OCS Study
BOEM 2023-010

California Floating Offshore Wind Regional Ports Assessment

U.S. Department of the Interior
Bureau of Ocean Energy Management
Pacific OCS Region, Camarillo, CA

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DISCLAIMER

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ABOUT THE COVER

Photo Description: Floating offshore wind turbines installed at sea and one turbine being towed out for installation.

Photo Credit: Moffatt & Nichol

ACKNOWLEDGMENTS

We would like to thank the following for their time and participation in completing this effort: City of Alameda, City of Morro Bay, Crescent City Harbor District, Diablo Canyon, Port of Benicia, Port of Hueneme, Port of Humboldt, Port of Long Beach, Port of Los Angeles, Port of Oakland, Port of Redwood City, Port of Richmond, Port of San Diego, Port San Luis, Port of San Francisco, Port of Stockton, Port of San Francisco, AMPORTS (Port of Benicia), BAE Systems (Port of San Diego), NASSCO (Port of San Diego), and Pasha Automotive Services (Port of San Diego).

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List of Abbreviations and Acronyms

AB	Assembly Bill
ABS	American Bureau of Shipping
ACI	American Concrete Institute
AFOD	AF Offshore Decommissioning
AISC	American Institute for Steel Construction
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
AWS	American Welding Society
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CARB	California Air Resources Board
CBC	California Building Code
CEC	California Energy Commission
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CSLC	California State Lands Commission
CTV	Crew transfer vessel
e.g.	*Exempli gratia* (for example)
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
etc.	et cetera
ft	feet
GBS	Gravity-based structure
GW	Gigawatts
i.e.	*id est* (that is)
IDIQ	Indefinite Delivery Indefinite Quantity
IDWG	Interagency Decommissioning Working Group
LSU	Louisiana State University
m	meter / meters
M&N	Moffatt & Nichol
MF	Manufacturing / Fabrication
MMS	Minerals Management Service
MW	Megawatt
N/A	Not applicable
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NOA	Notice of Availability
NOI	Notice of Intent
NOP	Notice of Preparation
NREL	National Renewable Energy Laboratory

O&M	Operation and Maintenance
OCIMF	Oil Companies International Marine Forum
OCS	Outer Continental Shelf
OEM	Original equipment manufacturers
OSW	Offshore wind
Pacific OCS	Outer Continental Shelf off the coasts of California, Oregon, Washington, and Hawaii
PARS	port access route study
PIANC	Permanent International Association of Navigation Congresses
PPE	Personal protection equipment
psf	pounds per square foot
ROD	Record of Decision
RORO	Roll-on / roll-off
S&I	Staging and Integration
SATV	Service accommodation transfer vessel
Schatz	Schatz Energy Research Center
SLO	San Luis Obispo
SOV	Service operations vessel
SPMTs	self-propelled modular trailers
TLP	Tension Leg Platform
U.K.	United Kingdom
UC	University of California
UFC	Unified Facilities Criteria
U.S.	United States
USACE	United States Army Corps of Engineers
USC	University of Southern California
USCG	U.S. Coast Guard
USDOE	U.S. Department of Energy
WEA	Wind Energy Area
WTG	Wind turbine generator
yr	Year

How to Read this Report

The overall goals of this California Floating Offshore Wind Energy Regional Ports Assessment are to:

1. Identify port requirements and deployment scenarios needed to support an offshore wind industry in California, concurrently with reasonably foreseeable Pacific Outer Continental Shelf (OCS) oil and gas decommissioning activities; and,
2. Assess physical, operational, and regulatory capabilities and constraints of port facilities and infrastructure.

This report has the following structure:

- **Section 1** provides an introduction and background to the study.
- **Section 2** documents the port requirements from a previous Bureau of Ocean Energy Management (BOEM) study titled *Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development* (Moffatt & Nichol 2022).
- **Section 3** identifies the five deployment scenarios for 2030 through 2050 and determines the number of required staging and integration (S&I) and manufacturing/fabrication (MF) sites needed to meet the above deployment scenarios.
- **Section 4** discusses the port outreach that was conducted as part of this study.
- **Section 5** identifies the number and type of California port sites that are potentially available for offshore wind development.
- **Section 6** identifies the port requirements for offshore oil and gas platform decommissioning and assesses which ports are ideal for this type of activity.
- **Section 7** provides a summary of the study and recommended next steps.

There are three (3) main port facilities that are required for offshore wind development: staging and integration (S&I), manufacturing/fabrication (MF), and operations and maintenance (O&M) facilities. The following describes the type of activities conducted at each. For details on the specific requirements of each site, refer to **Section 2**.

- **Staging and Integration (S&I) Site:** a site to receive, stage, and store offshore wind components and to assemble the floating turbine system for towing to the offshore wind area. This facility is likely to support the following services:
    - **Turbine Maintenance Site:** a facility to perform major maintenance on a fully assembled turbine system that cannot otherwise be performed in the offshore wind area, such as replacement of a nacelle or blade.
- **Manufacturing / Fabrication (MF) Site:** a port site located on a navigable waterway that receives raw materials via road, rail, or waterborne transport and creates larger components in the offshore wind supply chain. This site typically includes factory and/or warehouse buildings and space for storage of completed components.
- **Operations and Maintenance (O&M) Site:** a base of wind farm operations with warehouses/ offices, spare part storage, and marine facility to support vessel provisioning and refueling/ charging for the following O&M vessels during the operational period of the offshore wind farm:
    - **Crew Transfer Vessel (CTV):** transfers small crews to offshore wind turbine installations for day-trip O&M visits and inspections.
    - **Service Operating Vessel (SOV):** vessels that loiter and operate as in-field accommodations for workers and platform assist for wind turbine servicing and repair work. This vessel may remain in the vicinity of an offshore windfarm for an extended period of time with a permanent or semi-permanent personnel rotation.

- **Service Accommodation Transfer Vessel (SATV):** intermediate between SOVs and CTVs, with ability to sleep onboard for multiday trips.

Additional offshore wind port sites that are not included in this study but will be required for offshore wind industry use include:

- Other Types of Offshore Wind Port Sites:
    - **Installation Support Site:** a base of construction operations for the fleet of construction vessels necessary for construction and commissioning of the offshore wind farm.
    - **Mooring Line, Anchor, and Electrical Cable Laydown Site:** a site to receive and stage mooring lines, anchors, and electrical cables to support the installation of the offshore wind farm.
    - **Cable Landing Site:** locations for the electrical cables to transition from the offshore (e.g., subsea cables) to a grid connection location. These sites may include electrical infrastructure onshore.
    - **End of Life Decommissioning Site:** a site to decommission, disassemble, recycle, and dispose of turbine systems that are at end of life.

Executive Summary

The Bureau of Ocean Energy Management (BOEM) is interested in a study of California ports to support offshore wind development. Specifically, the infrastructure apart from the offshore energy facility itself, such as ports, navigation, transmission, and supply chain. This study will address the needs and requirements of California ports to support floating offshore wind. It will also support the California Assembly Bill (AB) 525 Strategic Plan that is due June 30, 2023 (Chiu 2021).

The objective of this study is to develop offshore wind deployment scenarios, which include size (gigawatts [GW]) and timing (e.g., years 2030 and 2045), as well as a high-level screening study to identify the required quantity and size of various port facilities needed to support the deployment scenarios. The feasibility of port upgrades and associated cost estimates are not included in this study but will be included in the following BOEM study titled *California Floating Offshore Wind Regional Ports Feasibility Analysis*. In addition to an assessment of existing ports, this study also considered port capabilities and requirements needed to accommodate current and anticipated Pacific Outer Continental Shelf (OCS) oil and gas decommissioning activities.

Based on this study, multiple port sites will need to be developed to meet the identified offshore wind deployment targets. Fortunately, **many existing port sites within California were identified** that could meet these goals. To do so, this will require significant investment into existing ports to support the offshore wind industry needs.

In a letter to the California Air Resources Board (CARB) dated July 22, 2022, Governor Gavin Newsom urged the California Energy Commission (CEC) to establish an offshore wind planning goal of at least 20 GW by 2045 (Newsom 2022). On August 1, 2022, the CEC established a preliminary offshore wind planning goal of 2 to 5 GW by 2030 and 25 GW by 2045 for California (Flint et al. 2022). Using these goals as a baseline, this study assessed a range of deployment scenarios for 2030 through 2050, which can be found in **Section 3**.

From these deployment targets, the required number of staging and integration (S&I) and manufacturing / fabrication (MF) sites were determined in **Section 3**. The determination of the number of operations and maintenance (O&M) sites is not included in this study but will be provided in the future AB 525 Strategic Plan. Refer to **Table 2** and **Section 2** for the requirements of each type of port site (e.g. acreage size, length of wharf, berth depth, etc.).

After the deployment targets and number of required port sites were identified, an inventory of potentially available port sites within California was taken. Moffatt & Nichol (M&N), BOEM, and California State Lands Commission (CSLC) conducted outreach meetings with seventeen (17) California ports/facilities and four (4) additional port tenants/operators to determine interest for offshore wind development and assess availability and suitability of potential sites without relocating existing uses (e.g., container, cargo, fishing, recreational boating, etc.). For a detailed list of the California ports and port tenants/operators that were contacted as part of this outreach, refer to **Section 5**.

Following outreach efforts with the California ports, an assessment of the ports was conducted in **Section 6**. It is important to note that currently, existing port sites on the United States (U.S.) West Coast are not ready to serve the offshore wind industry from a port infrastructure perspective (i.e., wharf, navigation channel, backlands, etc.). All potential port sites will require some level of investment to upgrade existing facilities, such as construction of a new wharf to withstand heavier loading and dredging of the navigation channel and/or berth pockets.

S&I sites require a large amount of space, deep navigation channels, and cannot have any air draft restrictions since the fully assembled turbine systems, which are 1,100 feet above water, need to be towed out to the installation site at the wind energy area (WEA). Therefore, only the ports of Humboldt, Los Angeles, and Long Beach were identified to have **good S&I candidate** sites that meet the required criteria.

MF sites can occupy less space than S&I sites and be at locations with air draft restrictions since the components (e.g., tower sections, nacelles, blades, and floating foundations) can be transported horizontally via vessel or barge. Therefore, ports located behind bridges, such as those in the Bay Area, are candidates for offshore wind development as MF sites. The following ports, ordered north to south, were identified to have **good MF candidate** sites with adequate acreage:

- Port of Humboldt
- Port of Benicia
- Port of Stockton
- Port of Richmond
- Port of San Francisco
- Port of Redwood City
- Port of Los Angeles
- Port of Long Beach
- Port of San Diego[1]

Ideally, O&M sites that transfer crew to and from the offshore wind farm shall be close to the wind farm location to minimize travel time. The following ports, ordered north to south, were identified to have **good O&M candidate** sites:

- Crescent City Harbor District
- Port of Humboldt
- City of Morro Bay
- Diablo Canyon Power Plant
- Port San Luis
- Port of Hueneme

While this study focuses on assessing the seventeen (17) existing California ports/facilities, another study for the CSLC assessed additional existing harbors between San Francisco and Long Beach to identify additional O&M sites that are closer to the Morro Bay WEA (Moffatt & Nichol 2023b).

The information gathered from this, and previous studies, will inform the next BOEM study titled *California Floating Offshore Wind Regional Ports Feasibility Analysis*, which will assess the feasibility of port upgrades and associated cost estimates and construction timelines. In addition, the AB 525 Strategic Plan, with support from the BOEM and CSLC studies, will include the following:

- Identify required port infrastructure improvements, including cost and schedule,
- Identify impacts to natural and cultural resources, including coastal resources, fisheries, and Native American and Indigenous peoples,
- Rank the recommended port sites,
- Determine workforce development needs, training, and strategy,
- Develop the seaport chapter for the AB 525 Strategic Plan due June 30, 2023.

[1] Within the Port of San Diego, manufacturing / fabrication of offshore wind floating foundations is possible at the NASSCO site and steel component fabrication and ship repair services are possible at the BAE Systems site.

As part of this study of assessing California ports, BOEM has also indicated the need to identify port requirements and capabilities to support Pacific OCS oil and gas decommissioning activities. As the twenty-three (23) Federal oil and gas platforms offshore southern California reach the end of their production lifetimes, decommissioning is the next step. As of this writing, eight Federal offshore oil and gas platforms have already ceased production, therefore requiring the platforms to undergo the decommissioning process. Identifying port requirements and capabilities to support the current and increasing Pacific OCS oil and gas decommissioning activities is an important outcome of this study. After identifying the necessary port requirements for decommissioning activities, an assessment was completed to determine whether these activities could be co-located with offshore wind port sites. Refer to Section 7 for offshore oil and gas decommissioning considerations.

There are some synergies between the offshore wind industry and the offshore oil and gas decommissioning industry. These synergies include similar business lines from a terminal equipment, operator, and vessel perspective, and the efficiency of two facilities located within the same port. However, they cannot be located at the same port site as both need designated berth and upland space for long periods of time. Of the ports in California, the **Port of Los Angeles and Port of Long Beach were identified to be the ideal locations for offshore oil and gas platform decommissioning** due to proximity to the offshore oil and gas platforms, access to steel recycling facilities, potential for large purpose-built sites, no air draft restrictions, wide entrance channels, and large navigation channels.

1 Introduction

The United States (U.S.) Department of the Interior, Bureau of Ocean Energy Management (BOEM), as mandated by the Outer Continental Shelf (OCS) Lands Act, administers exploration and development of energy and mineral resources in federal waters. This includes the responsibility of issuing a lease, easement, or right-of-way for offshore energy and mineral resources in federal waters off the coasts of California, Oregon, Washington, and Hawaii – the Pacific OCS Region.

The Pacific OCS is characterized by rapidly increasing water depths that exceed the feasible limits of traditional fixed-bottom offshore wind turbines. Thus, floating offshore wind technology is more suitable for this region. To construct floating offshore wind turbines, the turbine components will need to be fabricated, assembled, and transported from an onshore port to the offshore wind site. Existing port infrastructure on the U.S. West Coast, including the California coast, is not adequate to support these activities and significant port investment is required to develop offshore wind port facilities.

BOEM is interested in a study of California ports to support offshore wind development. Specifically, the infrastructure apart from the offshore energy facility itself, such as ports, navigation, transmission, and supply chain. This study will address the needs and requirements of California ports to support floating offshore wind. It will also support the California Assembly Bill (AB) 525 Strategic Plan that is due June 30, 2023 (Chiu 2021).

