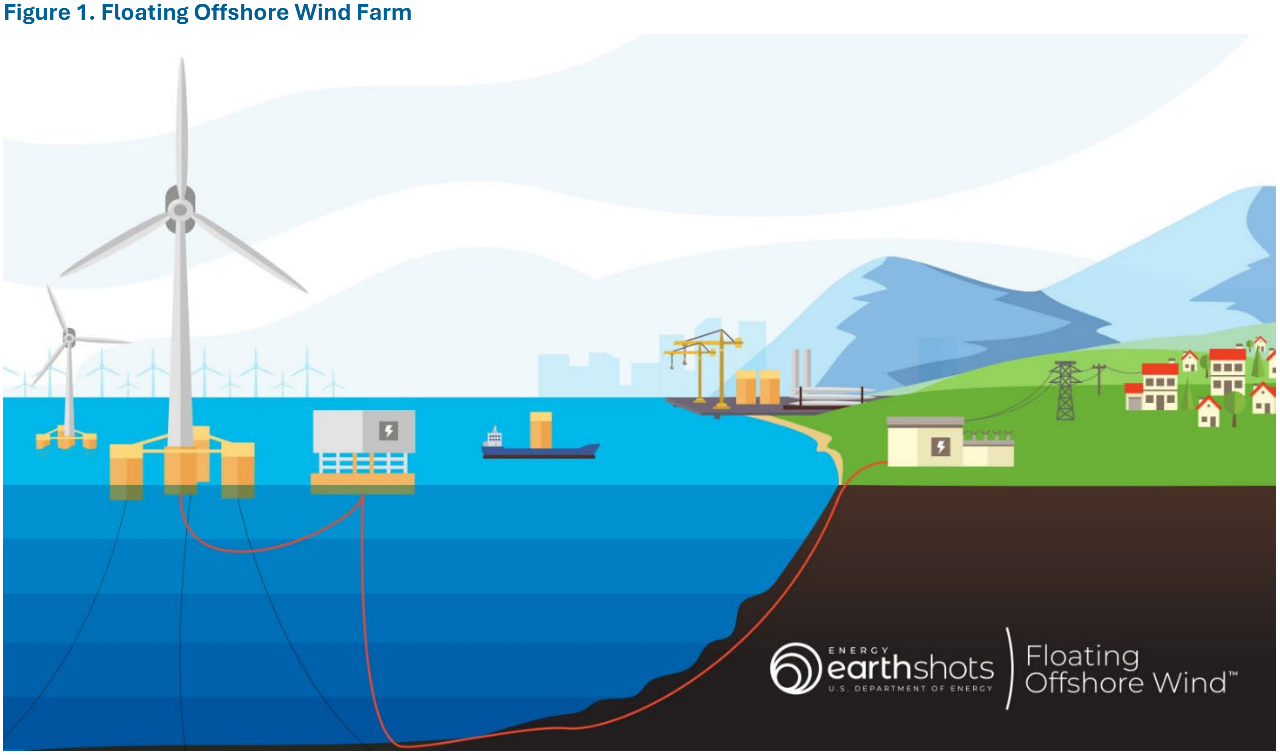
As BOEM announces and auctions lease areas, states develop further incentives to attract investments and build a local supply chain. With the California and Oregon lease areas, it will be key to implement local manufacturing of floating-specific components and bring assembly abilities to regional ports.

Floating Offshore Wind Farms & Turbines

Floating offshore wind requires a variety of structures onshore and offshore working together to generate electricity and supply it to the grid. Figure 1 shows a finalized floating offshore wind farm and the interactions between ports, vessels, turbines, and the electric infrastructure to provide power to the grid. The economic benefits that accrue to local communities vary as a floating offshore wind project matures, going from the jobs created in the manufacturing of components to the staging and integration of turbines and finally moving to a longer period of power generation and operations and maintenance activities.

The wind turbines manufactured and assembled in several ports and facilities onshore are towed out to sea using offshore wind-specific vessels and connected using array cables to provide electricity to the offshore substation, which sends the generated power onshore through high-voltage export cables.

Figure 1. Floating Offshore Wind Farm



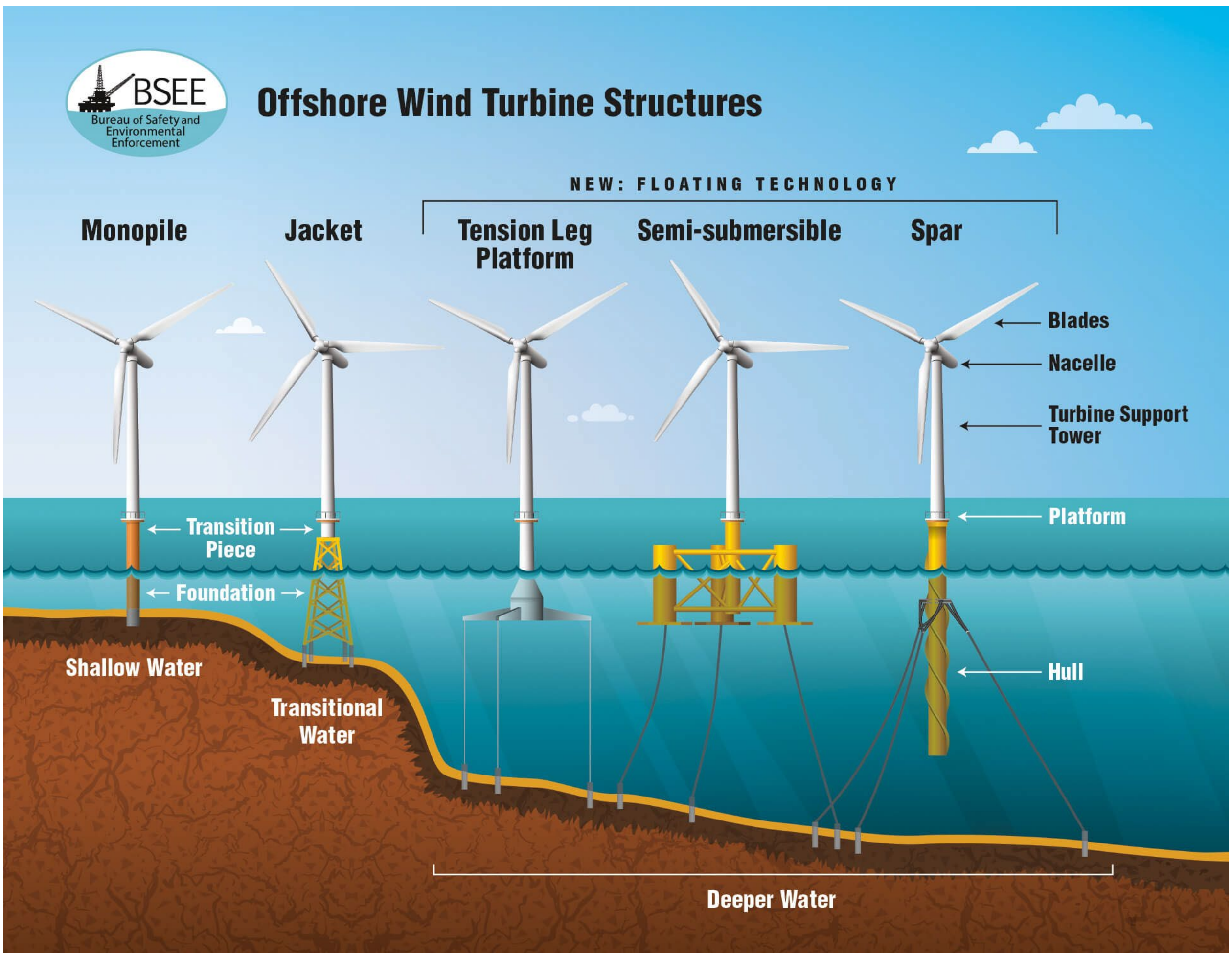
Source: US Department of Energy, "Floating Offshore Wind Shot", https://www.energy.gov/eere/wind/floating-offshore-wind-shot

Figure 2 shows the different structures in offshore wind, starting with fixed-bottom foundations (left) and moving on to floating platforms for deeper waters, such as those on the US West Coast. Floating offshore wind turbines have similar component needs. The three largest components common to all technologies are the blades, which capture the kinetic energy from the wind; the nacelle that houses the hub where the blades attach and support the turbine rotation to generate electricity; and the towers that lift the turbine about 400 feet, or 120 meters, over the sea surface. Floating platforms are another major component of floating turbines, and this study presents the port activities and requirements for three platform technologies: tension leg, semi-submersible, and spar.

The floating offshore wind industry has developed different technologies around floating platforms, but large-scale deployment on the West Coast has not started. This report dives deeper into the three floating technologies shown below since none of these technologies have established themselves as the clear path forward in the market, and each technology has different labor, materials, and logistics needs.

The following sections of this report cover the port activities, various requirements, and workforce impacts for each type of port involved in floating offshore wind development.

Figure 2. Offshore Wind Turbines: Components, Foundation Structures, and Water Depth Specifications



Source: Bureau of Safety and Environmental Enforcement, "Renewable Energy Policy Statement", https://web.archive.org/web/20200728214215/https:/www.bsee.gov/what-we-do/renewable-energy/renewable-energy-policy-statement.

Component Manufacturing Activities

Blades

Blades are the turbine components that capture the kinetic energy when displaced by the wind and their handling after manufacturing and in the assembly phases requires caution as they are highly fragile. Blade manufacturing facilities are key in ensuring a supply of blades for a local offshore wind farm. Blade manufacturing, along with the manufacturing of other large components, represents one of the most significant challenges to developing a robust floating wind supply chain because of the blades' size, complexity, and material needs. Due to the size requirements of floating offshore wind turbines, blades must be of an adequate size to fulfill the capacity expectations for floating wind farms.

Port Activities

Although several blade manufacturing processes exist, the most common practice involves resin infusion, large molds, and consumable vacuum bags to make two full-length shells with an aerodynamic design. The shells are then either glued around a central load-bearing spar or have other structural components incorporated and connected for proper load-bearing using glass fiber shear webs.