It should be noted that this study is part of an overarching BOEM Indefinite Delivery Indefinite Quantity (IDIQ) contract that includes the following three studies:

- Task Order 1: *Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development* study, published in 2022.
- Task Order 2: *California Floating Offshore Wind Regional Ports Assessment* study, to be published in 2023 (this report).
- Task Order 3: *California Floating Offshore Wind Regional Ports Feasibility Analysis* study, to be published in 2023 (next report).

Regarding port infrastructure, the AB 525 Strategic Plan shall identify available port space and the necessary investments to improve waterfront facilities for the floating offshore wind industry. In addition, the AB 525 Strategic Plan shall include identification of sea space for wind energy areas (WEAs) to accommodate the offshore wind planning goals for 2030 and 2045 (Chiu 2021). To date, BOEM has identified two offshore WEAs off the state of California, the Humboldt WEA and Morro Bay WEA**.**

The objective of this study is to develop offshore wind deployment scenarios, which include size (gigawatts [GW]) and timing (e.g., years 2030 and 2045), as well as a high-level screening study to identify the required quantity and size of various port facilities needed to support the deployment scenarios. The feasibility of port upgrades and associated cost estimates are not included in this study, but will be included in the following BOEM study titled *California Floating Offshore Wind Regional Ports Feasibility Analysis*. In addition to an assessment of existing ports, this study also considered port capabilities and requirements needed to accommodate current and anticipated OCS oil and gas decommissioning activities.

The overall goals of the California Floating Offshore Wind Regional Ports Assessment are to:

1. Identify port requirements and deployment scenarios needed to support an offshore wind industry in California, concurrently with reasonably foreseeable OCS oil and gas decommissioning activities; and,

2. Assess physical, operational, and regulatory capabilities and constraints of port facilities and infrastructure.

The key to a successful port development strategy requires coupling it with the proposed California offshore wind solicitation schedule and deployment scenarios. On December 6, 2022, BOEM held an offshore wind energy lease sale for five lease areas, two within the Humboldt WEA and three within the Morro Bay WEA (BOEM 2022). The size of each lease area ranges from 63,338 to 80,418 acres and has a potential installation capacity of 769 to 976 megawatts (MW), refer to **Figure 1**. On December 7, 2022, the lease sale ended and five provisional winners were announced – RWE Offshore Wind Holdings, LLC; California North Floating LLC; Equinor Wind US LLC; Central California Offshore Wind LLC; and Invenergy California Offshore LLC. It is imperative that the build out of port infrastructure can support this proposed schedule and offshore wind deployment scenarios. This study examines the following port development options:

- Utilize a single port (or as few as possible) to support all floating offshore wind fabrication, assembly, and operations (e.g., co-locate integration, fabrication, and operations and maintenance facilities).
- Utilize multiple port facilities to optimize development at the most ideal locations and to spread the economic impact throughout the state (e.g., separate integration, fabrication, and operations and maintenance facilities).

This study, and additional offshore wind studies, will help inform the AB 525 Strategic Plan that is intended to present findings that will help the state make decisions regarding the offshore wind industry within California. The AB 525 Strategic Plan will be informed by the following studies:

- BOEM Study (Task Order 1), *Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development* (Moffatt & Nichol 2022)
    - Extensive offshore wind developer outreach was conducted within this Port of Coos Bay, Oregon study to help inform the port facility requirements for offshore wind development on the U.S. West Coast. These port requirements are summarized within **Section 2**.
- BOEM Study (Task Order 2), *California Floating Offshore Wind Regional Ports Assessment* (this report)
    - Extensive California port outreach was conducted for the entire state within this study to assess how much space/acreage the existing California ports have available to support the offshore wind industry.
- BOEM Study (Task Order 3), *California Floating Offshore Wind Regional Ports Feasibility Analysis* (Moffatt & Nichol 2023a) (next BOEM study)
    - The feasibility of port upgrades and associated cost estimates and timelines will be determined and assessed for the sites previously identified in BOEM Task Order 2.
- California State Lands Commission (CSLC) Study, *Alternative Port Assessment to Support Offshore Wind* (Moffatt & Nichol 2023b)
    - A feasibility assessment was conducted for the region between San Francisco and Long Beach to determine the opportunities and limitations for creating new alternative port locations to support the offshore wind industry.

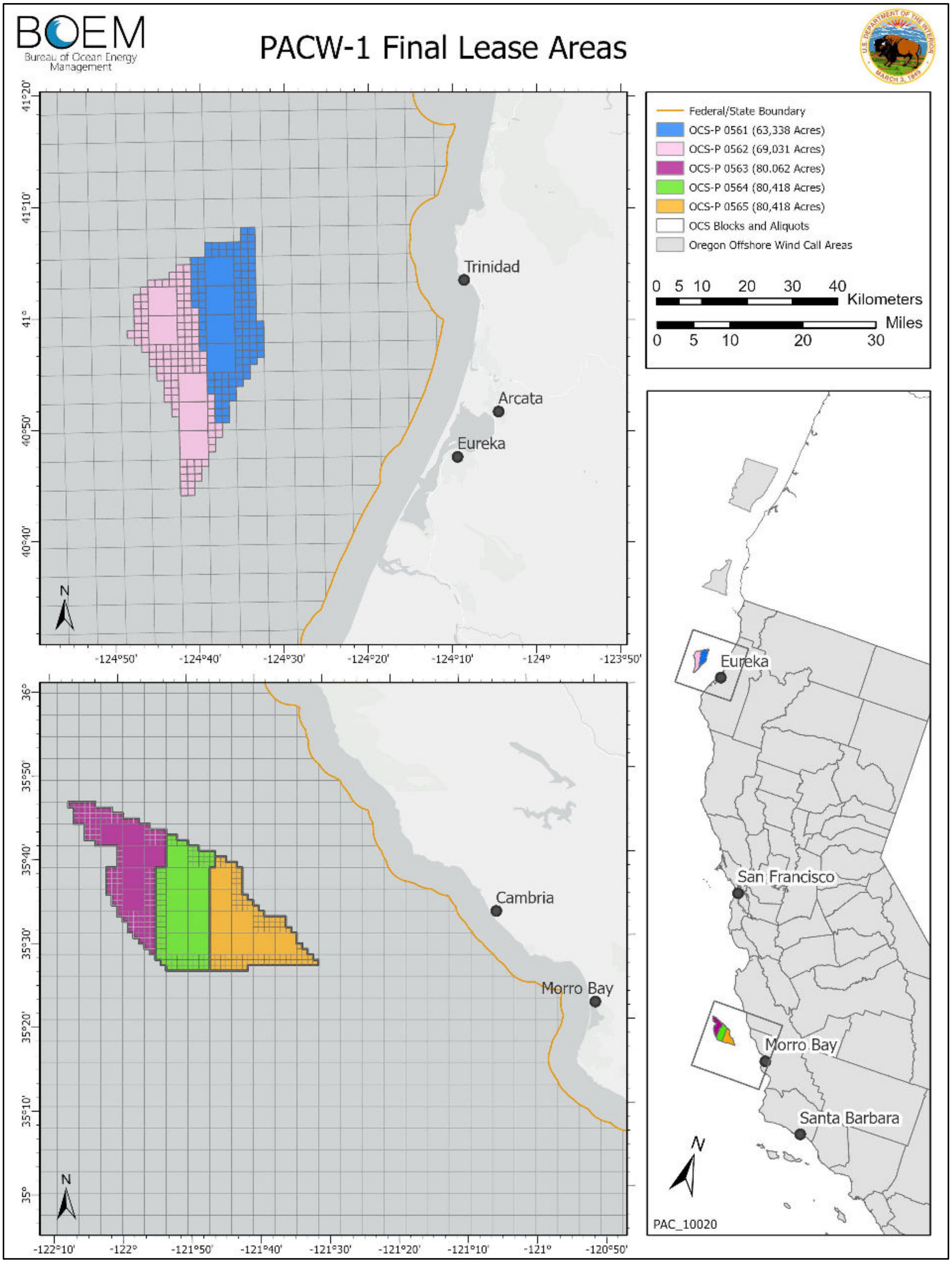

Figure 1. California final lease areas (BOEM 2022)

2 Port Requirements

The floating offshore wind industry requires port sites to stage, assemble, and provide ongoing operations and maintenance of the wind turbines. Based on the industry outreach completed for the BOEM study titled *Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development*, this section defines the requirements of this port assessment and the design criteria for the following types of offshore wind port sites (Moffatt & Nichol 2022):

- **Staging and Integration (S&I) Site:** a site to receive, stage, and store offshore wind components and to assemble the floating turbine system for towing to the offshore wind area. This facility is likely to support the following services:
    - **Turbine Maintenance Site:** a facility to perform major maintenance on a fully assembled turbine system that cannot otherwise be performed in the offshore wind area such as replacement of a nacelle or blade.
- **Manufacturing/Fabrication (MF) Site:** a port site located on a navigable waterway that receives raw materials via road, rail, or waterborne transport and creates larger components in the offshore wind supply chain. This site typically includes factory and/or warehouse buildings and space for storage of completed components.
- **Operation and Maintenance (O&M) Site:** a base of wind farm operations with warehouses/ offices, spare part storage, and marine facility to support vessel provisioning and refueling/ charging for the following O&M vessels during the operational period of the offshore wind farm:
    - **Crew Transfer Vessel (CTV):** transfers small crews to offshore wind turbine installations for day-trip O&M visits and inspections.
    - **Service Operating Vessel (SOV):** vessels that loiter and operate as in-field accommodations for workers and platform assist for wind turbine servicing and repair work. This vessel may remain in the vicinity of an offshore windfarm for an extended period of time with a permanent or semi-permanent personnel rotation.
    - **Service Accommodation Transfer Vessel (SATV):** intermediate between SOVs and CTVs, with ability to sleep onboard for multiday trips.

Additional offshore wind port sites that are not included in this study but will be required for offshore wind industry use include:

- Other Types of Offshore Wind Port Sites:
    - **Installation Support Site:** a base of construction operations for the fleet of construction vessels necessary for construction and commissioning of the offshore wind farm.
    - **Mooring Line, Anchor, and Electrical Cable Laydown Site:** a site to receive and stage mooring lines, anchors, and electrical cables to support the installation of the offshore wind farm.
    - **Cable Landing Site:** locations for the electrical cables to transition from the offshore (e.g., subsea cables) to a grid connection location. These sites may include electrical infrastructure onshore.
    - **End of Life Decommissioning Site:** a site to decommission, disassemble, recycle, and dispose of turbine systems that are at end of life.

2.1 Turbine Size

Based on the information obtained from a previous BOEM study and industry outreach, currently 12-MW offshore wind turbine systems are commercially available; however, the anticipated size of turbine systems to be installed on the U.S. West Coast may be 15 MW or larger (Moffatt & Nichol 2022). **Table 1** summarizes the anticipated dimensions for a floating turbine system with capacity of up to 20 – 25 MW. Turbine device dimensions provided are relative to the future industry needs for 15 to 25-MW size devices. Smaller size devices (beam, draft) are currently in development but are at reduced turbine capacity. The values outlined in the table are those recommended for planning a major port terminal on a 50-year time horizon to meet the anticipated needs of the continuously developing offshore wind industry. In addition, **Figure 2** shows a depiction of the turbine dimensions.

Table 1. Floating offshore wind turbine dimensions (20 – 25 MW)

Floating Offshore Wind Turbine	Approximate Dimension [ft]	Approximate Dimension [m]
Foundation Beam / Width	Up to 425 ft x 425 ft	Up to 130 m x 130 m
Draft (Before Integration)	15 – 25 ft	4.5 – 7.5 m
Draft (After integration)	20 – 50 ft	6 – 15 m
Hub/Nacelle Height (from Water Level)	Up to 600 ft	Up to 183 m
Tip Height (from Water Level)	Up to 1,100 ft	Up to 335 m
Rotor Diameter	Up to 1,000 ft	Up to 305 m

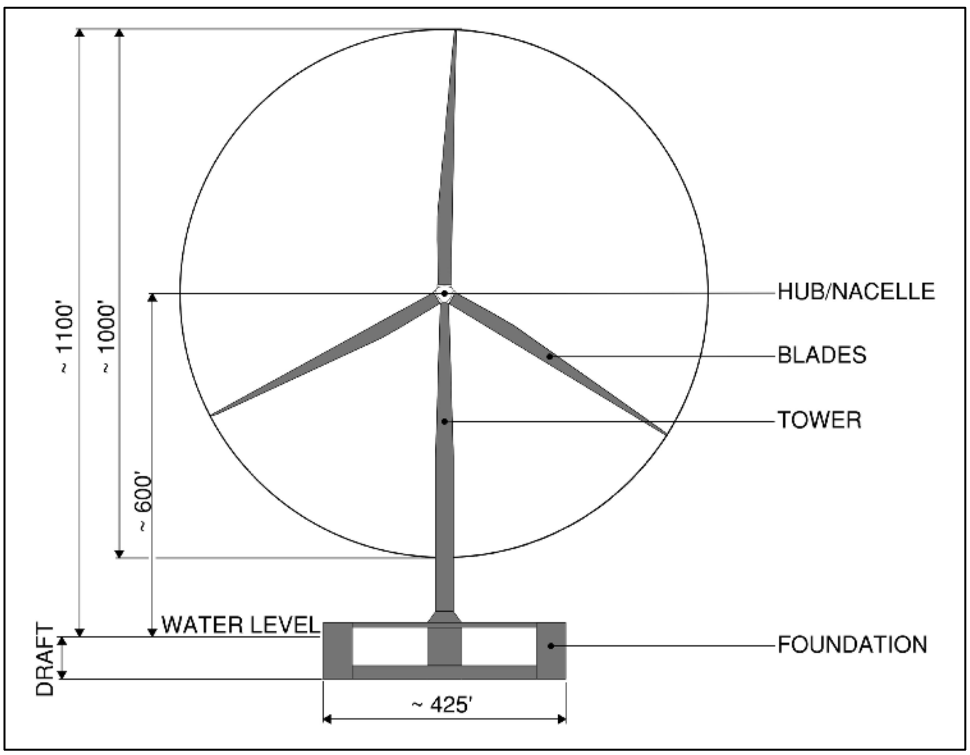

Figure 2. Floating offshore wind turbine dimensions (20 – 25 MW)

2.2 Port Requirements

The following parameters document the required port infrastructure to unload, store, pre-commission, and pre-assemble floating offshore wind farm components per the BOEM Port of Coos Bay study (Moffatt & Nichol 2022).

2.2.1 Port Wharf and Loading Requirements

Per discussions with industry, the S&I wharf shall accommodate the delivery of components and at least two turbine assemblies moored adjacent to one another, resulting in approximately 1,500 feet of quayside space, as summarized in **Table 2**. For O&M and component manufacturing facilities, the length of the wharf is dependent on the vessel type it serves. For example, SOV and CTV for O&M facilities and delivery vessels and delivery barges for component manufacturing facilities.

In general, the wharf and uplands area for component manufacturing sites shall have a capacity of 2,000 – 3,000 pounds per square foot (psf) to support offshore wind turbine generator (WTG) components. At S&I sites, the wharf loading will be higher where the crane for turbine assembly is located. Existing crawler cranes, such as the Liebherr 1300, are not large enough to assemble turbines greater than 15 MW. Thus, ring cranes or larger crawler or mobile cranes will likely be required to integrate components, requiring a loading capacity of 6,000 psf on the wharf. Loading at O&M facilities is expected to range from 100 – 500 psf.

The size of a site is also dependent on the type of facility it is. For an O&M facility, the site shall be approximately 5 – 10 acres. For component manufacturing and staging and integration sites, a range of 30 – 100 acres is requested depending on the developer and their use.

Table 2. Port infrastructure requirements

Floating Offshore Wind Turbine	Approximate Criteria for S&I Sites	Approximate Criteria for MF Sites	Approximate Criteria for O&M Sites
Acreage, minimum	30 – 100 acres	30 – 100 acres	5 – 10 acres
Wharf Length	1,500 ft	800 ft	300 ft
Minimum Draft at Berth	38 ft	38 ft	20 – 30 ft
Draft at Sinking Basin*	40 – 100 ft	N/A	N/A
Wharf Loading	> 6,000 psf	Up to 6,000 psf	100 – 500 psf
Uplands / Yard Loading (for WTG components)	> 2,000 – 3,000 psf	> 2,000 – 3,000 psf	N/A

*Options for transfer of floating foundation from land to water include use of semi-submersible barge and sinking basin, ramp system, or direct transfer methods (lifting portions or complete foundation units from land into water)

2.2.2 Floating Foundation Type and Launching

Currently, there are three types of floating foundations for floating offshore wind turbines, as shown in **Figure 3**:

- **Spar:** A Spar floating foundation, constructed of either concrete, steel, or a hybrid combination, is a cylinder that floats vertically in the water.

- **Tension Leg Platform (TLP):** A TLP floating foundation, constructed of steel, is comprised of multiple columns and pontoons. It's mooring system requires vertical tensioned tendons, which provide stability to the structure.
- **Semi-submersible:** A semi-submersible floating foundation, constructed of either concrete, steel, or a hybrid combination, is comprised of a submerged hull with multiple pontoons and columns.

Figure 3. Illustration of floating foundation types (left to right: spar, semi-submersible, TLP) (NREL 2022)

Although a semi-submersible floating foundation requires increased port infrastructure capacity, it is the most probable technology to be used on the U.S. West Coast as Spar foundations are not feasible on the West Coast, due to required deep draft, and offshore wind developers have indicated that semi-submersible foundations are preferred. Therefore, by assuming semi-submersible foundations will be utilized for offshore wind development on the West Coast, the port requirements developed in **Table 2** are also suitable for TLP foundations – if utilized – as they are smaller and require less port infrastructure capacity.

A major challenge the industry identified is the transfer of the completed floating foundation from the assembly wharf into the water (i.e., launching). Several options are available to overcome this challenge and each developer may prefer a different option; however, a few common approaches were identified:

- **Semi-Submersible Barge:** The floating foundation is moved from the wharf onto the barge and the barge is moved to a 40 – 100-foot-deep sinking basin where the barge is partially submerged by taking on ballast and the foundation is floated off the barge.

- **Ramp System:** The floating foundation is moved onto a rail system and travels down a sloped ramp into the water. This methodology is similar to a marine railway ship launching system.
- **Direct Transfer:** Methods that include lifting the floating foundation directly from the wharf into the water (includes methods that involve placing pieces of the foundation into the water and finalizing the construction in the water).

2.2.3 Wet Storage Requirements

Wet storage space is also required in addition to the water frontage and upland acreage. Ports must have locations where floating foundation or integrated turbines can be safely moored to mitigate the risk of weather downtime, vessel traffic, entrance channel congestion, and other transportation risks. This also allows the developers to store and test the completed units and floating foundations to ensure they can deliver the lease area on schedule. The size of the wet storage area is dependent on the developer's strategy, deployment schedule, and downtime risk.

2.2.4 Additional Port Requirements

Several additional port requirements include the following:

- **Roll-on/Roll-Off (RORO) Capabilities:** port sites shall have RORO capability built into the wharf and yard to allow for a range of fabrication and assembly needs. Of particular importance would be to allow for inside port transfers between multiple facilities. This may require the construction of a sinking basin deeper than the proposed navigation channel depth.
- **Green Port:** new port terminals shall have infrastructure and equipment to support state and federal carbon reduction initiatives, including electrification of the terminal operations and the ability to accommodate vessel shore power. Considering greenhouse gas emission reduction initiatives and desire to develop green ports, considerable load on the transmission grid may be needed. An assessment of power grid upgrades for the proposed development site will be needed to assess the range of power transmission upgrades needed to meet the vessel and terminal operational needs.
- **Shoreside Vessel Services:** port sites will require all standard ship services (e.g., potable water), shore power and security requirements.
- **Buildings:** indoor storage/warehouses are required for some items (e.g., floating foundation mechanical equipment, painting, welding, etc.).

2.3 Design Life

All new marine structures at the port shall be designed for a 50-year service life. Design service life is generally considered as the period of time during which a properly built and maintained structure is expected to operate as designed without requiring major replacement or rehabilitation.

2.4 Governing Codes, Standards, and References

The following codes, standards, and references govern the design of port infrastructure and offshore wind vessels.

American Bureau of Shipping (ABS):

- Guide for Building and Classing Floating Offshore Wind Turbine Installation, updated July 2014

American Concrete Institute (ACI):

- ACI 318-19, Building Code Requirements for Structural Concrete

American Institute for Steel Construction (AISC):

- AISC 303-16, Code of Standard Practice for Steel Buildings and Bridges
- AISC 341-16, Seismic Provisions for Structural Steel Buildings
- AISC 360-16, Specification for Structural Steel Buildings

American Petroleum Institute (API):

- API RP 2A-LRFD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design

American Society of Civil Engineers (ASCE):

- ASCE 7-16, Minimum Design Loads for Buildings and Other Structures
- ASCE 61-14, Seismic Design of Piers and Wharves

American Welding Society (AWS):

- AWS D1.1, Structural Welding Code, 2015

California Building Code (CBC):

- 2022 California Building Codes

National Fire Protection Association (NFPA):

- NFPA 307, Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves

Oil Companies International Marine Forum (OCIMF):

- Mooring Equipment Guidelines (MEG4), 4th Edition, 2018

Permanent International Association of Navigation Congresses (PIANC):

- PIANC MarCom WG 145, Berthing Velocity Analysis of Seagoing Vessels over 30,000 dwt, 2022
- PIANC WG 121, Harbour Approach Channels – Design Guidelines, 2014
- PIANC WG 33, Guidelines for the Design of Fenders Systems, 2002
- PIANC WG 34, Seismic Design Guidelines for Port Structures, 2001
- PIANC WG 153, Recommendations for the Design & Assessment of Marine Oil & Petrochemical Terminals, 2016

United States Army Corps of Engineers (USACE):

- USACE EM 1110-2-1100, Coastal Engineering Manual, 2002
- USACE EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects, 2006
- USACE EM 1110-2-2502, Retaining and Flood Walls, 1989

Unified Facilities Criteria (UFC):

- UFC 4-152-01 Design: Piers and Wharves, 2017
- UFC 4-159-03 Design: Moorings, 2020

3 Deployment Scenarios

On March 29, 2021, the Biden Administration established the goal of deploying 30 GW of offshore wind power in the U.S. by 2030, which will largely be met using fixed-bottom wind turbines on the East Coast and in the Gulf of Mexico (U.S. Government 2021). However, the water on the West Coast is significantly deeper and will require floating wind turbines. Therefore, on September 15, 2022, the Biden Administration announced the goal of deploying 15 GW of *floating* offshore wind power in the U.S. by 2035, building on the existing goal of 30 GW by 2030 (U.S. Government 2022).

In a letter to the California Air Resources Board (CARB) dated July 22, 2022, Governor Gavin Newsom urged the California Energy Commission (CEC) to establish an offshore wind planning goal for the state of California of at least 20 GW by 2045 (Newsom 2022). On August 1, 2022, the CEC established a preliminary offshore wind planning goal of 2-5 GW by 2030 and 25 GW by 2045 (Flint 2022). Using these goals as a baseline, this study assessed a range of deployment scenarios for 2030 through 2050, specifically for the state of California. This section outlines the deployment scenarios and identifies the number of port sites needed to achieve those goals.

3.1 Deployment Targets and Planning Goals

On June 6, 2022, BOEM, CSLC, and Moffatt & Nichol (M&N) held a Deployment Scenarios Workshop to identify five deployment scenarios for 2030 through 2050. Using the CEC offshore wind planning goals as the medium baseline, as discussed above, the additional deployment scenarios were established using an incremental value of 0.5 GW per year. **Table 3** summarizes these deployment targets.

Table 3. Deployment targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	1 GW	2 GW	3 GW	4 GW	5 GW
2035	3.5 GW	7 GW	10.5 GW	14 GW	17.5 GW
2038	5 GW	10 GW	15 GW	20 GW	25 GW
2045	8.5 GW	17 GW	25.5 GW	34 GW	42.5 GW
2048	10 GW	20 GW	30 GW	40 GW	50 GW
2050	11 GW	23 GW	33 GW	44 GW	55 GW

3.2 Required Number of Port Sites

From the various deployment targets, the required number of S&I and MF sites needed within California to meet these targets can be determined. For this study, four different MF sites were considered:

- Blade MF Sites: a site that receives raw materials and manufactures blades
- Tower MF Sites: a site that receives raw materials and manufactures tower sections
- Nacelle Assembly Sites: a site that receives furnished parts of the nacelle and assembles the full nacelle for turbine integration
- Foundation Assembly Sites: a site that receives furnished parts of the floating foundation and assembles the full foundation system for turbine integration

The determination of the number of O&M sites will be provided in the future AB 525 Strategic Plan. **Table 4** summarizes the number of S&I and MF sites required to meet the 2045 deployment targets identified above.

Table 4. Required number of sites to meet 2045 deployment targets

Type of Site	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
S&I Sites	1	2	3	4	5
Blade MF Sites	1	2	2	3	3
Tower MF Sites	1	1	1	1	2
Nacelle Assembly Sites	1	1	1	1	1
Foundation Assembly Sites	1	2	2	3	4

Note: Number of port sites for each target and site type have been rounded up to the nearest whole number.

The following sections list the number of S&I and MF sites required to meet the deployment scenarios as described in **Table 3**.

3.2.1 Required Number of Staging and Integration Sites

To meet the five deployment scenarios for 2030 through 2050, California would require the number of S&I sites shown in **Table 5**. For **Table 5** through **Table 10**, not applicable (N/A) is used to demonstrate when it is not feasible to meet a target due to the assumed date when port sites are available for industry use due to planning, permitting and regulatory approvals, engineering, and construction.

Table 5. Required number of S&I sites to meet deployment scenario targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	1	N/A	N/A	N/A	N/A
2035	1	N/A	N/A	N/A	N/A
2038	1	3	4	N/A	N/A
2045	1	2	3	4	5
2048	1	2	3	4	5
2050	1	2	3	4	5

Note: Number of S&I sites for each target and year have been rounded up to the nearest whole number.

S&I Site Assumptions:

- **Yard/Wharf Site Requirements:** Sites in an existing California port are assumed to be upgraded to provide at least 1,500 feet of heavy lift wharf with greater than 6,000 psf capacity and a minimum of 75 acres of available land for developer use.
- **Timing:**
  - Sites 1 and 2 are assumed to be located within the same port and ready for developer use by 2028 and 2030, respectively.
  - Sites 3 – 5 are assumed to be located within the same port complex and ready for developer use by 2035.
- **Turbine Size:** Turbine sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.
- **Production Rate:** Assumed turbine system production rates per site are shown in **Table 6**.

Table 6. Assumed turbine production rate per week

Year	Site 1	Site 2	Site 3	Site 4	Site 5	Total
2028 – 2030	0.75	0	0	0	0	0.75
2030 – 2035	0.625	0.625	0	0	0	1.25
After 2035	0.625	0.625	1	1	1	4.25

3.2.2 Required Number of Blade Manufacturing / Fabrication Sites

To meet the five deployment scenarios for 2030 through 2050, California would require the number of blade MF sites shown in **Table 7**. Note that this analysis assumes that blades required for projects before 2030 would need to be sourced outside of California. N/A is used to demonstrate when it is not feasible to meet a target due to the assumed date when port sites are available for industry use due to planning, permitting and regulatory approvals, engineering, and construction.

Table 7. Required number of blade MF sites to meet deployment targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	N/A	N/A	N/A	N/A	N/A
2035	1	2	N/A	N/A	N/A
2038	1	2	3	N/A	N/A
2045	1	2	2	3	3
2048	1	1	2	3	3
2050	1	1	2	3	3

Note: Number of MF sites for each target and year have been rounded up to the nearest whole number.

Blade MF Site Assumptions:

- **Yard/Wharf Site Requirements:** Sites in an existing California port are assumed to be upgraded to provide at least 600 feet of heavy lift wharf with greater than 6,000 psf capacity and a minimum of 100 acres of available land for manufacturer use.
- **Timing:** Sites are assumed to be ready for use by 2030, 2032, and 2035.
- **Production Rate:** Blade MF sites are assumed to have a production rate of 182 blades per year. Three blades are required for each turbine system.
- **Turbine Size:** Turbine sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.

3.2.3 Required Number of Tower Manufacturing / Fabrication Sites

To meet the five deployment scenarios for 2030 through 2050, California would require the number of tower MF sites shown in **Table 8**. Note that this analysis assumes that tower sections required for projects before 2030 would need to be sourced outside of California. N/A is used to demonstrate when it is not feasible to meet a target due to the assumed date when port sites are available for industry use due to planning, permitting and regulatory approvals, engineering, and construction.

Table 8. Required number of tower MF sites to meet deployment targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	N/A	N/A	N/A	N/A	N/A
2035	1	1	2	2	N/A
2038	1	1	1	2	2
2045	1	1	1	1	2
2048	1	1	1	1	2
2050	1	1	1	1	2

Note: Number of MF sites for each target and year have been rounded up to the nearest whole number.