MOLDED
Fiberglass or carbon fiber material is molded and cured into the blades, which can be over 328 ft (100 m) long for the new generation of floating OSW turbines

COATED
The blades are finished with an outer coating, and sensors are installed

INSPECTED/TESTED
The completed blades are inspected and tested

LOADED
Once fabricated, they may be loaded by crane, either individually or in bundles of three, onto a transport vessel

SHIPPED
Later, they are transferred onto specialized vessels (bulk carriers or deck barges) to be shipped to the assembly or S&I port

EXAMPLES OF EXISTING PORTS OR FACILITIES

General Electric facility in Gaspé, Quebec, Canada
LM Wind Power facilities in Kolding, Denmark and Bergama, Turkey
Previously planned Siemens Gamesa facility at Port of Coeymans, New York, USA

Logistics Requirements

Road access required to receive materials

Rail access required to receive materials

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1 year

CONSTRUCTION OF FACILITY
Approximately 1.5 - 2 years

Operations are estimated to start 2.5 – 3 years after permitting process begins

Blades

Physical Port Requirements

TOTAL AREA
100 acres
Minimum

NAVIGABLE WIDTH
200-400 ft

NAVIGABLE DEPTH
Must be able to accommodate heavy-lift cargo vessels, including bulk carrier vessel with 32 ft draft

DRAFT AT BIRTH
18 ft
Minimum for deck barge vessel
32 ft
Minimum bulk carrier vessel

WHARF LENGTH
650 ft
Minimum (heavy-lift wharf)
With minimum width of
120 ft Quayside

NUMBER & SIZE OF TERMINALS OR BERTHS
One terminal for manufacturing facility & shipping

SIZE OF BERTH
A port's berth must accommodate a bulk carrier and a deck barge, with the following dimensions, at a minimum:
BULK CARRIER – D 37 ft W 113 ft L 588 ft
DECK BARGE – D 21 ft W 114 ft L 429 ft

LOADING & BEARING CAPACITIES

WHARF LOADING	4,000 – 6,000 psf
YARD LOADING	4,000 – 6,000 psf
BEARING CAPACITY	2,000 – 3,000 psf

STORAGE NEEDS
Large bespoke transportation frames to store blades
Storage space of 14.8-17.3 acres for 240 blades

AIR DRAFT
200 ft
Minimum clearance above the water line

Workforce

$51,200 - $126,800
U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 59 direct jobs and 64 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Aerospace engineers
Computer-controlled machine tool operators, metal and plastic
Engineering technicians
Heavy equipment operators
Industrial production managers
Inspectors, testers, sorters, samplers, and weighers
Machinists
Materials engineers
Mechanical engineers
Team assemblers
Welders, cutters, solderers, and brazers

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS
(what types of cargo will need to be handled for the activities)

Primarily fiberglass and carbon fiber

CRANE NEEDS

- Gantry cranes to lift and transfer the blades onsite
- Vessel-based cranage to lift and transport the blades onto the vessel
- Mobile cranage preferred

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

OTHER NEEDS

Crawler cranes, forklifts, cherry pickers, multiple axle trailer

Self-propelled modular trailers (SPMTs)

Rotor lifts and bespoke trolleys

Bulk carriers or deck barges (specialized to carry blades)

Roll-on/roll-off capabilities

Greenhouse gas emission reduction initiatives

Shoreside vessel services (standard ship services and security requirements)

Offices, bathroom, and indoor storage/warehouse buildings

Component Manufacturing Activities

Nacelles

Nacelle manufacturing sites are essential to the floating offshore wind supply chain. Located at the top of the tower, nacelles support turbine rotation and electricity generation. Nacelles are complex components that require a supply of steel and other composite components and are, therefore, a major source of local skilled direct and indirect jobs. Nacelle facilities usually represent a large investment and are an important source of domestic content as different US states seek to create a local supply chain.

Port Activities

PRODUCTION
Production of individual nacelle subcomponents (e.g. structural housing, gearboxes, rotor shaft, generators, transformers, control systems, etc.)

ASSEMBLY OF DRIVETRAIN
Assembly of the drivetrain with rotor shaft, gearbox, and generator

ASSEMBLY OF NACELLE
Structural and electrical assembly of the nacelle using the drivetrain, yaw drive, and electrical controls

QUALITY CONTROL
Quality control testing of assembled nacelles before being transported to a Staging & Integration port/site

EXAMPLES OF EXISTING PORTS OR FACILITIES

GE Renewable Energy factory in Montoir-de-Bretagne, France
Siemens Gamesa facilities in Cuxhaven, Germany and Taichung, Taiwan
Planned Vestas facility in Szczecin, Poland
Previously planned Siemens Gamesa facility at Port of Coeymans, New York, U.S.

Logistics Requirements

Road access required

Rail access required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Construction is able to start halfway through the permitting process, so operations are estimated to start 3 years after permitting process begins

Component Manufacturing Activities

Nacelles

Physical Port Requirements

TOTAL AREA

25 acres

Minimum

NAVIGABLE DEPTH & WIDTH

Must allow for heavy-lift cargo vessels to travel, may be over

1,000 ft long

400 ft wide

DRAFT AT BIRTH

Must allow for heavy-lift cargo vessels to travel

33-90 ft

WHARF LENGTH

800 ft

Minimum (heavy-lift wharf)

NUMBER & SIZE OF TERMINALS OR BERTHS

One terminal for manufacturing facility & shipping

SIZE OF BERTH

500 ft

Minimum

LOADING & BEARING CAPACITIES

WHARF LOADING	4,000 – 6,000 psf
YARD LOADING	4,000 – 6,000 psf
BEARING CAPACITY	2,000 – 3,000 psf

STORAGE NEEDS

Frames and warehouse(s) to store completed nacelles

AIR DRAFT

200 ft

Minimum clearance above the water line

Workforce

$51,200 - $126,800

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 225 direct jobs and 407 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Aerospace engineers
Computer-controlled machine tool operators, metal and plastic
Engineering technicians
Heavy equipment operators
Industrial production managers
Inspectors, testers, sorters, samplers, and weighers
Machinists
Materials engineers
Mechanical engineers
Team assemblers
Welders, cutters, solderers, and brazers

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Nacelles and their components (including the generator, gearbox, control system, main bearing, and more)

CRANE NEEDS

- Electric Over-Head Travelling (EOHT) cranage, up to 75 tons capacity, to move within fabrication facility
- Multiple 350-ton capacity mobile cranes for loadout activities
- Crawler cranes

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

OTHER NEEDS

Self-propelled modular transporters (SPMTs) used to transport nacelles leaving fabrication facility

Forklifts, cherry pickers, multiple axle trailer

Roll-on/roll-off capabilities

Greenhouse gas emission reduction initiatives

Shoreside vessel services (standard ship services and security requirements)

Offices, bathroom, and indoor storage/warehouse buildings

Component Manufacturing Activities

Towers

Towers for offshore wind are manufactured at ports due to their size and weight, and they are transported to S&I ports using vessels. Tower manufacturing facilities are key to regions' long-term plans for offshore wind since they have the potential to create various skilled jobs and are steel-intensive, which makes tower facilities an attractive source of federal funding for domestic steel. It is important to consider not only the labor requirements of these facilities but also the need for energy and materials since these components require large amounts of steel and energy. Towers lift turbines off the sea surface to provide access to the nacelle and other control equipment for maintenance and repair and to create height and space for the turbines to spin. It is a tapered cylinder rooted into the platform at the base and supports the nacelle at the head. Each turbine incorporates four tower pieces. Towers are usually around 400 ft (120 m) tall and weigh over 800 tons.

Port Activities

RECEIVE
Receive construction materials for towers via road, rail, or waterborne transport

METAL SHEET BENDING
Begin the manufacturing process by bending metal sheets into a cylindrical form

STACKING & WELDING
Individual segments are stacked and welded with union melt welding technology, forming the structure of the tower

COATING
Structure is sandblasted and coated for better resistance

QUALITY CONTROL
Final quality control process to guarantee structural integrity

HOUSED
Houses a factory and warehouse buildings, as well as storage spaces for parts

EXAMPLES OF EXISTING PORTS OR FACILITIES

Port of Bilbao in Bilbao, Spain
Planned facility at Port of Albany, New York, U.S.

Logistics Requirements

Road access required

Rail access required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3-4 years after permitting process begins

Component Manufacturing Activities

Towers

Physical Port Requirements

TOTAL AREA **50-100+ acres**	NAVIGABLE DEPTH **25-38 ft** NAVIGABLE WIDTH **150-200 ft**	DRAFT AT BIRTH **38 ft** Minimum
WHARF LENGTH **800 ft** Minimum (heavy-lift wharf)	NUMBER & SIZE OF TERMINALS OR BERTHS One terminal for manufacturing facility & shipping with minimum 1 deep draft berth	SIZE OF BERTH **650 ft** Minimum of quayside length
LOADING & BEARING CAPACITIES WHARF LOADING 6,000 psf minimum under crane YARD LOADING 2,000 – 3,000 psf BEARING CAPACITY 2,000 – 3,000 psf	STORAGE NEEDS Completed component storage, on frames to raise off the ground	AIR DRAFT **200 ft** Minimum clearance above the water line. *Towers are typically transported horizontally to the S&I port or out to sea*

Workforce

$45,400 - $126,800

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 73 direct jobs and 94 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Assemblers and Fabricators
Coating, Painting, Spraying Machine Setters, Operators, and Tenders
Drafters
First-Line Supervisors of Mechanics, Installers, and Repairers
Industrial Engineers
Industrial Machinery Mechanics
Industrial Production Managers
Inspectors, Testers, Sorters, Samplers, and Weighers
Material Moving Workers
Mechanical Engineers
Mechanical Engineering Technologists and Technicians
Mining and Geological Engineers, Including Mining Safety Engineers
Office Clerks
Welders, Cutters, Solderers, and Brazers

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel, fiberglass, iron and copper

CRANE NEEDS

500 - 1,000 tons

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

Natural gas to be used as energy source for bending the steel at tower facilities

OTHER NEEDS

75ft of clearance between vessels

Greenhouse gas emission reduction initiatives

Shoreside Vessel Services (standard ship services and security requirements)

Offices, bathroom, and indoor storage/warehouse buildings

Specialized equipment, including forklifts, crawler cranes, cherry pickers

Self-propelled modular transporters (SPMTs) or marine railway

Roll-on/roll-off capabilities

Component Manufacturing Activities

Semi-Submersible Platforms

Semi-submersible platforms have been one of the most popular technologies in floating wind. However, adopting it on a large scale for higher capacity (and consequently, much heavier) turbines will be determined by developer preferences. These platforms are appealing since they have a lower cost than other floating platform options, but there are supply chain implications since they can be made of steel, concrete, or a combination of both. Semi-submersibles consist of multiple columns and pontoons for stability and buoyancy but are less stable than Spars and TLPs. Turbines are usually installed on these platforms onshore and then towed offshore. Note that the details included are primarily based on steel semi-submersible platforms.

Port Activities

FOR STEEL-BASED PLATFORMS:

COMPONENT FABRICATION
Large steel plates are bent and shaped to create individual sections of the platform

WELDING AND ASSEMBLY
Specialized welding techniques are used to join the steel components.

QUALITY CONTROL
Testing and inspection of welds and overall structural integrity is performed

MOORING SYSTEM INTEGRATION
Attachment points for mooring lines are incorporated into the platform design.

ELECTRICAL SYSTEMS
Integration of electrical components and cabling systems for power transmission

CORROSION PROTECTION
Applying protective coatings to prevent corrosion in the marine environment.

TRANSPORT AND ASSEMBLY
Large components are transported to coastal assembly sites or shipyards. When concrete is utilized, the concrete is typically poured and set around steel rods for reinforcement

EXAMPLES OF EXISTING PORTS OR FACILITIES

Pemamek Ltd. in Houston, Texas, U.S.
Fred. Olsen in Oslo Norway
Principle Power in Portugal and Scotland

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Semi-Submersible Platforms

Physical Port Requirements

TOTAL AREA **75-80 acres** Minimum with 20-40 acre fabrication yard	NAVIGABLE DEPTH 33-40 ft (10-12 m) NAVIGABLE WIDTH 328-443 ft (100-135 m)	DRAFT AT BIRTH **28-38+ ft**
WHARF LENGTH **1,200 ft** Minimum (heavy-lift wharf)	NUMBER & SIZE OF TERMINALS OR BERTHS **1-2 deep draft berths**	SIZE OF BERTH **470 ft length Minimum** **38 ft depth Minimum**
LOADING & BEARING CAPACITIES WHARF LOADING 6,000 psf Minimum under crane YARD LOADING 4,000-6,000 psf BEARING CAPACITY 7,000 psf Minimum (approx. 10 tons per square meter)	STORAGE NEEDS Land and Wet Storage are required. Wet storage area is approximately 1.9 square miles or 1,236 acres to store six 15 MW turbines, which is the usual upper limit of turbines stored at a time, but this might vary according to deployment schedules and downtime risks.	AIR DRAFT **650 ft** Minimum clearance above the water line

Workforce

$43,300 - $107,500

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 84 direct jobs and 160 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Team Assemblers

Welders, Cutters, Solderers, and Brazers

Marine Engineers and Naval Architects

Plumbers, Pipefitters, and Steamfitters

Structural Metal Fabricators and Fitters

Coating, Painting, and Spraying Machine Setters, Operators, and Tenders

Drafters

First-Line Supervisors of Mechanics, Installers, and Repairers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel, concrete, or both

CRANE NEEDS

- 500-1,000+ ton capabilities
- Crawler cranes

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

OTHER NEEDS

Forklifts, cherry pickers

Roll-on/roll-off capabilities

Greenhouse gas emission reduction initiatives

Shoreside vessel services (standard ship services and security requirements)

Offices, bathrooms, and indoor storage/warehouse buildings

Self-propelled modular transporters (SPMT)

Submersible barge, heavy transport vessel (HTV), ramp system, or direct transfer capabilities for transferring platform from land into water

Installation vessels: Anchor Handling Tug and support tugs

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Component Manufacturing Activities

Spar Buoys Platforms

Spar foundations are suitable for waters deeper than 100 meters since they consist of a vertically floating cylinder, but their height presents challenges for transportation and installation. The supply chain for this technology might include steel, concrete, or a mix of both, depending on developer preferences. Spar platforms, however, are not considered likely to happen for large-scale floating offshore wind on the US West Coast, as the California State Lands Commission sees the technology unfeasible due to the deep draft requirements. Note that the details included are primarily based on spar buoy platforms constructed of steel.

Port Activities

FOR STEEL-BASED PLATFORMS:

COMPONENT FABRICATION
Large steel plates are bent & shaped to create individual sections of the platform

WELDING & ASSEMBLY
Specialized welding techniques are used to join the steel components.

QUALITY CONTROL
Testing and inspection of welds and overall structural integrity is performed

MOORING SYSTEM INTEGRATION
Attachment points for mooring lines are incorporated into the platform design.

ELECTRICAL SYSTEMS
Integration of electrical components and cabling systems for power transmission

CORROSION PROTECTION
Application of protective coatings to prevent corrosion in the marine environment.

TRANSPORT & ASSEMBLY
Large components are transported to coastal assembly sites or shipyards. When concrete is utilized, the concrete is typically poured and set around steel rods for reinforcement

EXAMPLES OF EXISTING PORTS OR FACILITIES

Pemamek Ltd. in Houston, Texas, U.S.
Siemens Gamesa's TetraSpar in Norway

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Spar Buoys Platforms

Physical Port Requirements

TOTAL AREA
75-80 acres
Minimum with 20 - 40 acre fabrication yard

NAVIGABLE DEPTH
296 ft in sheltered
NAVIGABLE WIDTH
197-296 ft (60-90 m)

DRAFT AT BIRTH
20-270 ft

WHARF LENGTH
1,200 ft
Minimum (heavy-lift wharf)

NUMBER & SIZE OF TERMINALS OR BERTHS
1-2 deep draft berths

SIZE OF BERTH
470 ft
Minimum length

LOADING & BEARING CAPACITIES
WHARF LOADING Minimum 6,000 psf under crane
YARD LOADING 4,000 - 6,000 psf
BEARING CAPACITY 7,000 psf Minimum (approx. 10 tons per square meter)

STORAGE NEEDS
Land and Wet storage are Required. Wet storage area is approximately 1.9 square miles or 1,236 acres to store six 15 MW turbines, which is the usual upper limit of turbines stored at a time, but this might vary according to deployment schedules and downtime risks.

AIR DRAFT
650 ft
Minimum clearance above the water line

Workforce

$43,300 - $107,500
U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 84 direct jobs and 160 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Team Assemblers
Welders, Cutters, Solderers, and Brazers
Marine Engineers and Naval Architects
Plumbers, Pipefitters, and Steamfitters
Structural Metal Fabricators and Fitters
Coating, Painting, and Spraying Machine Setters, Operators, and Tenders
Drafters
First-Line Supervisors of Mechanics, Installers, and Repairers

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel, concrete, or both

CRANE NEEDS

- 500-1,000+ ton capabilities
- Crawler cranes

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

OTHER NEEDS

Forklifts, cherry pickers
Roll-on/roll-off capabilities
Greenhouse gas emission reduction initiatives
Shoreside vessel services (standard ship services, shore power, and security requirements)
Offices, bathroom, and indoor storage/warehouse buildings
Self-propelled modular transporters (SPMT)
Submersible barge or heavy transport vessel (HTV)
Installation vessels: Anchor handling tug and crane barge

Component Manufacturing Activities

Tension Leg Platforms (TLP)

Tension Leg Platforms (TLP) have less technology readiness than Semi-submersible or Spar technologies but present the most stability of the three platform types. These foundations are made of steel and, therefore, require a strong supply of these materials for the manufacturing process. Since turbines can be installed on the TLP onshore, the installation process is facilitated, like semi-submersible platforms; thus, their port requirements are similar.

Port Activities

COMPONENT FABRICATION
Large steel plates are bent & shaped to create individual sections of the platform

WELDING & ASSEMBLY
Specialized welding techniques are used to join the steel components.

QUALITY CONTROL
Testing and inspection of welds and overall structural integrity is performed

MOORING SYSTEM INTEGRATION
Attachment points for mooring lines are incorporated into the platform design.

ELECTRICAL SYSTEMS
Integration of electrical components and cabling systems for power transmission

CORROSION PROTECTION
Application of protective coatings to prevent corrosion in the marine environment.

TRANSPORT & ASSEMBLY
Large components are transported to coastal assembly sites or shipyards.

EXAMPLES OF EXISTING PORTS OR FACILITIES

Pemamek Ltd. in Houston, Texas, U.S.
PelaStar in partnership with General Electric

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Tension Leg Platforms

Physical Port Requirements

TOTAL AREA **75-80** Minimum acres with 20-40 acre fabrication yard	NAVIGABLE DEPTH 33 ft Minimum NAVIGABLE WIDTH 296-443 ft (90-135 m)	DRAFT AT BIRTH **28-38+ ft**
WHARF LENGTH **1,200 ft** Minimum (heavy-lift wharf)	NUMBER & SIZE OF TERMINALS OR BERTHS **1-2 deep draft berths**	SIZE OF BERTH **470 ft** Minimum length **38 ft** Minimum depth
LOADING & BEARING CAPACITIES WHARF LOADING 6,000 psf Minimum under crane YARD LOADING 4,000-6,000 psf BEARING CAPACITY 7,000 psf Minimum (approx. 10 tons per square meter)	STORAGE NEEDS Land and Wet Storage are required. Wet storage area is approximately 1.9 square miles or 1,236 acres to store six 15 MW turbines, which is the usual upper limit of turbines stored at a time, but this might vary according to deployment schedules and downtime risks.	AIR DRAFT **650 ft** Minimum clearance above the water line

Workforce

$43,300 - $107,500

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 84 direct jobs and 160 indirect jobs per 1 GW, on average, annually between 2024 and 2030.

OCCUPATIONS

Team Assemblers

Welders, Cutters, Solderers, and Brazers

Marine Engineers and Naval Architects

Plumbers, Pipefitters, and Steamfitters

Structural Metal Fabricators and Fitters

Coating, Painting, and Spraying Machine Setters, Operators, and Tenders

Drafters

First-Line Supervisors of Mechanics, Installers, and Repairers

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel

CRANE NEEDS

- 500-1,000+ ton capabilities
- Crawler cranes

ELECTRICITY/UTILITY NEEDS

A shore power connection for vessels

OTHER NEEDS

Forklifts, cherry pickers

Roll-on/roll-off capabilities

Greenhouse gas emission reduction initiatives

Shoreside vessel services (standard ship services, shore power, and security requirements)

Offices, bathroom, and indoor storage/warehouse buildings

Self-propelled modular transporters (SPMT)

Submersible barge, heavy transport vessel (HTV), ramp system, or direct transfer capabilities for transferring platform from land into water

Installation vessels: Anchor Handling Tug and support tugs

Component Manufacturing Activities

Array Cables

Array cables require transportation from ports to the offshore wind farm but are not usually manufactured at or near port facilities; they are only stored. They are shorter and lighter than export cables and are used to transmit power from the array of floating wind turbines to the offshore substation. Sometimes, array cables are also used to transmit power from the substation to the turbines when wind generation from the turbines is not working properly. Array cables can be manufactured at inland facilities and later stored at staging and integration ports or sites.

Port Activities

INSULATED
The cable cores are insulated through a catenary continuous vulcanization (CCV) process

WOUND
The cores are then wound together with a fiber optic cable into a helix structure

STABILIZED
Armor and ropes are applied and twisted around the cable to stabilize the helix

LOADED
Cables may be loaded onto the vessel to be would using carousels, turntables, or cable tanks onboard, or they may be wound onshore using drums and then lifted onto the vessel with a heavy-lift crane

STORED
Array cables are often stored at Staging and Integration ports or sites

EXAMPLES OF EXISTING PORTS OR FACILITIES
Prysmian facility in Brayton Point, Massachusetts, USA
JDR Cables facility in Cambios, England
Hellenic Cables facility in Corinth, Greece

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Array Cables

Physical Port Requirements

TOTAL AREA

5-30+ acres

(for 25 MW pre-commercial farm to 300 MW commercial farm)

NAVIGABLE WIDTH

92 ft Minimum

NAVIGABLE DEPTH

16.5 ft Minimum

at Lowest Astronomical Tide (LAT)

DRAFT AT BIRTH

20-30 ft

For loaded cable installation vessel

30 ft

Minimum berth depth

WHARF LENGTH

500 ft

Minimum

NUMBER & SIZE OF TERMINALS OR BERTHS

Need multiple terminals for consistent port access since the loading time for array cables can span several days.