Tower MF Site Assumptions:

- **Yard/Wharf Site Requirements:** Sites in an existing California port are assumed to be upgraded to provide at least 600 feet of heavy lift wharf with greater than 6,000 psf capacity and a minimum of 100 acres of available land for manufacturer use.
- **Timing:** Sites are assumed to be ready for use by 2030 and 2032.
- **Production Rate:** Tower MF sites are assumed to have a production rate of 500 sections per year. Four tower sections are required for each turbine system.
- **Turbine Size:** Turbine sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.

3.2.4 Required Number of Nacelle Assembly Sites

To meet the five deployment scenarios for 2030 through 2050, California would require the number of nacelle assembly sites shown in **Table 9**. Note that this analysis assumes that nacelles required for projects before 2030 would need to be sourced outside of California. N/A is used to demonstrate when it is not feasible to meet a target due to the assumed date when port sites are available for industry use due to planning, permitting and regulatory approvals, engineering, and construction.

Table 9. Required number of nacelle assembly sites to meet deployment targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	N/A	N/A	N/A	N/A	N/A
2035	1	1	1	1	N/A
2038	1	1	1	1	1
2045	1	1	1	1	1
2048	1	1	1	1	1
2050	1	1	1	1	1

Note: Number of nacelle assembly sites for each target and year have been rounded up to the nearest whole number.

Nacelle Assembly Site Assumptions:

- **Yard/Wharf Site Requirements:** Sites in an existing California port are assumed to be upgraded to provide at least 600 feet of heavy lift wharf with greater than 6,000 psf capacity and a minimum of 100 acres of available land for manufacturer use.
- **Timing:** Sites is assumed to be ready for use by 2030.

- **Production Rate:** Nacelle assembly sites receive components and assemble the nacelles at a rate of 275 nacelles per year. One nacelle is required for each turbine system.
- **Turbine Size:** Turbine sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.

3.2.5 Required Number of Foundation Assembly Sites

To meet the five deployment scenarios for 2030 through 2050, California would require the number of foundation assembly sites shown in **Table 10**. N/A is used to demonstrate when it is not feasible to meet a target due to the assumed date when port sites are available for industry use due to planning, permitting and regulatory approvals, engineering, and construction.

Table 10. Required number of foundation assembly sites to meet deployment targets

Year	Low (0.5 GW/yr)	Low-Medium (1 GW/yr)	Medium (1.5 GW/yr)	Medium-High (2 GW/yr)	High (2.5 GW/yr)
2030	1	N/A	N/A	N/A	N/A
2035	1	2	N/A	N/A	N/A
2038	1	2	2	4	4
2045	1	2	2	3	4
2048	1	2	2	3	4
2050	1	2	2	3	3

Note: Number of foundation assembly sites for each target and year have been rounded up to the nearest whole number.

Foundation Assembly Site Assumptions:

- **Yard/Wharf Size Requirements:** Sites in an existing California port are assumed to be upgraded to provide at least 1,200 feet of heavy lift wharf with greater that 6,000 psf capacity and a minimum of 75 acres of available land for developer use.
- **Timing:**
  - Sites 1 and 2 are assumed to ready for developer use by 2028 and 2030 respectively.
  - Sites 3 and 4 are assumed to be ready for developer use by 2035.
- **Production Rate:** Foundation assembly sites receive components and assemble the foundations at a rate of 52 foundations per year. One foundation is required for each turbine system.
- **Turbine Size:** Turbine sizes are assumed to be 15 MW up to 2035, then 20 MW after 2035.

4 Port Outreach

Once the deployment targets and number of required port sites were identified, an inventory of potentially available port sites was taken. M&N, BOEM, and CSLC conducted outreach meetings with the following seventeen (17) California ports/facilities:

- June 30, 2022: City of Alameda
- July 05, 2022: Port of San Francisco
- July 07, 2022: Port of Oakland
- July 08, 2022: Diablo Canyon
- July 11, 2022: Port of West Sacramento
- July 12, 2022: Humboldt Bay Harbor District (Port of Humboldt)
- July 13, 2022: Crescent City Harbor District
- July 14, 2022: Port of Los Angeles
- July 25, 2022: Port of Benicia
- July 25, 2022: Port San Luis
- July 26, 2022: City of Morro Bay
- July 26, 2022: Port of Long Beach
- July 27, 2022: Port of San Diego
- July 28, 2022: Port of Redwood City
- July 29, 2022: Port of Hueneme
- August 05, 2022: Port of Stockton
- August 09, 2022: Port of Richmond

During the meetings with the Port of San Diego and Port of Benicia, the following four (4) port tenants/operators were recommended for additional outreach meetings:

- August 04, 2022: NASSCO (Port of San Diego)
- August 10, 2022: Pasha Automotive Services (Port of San Diego)
- August 16, 2022: BAE Systems (Port of San Diego)
- August 17, 2022: AMPORTS (Port of Benicia)

The following topics were discussed in the outreach meetings to determine interest for offshore wind development and assess availability of potential sites without pushing out existing uses (e.g., container, rail, etc.).

- Type and size of offshore wind components/equipment
- Port requirements for component delivery and integration of finished components
- Device integration operational requirements
- Installed wind farm operational and maintenance needs
- Physical, operational, and regulatory capabilities and constraints of port facilities and infrastructure
- Interest in offshore wind development
- Available sites within the port

Feedback provided by the ports/facilities and port tenants/operators during outreach meetings is summarized in **Table 11** in **Section 5**.

5 Port Inventory and Assessment

Following outreach efforts with the California ports to discuss potential sites that are available or could be made available for the offshore wind industry, an assessment of the ports was conducted. It is important to note that currently, existing port sites on the U.S. West Coast are not ready to serve the offshore wind industry from a port infrastructure perspective (i.e. wharf, navigation channel, backlands, etc.). All potential port sites will require some level of investment to upgrade existing facilities, such as construct a new wharf to withstand heavier loading or dredge the navigation channel and/or berth pockets. It should also be noted that this study does not consider the displacement of any port operators/tenants. An assessment of military facilities was not included in this study.

This assessment focuses on S&I, MF, and O&M sites. The following general criteria were utilized to assess each port:

- Distance to nearest boundary of BOEM lease areas
- Availability of adequate acreage of uplands area with capability to support or be improved to support heavy loading operations
- Adequacy of existing navigation channel, including entrance channel depth and width, channel depth and width for both existing and planned conditions including maintenance dredging requirements
- Existing and planned infrastructure projects (bridges, airports, tunnels) that may impact operations
- Air draft at bridges or other overhead obstructions (e.g., overhead power lines)
- Potential for port expansion or development of a new in-water area

The figures and table presented in the following sections utilize a symbol and color-coding system to represent a port's potential for offshore wind development for the various facility types – S&I, MF, and O&M:

♦ (green): Port is a good candidate site for offshore wind development

♦♦ (yellow): Port is a moderate candidate for offshore wind development

♦♦♦ (red): Port is not a candidate for offshore wind development

It is important to note that the U.S. Coast Guard (USCG) is currently conducting a port access route study (PARS) to evaluate safe access routes for the movement of vessel traffic proceeding to or from ports or places along the western seaboard of the U.S. and to determine whether a Shipping Safety Fairway and/or routing measures should be established, adjusted, or modified (USCG 2021). The PARS will evaluate the continued applicability of, and the need for modifications to, current vessel routing measures.

5.1 Staging and Integration (S&I) Sites

S&I sites are where the turbine components, such as tower sections, nacelles, blades, and the floating foundations, are received via waterborne transport, stored in the uplands area, and then assembled and erected by a large crane at the quayside. These sites are more difficult to identify within existing ports because they require a large amount of space, need deep draft channels, and cannot have any air draft restrictions since the fully assembled turbine systems, which are 1,100 feet above water, need to be towed out to the installation site at the WEA. The following ports, ordered north to south, were identified to have **good S&I candidate** sites with adequate acreage:

- Port of Humboldt

- Port of Los Angeles
- Port of Long Beach

These three (3) ports have potential sites that are in front of bridges so there are no air draft restrictions, have large amounts of acreage – greater than 100 acres, and have deep draft navigation channels. These S&I port locations can also be combined with MF and O&M facilities if space allows. Currently, the Port of Humboldt is in the detailed design and permitting phase for a 180-acre offshore wind S&I and/or MF site and the Port of Long Beach is in the conceptual design phase for a 300 to 400-acre offshore wind S&I and/or MF site.

All other port locations either don't have enough potential acreage available or have air draft restrictions, such as the ports within the Bay Area with bridges, and thus do not have any S&I candidate sites. **Figure 4** and **Table 11** summarize the mentioned S&I candidate status for each port and potentially available sites.

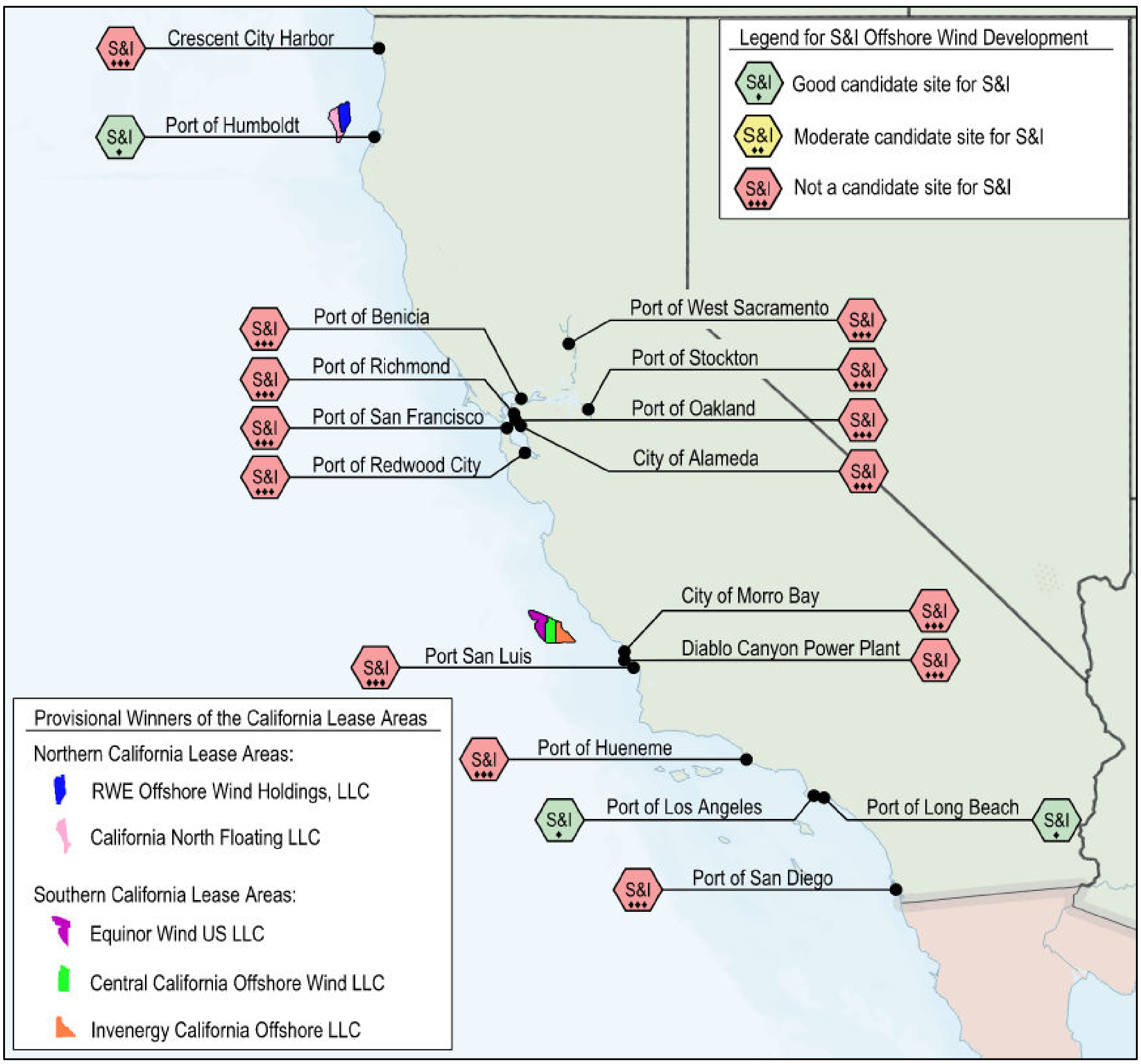

Figure 4. Staging and integration (S&I) candidate status of each port

5.2 Manufacturing / Fabrication (MF) Sites

MF sites receive raw materials via road, rail, or waterborne transport and create larger components in the offshore wind supply chain that will be exported via waterborne transport on a vessel or barge. These sites can occupy less space than S&I sites and be at locations with air draft restrictions since the components (e.g., tower sections, nacelles, blades, and floating foundations) can be transported horizontally via vessel or barge. Therefore, ports located behind bridges, such as those in the Bay Area, are candidates for offshore wind development as MF sites. The following ports, ordered north to south, were identified to have **good MF candidate** sites with adequate acreage:

- Port of Humboldt
- Port of Benicia
- Port of Stockton
- Port of Richmond
- Port of San Francisco
- Port of Redwood City
- Port of Los Angeles
- Port of Long Beach
- Port of San Diego
    - Foundation component manufacturing at NASSCO
    - Steel component fabrication and ship repair services at BAE Systems

The following ports, ordered north to south, were identified to have **moderate MF candidate** sites:

- Port of Oakland
- City of Alameda

Currently, a potential MF site of up to 130 acres was identified at the Port of Oakland; however, it may be used by other industries in the future. At the City of Alameda, a potential 25- to 60-acre site was identified; however, it does not have direct access to the waterfront, so it is categorized as a moderate candidate.

All other port locations don’t have enough potential acreage available and thus no MF candidate sites. **Figure 5** and **Table 11** summarize the MF candidate status for each port and potentially available sites.