SIZE OF BERTH

328-492 ft

Quayside length

LOADING & BEARING CAPACITIES

Depending on the wind farm size, array cable weight may range from 100 to 1,000 tons in total

WHARF LOADING	1,000 psf Minimum
YARD LOADING	1,000 – 2,000 psf
BEARING CAPACITY	1,000 psf Minimum

STORAGE NEEDS

Often stored at the staging and integration ports. For every 1-2 array cable carousels, 3-7 acres is required.

AIR DRAFT

200 ft Minimum clearance above the water line

Workforce

$48,000 - $119,700

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 17 direct jobs and 27 indirect jobs per 1 GW, on average, annually between 2024 and 2030. OFW facilities that manufacture array and export cable together can be compared to submarine cable manufacturing facilities, which create around 100 full-time, operations jobs and an additional 500 jobs for construction of the facility.

OCCUPATIONS

Coil Winders, Tapers, and Finishers

Electrical & Electronic Engineering Technologists and Technicians

Electrical & Electronics Repairers, Commercial and Industrial Equipment

Electrical & Electronics Repairers, Powerhouse, Substation, and Relay

Electrical, Electronic, & Electromechanical Equipment Assemblers, Except Coil Winders, Tapers, and Finishers

Electrical Engineers

Engineers, All Other

First-Line Supervisors of Mechanics, Installers, & Repairers

Riggers

Welders, Cutters, Solderers, and Brazers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Core materials:
Copper, aluminum, ethylene propylene (EPR) or cross-linked polyethylene (XLPE), steel wire

Fiber-optic cables required for winding the cores

CRANE NEEDS

Heavy-lift crane at the quayside if cables were pre-wound onshore to load onto the vessels (if the vessels do not have heavy-lift cranes onboard)

ELECTRICITY/UTILITY NEEDS

Dynamic and dry- and wet-static cables of 132 kilovolts should be tested.

OTHER NEEDS

If pre-winding the cables onshore, drums are needed to wind the cables

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Component Manufacturing Activities

Export Cables

Export cables do not require manufacturing at or near ports, but their installation requires heavy subsea and onshore engineering activities. Export cables are long and heavy cables that transmit power from the offshore substation to the electrical infrastructure onshore. Once fabricated, export cables are typically loaded directly onto vessels.

Port Activities

INSULATED
The cable cores are insulated through a catenary continuous vulcanization (CCV) process

WOUND
The cores are then wound together with a fiber optic cable into a helix structure

APPLIED/TWISTED
Armor and ropes are applied and twisted around the cable to stabilize the helix

COILED
The cables are coiled using a cable turntable to be stored later

FED
Lastly, the cables are fed from the storage facility directly to the vessel, which requires a direct path from the storage facility to the vessel docking site, using a large cable carousel

EXAMPLES OF EXISTING PORTS OR FACILITIES

Nexans facility in Charleston, North Carolina, USA
Prysmian facility in Brayton Point, Massachusetts, USA
JDR Cables facility in Cambios, England
Hellenic Cables facility in Corinth, Greece

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Export Cables

Physical Port Requirements

TOTAL AREA **17-30+ acres** For 300 MV Commercial Farm	**NAVIGABLE WIDTH** 92 ft Minimum **NAVIGABLE DEPTH** 16.5 ft Minimum at Lowest Astronomical Tide (LAT)	**DRAFT AT BIRTH** 20-30 ft for loaded cable installation vessel 30 ft Minimum berth depth
WHARF LENGTH **500 ft** Minimum	**NUMBER & SIZE OF TERMINALS OR BERTHS** Need multiple terminals for consistent port access since the loading time for export cables can span several days. Rate of loading is about 26ft/min	**SIZE OF BERTH** **328-492 ft** Quayside length
LOADING & BEARING CAPACITIES Must withstand the weight of the coiled cables (AC cable weighs approx. 50 lb/ft) WHARF LOADING 1,000 psf Minimum YARD LOADING 1,000 – 2,000 psf BEARING CAPACITY 1,000 psf Minimum	**STORAGE NEEDS** Cables are coiled around turntables in storage. Both dry- and wet-storage strategies exist for cables. For every 2-6 export cable carousels, 3-7 acres is required.	**AIR DRAFT** 200 ft Minimum clearance above the water line

Workforce

$48,000 - $119,700

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Approximately 34 direct jobs and 54 indirect jobs per 1 GW, on average, annually between 2024 and 2030. OFW facilities that manufacture array and export cable together can be compared to submarine cable manufacturing facilities, which create around 100 full-time, operations jobs and an additional 500 jobs for construction of the facility.

OCCUPATIONS

Coil Winders, Tapers, and Finishers

Electrical and Electronic Engineering Technologists and Technicians

Electrical and Electronics Repairers, Commercial and Industrial Equipment

Electrical and Electronics Repairers, Powerhouse, Substation, and Relay

Electrical, Electronic & Electromechanical Equipment Assemblers, Except Coil Winders, Tapers & Finishers

Electrical Engineers

Engineers, All Other

First-Line Supervisors of Mechanics, Installers, and Repairers

Riggers

Welders, Cutters, Solderers, and Brazers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Core materials: copper, aluminum, ethylene propylene (EPR) or cross-linked polyethylene (XLPE), lead, polypropylene, metal, and bitumen

Fiber-optic cables required for winding the cores

CRANE NEEDS

A crane is not typically used

ELECTRICITY/UTILITY NEEDS

North American and international standards require the testing of cables with up to 550 kilovolts

OTHER NEEDS

Horizontal armoring machine

Cable turntables, each approximately 98 ft wide

Large cable carousel security requirements)

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Component Manufacturing Activities

Anchors

There are four main types of anchors used in floating offshore wind, and a region's floating wind plans must consider establishing local manufacturing of one or more types of anchors to avoid project delays and supply chain uncertainties. These are heavy components, part of the mooring system, and can only be transported to the wind farm using vessels. Therefore, they have specific port requirements that vary depending on the chosen anchor type. The four types of anchors used in floating OSW are Drag embedment, Suction pile, Driven pile, and Gravity base. Anchors secure floating wind turbines and mooring lines in place, in or on the seabed. Each anchor type has a unique form and specific requirements around raw materials and is suited for different ocean geographies. There are typically five anchors used per turbine.

Port Activities

FOR DRAG EMBEDMENT ANCHOR
Steel plates are cut into desired profiles and welded together for the final profile. Most drag embedment anchors will consist of flat plate, but sometimes rolled steel is used.

FOR SUCTION & DRIVEN PILE ANCHORS
Sections of seam-welded rolled steel plates are welded together.

FOR GRAVITY BASE ANCHORS
Concrete is formed around steel rebar framework.

EXAMPLES OF EXISTING PORTS

Anchors can be manufactured or fabricated anywhere on land.
Current anchor suppliers include Delmar Systems Vryhof, Bruce Anchor, Swift Anchors, Subsea Micropiles, Global Energy Group, RCAM Technologies, and Mooreast

Logistics Requirements

Road access required
(Must be able to accommodate 150-500 tons of anchors per turbine or over 3,000 tons per turbine with gravity anchors)

No rail requirements

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Component Manufacturing Activities

Anchors

Physical Port Requirements

TOTAL AREA

10-30 acres

NAVIGABLE WIDTH

200-400 ft

NAVIGABLE DEPTH

33 ft Minimum, must be able to accommodate heavy-lift cargo as individual drag embedment anchors can weigh up to 100 tons

DRAFT AT BIRTH

20-30 ft

Minimum

WHARF LENGTH

300 ft

Minimum

NUMBER & SIZE OF TERMINALS OR BERTHS

Two terminals, one for shipping and one for manufacturing and assembly. Size depends on production volume.

SIZE OF BERTH

Varies according to size of Anchor Handling Vessel, usually over 165 ft

LOADING & BEARING CAPACITIES

Must be able to accommodate 150-500 tons of anchors per turbine or over 3,000 tons per turbine with gravity anchors

WHARF LOADING	500 psf Mininum
YARD LOADING	500 psf Mininum
BEARING CAPACITY	500 psf Mininum

STORAGE NEEDS

Must be stored at an anchor laydown area, approximately 5-15 acres for facilities serving a single staging and integration port with 30-40 anchors.

AIR DRAFT

No air draft restrictions

Workforce

$71,800 - $129,000

U.S. MEAN ANNUAL WAGES AS OF 2023Q4 AT A STAGING & INTEGRATION PORT

JOB CREATION POTENTIAL

Anchor storage areas may be located at independent facilities, but are often part of larger facilities such as a staging and integration port.

100-200 jobs may be created at an S&I port for a single wind farm or project.

**Upper bound reflects the larger project sizes expected on the west coast of the U.S.*

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Typically, S355 steel, shackles, and caps with valves
For gravity anchors, concrete, shackles, and rebar

OTHER NEEDS

CAD and CNC software
CNC cutters and machining equipment
Press brakes
Roll forming machines
Lifting equipment
Induction pipe bending machines
Various drills, grinders, and saws
Surfacing equipment
Welding equipment
Sometimes coating equipment
For gravity anchors, slip forming, or concrete casting equipment
Lifting and handling equipment

Component Manufacturing Activities

Mooring Lines

Mooring lines often require several raw materials to manufacture since they connect the anchor to the turbine substructure and need different tension levels and flexibility throughout the component. Although their manufacturing does not need to be at ports, access to ports by road is required to transport the finished mooring lines to the ports where they will be installed. Several considerations exist for establishing local manufacturing of these components since their materials can vary from steel to nylon or polyester to wire ropes.

Port Activities

FORM THE CHAINS
Manufacturing workers heat, form, weld, shape, and coat multiple lengths of bar stock to form the chains

FORM ROPES
At a manufacturing facility, synthetic strands are twisted together to form the mooring line ropes.

FORGING AND WELDING
Steel is forged and welded to create the jewelry that connects the ropes, chains, and anchors

EXAMPLES OF EXISTING PORTS OR FACILITIES

Mooring lines, like anchors, can be manufactured or fabricated anywhere on land.
Current Mooring line suppliers include Bexco, Bridon-Bekaert, Dynamica Ropes, Lankhorst, Vicinay, FibreMax, InterMoor, and Mooreast

Logistics Requirements

Road access required
(must be able to accommodate the weights of the chains (1,100-1,600 lbs per link), synthetic rope (33.5 lbs per foot), and jewelry (550-20,000 lbs))

No rail requirement

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1-2 years

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 3 – 4 years after permitting process begins

Mooring Lines

Physical Port Requirements

TOTAL AREA **10-30 acres**	**NAVIGABLE WIDTH** **200-400 ft** **NAVIGABLE DEPTH** 33 ft Minimum, must be able to accommodate heavy-lift cargo vessels	**DRAFT AT BIRTH** **20-30 ft** Minimum
WHARF LENGTH **300 ft** Minimum	**NUMBER & SIZE OF TERMINALS OR BERTHS** Two terminals, one for shipping and one for manufacturing and assembly. Size depends on production volume.	**SIZE OF BERTH** Varies according to size of Anchor Handling Vessel, usually over 165 ft
LOADING & BEARING CAPACITIES Must be able to accommodate the weights of the chains (1,100-1,600 lbs per link), synthetic rope (33.5 lbs per foot), and jewelry (550-20,000 lbs) WHARF LOADING 500 psf Minimum YARD LOADING 500 psf Minimum BEARING CAPACITY 500 psf Minimum	**STORAGE NEEDS** Must be stored at a mooring laydown area, approximately 5-15 acres for facilities serving a single staging and integration port with 50,000-100,000 ft of chain.	**AIR DRAFT** No air draft restrictions

Workforce

$71,800 - $129,000

U.S. MEAN ANNUAL WAGES AS OF 2023Q4 AT A STAGING & INTEGRATION PORT

JOB CREATION POTENTIAL

Mooring line storage areas may be located at independent facilities but are often part of larger facilities such as a staging and integration port.

100-200 jobs may be created at an S&I port for a single wind farm or project.

** Upper bound reflects the larger project sizes expected on the west coast of the U.S.*

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel (R3, R3S, R4, R4S or R5 steel bar) and synthetic rope fiber (polyester or nylon)

OTHER NEEDS

CAD and CNC software
CNC cutters & machining equipment
Press brakes
Roll forming machines
Lifting equipment
Induction pipe bending machines
Various drills, grinders and saws
Surfacing equipment
Welding equipment
Sometimes coating equipment
Heat treatment equipment
Extrusion machines
Twisting or braiding equipment
Tensioning and spooling equipment
Cutting and splicing equipment
Oven for curing/heat setting
Lifting and handling equipment

Component Manufacturing Activities

Secondary Steel

Secondary steel manufacturing is one of the focal points in the planning and implementation of a floating offshore wind industry for two main reasons: it represents a large portion of the subcomponents added to the assembled turbine (including ladders, walkways, and railings); and domestic steel and manufactured steel products are heavily emphasized in federal funding policies, including the Build America and Buy America Act, and for that reason, developers show interest in local supply.

Primary steel is incorporated into tower and platform technologies.

Port Activities

A steel fabrication facility has multiple production cells to produce multiple goods

HEAT/MELT
An electric arc furnace is used to heat and melt scrap iron to produce secondary steel

MIXED
Once melted, the molten iron is mixed with carbon

SHAPED
The iron and carbon mixture is converted into a new piece of steel and shaped as needed

CONVERTED
Other times, secondary steel manufacturers may convert pre-fabricated steel into the necessary components for the industry

COATED
Finally, the steel is coated for corrosion protection

EXAMPLES OF EXISTING PORTS OR FACILTIES

Secondary steel can be manufactured or fabricated anywhere on land.
Current suppliers include Hutchinson Engineering, Kersten, Smulders, Vallourec, and Wilton Engineering

Logistics Requirements

Road access required
(if facility is at a port or shipyard, road access is only required for receiving the raw materials)

Rail access required
(if facility is at a port or shipyard, rail access is only required for receiving the raw materials)

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 5 – 8 months

CONSTRUCTION OF FACILITY
Approximately 2 years

Operations are estimated to start 2.5 – 3 years after permitting process begins

Component Manufacturing Activities

Secondary Steel

Physical Port Requirements

TOTAL AREA **2.5 - 50+ acres**	NAVIGABLE DEPTH **22-40 ft** NAVIGABLE WIDTH **75 – 200 ft**	DRAFT AT BIRTH **30-40 ft**
WHARF LENGTH **300-700 ft** Quayside length	NUMBER & SIZE OF TERMINALS OR BERTHS At least one terminal, depends on manufacturing output.	SIZE OF BERTH **150-700 ft** length **22-40 ft** depth
LOADING & BEARING CAPACITIES WHARF LOADING 2,000 – 3,000 psf YARD LOADING 2,000 – 3,000 psf BEARING CAPACITY 2,000 – 3,000 psf	STORAGE NEEDS Space required to store prefabricated parts, 1-8 acres	AIR DRAFT **100-200 ft**

Workforce

$42,500 - $126,800

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

In 2021, there were 131,400 workers in the steel industry across the U.S.

OCCUPATIONS

First-Line Supervisors of Production and Operating Workers
Industrial Production Manager
Inspectors, Testers, Sorters, Samplers, and Weighers
Machinist
Molding, coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic
Welders, Cutters, Solderers, and Brazers
Electricians
Carpenters
Construction Laborers
Materials Engineers
Team Assemblers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Aluminum
Glass-fiber reinforced plastic
Rubber
Paint and coating material
S355, S460, S690 and S700 steel - may be in standard forms, such as box sections, tubulars, and plate

CRANE NEEDS

Gantry crane
Cranes must be able to accommodate secondary steel weighing approximately 100 tons for a single, steel semi-submersible platform for a 15 MW turbine

ELECTRICITY/UTILITY NEEDS

Metallurgical plants typically use coal, coke, oil, gas, and electricity (generally coal-based) to meet their needs for energy

OTHER NEEDS

Requires a fabrication building (approximately 36,000-165,000 square feet) and a laydown or storage area

Equipment needs:
CAD and CNC software
CNC cutters and machining equipment
Press brakes
Roll forming machines
Lifting equipment
Induction pipe bending machines
Various drills, grinders, and saws
Surfacing equipment
Welding equipment
Coating equipment

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Component Manufacturing Activities

Crew Transfer Vessels (CTV), Service Accommodation Transfer Vessels (SATV), and Service Operation Vessels (SOV)

Various vessel types are involved in installing a floating offshore wind farm. Vessels are subject to the Jones Act, a law regulating maritime shipping in the United States generally, which also affects the manufacturing, operations, and ownership requirements of offshore wind vessels. Vessel manufacturing is, therefore, a required aspect of the local supply chain for a future offshore wind ecosystem. Since floating offshore wind is a nascent industry in the United States, this chapter covers various vessel types, including:

- Crew Transfer Vessels (CTVs): transport individuals and some equipment from the mainland to the offshore wind farms.
- Service Accommodation Transfer Vessels (SATVs): transport workers from the mainland to the offshore wind farm, similar to CTVs, but also provide sleeping accommodations to allow workers to stay at sea for several weeks. Construction for these vessels started recently, with the first delivered in Singapore in 2020.
- Service Operation Vessels (SOVs): stay at sea close to the wind farms to provide accommodations for workers and platform assistance to workers who need to perform maintenance and repair work on the turbines.

Port Activities

DESIGN
Designing the vessel from initial production development

MATERIALS
Purchasing and materials management of entire process

BUILDING
General shipbuilding practices, coating, and including offshore wind-specific machinery

ENGINEERING
Production engineering (to increase the efficiency of the production methods)

QUALITY CONTROL
Ensure the product meets all customer and regulatory requirements

COMMERICAL ACTIVITIES
Commercial activities, including marketing of the shipyard and contract management

EXAMPLES OF EXISTING PORTS OR FACILITIES

There are few vessel manufacturers for OSW in the U.S. Below are examples of facilities that manufacture CTVs, SATVs, and SOVs. Not all are specific to OSW- some are built to serve multiple industries.

Crew Transfer Vessels:
St. Johns Ship Building in Palatka, Florida, U.S.
Blount Boats in Warren, Rhode Island, U.S.
Colonna's Shipyard in Norfolk, Virginia, U.S.

Service Accommodation Transfer Vessels:
DLBA Naval Architects in Chesapeake, Virginia, U.S.
Penguin Shipyard in Singapore

Service Operation Vessels:
Edison Chouest Offshore (with Ørsted and Eversource) in Florida, Mississippi, and Louisiana, U.S.
Ulstein in Ulsteinvik, Norway
Other manufacturers include Siemens Gamesa, ICE Marine Design, ABB Marine Services, and Vard Marine

Physical Port Requirements

TERMINAL & BERTH LENGTH REQUIREMENTS

Must be able to accommodate:

CTVs	65-90 ft long
SATVs	100-130 ft long
SOVs	200-400 ft long

TERMINAL & BERTH WIDTH REQUIREMENTS

Must be able to accommodate:

CTVs	22-30 ft long
SATVs	30-50 ft long
SOVs	50-80 ft long

DRAFT AT BIRTH

CTVs	5-10 ft
SATVs	10-16 ft
SOVs	16-25 ft

WEIGHT OR BEARING REQUIREMENTS

Must be able to accommodate:

CTVs that weigh 15-30 tons & can bear around 1-15 tons
SATVs that weigh around 5,000 tons & can bear around 1.4 tons per square foot
SOVs that weigh around 2,000-4,000 tons

STORAGE NEEDS

No minimum storage size requirements, wet storage required

Workforce

$50,900 - $107,500

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

Edison Chouest Offshore Jones Act-compliant SOV involved over 600 workers across Florida, Mississippi, and Louisiana.

OCCUPATIONS

Carpenters
Electricians
First-Line Supervisors of Production and Operating Workers
Inspectors, Testers, Sorters, Samplers, and Weighers
Marine Engineers and Naval Architects
Plumbers, Pipefitters, and Steamfitters
Riggers
Structural Metal Fabricators and Fitters
Surveyors
Welders, Cutters, Solderers, and Brazers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Steel, fiberglass, aluminum, wood, and other materials

OTHER NEEDS

Shipyards may include several support shops including electrical, carpentry, pipe, sandblasting, and painting specializations alongside pier space, dry docks, railway, boat yard, and administrative offices

Marine Travelift boat hoist with 820 metric ton capacity

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Port Activities

Staging & Integration (S&I)

Staging and Integration (S&I) ports are specialized port facilities used for receiving, storing, assembling, and integrating the various components of floating offshore wind turbines before being towed to the installation site at sea. S&I ports are responsible for all the assembly requirements that will not be completed offshore, requiring specific maritime equipment capable of performing heavy lifting at the installation site. S&I ports, in contrast to manufacturing ports that typically only manufacture single components, need to be able to accommodate fully constructed turbines, which requires a very specific set of infrastructures. The latest generation of floating offshore wind turbines requires purpose-built ports to facilitate the complex assembly and installation of structures.

Port Activities

RECEIVE/STAGE/STORE
Receive, stage, and store all types of floating offshore wind turbine components

ASSEMBLE
Assemble the floating wind turbine system for towing to the offshore wind area

TRANSPORT
Transport the assembled turbine out to sea in the appropriate vessel

MAINTENANCE
Conduct major maintenance tasks, such as replacing a nacelle or blade

May eventually be involved in decommissioning floating wind projects

EXAMPLES OF EXISTING PORTS OR FACILITIES

New Bedford Marine Commerce Terminal in New Bedford, Massachusetts, U.S.
Port of Hull in East Riding of Yorkshire, England
Eemshaven in Eemshaven, Netherlands
Port of Esbjerg, Denmark

Logistics Requirements

Road access required

Rail access preferred but

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1.5 years

CONSTRUCTION OF FACILITY
Approximately 1.5 - 2 years

Facility operations are estimated to start partially 3 years after permitting process begins and to be fully operational approximately 3.5 years after permitting begins.