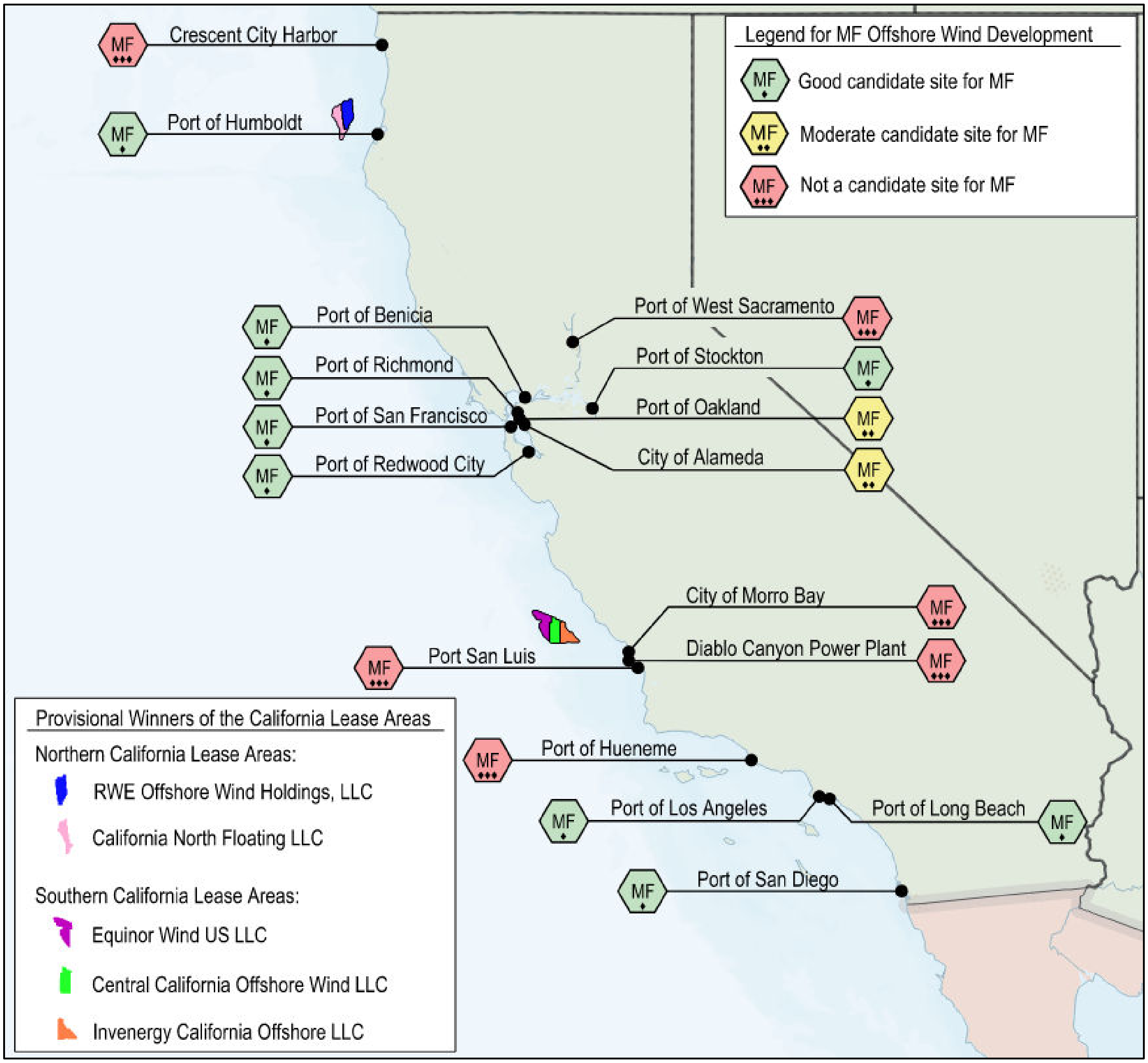

Figure 5. Manufacturing / fabrication (MF) candidate status of each port

5.3 Operations and Maintenance (O&M) Sites

O&M sites serve as a home port site for O&M vessels and supporting warehouse/offices during the operation period of the offshore wind farm. Ideally, these O&M sites that transfer crew to and from the offshore wind farm shall be close to the wind farm location to minimize travel time. Other maintenance activities, where the turbine system needs to be towed back to port from the offshore wind farm, would be performed at the S&I sites where the large assembly cranes are – Port of Humboldt, Port of Los Angeles, and Port of Long Beach. The following ports, ordered north to south, were identified to have **good O&M candidate** sites:

- Crescent City Harbor District
- Port of Humboldt
- City of Morro Bay

- Diablo Canyon Power Plant
- Port San Luis
- Port of Hueneme

Crescent City Harbor District is ideal for crew transfer due to its proximity to the Humboldt WEA. The Port of Humboldt can perform both crew transfer and maintenance of the fully assembled turbine system due to its proximity to the Humboldt WEA and S&I site capabilities, respectively. The City of Morro Bay, Diablo Canyon Power Plant, Port San Luis, and Port of Hueneme are ideal for crew transfer due to their proximity to the Morro Bay WEA, in comparison to the other ports; however, they do not have enough acreage for an S&I site and would not be able to service a fully assembled turbine system from the offshore wind farm – this turbine system would need to be towed to the Port of Los Angeles or Port of Long Beach. The following ports, ordered north to south, were identified to have **moderate O&M candidate** sites:

- Port of Richmond
- Port of Oakland
- Port of San Francisco
- City of Alameda

These ports are categorized as moderate O&M candidates due to their distance from the Humboldt and Morro Bay WEAs, making them less preferable for crew transfer since there are closer sites identified. While this study focuses on assessing the seventeen (17) existing California ports/facilities, another study for the CSLC assessed additional existing harbors and marine sites between San Francisco and Long Beach to identify additional O&M sites that are closer to the Morro Bay WEA (Moffatt & Nichol 2023b). Therefore, the ports within the Bay Area and south of the Port of Hueneme are less preferable for O&M due to distance.

All other sites not listed are not ideal O&M sites due to the substantial distance to the WEAs. **Figure 6** and **Table 11** summarize the O&M candidate status for each port and number of potentially available sites.

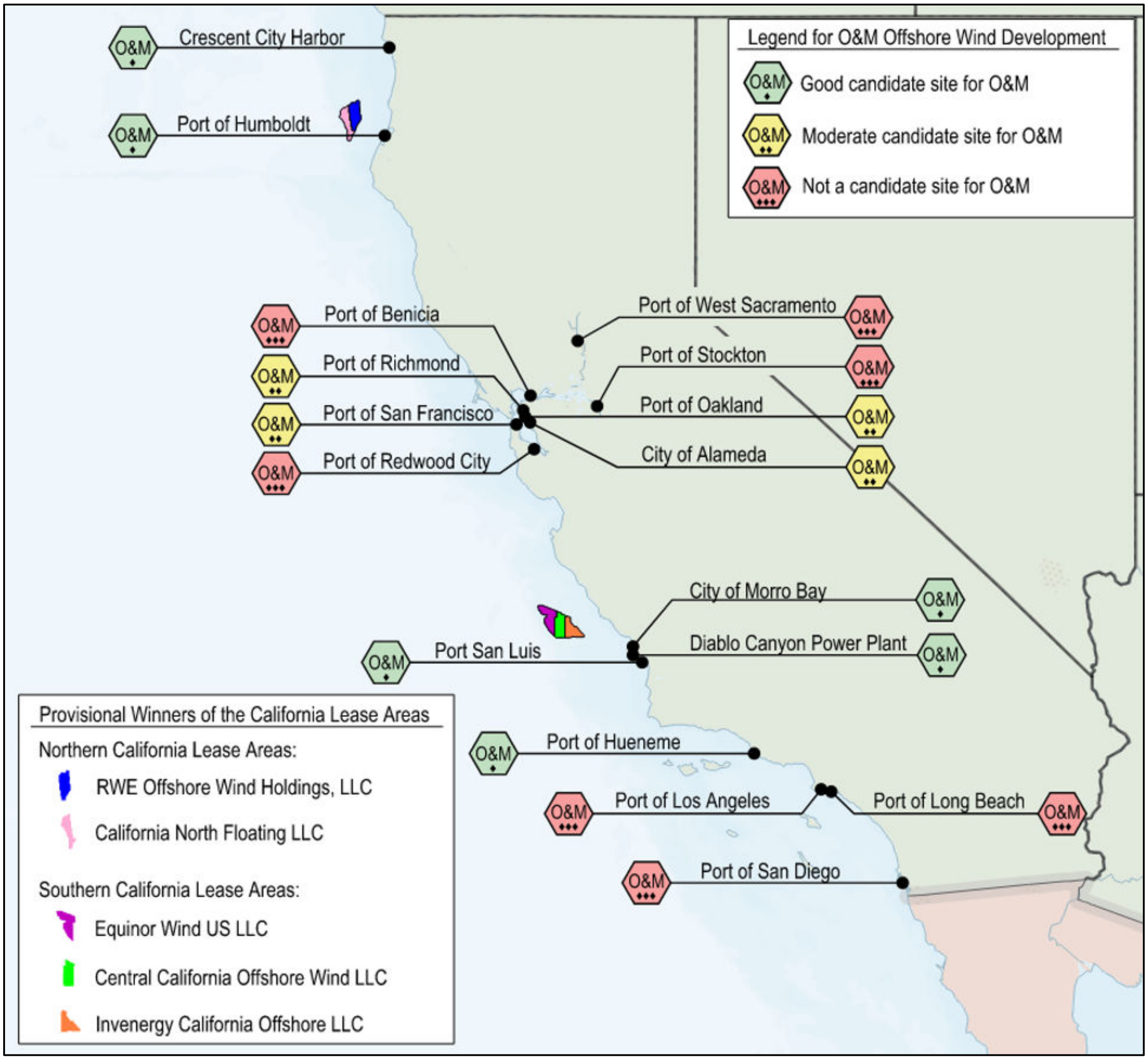

Figure 6. Operation and maintenance (O&M) candidate status of each port

5.4 Summary

A map that combines the S&I, MF, and O&M candidate status at each port is shown in **Figure 7**. **Table 11** summarizes the following:

- Interest in offshore wind
  - ♦ (green): Port is interested in offshore wind development
  - ♦♦ (yellow): Port is somewhat interested in offshore wind development
  - ♦♦♦ (red): Port is not interested in offshore wind development or may not have available sites
- Bridge clearances
- Distance to Humboldt and Morro Bay WEAs

- Channel depths
- S&I, MF, and O&M candidate status
  - ♦ (green): Port is a good candidate site for offshore wind development
  - ♦♦ (yellow): Port is a moderate candidate site for offshore wind development
  - ♦♦♦ (red): Port is not a candidate site for offshore wind development
- Number and size of potential sites at each port