Staging & Integration

Physical Port Requirements

TOTAL AREA **30-100 acres**	**NAVIGABLE DEPTH** **40-100 ft** Draft at sinking basin **NAVIGABLE WIDTH** **150-200 ft**	**DRAFT AT BIRTH** **32-40 ft** Minimum Mean Lower Low Water
WHARF LENGTH **1,000 - 2,000 ft**	**NUMBER & SIZE OF TERMINALS OR BERTHS** Small commercial terminals: 1 multi-purpose berth Large commercial terminals: 2-3 Minimum berths	**SIZE OF BERTH** **1,000-1,500 ft** of quayside length **100 ft** Minimum width
LOADING & BEARING CAPACITIES WHARF LOADING 6,000 psf Minimum under crane YARD LOADING 2,000 – 4,000 psf BEARING CAPACITY 3,000 – 6,000+ psf	**STORAGE NEEDS** Land and Wet Storage are required. Wet storage area is approximately 1.9 square miles or 1,236 acres to store six 15 MW turbines, which is the usual upper limit of turbines stored at a time, but this might vary according to deployment schedules and downtime risks.	**AIR DRAFT** **1,100 ft** Minimum clearance above the water line May require coordination with airport and federal aviation administration

Workforce

$71,800 - $129,000

U.S. MEAN ANNUAL WAGES AS OF 2023Q4

JOB CREATION POTENTIAL

100-200 jobs may be created at an S&I port for a single wind farm or project.

OCCUPATIONS

Carpenters
Construction laborers
Crane operators
Electricians
High voltage technicians
Mechanical engineers
Project engineers
Riggers
Vessel administrators
Welders
Wind turbine installation managers

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Turbine components (blades, nacelles, towers, platforms, cables, anchors, mooring lines)

CRANE NEEDS

- Minimum 1,000 tons
- Minimum 300 ft height
- On wharf with loading capacity of > 6,000 psf

ELECTRICITY/UTILITY NEEDS

Electricity must run to both the berth and the wharf for the port operations (equipment and lighting) and the moored vessels
Water must run to both the berth (potable) and the wharf (non-potable)
Internet
Need refueling options for vessels

OTHER NEEDS

Breakwater for metocean protection
Environmental mitigation allowance
Specialized equipment
Forklifts
Crawler cranes
Cherry pickers
SPMT or marine railway
Roll-on/roll-off capabilities
Greenhouse gas emission reduction initiatives
Offices, bathroom, and indoor storage/warehouse buildings
Provisioning for vessels (e.g., food, water, sewage system)

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

Port Activities

Operations & Maintenance (O&M)

Operations and Maintenance (O&M) sites serve as a long-term base for wind farm operations. They need storage space for spare parts, warehouses, offices, ship repair services, provisioning and fuel for vessels, marine facilities, and onshore lodging. To respond quickly to potential issues or malfunctions at the farm, they must be within 40 nautical miles of a floating offshore wind farm. In addition to repairs and daily operations, O&M sites also support regular maintenance of the wind turbines.

Port Activities

STATIONED
Wind farm workers and vessels to carry workers and equipment are all stationed at an O&M port

MONITOR
Monitor the OSW farm and turbine functioning to stay alert on any accidents or other concerns

EXAMPLES OF EXISTING PORTS OR FACILITIES

New Bedford Foss Marine Terminal in New Bedford, Massachusetts, U.S.
Port of Peterhead in Peterhead, England
Thyboron Port in Thyboron, Denmark
Port of Grimsby in Humber, England

Logistics Requirements

Road access required

Rail access preferred but not required

Estimated Permitting & Construction Timelines

PERMITTING
Approximately 1.5 years

CONSTRUCTION OF FACILITY
Approximately 1.5 - 2 years

Facility operations are estimated to start partially 3 years after permitting process begins and to be fully operational approximately 3.5 years after permitting begins.

Operations & Maintenance

Physical Port Requirements

TOTAL AREA **5-10 acres** per project or farm	NAVIGABLE WIDTH Minimum **100 ft** NAVIGABLE DEPTH Minimum 12-25 ft, More for larger vessels	DRAFT AT BIRTH **20-30 ft** Minimum
WHARF LENGTH **300 ft** Minimum	NUMBER & SIZE OF TERMINALS OR BERTHS **1-5 berths**	SIZE OF BERTH **135-195 ft width** **500-750 ft length**
LOADING & BEARING CAPACITIES WHARF LOADING 100 – 500 psf YARD LOADING Not applicable BEARING CAPACITY 500 – 600 psf	STORAGE NEEDS **Spare part storage**	AIR DRAFT or BRIDGE HEIGHTS **100-150 ft** clearance above the water line

Workforce

TECHNICIANS & MANAGEMENT
$79,000

OPERATIONS & MAINTENANCE
$55,000

ANNUAL WAGES
BASED ON SOURCE PUBLISHED IN 2021

JOB CREATION POTENTIAL

Approximately 447 workers per 1 GW will be employed annually at O&M sites, for both fixed-bottom and floating OSW.

Equipment and Amenities

CARGO REQUIREMENTS

(what types of cargo will need to be handled for the activities)

Turbine components (blades, nacelles, towers, platforms, cables, anchors, mooring lines)

CRANE NEEDS

- 400-500 psf
- Crawler cranes

ELECTRICITY/UTILITY NEEDS

Electricity must run to both the berth and the wharf for the ports operations (equipment and lighting) and for the moored vessels
Water must run to both the berth (potable) and the wharf (non-potable)
Internet
Need refueling options for vessels

OTHER NEEDS

Crew Transfer Vessel (CTV)
Service Accommodation Transfer Vessel (SATV)
Service Operating Vessel (SOV)
Floating Offshore Installation Vessels
Vessel or ship repair services
Protected Harbor
Forklifts
Offices, bathroom, and indoor storage/warehouse buildings
Onshore lodging and amenities
Provisioning for vessels (e.g., food, water, sewage system)

UNITS OF MEASURE psf = pounds per square foot ft = feet GW = gigawatt

References

Chapter: Blades

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Catapult Offshore Renewable Energy. "Guide to an Offshore Wind Farm." Accessed June 2024. https://guidetoanoffshorewindfarm.com/guide

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." Journal of Engineering for the Maritime Environment. 2022. Accessed 25 June 2024. https://journals.sagepub.com/doi/full/10.1177/14750902221078425

Elkinton, C. Blatiak, A. et al. "ASSESSMENT OF PORTS FOR OFFSHORE WIND DEVELOPMENT IN THE UNITED STATES." Garrad Hassan America, Inc. 2014. Accessed 25 June 2024. www.osti.gov/servlets/purl/1124491

Guide to a Floating Offshore Wind Farm. "T.2 Rotor." Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/t-wind-turbine/t-2-rotor/

Hamilton, James. Liming, Drew. "Careers in Wind Energy." Bureau of Labor Statistics. 2010. Accessed 25 June 2024. https://www.bls.gov/green/wind_energy/#relevmanu

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

LM Wind Power. "Global Blade Service." Accessed August 2024. https://www.lmwindpower.com/en/services/blade-service

Mishnaevsky Jr., Leon. Branner, Kim. et al. "Materials for Wind Turbine Blades: An Overview." Materials (Basel). 2023. Accessed 25 June 2024. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5706232/

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Thomsen, Kurt E. Offshore Wind: A Comprehensive Guide to Successful Offshore Wind Farm Instillation. Elsevier Inc. 2014. Accessed 25 June 2024. https://ebookcentral.proquest.com/lib/providence/reader.action?docID=809152&query=Offshore+Wind+%3A+A+Comprehensive+Guide+to+Successful+Offshore+Wind+Farm+Installation

Trowbridge, Matt. Lim, Jennifer. "California Floating Offshore Wind Regional Ports Assessment." Bureau of Ocean Energy Management Pacific OCS Region. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/documents/renewable-energy/studies/BOEM-2023-010.pdf

Chapter: Nacelles

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." Journal of Engineering for the Maritime Environment. 2022. Accessed 25 June 2024. https://journals.sagepub.com/doi/full/10.1177/14750902221078425

Elkinton, C. Blatiak, A. et al. "ASSESSMENT OF PORTS FOR OFFSHORE WIND DEVELOPMENT IN THE UNITED STATES." Garrad Hassan America, Inc. 2014. Accessed 25 June 2024. www.osti.gov/servlets/purl/1124491

Guide to a Floating Offshore Wind Farm. "T.1 Nacelle." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/t-wind-turbine/t-1-nacelle/

Hamilton, James. Liming, Drew. "Careers in Wind Energy." Bureau of Labor Statistics. 2010. Accessed 25 June 2024. https://www.bls.gov/green/wind_energy/#relevmanu

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Trowbridge, Matt. Lim, Jennifer. "California Floating Offshore Wind Regional Ports Assessment." Bureau of Ocean Energy Management Pacific OCS Region. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/documents/renewable-energy/studies/BOEM-2023-010.pdf

Chapter: Towers

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Cooper, Brent. "Port Development Considerations for Offshore Wind." COWI. 2022. Accessed 25 June 2024. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Offshore-Wind/2022-01-12-Port-Development-Considerations-for-Offshore-Wind.pdf

Davies, Claire. Logan, Andy. et al. "Job Roles in Offshore Wind." Green Port Hull. BVG Associates. 2017. Accessed 25 June 2024. https://www.bluegemwind.com/wp-content/uploads/2020/07/Job-Roles-in-Offshore-Wind.pdf

Guide to a Floating Offshore Wind Farm. "T.3 Tower." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/t-wind-turbine/t-3-tower/#:~:text=The%20tower%20is%20typically%20a,and%20storage%20for%20safety%20equipment

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Trowbridge, Matt; Lim, Jennifer; and Knipe, Ashley. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

United States Geological Survey. "What materials are used to make wind turbines?" Accessed 25 June 2024. https://www.usgs.gov/faqs/what-materials-are-used-make-wind-turbines#:~:text=According%20to%20a%20report%20from,aluminum%20(0%2D2%25)

Chapter: Semi-Submersible Platforms

***Where data was reported in the metric system, it was converted to imperial system for consistency.**

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

BVG Associates Limited. "Guide to a Floating Offshore Wind Farm." Published on behalf of the Offshore Renewable Energy Catapult, The Crown Estate, and Crown Estate Scotland. May 2023. Accessed 27 June 2024. https://tethys.pnnl.gov/sites/default/files/publications/BVG_2023.pdf

Crowle, A. Thies, PR. "Construction Port Requirements for Floating Offshore Wind Turbines." University of Exeter. Accessed 25 June 2024. https://core.ac.uk/download/pdf/489426821.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." Journal of Engineering for the Maritime Environment. 2022. Accessed 25 June 2024. https://journals.sagepub.com/doi/full/10.1177/14750902221078425