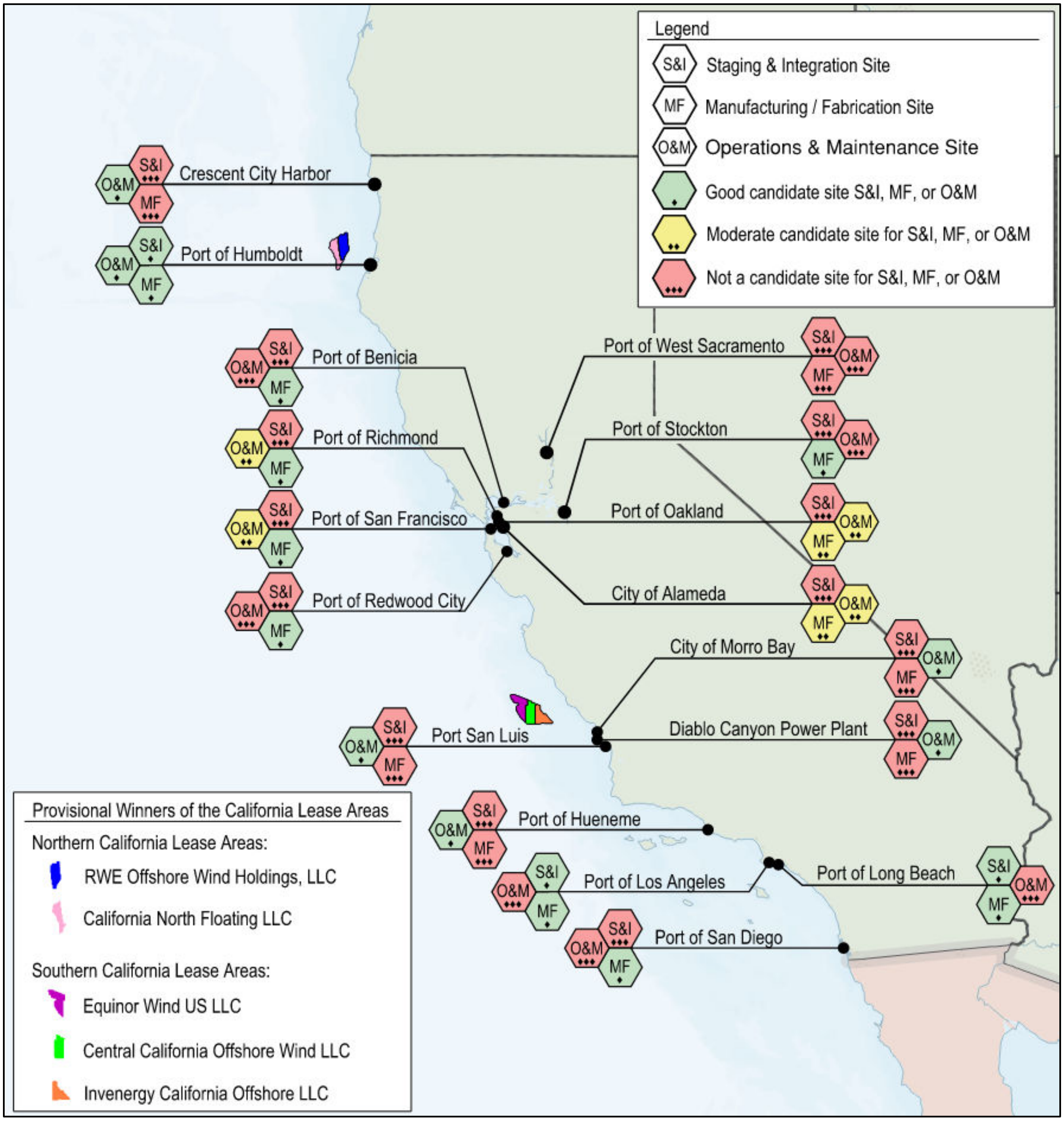

Figure 7. S&I, MF, and O&M candidate status for each port

Table 11. Summary of potential California offshore wind port sites

Port Location	Interest in OSW	Bridge Vertical Clearance *(ft)*	Distance to Humboldt WEA *(NM)*	Distance to Morro Bay WEA *(NM)*	Channel Depth *(ft)*	S&I Candidate Status	MF Candidate Status	O&M Candidate Status	Potential Sites
Crescent City Harbor District	♦	None	50	400	14-20	♦♦♦	♦♦♦	♦	(1) <10-ac O&M site
Port of Humboldt	♦	None	30	360	38	♦	♦	♦	(2) 180-ac sites (4) <10-ac O&M sites
Port of West Sacramento	♦♦♦	132	330	235	30	♦♦♦	♦♦♦	♦♦♦	No sites available
Port of Stockton	♦	132	295	200	35	♦♦♦	♦	♦♦♦	(1) 20-40-ac MF site (1) 150-200-ac MF site (<1 mile from the water)
Port of Benicia	♦	132	275	180	45	♦♦♦	♦	♦♦♦	(1) 10-40-ac MF site
Port of Richmond	♦	210	255	160	38	♦♦♦	♦	♦♦	(1) 30-40-ac MF site
Port of Oakland	♦♦	174	255	160	50	♦♦♦	♦♦	♦♦	(1) <130-ac MF site (may be used by other industries prior to 2030)
Port of San Francisco	♦	174	255	160	> 40 ***	♦♦♦	♦	♦♦	(1) 50-ac MF site (1) 15-ac MF
City of Alameda	♦	174	255	160	20-30	♦♦♦	♦♦	♦♦	(1) 25-60-ac O&M / MF site
Port of Redwood City	♦	135	275	180	30	♦♦♦	♦	♦♦♦	(1) 20-80-ac MF site
City of Morro Bay	♦	None	430	55	15-24	♦♦♦	♦♦♦	♦	(1) O&M site
Diablo Canyon Power Plant	♦	None	445	70	< 25	♦♦♦	♦♦♦	♦	(1) O&M or construction support site
Port San Luis	♦	None	450	75	< 40	♦♦♦	♦♦♦	♦	(1) O&M site
Port of Hueneme	♦	None	570	200	30-45	♦♦♦	♦♦♦	♦	(1) O&M site. See **** for MF candidate status
Port of Los Angeles	♦	See *	630	260	> 50	♦	♦	♦♦♦	(1) 100-200-ac S&I site (2) 10-30-ac MF sites
Port of Long Beach	♦	See **	630	260	> 50	♦	♦	♦♦♦	(1) >300-ac S&I / MF site (1) 20-ac MF site
Port of San Diego	♦	175	700	340	> 35	♦♦♦	♦	♦♦♦	(1) Floating Foundation MF site (1) Steel component fabrication/ship repair site

* There are sites available in front of the Vincent Thomas Bridge (185 feet) at the Port of Los Angeles, so there are no air draft restrictions for these sites.

** There are sites available in front of the Long Beach International Gateway Bridge (205 feet) at the Port of Long Beach, so there are no air draft restrictions for these sites.

*** There are potential sinking basin(s) with water depth 60 – 100 ft within the San Francisco Bay that may be feasible for offshore wind floating foundation use. Note, these potential sinking basin locations will need to be verified with the U.S. Coast Guard and the S.F. Bar Pilots.

****An assessment of military uses was not addressed in this study.

Based on the above inventory of potentially available port sites, California has enough potential port sites to meet the five deployment targets ranging from low to high, as shown in **Table 3**. The offshore wind port sites require a significant amount of investment to upgrade and improve the existing infrastructure to serve the offshore wind industry. As part of the next BOEM study titled *California Floating Offshore Wind Regional Ports Feasibility Analysis,* cost estimates and project timelines for developing these offshore wind port sites will be provided. This study will also support the AB 525 Strategic Plan, due June 30, 2023.

6 Offshore Oil and Gas Decommissioning Considerations

According to Title 30 Code of Federal Regulations (30 CFR 250.1716(a) and 250.1728(a)), decommissioning of offshore oil and gas platforms is required when the facilities are no longer useful for operations or, in other words, when a lease expires (National Archives and Records Administration 2012). As the twenty-three (23) Federal oil and gas platforms offshore southern California reach the end of their production lifetimes, decommissioning is the next step. There are several options to decommission the offshore platforms, each with their own legal, environmental, socioeconomic, and policy issues. However, the state of California has historically only allowed one method of decommissioning, complete removal. This presents not only a challenge in removing the platforms, but for port infrastructure capabilities as well, as eight platforms off southern California are in water depths exceeding 400 feet, with the deepest at 1,198 feet at platform Harmony. The steel jacket (support structure) for platform Harmony, pre-installation, is shown in **Figure 8**, (Bernstein 2017).

Figure 8. Platform Harmony jacket onshore prior to installation (Bull 2018)

As of this writing, eight Federal offshore oil and gas platforms off the coast of California have already ceased production, therefore requiring the platforms to undergo the decommissioning process. Identifying port requirements and capabilities to support the current and increasing Pacific OCS oil and gas decommissioning activities is an important outcome of this study as up to eight platforms may be decommissioned within 10 years (InterAct PMTI 2020). This section identifies port requirements for oil and gas decommissioning assuming the complete removal option will be utilized as this option will impose the highest strain on the port and, as a result, generate the most conservative port infrastructure requirements. This section also determines whether these activities can be co-located with offshore wind development within the ports.

6.1 California Offshore Oil and Gas Platforms Background

There are currently twenty-seven (27) oil and gas platforms off the California coast, four (4) located in State waters and twenty-three (23) located in Federal waters (Argonne National Laboratory 2022. There are also five (5) production facilities located in State waters that are artificial islands, however this report focuses on decommissioning of offshore oil and gas platforms at port facilities, therefore these five production facilities were not included in developing the port infrastructure requirements.

The platforms are positioned as far south as San Pedro Bay and as far north as the Santa Maria Basin. The beginning stages of decommissioning have commenced at five (5) Federal platforms – Gail, Grace, Harvest, Hermosa, and Hidalgo, and one (1) State platform – Holly. Three (3) Federal platforms – Habitat, Hogan, and Houchin – currently have no active leases and will soon start the decommissioning process (IDWG 2019).

The twenty-seven (27) platforms are owned by several operators and are in varying water depths. **Table 12** and **Table 13** summarize the operators and water depths, as well as the topside and jacket weights and **Figure 9** shows the locations of the offshore oil and gas platforms.

Table 12. Data for platforms in state waters

Platform	Operator[1]	Water Depth (ft)	Topside Weight (tons)	Jacket Weight (tons)
Emmy	So. Cal Holdings	47	2,201	1,746
Esther	DCOR	35	2,000	1,597
Eva	DCOR	41	2,000	1,050
Holly	CSLC	211	2,890	2,882

Water depth obtained from *A Citizen's Guide to Offshore Oil and Gas Decommissioning in Federal Waters Off California* (IDWG 2019)
Topside/jacket weight obtained from *Evaluating Alternatives for Decommissioning California's Offshore Oil and Gas Platforms: A Technical Analysis to Inform State Policy* (Bernstein 2017)

Table 13. Data for platforms in federal waters

Platform	Operator[1]	Water Depth (ft)	Topside Weight (tons)	Jacket Weight (tons)
A	DCOR	188	1,357	1,500
B	DCOR	190	1,357	1,500
C	DCOR	192	1,357	1,500
Edith	DCOR	161	4,134	3,454
Ellen	Beta Operating Company	265	5,300	3,200
Elly	Beta Operating Company	255	8,000	3,300
Eureka	Beta Operating Company	700	4,700	19,000
Gail	Beacon West Energy Group	739	7,693	18,300
Gilda	DCOR	205	3,792	3,220
Gina	DCOR	95	447	434
Grace	Beacon West Energy Group	318	3,800	3,090
Habitat	DCOR	290	3,514	2,550

Platform	Operator[1]	Water Depth (ft)	Topside Weight (tons)	Jacket Weight (tons)
Harmony	Exxon-Mobil	1,198	9,839	42,900
Harvest	Freeport-McMoRan	675	9,024	16,633
Henry	DCOR	173	1,371	1,311
Heritage	Exxon-Mobil	1,075	9,826	32,420
Hermosa	Freeport-McMoRan	603	7,830	17,000
Hidalgo	Freeport-McMoRan	430	8,100	10,950
Hillhouse	DCOR	190	1,200	1,500
Hogan	Pacific Operators Offshore	154	2,259	1,263
Hondo	Exxon-Mobil	842	8,450	12,200
Houchin	Pacific Operators Offshore	163	2,591	1,486
Irene	Freeport-McMoRan	242	2,500	3,100

Water depth obtained from *A Citizen's Guide to Offshore Oil and Gas Decommissioning in Federal Waters Off California* (IDWG 2019)
Topside/jacket weight obtained from *Decommissioning Cost Update for Pacific OCS Region Facilities, Volume 1* (BSEE 2020)

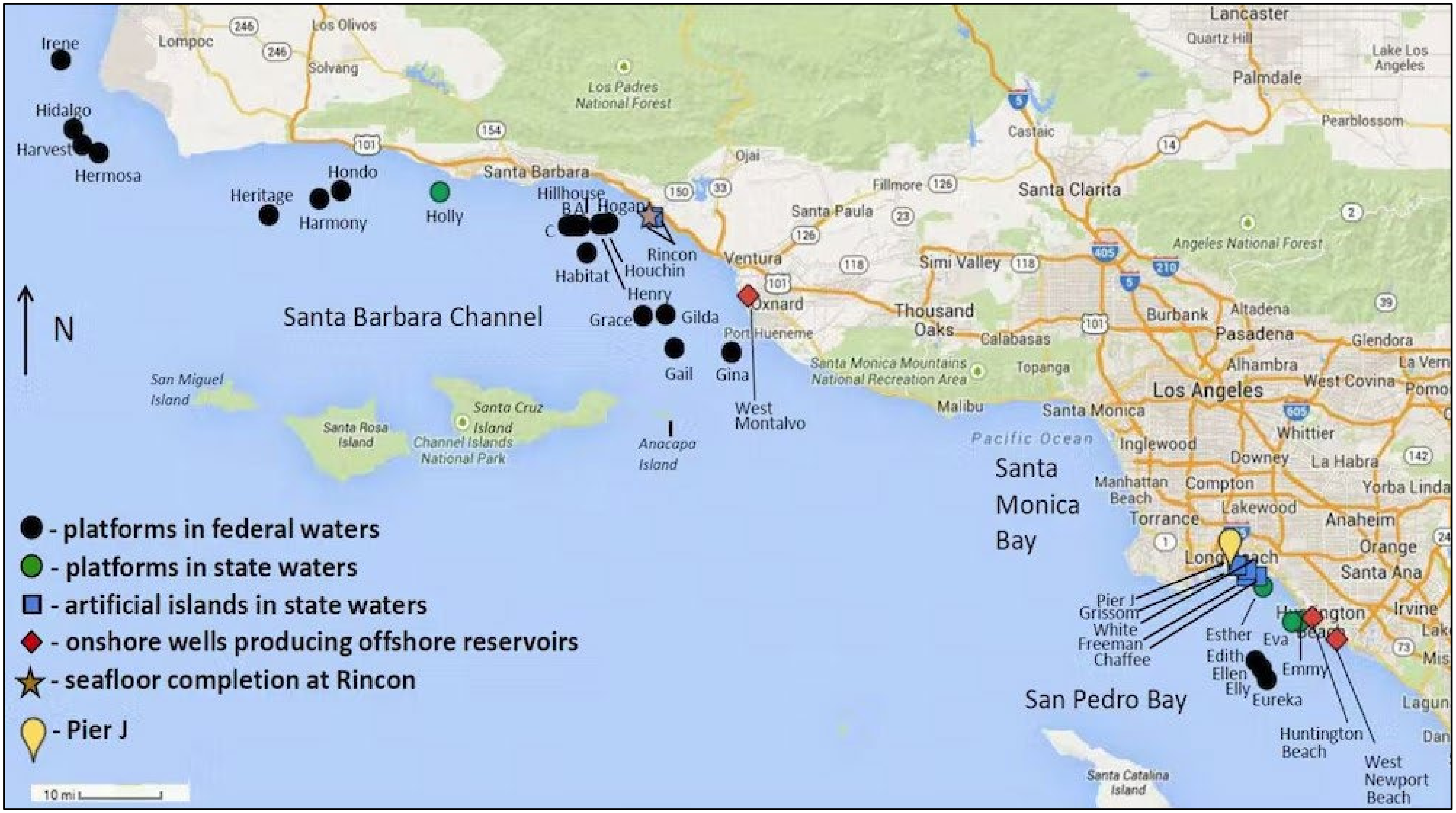

Figure 9. California offshore oil & gas platforms (CSLC 2018)

Oil and gas platforms typically consist of two main components:

- Topside: this consists of everything above the waterline. The topside holds the living quarters, production equipment, drilling rig, and any other equipment necessary for drilling and production activities.
- Jacket (Support Structure): this consists of everything between the waterline and seabed, as shown in **Figure 10**. Typically, the support structure is either a steel jacket or concrete gravity-based structure (GBS). All oil platforms off the California coast are supported by steel jackets. The steel jacket supports the topside and is secured to the seabed by steel skirt piles driven through pile sleeves that are attached to the legs of the jacket, as shown in **Figure 11.**

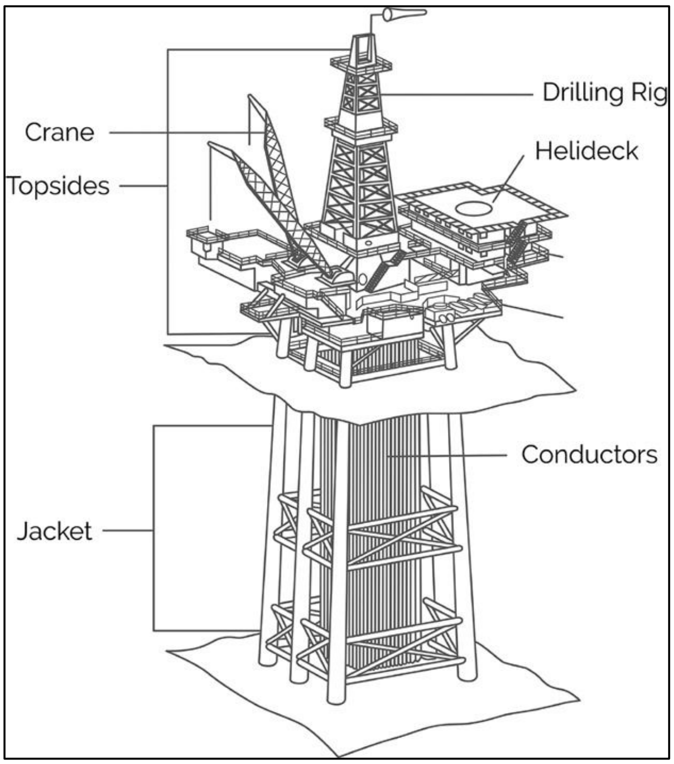

Figure 10. Schematic of typical offshore oil & gas platform (Bernstein 2017)