Fred. Olsen 1848. "The Floating Foundation BRUNEL." Accessed 26 June 2024. https://www.fredolsen1848.com/floating-wind/brunel/

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Pemamek. "Production of offshore wind turbines and floating foundations." 2022. Accessed 25 June 2024. https://pemamek.com/us/discover/production-of-offshore-wind-turbines-and-floating-foundations/

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

Principle Power. "WindFloat." Accessed 26 June 2024. https://www.principlepower.com/windfloat

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Trowbridge, Matt. Lim, Jennifer. et al. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

Trowbridge, Matt. Lim, Jennifer. "California Floating Offshore Wind Regional Ports Assessment." Bureau of Ocean Energy Management Pacific OCS Region. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/documents/renewable-energy/studies/BOEM-2023-010.pdf

Chapter: Spar Buoy Platforms

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." 2021. Accessed 24 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Braendstrup, Line. "Fantastic floating foundation: Siemens Gamesa sails with TetraSpar." Siemens Gamesa. 7 July 2021. Accessed 26 June 2024. https://www.siemensgamesa.com/en-int/explore/journal/2021/07/tetraspar-world-first-demonstration-industrialized-floating-offshore

BVG Associates Limited. "Guide to a Floating Offshore Wind Farm." Published on behalf of the Offshore Renewable Energy Catapult, The Crown Estate, and Crown Estate Scotland. May 2023. Accessed 27 June 2024. https://tethys.pnnl.gov/sites/default/files/publications/BVG_2023.pdf

Crowle, A. Thies, PR. "Construction Port Requirements for Floating Offshore Wind Turbines." University of Exeter. Accessed 25 June 2024. https://core.ac.uk/download/pdf/489426821.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." University of Exeter. 2021. Accessed 25 June 2024. https://core.ac.uk/download/489426531.pdf

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Pemamek. "Production of offshore wind turbines and floating foundations." 2022. Accessed 25 June 2024. https://pemamek.com/us/discover/production-of-offshore-wind-turbines-and-floating-foundations/

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." 2016. Accessed 24 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Trowbridge, Matt. Lim, Jennifer. et al. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

Trowbridge, Matt. Lim, Jennifer. "California Floating Offshore Wind Regional Ports Assessment." Bureau of Ocean Energy Management Pacific OCS Region. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/documents/renewable-energy/studies/BOEM-2023-010.pdf

Chapter: Tension Leg Platforms

***Where data was reported in the metric system, it was converted to imperial system for consistency.**

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." 2021. Accessed 24 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Crowle, A. Thies, PR. "Construction Port Requirements for Floating Offshore Wind Turbines." University of Exeter. Accessed 25 June 2024. https://core.ac.uk/download/pdf/489426821.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." University of Exeter. 2021. Accessed 25 June 2024. https://core.ac.uk/download/489426531.pdf

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

PelaStar, a Glosten Company. "About Us." Accessed 27 June 2024. https://pelastar.com/about-us/

Pemamek. "Production of offshore wind turbines and floating foundations." 2022. Accessed 25 June 2024. https://pemamek.com/us/discover/production-of-offshore-wind-turbines-and-floating-foundations/

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." 2016. Accessed 24 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Trowbridge, Matt. Lim, Jennifer. et al. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

Trowbridge, Matt. Lim, Jennifer. "California Floating Offshore Wind Regional Ports Assessment." Bureau of Ocean Energy Management Pacific OCS Region. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/documents/renewable-energy/studies/BOEM-2023-010.pdf

Chapter: Array Cables

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boskalis. "Equipment Sheet: Spirit Cable Lay Vessel." April 2018. Accessed 25 June 2024. https://boskalis.com/media/ehipyxrm/cablelaying_vessel_spirit.pdf

LS Cable & System Ltd. "LS Cable & System invests approximately 1 trillion won to build the largest submarine cable factory in the U.S." 10 July 2024. https://www.lscns.co.kr/en/pr/news_view.asp?brd_id=news1&mode=MOD&idx=117913&lang_cd=kr

BVG Associates. "Fact Sheet 4: Cables and Accessories." Published on behalf of Scottish Enterprise, Highlands and Islands Enterprise, and South of Scotland Enterprise. Accessed 25 June 2024. https://www.offshorewindscotland.org.uk/media/g3mbquou/04-cables-accessories.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." Journal of Engineering for the Maritime Environment. 2022. Accessed 25 June 2024. https://ore.exeter.ac.uk/repository/bitstream/handle/10871/128828/Floating%20offshore%20wind%20turbines%20port%20requirements%20for%20construction.pdf?sequence=1

Davies, Claire. Logan, Andy. et al. "Job Roles in Offshore Wind." Green Port Hull. BVG Associates. 2017. Accessed 25 June 2024. https://www.bluegemwind.com/wp-content/uploads/2020/07/Job-Roles-in-Offshore-Wind.pdf

Elkinton, C. Blatiak, A. et al. "ASSESSMENT OF PORTS FOR OFFSHORE WIND DEVELOPMENT IN THE UNITED STATES." Garrad Hassan America, Inc. 2014. Accessed 25 June 2024. www.osti.gov/servlets/purl/1124491

Guide to a Floating Offshore Wind Farm. "B.1.1 Array cable." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-1-cables/b-1-1-array-cable/

Jan De Nul Group. "Isaac Newton." Accessed 25 June 2024. https://www.jandenul.com/sites/default/files/2023-03/Isaac%20Newton%20%28EN%29.pdf

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Marcollo, Hayden. Efthimiou, Louise. "Floating Offshore Wind Dynamic Cables: Overview of Design and Risks." World Forum Offshore Wind. 2024. Accessed 25 June. 2024. https://wfo-global.org/wp-content/uploads/2024/02/WFO-Cables-and-FOSS-White-Paper.pdf

NOV. "Enhydra FWIV." Accessed 25 June 2024. https://www.nov.com/products/enhydra-fwiv

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Van Oord. "Cable-laying equipment." Accessed 25 June 2024. https://www.vanoord.com/en/equipment/cable-laying-equipment

Chapter: Export Cables

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boskalis. "Equipment Sheet: Spirit Cable Lay Vessel." April 2018. Accessed 25 June 2024. https://boskalis.com/media/ehipyxrm/cablelaying_vessel_spirit.pdf

LS Cable & System Ltd. "LS Cable & System invests approximately 1 trillion won to build the largest submarine cable factory in the U.S." 10 July 2024. https://www.lscns.co.kr/en/pr/news_view.asp?brd_id=news1&mode=MOD&idx=117913&lang_cd=kr

BVG Associates. " Fact Sheet 4: Cables and Accessories." Published on behalf of Scottish Enterprise, Highlands and Islands Enterprise, and South of Scotland Enterprise. Accessed 25 June 2024. https://www.offshorewindscotland.org.uk/media/g3mbquou/04-cables-accessories.pdf

Crowle, A. Thies, PR. "Floating offshore wind turbines port requirements for construction." Journal of Engineering for the Maritime Environment. 2022. Accessed 25 June 2024. https://ore.exeter.ac.uk/repository/bitstream/handle/10871/128828/Floating%20offshore%20wind%20turbines%20port%20requirements%20for%20construction.pdf?sequence=1

Davies, Claire. Logan, Andy. et al. "Job Roles in Offshore Wind." Green Port Hull. BVG Associates. 2017. Accessed 25 June. 2024. https://www.bluegemwind.com/wp-content/uploads/2020/07/Job-Roles-in-Offshore-Wind.pdf

Elkinton, C. Blatiak, A. et al. "ASSESSMENT OF PORTS FOR OFFSHORE WIND DEVELOPMENT IN THE UNITED STATES." Garrad Hassan America, Inc. 2014. Accessed 25 June 2024. www.osti.gov/servlets/purl/1124491

Guide to a Floating Offshore Wind Farm. "B.1.2 Export cable." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-1-cables/b-1-2-export-cable/

Guide to a Floating Offshore Wind Farm. "B.1.2.1 Export cable core." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-1-cables/b-1-2-export-cable/b-1-2-1-export-cable-core/

Guide to a Floating Offshore Wind Farm. "B.1.2.2 Export cable outer." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-1-cables/b-1-2-export-cable/b-1-2-2-export-cable-outer/

Jan De Nul Group. "Isaac Newton." Accessed 25 June 2024. https://www.jandenul.com/sites/default/files/2023-03/Isaac%20Newton%20%28EN%29.pdf

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Marcollo, Hayden. Efthimiou, Louise. "Floating Offshore Wind Dynamic Cables: Overview of Design and Risks." World Forum Offshore Wind. 2024. Accessed 25 June. 2024. https://wfo-global.org/wp-content/uploads/2024/02/WFO-Cables-and-FOSS-White-Paper.pdf

Nexans. "Nexans Opens its New South Carolina Plant to Meet the Growing Demand for High-Voltage Cables." Accessed 25 June 2024. https://www.offshore-technology.com/contractors/cables/nexans/pressreleases/presssouth-carolina-plant/

NOV. "Enhydra FWIV." Accessed 25 June 2024. https://www.nov.com/products/enhydra-fwiv

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

Stefek, Jeremy. Constant, Chloe. et al. "U.S. Offshore Wind Workforce Assessment." National Renewable Energy Laboratory. 2022. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/81798.pdf

Van Oord. "Cable-laying equipment." Accessed 25 June 2024. https://www.vanoord.com/en/equipment/cable-laying-equipment

Chapter: Anchors

Where data was reported in the metric system, it was converted to imperial system for consistency.

BVG Associates. "Fact Sheet 2: Anchors and Moorings." Published on behalf of Scottish Enterprise, Highlands and Islands Enterprise, and South of Scotland Enterprise. Accessed 25 June 2025. https://www.sdi.co.uk/media/l31f0f42/02-anchors-moorings.pdf

Guide to a Floating Offshore Wind Farm. "B.3.1 Anchors." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-3-mooring-system/b-3-1-anchors/

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Chapter: Mooring Lines

Where data was reported in the metric system, it was converted to imperial system for consistency.