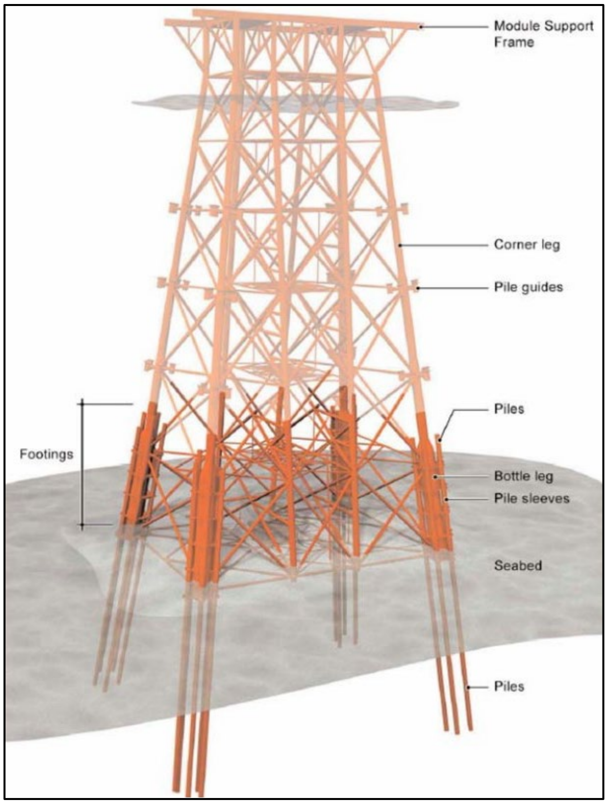

Figure 11. Schematic of skirt piles (Frieze, year unknown)

6.2 Planning Process for Decommissioning Offshore Oil and Gas Platforms on the Pacific Federal OCS

The general decommissioning planning process for offshore oil and gas platforms located in Federal waters is summarized below per the Interagency Decommissioning Working Group (IDWG) comprised of BOEM, Bureau of Safety and Environmental Enforcement (BSEE), and CSLC. Detailed information can be found in *A Citizen's Guide to Offshore Oil and Gas Decommissioning in Federal Waters Off California*, issued by the IDWG in 2019.

1. Early Notification of Intent to Decommission
   - Facility operator required to submit initial platform removal application to BSEE 2+ years before production will cease.
     - BSEE informs BOEM about planned decommissioning.
     - BSEE/BOEM inform IDWG about planned decommissioning.
     - Lead federal and state agencies meet, as needed.
2. Pre-Application Meetings
   - Operator meets with IDWG and/or federal, state, and local regulatory agencies and stakeholders to discuss plans, issues, and information needs.
3. Operator Submits & Revises its Final Application
   - Based on information exchanged during Step 2, Operator submits a final platform removal application to BSEE, CSLC, and other federal, state, and local agencies.

    - Agencies review application for completeness and notify Operator of information needs.
    - Operator revises and resubmits application, as needed.
    - Lead federal, state, and local agencies deem final application complete.

4. Environmental Review Process
    - The platform removal is evaluated according to federal (National Environmental Policy Act, NEPA) and state (California Environmental Quality Act, CEQA) laws with an Environmental Impact Statement (EIS) and Environmental Impact Report (EIR), respectively. Agencies may decide to prepare a joint EIS/EIR.
        - State or federal lead agency selects environmental consultant to prepare EIS and EIR, or joint EIS/EIR.
        - Lead agencies publish Notice of Intent (NOI)/Notice of Preparation (NOP) to issue EIS and EIR (or joint EIS/EIR), hold public scoping meetings and evaluate comments.
        - Lead agencies prepare an administrative draft EIS and EIR (or joint EIS/EIR), conduct agency review and revision of the document(s), and prepare draft version(s) for public review.
        - Lead agencies publish Notice of Availability (NOA)/NOP of the draft EIS and EIR (or joint EIS/EIR), hold public hearings on the draft(s), and respond to comments.
        - BSEE and Operator conduct consultations and/or issue permits with federal, state, local, and/or tribal entities, as needed.
        - Lead agencies publish final EIS and EIR (or joint EIS/EIR) and federal Record of Decision (ROD).
5. State Lead Agency Decisions
    - CSLC and County Planning Department each hold hearings on the project, certify the final EIS and EIR (or joint EIS/EIR), and issue decisions on the project.
6. BSEE Approves the Project

The general decommissioning process summarized above is similar for offshore platforms located in State waters. The lead agency for decommissioning offshore oil and gas platforms in State waters is the California Natural Resources Agency consulting with state resource agencies for CEQA purposes. The platform operators must still coordinate with Federal entities that have authority in State waters.

6.3 Case Study – Decommissioning of Brent Field Platforms Alpha and Delta

To identify port requirements for offshore oil and gas decommissioning activities, two representative case studies of successful offshore oil and gas platform decommissioning projects were reviewed – Brent Alpha, decommissioned in 2020 and Brent Delta, decommissioned in 2017. These two offshore oil and gas platforms were two of four platforms located in Brent Field in the North Sea, 320 miles northeast of Aberdeen, Scotland. Both platforms were installed in 1976 and operated by Shell United Kingdom (U.K.) Limited. Additionally, both decommissioning projects included platforms larger than, or similar in size to, the largest platform off the California coast, platform Harmony. A comparison of platforms Brent Alpha, Brent Delta, and Harmony is provided in **Table 14** below.

Table 14. Comparison of platforms Brent Alpha, Brent Delta, and Harmony

Dimension	Brent Alpha	Brent Delta	Harmony
Topside Weight	18,650 tons	25,900 tons	9,839 tons
Supporting Structure Type	Steel Jacket	Concrete GBS	Steel Jacket
Supporting Structure Weight	34,200 tons	365,017 tons	42,900 tons
Water Depth	460 ft	460 ft	1,198 ft

The topside weight for Platform Brent Alpha was found in *Decommissioning Progress Report: Brent Alpha Topside*, issued by Shell U.K. Limited in 2020 (Shell 2020a).
The supporting structure type and weight, as well as water depth, for Platform Brent Alpha were found in "Brent Field Alpha Jacket" on the Shell U.K. Limited website (Shell c2022).
The topside weight for Platform Brent Delta was found in *Brent Delta Topside Decommissioning Close-out Report*, issued by Shell U.K. Limited in 2019 (Shell 2019).
The supporting structure type and weight, as well as water depth, for Platform Brent Delta were found in *Brent Bravo, Charlie, and Delta GBS Decommissioning – Technical Document*, issued by Shell U.K. Limited in 2017 (Shell 2017a).
All information for Platform Harmony was found in *Decommissioning Cost Update for Pacific Outer Continental Shelf Region Facilities, Volume 1*, issued by the Bureau of Safety and Environmental Enforcement (BSEE) in 2020.

Brent Alpha's topside was supported by a steel jacket substructure with six full-height legs, as shown in **Figure 12**, similar to platforms off the California coast, and Brent Delta's topside was supported by a three-legged concrete GBS, as shown in **Figure 13**. Shell had the decommissioned topsides of both platforms transported to the Able Seaton Port facility at Teesside in the U.K. to be dismantled and recycled (Shell 2020a and 2020b).

For the supporting substructure, the top portion of the Brent Alpha's steel jacket was removed and transported to the AF Environmental Base Vats in Rogaland, Norway for dismantlement and recycling (Shell 2020b). Shell has not yet published a progress report for the removal of Brent Delta's concrete GBS; therefore, the removal method is currently unknown.

Figure 12. Photo of Brent Alpha prior to decommissioning in the North Sea (Shell 2020a)

Figure 13. Photo of Brent Delta prior to decommissioning in the North Sea (Adams 2015)

6.3.1 Topside Removal

All information regarding the Brent Alpha topside decommissioning was found in *Decommissioning Progress Report – Brent Alpha Topside*, issued by Shell U.K. Limited in 2020 (Shell 2020a). All information regarding the Brent Delta topside decommissioning was found in *Brent Delta Topside Decommissioning Close-out Report*, issued by Shell U.K. Limited in 2019 (Shell 2019).

The approach to remove Brent Alpha and Brent Delta's topsides involved using a heavy lift vessel known as the *Pioneering Spirit*, in conjunction with the *Iron Lady* cargo barge, both owned and operated by Allseas, refer to **Figure 14** and **Figure 15**. The *Pioneering Spirit* was used to remove each platform topside in a single unit in open water after it was cut away from its supporting structure. The topside was then transferred to the *Iron Lady* barge in the sheltered harbor of the River Tees estuary for delivery to Able Seaton Port. The barge was fit with the necessary skidding equipment prior to mobilization from Port of Rotterdam to transfer the load of the topside onto the barge and to later load the topside onto the wharf at the Able Seaton Port facility. Vessel characteristics for the *Pioneering Spirit* and *Iron Lady* are shown in **Table 15**.

Figure 14. ***Pioneering Spirit*** **transporting the Brent Delta topside (Shell 2019)**

Figure 15. ***Iron Lady*** **barge transporting the Brent Delta topside (Shell 2017b)**

Table 15. Design vessel characteristics

Characteristic	***Pioneering Spirit*** (Heavy Lift Vessel)	***Iron Lady*** (Cargo Barge)
Length	1,253 ft	656 ft
Breadth	407 ft	164 ft
Operating Draft	33 – 89 ft	33 ft (assumed)
Topside Lift Capacity	52,911 tons	N/A
Jacket Lift Capacity	22,046 tons	N/A
Cargo Capacity	N/A	42,680 tons

Vessel characteristics for the *Pioneering Spirit* were found on the Allseas website: www.allseas.com
Vessel characteristics for the *Iron Lady* were found on the vessel tracking website: www.fleetmon.com

Once the topside was secure on the *Iron Lady*, the barge was towed directly to the transfer site by tugs and moored with its stern to the wharf. To ensure the barge remained level as the topside was skidded onto the wharf, the barge carefully ballasted down until it rested on a pre-installed grounding bed prior to the transfer, shown below in **Figure 16**. The heavy lifting specialist Mammoet then fit skid beams from the wharf, across the wharf wall, and onto the barge, as shown in **Figure 17** and **Figure 18**. The beams were also shimmed and grouted to ensure they remained in place and level during the transfer process. The skidding operation was completed in one day (Shell 2019). Able Seaton Port reports the capacity of their heavy lift pad, which each topside rested on, as 12,290 psf (60 metric tons/m^2) and the capacity of the uplands area as 2,050 psf (10 metric tons/m^2) (Able UK Limited 2013).

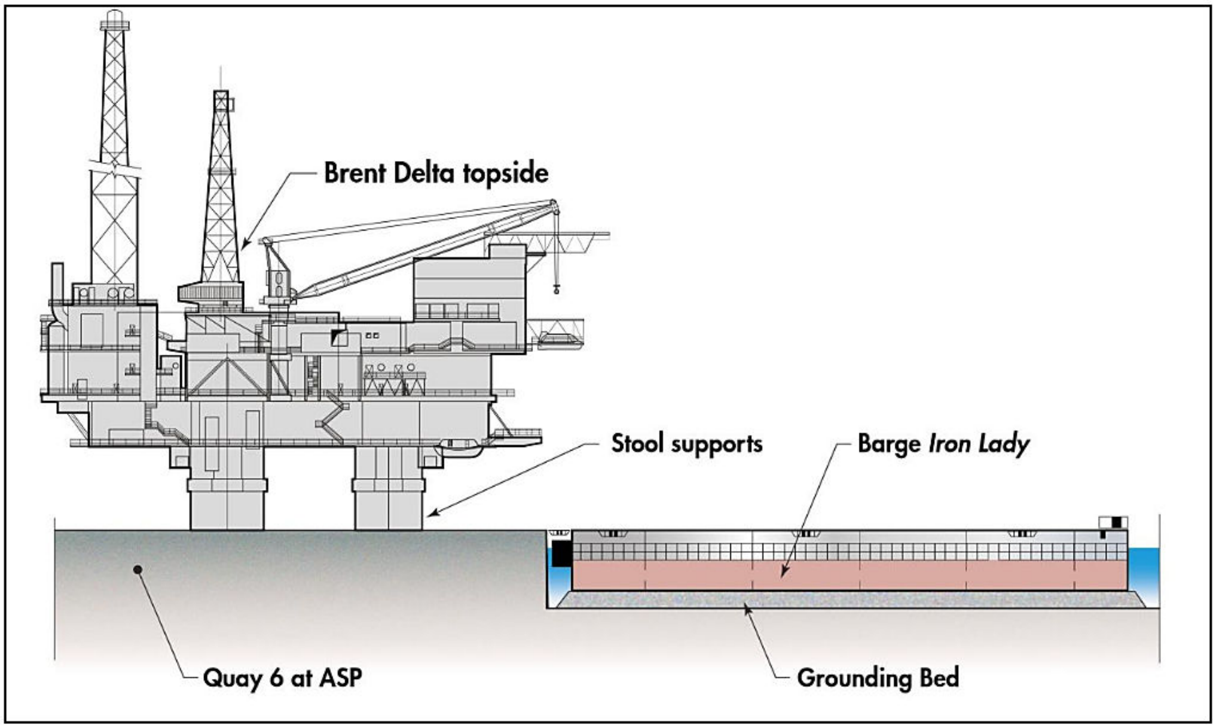

Figure 16. Skidding the Brent Delta topside from *Iron Lady* to Quay 6 at the Able Seaton Port Facility, U.K. (Shell 2019)

Figure 17. Skidding Brent Delta topside onto Able Seaton Port (Shell 2019)

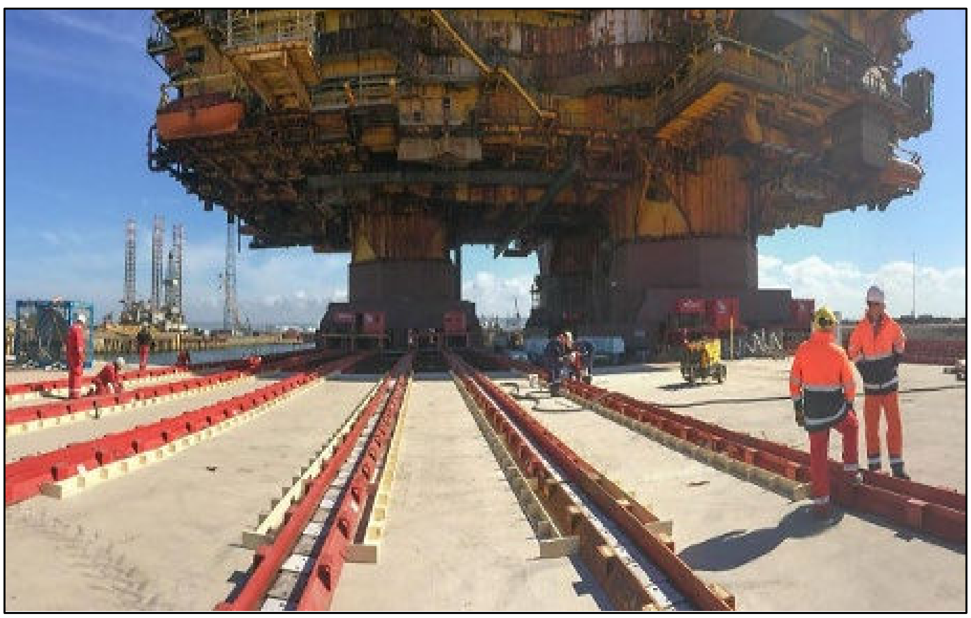

Figure 18. Skidding Brent Delta topside onto Able Seaton Port (Shell 2019)

Following the skidding operation, the dismantling and disposal operation occurred. The terminal operator first surveyed and cleaned the topside components of any remaining hazardous materials before commencing dismantlement. Then the topside was "soft stripped" of a "wide range of relatively small and easily removed items such as non-perishable foodstuff, furniture, fittings, domestic and recreational equipment, tools, and small pieces of equipment. Where possible, these were distributed to local charities and emergency services" (Shell 2019). Air compressors, leg levelling and monitoring equipment, pigging valves, a fire pump control panel, an emergency generator, a fire pump module, and personal protection equipment (PPE) were removed and transported to Aberdeen for re-use by Shell.