BVG Associates. "Fact Sheet 2: Anchors and Moorings." Published on behalf of Scottish Enterprise, Highlands and Islands Enterprise, and South of Scotland Enterprise. Accessed 25 June 2025. https://www.sdi.co.uk/media/l31f0f42/02-anchors-moorings.pdf

Guide to a Floating Offshore Wind Farm. "B.3.2 Mooring lines." 2023. Accessed 25 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-3-mooring-system/b-3-2-mooring-lines/

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Chapter: Secondary Steel

***Where data was reported in the metric system, it was converted to imperial system for consistency**.*

BVG Associates. "Fact Sheet 1: Secondary Steel." Published on behalf of Scottish Enterprise, Highlands and Islands Enterprise, and South of Scotland Enterprise. Accessed 23 May 2024. https://www.sdi.co.uk/media/u0fnfa1m/01-secondary-steel.pdf & https://www.offshorewindscotland.org.uk/media/vgfjtf2o/01-secondary-steel.pdf

Davies, Claire. Logan, Andy. et al. "Job Roles in Offshore Wind." Green Port Hull. BVG Associates. 2017. Accessed 25 June 2024. https://www.bluegemwind.com/wp-content/uploads/2020/07/Job-Roles-in-Offshore-Wind.pdf

Guide to a Floating Offshore Wind Farm. "B.2.2 Secondary steel." 2023. Accessed 26 June 2024. https://guidetofloatingoffshorewind.com/guide/b-balance-of-plant/b-2-floating-substructure/b-2-2-secondary-steel/

Gupta, R.C. "Energy Resources, Its Role and Use in Metallurgical Industries." *Treatise on Process Metallurgy: Industrial Processes*. ScienceDirect. 2014. Accessed 26 June 2024. https://www.sciencedirect.com/topics/engineering/metallurgical-plant

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Massachusetts Clean Energy Center. "15 Sites Identified for the Manufacture and Assembly of Secondary Steel." accessed 26 June 2024. https://www.masscec.com/ports-and-infrastructure-maps/secondary-steel

Matha, Denis. Mitzlaff, Alexander. et al. "Fabrication and installation constraints for floating wind and implications on current infrastructure and design." European Union Horizon2020. Ramboll. accessed 26 June 2024. https://www.sintef.no/globalassets/project/eera-deepwind2017/presentasjoner/e2_matha_updated.pdf

Office of Acquisition Management. "Build America Buy America." accessed 26 June 2024. https://www.commerce.gov/oam/build-america-buy-america

OneMonroe. "Primary vs Secondary Steelmaking: What's the Difference?" 2019. Accessed 26 June 2024. https://monroeengineering.com/blog/primary-vs-secondary-steelmaking-whats-the-difference/#:~:text=Also%20known%20as%20electric%20arc,is%20used%20as%20the%20furnace

Watson, Christopher. "Domestic Steel Manufacturing: Overview and Prospects." Congressional Research Service 2022. Accessed 26 2024. https://crsreports.congress.gov/product/pdf/R/R47107

U.S. Department of Energy and Bureau of Ocean Energy Management. "Advancing the Growth of the U.S. Offshore Wind Industry: Federal Funding and Incentives." April 2024. Accessed 26 June 2024. https://www.energy.gov/sites/default/files/2024-04/DOE-BOEM-Fed-Offshore-wind-v3_w150.updated.pdf

Chapter: Crew Transfer Vessels (CTV), Service Accommodation Transfer Vessels (SATV), and Service Operation Vessels (SOV)

Where data was reported in the metric system, it was converted to imperial system for consistency.

American Clean Power. "Offshore Wind Investments in U.S.-flagged Vessels." 2024. Accessed 25 June 2024. https://cleanpower.org/wp-content/uploads/gateway/2024/02/OffshoreWind_Vessel_Investments_240410.pdf

ABB. "Service Operation Vessel (SOV)." Accessed 26 June 2024. https://new.abb.com/marine/vessel-segments/offshore/offshore-wind/service-operation-vessel

Bruce, George. Shipbuilding Management. Springer. 2021. Accessed 25 June 2024. https://link.springer.com/content/pdf/10.1007/978-981-15-8975-1.pdf

Chakraborty, Soumya. "Different Jobs in a Shipyard & Shipbuilding Industry." Marine Insight. 2021. Accessed 25 June 2024. https://www.marineinsight.com/careers-2/different-jobs-in-a-shipyard-shipbuilding-industry/

Colonna's Shipyard Inc. "Facilities." Accessed 25 June 2024. https://www.colonnaship.com/facilities/

DLBA Inc. "The 120' SATV Service Accommodation and Transfer Vessel." 2020. Accessed 25 June 2024. https://dlba-inc.com/commercial-news/the-120-satv-service-accommodation-and-transfer-vessel%E2%80%8B/

Eastern Shipbuilding Group Inc. "Facilities." Accessed 25 June 2024. https://www.easternshipbuilding.com/who-we-are/facilities/

Edison Chouset Offshore. "Edison Chouest Offshore Affiliate Executes Long-Term Charter Agreement with Ørsted and Eversource for Provision of the First U.S. Jones Act Compliant Windfarm Service Operation Vessel." October 2020. Accessed 26 June 2024. https://www.chouest.com/press/windfarm-service-operation-vessel.html

Foxwell, David. "Innovative accommodation and transfer vessel for Formosa 1 delivered." Riviera. 2020. Accessed 25 June 2024. https://www.rivieramm.com/news-content-hub/news-content-hub/innovative-accommodation-and-transfer-vessel-delivered-for-formosa-1-58308

Gladding-Hearn. "Infrastructure." Accessed 25 June 2024. https://gladding-hearn.com/about/infrastructure/

GRS Group. "Marine Assets for Sale." Accessed 26 June 2024. https://grs.group/grs-offshore-renewables/purchase/offshore-vessels-for-sale/offshore-vessels-for-sale-results/

Hu, B. Yung, C. "Offshore Wind Access Report 2020." TNO. 2020. Accessed 25 June 2024. https://publications.tno.nl/publication/34637592/uSPDJu/TNO-2020-R11992.pdf

Ice Marine Design. "Zero-emission Service Operation Vessel (WS-90-SOV)." accessed 26 June 2024. https://www.icedesign.info/services/proprietary-designs/service-operation-vessels/

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Landfall Marine Contractors bv. "Multi-purpose Accommodation Pontoon." Accessed 27 June 2024. https://www.landfall.nl/wp-content/uploads/2020/02/ASV-Pioneer-Brochure.pdf

MARAD. "The Economic Importance of the U.S. Private Shipbuilding and Repairing Industry." 2021. Accessed 25 June 2024. https://www.maritime.dot.gov/sites/marad.dot.gov/files/2021-06/Economic%20Contributions%20of%20U.S.%20Shipbuilding%20and%20Repairing%20Industry.pdf

Marine Travelift. "Yank Marine Expands Dorchester Facility With Delivery Of New Marine Travelift 820 C Mobile Boat Hoist." 2017. Accessed 25 June 2024. https://www.marinetravelift.com/yank-marine-expands-dorchester-facility-delivery-new-marine-travelift-820-c-mobile-boat-hoist/

Maritime Directory. "EDISON CHOUEST." Accessed 27 June 2024. https://directory.marinelink.com/ships/ship/edison-chouest-10601

The National Iron & Steel Heritage Museum. "Vessels & What They Are Made Of." 2012. Accessed 27 June 2024. https://steelmuseum.org/americas_cup_exhibit_2017/vessels_made_of.cfm#:~:text=Today%2C%20ships%2C%20yachts%20and%20other,the%20most%20widely%2Dused%20material.

Ørsted. "Ørsted and Shipbuilder Edison Chouest Christen First-Ever American-Built, Offshore Wind Service Operations Vessel." 2024. Accessed 26 June 2024. https://us.orsted.com/news-archive/2024/05/orsted-and-shipbuilder-edison-chouest-christen-american-built-offshore-wind-service-operations-vessel

Ship Technology. "Bibby WaveMaster 1 Service Operations Vessel." 10 December 2028. Accessed 26 June 2024. https://www.ship-technology.com/projects/bibby-wavemaster-1-service-operations-vessel/?cf-view

Siemens Gamesa. "Offshore Logistics For maximum yield." Accessed 26 June 2024. https://www.siemensgamesa.com/products-and-services/service-wind/offshore-logistics#:~:text=Taking%20offshore%20service%20into%20new,servicing%20offshore%20wind%20power%20plants.

Trowbridge, Matt. Lim, Jennifer. et al. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

Ulstein. "Ulstein Elektro Installasjon AS." Accessed 26 June 2024. https://ulstein.com/companies/ulstein-elektro-installasjon-as

Vard. "Renewable Vessels / Service Operations Vessels." Accessed 26 June 2024. https://vardmarine.com/vessels/renewable-vessels-service-operations-vessels/

Chapter: Staging & Integration

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Connecticut Port Authority. "State Pier Infrastructure Improvements Project." Accessed 25 June 2024. https://statepiernewlondon.com/

Davies, Claire. Logan, Andy. et al. "Job Roles in Offshore Wind." Green Port Hull. BVG Associates. 2017. Accessed 25 June 2024. https://www.bluegemwind.com/wp-content/uploads/2020/07/Job-Roles-in-Offshore-Wind.pdf

Groningen Seaports. "Organisation Profile." Accessed 25 June 2024. https://www.groningen-seaports.com/en/groningen-seaports/organisation-profile/

JobsEQ. Data as of 2023Q4, based on a 4-quarter moving average. Accessed June 2024.

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Trowbridge, Matt; Lim, Jennifer; and Knipe, Ashley. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf

Chapter: Operations & Maintenance

Where data was reported in the metric system, it was converted to imperial system for consistency.

Boyce, Douglas. "North Atlantic Ports Association AGM: Offshore Wind – Ports and Marine requirements." Worley. 2021. Accessed 25 June 2024. https://www.northatlanticports.org/resources/Documents/2-%20NAPA%20AGM%20%20Ports%20and%20Marine-%20Dec%202021-rev2-shared.pdf

Guide to a Floating Offshore Wind Farm. "Lifecycle Overview - O&M Port". Accessed 24 June 2024. https://guidetofloatingoffshorewind.com/guide/o-operations-and-maintenance/o-5-om-port/

Lantz, Eric. Barter, Garrett. et al. "Power Sector, Supply Chain, Jobs, and Emissions Implications of 30 Gigawatts of Offshore Wind Power by 2030." National Renewable Energy Laboratory. 2021. Accessed 25 June 2024. https://www.nrel.gov/docs/fy21osti/80031.pdf

Lim, Jennifer. Trowbridge, Matt. "AB 525 Port Readiness Plan." Bureau of Ocean Energy Management Pacific OCS Region. Moffat & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/07/AB525-Port-Readiness-Plan_acc.pdf

Porter, Aaron. Phillips, Shane. "Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii." Bureau of Ocean Energy Management Pacific OCS Region. 2016. Accessed 25 June 2024. https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-011.pdf

The Schatz Energy Research Center at Humboldt State University. "California North Coast Offshore Wind Studies Port Infrastructure Assessment Report." 2020. Accessed 25 June 2024. https://schatzcenter.org/pubs/2020-OSW-R19.pdf

Shields, Matt. Cooperman, Aubryn. et al. "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States." National Renewable Energy Laboratory. 2023. Accessed 25 June 2024. https://www.nrel.gov/docs/fy23osti/86864.pdf

Trowbridge, Matt; Lim, Jennifer; and Knipe, Ashley. "ALTERNATIVE PORT ASSESSMENT TO SUPPORT OFFSHORE WIND." California State Lands Commission. Moffatt & Nichol. 2023. Accessed 25 June 2024. https://slcprdwordpressstorage.blob.core.windows.net/wordpressdata/2023/02/Alternative-Port-Assessment-To-Support-Offshore-Wind-Final.pdf