Using the Liebherr LHM 600 SHL mobile harbor crane and the Liebherr LR 1300 crawler crane and several other smaller cranes, a sequential top-down approach was implemented in the dismantlement of the main structure (Offshore & Heavy Lift Services c2015). The approach consisted of weakening parts of the structure by cutting and/or pulling with ropes and allowing them to drop onto the ground. To absorb the force of the falling components, as well as protect the wharf deck, large amounts of sand were placed around the base of the topside (Shell 2019). Scheuerle 6 axle self-propelled modular trailers (SPMTs) and forklifts were then utilized in moving and stripping these separated components for scrap to be recycled. More than 97% of the material from the Brent Delta topside was recycled. The percentage of topside material recycled from the Brent Alpha is currently unknown as Shell has not yet published the close-out report for this topside decommissioning.

6.3.2 Steel Jacket Removal

All information regarding the Brent Alpha jacket decommissioning was found in *Decommissioning Progress Report – Brent Alpha Jacket*, issued by Shell U.K. Limited in 2020 (Shell 2020b). The approach to remove Brent Alpha's steel jacket involved using the semi-submersible crane vessel named the *Sleipnir*, owned and operated by Heerema Marine Contractors. The *Sleipnir* was used to remove the top 280 feet of the steel jacket in a single unit in open water after it was cut away from the lower section, as shown in **Figure 19**. The upper section was then transported to AF Environmental Base Vats in Rogaland, Norway for dismantling and disposal. Vessel characteristics for the *Sleipnir* are shown in **Table 16** below.

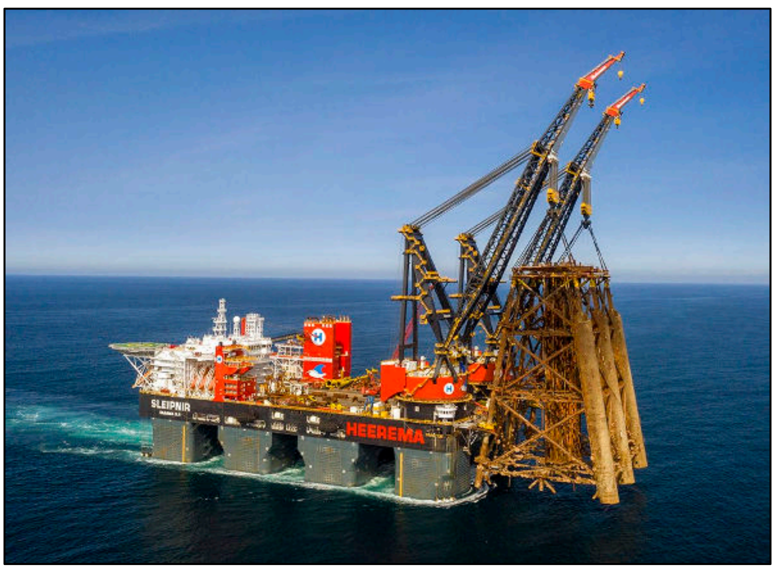

Figure 19. *Sleipnir* transporting upper Brent Alpha's upper jacket (Heerema Marine Contractors)

Table 16. Vessel characteristics

Characteristic	*Sleipnir* (Semi-submersible Crane Vessel)
Length	722 ft
Breadth	335 ft
Operating Draft	39 – 105 ft
Lift Capacity	22,046 tons

Vessel characteristics for the *Sleipnir* were found on the Heerema Marine Contractors website: heerema.com

After all leg cuts were complete, the upper section of the jacket was lifted clear of the lower section "by a combination of hoisting by the cranes and deballasting of the heavy lift vessel to account for the increase in the weight of the upper jacket as it was raised out of the water" (Shell 2020b). Once the upper jacket section was lifted clear, it was secured to the stern of the *Sleipnir* using two restraining clamps. The *Sleipnir* then transported the jacket section to the AF Offshore Decommissioning (AFOD) facility at Vats where it was lowered onto pre-installed steel and concrete supports, as shown in **Figure 20**. The total mass of the removed upper jacket section delivered to the AFOD facility was 10,360 tons.

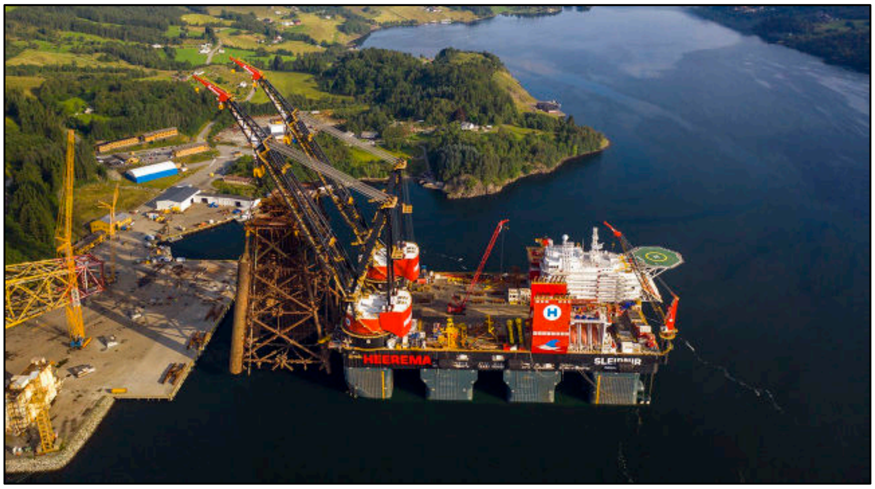

Figure 20. *Sleipnir* loading Brent Alpha's upper jacket onto the wharf at AFOD Facility in Norway (Heerema Marine Contractors)

6.4 California Port Needs

There are several options to decommission the offshore platforms, each with their own legal, environmental, socioeconomic, and policy issues. However, the state of California has historically only allowed one method of decommissioning, complete removal. BSEE requires all bottom-founded components of the jacket to be severed at least 15 feet below the mudline to avoid interference with any future leases or other activities in the area. To establish the most conservative design criteria for ports and port infrastructure, this study assumes complete removal of the California platform jackets down to 15 feet below mudline and a similar decommissioning approach to platform Brent Delta. The following decommissioning approach is assumed to establish California port infrastructure requirements:

1. Prior to any removal activities, the platform must be cleaned of any hazardous materials such as hydrocarbons, asbestos, etc. Surveys will be conducted once onshore to ensure no hazardous materials remain.
2. The topside is severed from its supporting structure (i.e., jacket) and the jacket is removed from its foundation by severing all bottom-founded components at least 15 feet below mudline, per Title 30 Code of Federal Regulations (30 CFR 250.1716(a) and 250.1728(a)) (National Archives and Records Administration 2012).
3. The topside and jacket are each removed and transported to a protected port or harbor (e.g., breakwater) by heavy lift vessel.
4. Once inside protected harbor, the heavy lift vessel transfers the components – topside or jacket – to a cargo barge to be towed to the dismantling location.

5. Once the barge has reached the pre-determined dismantling location, the component is loaded onto the wharf by crane or skidding equipment.
6. Each component is then dismantled and sorted for recycling.
7. All recyclable materials are transported to a recycling facility and all non-recyclable materials are properly disposed of.

This strategy allows for the most efficient and safe removal of platforms by minimizing the number of crane lifts at sea, the number of trips to and from the platform site, the amount of time spent at sea, the amount of work to be performed at sea, and the environmental impacts caused by decommissioning. By assuming that the entire platform – including topside and jacket – will be completely removed, this strategy also provides the most flexibility for decommissioning options as the decommissioning port facility will need to be able to accommodate not only both the topside and jacket, but all platform sizes as well. Therefore, this strategy accounts for the worst-case-scenario, which will result in conservative port requirements.

Consequently, to determine the largest possible demand on the port infrastructure, it is assumed that the heavy lift vessel, the *Pioneering Spirit*, and the cargo barge, the *Iron Lady*, will be utilized in the decommissioning activities. Additionally, to determine the required size and capacity of the heavy lift pad, platform Harmony was chosen as the design platform since it is the largest platform off the California coast. Clearance for heavy lift equipment will also need to be accounted for in the size of the heavy lift pad.

Since the transfer of the platform components from the *Pioneering Spirit* to the *Iron Lady* barge requires protected harbor, the channel entrance must be wide enough to accommodate twice the width of the *Pioneering Spirit* as a safety precaution. Once the cargo is safely on the barge, it will be towed to berth, requiring the navigable width of the channel to be at least twice the width of the *Iron Lady* to allow room for tugboats. The length of the berth will need to be, at a minimum, the length of the *Iron Lady* and the depth will need to be quite shallow as the barge will likely need to rest on a grounding bed for stability, as previously shown in **Figure 16**.

The amount of acreage required for the dismantlement process, including the heavy lift pad and uplands, was estimated based on the size of Able Seaton Port. This port has dismantled several offshore oil and gas platforms larger than the platforms off the California coast, such as Brent Delta; therefore, it can be assumed that the acreage estimation is conservative. The capacity of the heavy lift pad was then determined by dividing the weight of platform Harmony's topside by its footprint area and then multiplying by the skid rail spacing, which was assumed to be approximately 8.2 feet (2.5 m). A load factor of 1.2 was applied to achieve a conservative capacity. The capacity of the uplands area was chosen based on the capacity used at Able Seaton Port.

Due to the considerable height of the topsides when placed on the *Iron Lady* barge, the dismantling site must not have any air draft restrictions, as it would significantly increase cost and safety risks.

A few notable air draft restrictions include the following:

- Golden Gate Bridge (San Francisco) = 210 feet
- Vincent Thomas Bridge (Los Angeles) = 185 feet
- Long Beach International Gateway (Long Beach) = 205 feet

The Vincent Thomas Bridge and Long Beach International Gateway Bridge only impact locations within the inner harbors of the ports. Both the Port of Los Angeles and Port of Long Beach have many locations outside of the above air draft restrictions. The port infrastructure requirements discussed above are summarized in **Table 17** below.

Table 17. Port infrastructure requirements for offshore oil & gas platform decommissioning

Port Infrastructure Requirement	Dimensions (US)	Dimensions (metric)	Reasoning
Acreage, minimum	35 acres	142,000 m^2	Estimated size for topside and jacket dismantlement operations occurring separately
Ideal Acreage	≥ 70 acres	284,000 m^2	Estimated size for topside and jacket dismantlement operations occurring simultaneously
Berth Length	660 ft	200 m	Length of *Iron Lady* barge
Berth Depth	33 ft	10 m	Assumed operating draft of *Iron Lady* barge
Heavy Lift Pad Length, minimum	350 ft	107 m	Length of platform Harmony + 100-ft clearance for equipment
Heavy Lift Pad Width, minimum	350 ft	107 m	Width of platform Harmony + 100-ft clearance for equipment
Heavy Lift Pad Loading	> 4,000 psf	> 20 t/m^2	Weight of Platform Harmony Topside x Skid Rail Spacing x Load Factor / Topside Footprint Area
Uplands / Yard Loading	> 2,000 psf	> 10 t/m^2	Uplands Capacity at Able Seaton Port, U.K.*
Channel Entrance Width	815 ft	248 m	Double the width of *Pioneering Spirit*
Channel Navigation Width	330 ft	100 m	Double the width of *Iron Lady* barge
Channel Entrance Depth	33-89 ft	10-27 m	Operating draft of *Pioneering Spirit*
Air Draft Clearance	500 ft	140 m	Height of platform Brent Delta topside while on *Iron Lady* barge*. Value to be replaced with height of CA platform Harmony when confirmed

**Able Seaton Port Site Plan*, 2016, provided on the Able U.K. website: ableuk.com.

**Platform Brent Delta was dismantled at the Able Seaton Port facility in the U.K. All information regarding this dismantlement was found in *Brent Delta Topside Decommissioning Close-out Report*, issued by Shell U.K. Limited in 2019 (Shell 2019).

In addition, some of the required port equipment include:

- Heavy lift capacity crawler / ring crane (the larger capacity, the better)
- Additional smaller crawler cranes
- Rough terrain crane
- SPMTs
- Various sizes of forklifts
- Heavy weight skidding system

A significant amount of material recovered during dismantlement can be recycled; therefore, proximity to metal recycling facilities is an important factor in determining the dismantlement location. For recycling facilities to be able to accept the material, it must be cleaned of any hazardous materials such as hydrocarbons, asbestos, etc. All debris must be disposed of or recycled in accordance with hazardous waste requirements. Possible metal recycling companies to process the recyclable material obtained during dismantlement are SA Recycling, which has several locations from San Diego to Fresno, and Schnitzer Steel, which has locations in Fresno, Oakland, Sacramento, and San Jose – refer to **Figure 21**.

6.5 Port Assessment

By assuming the complete removal option will be utilized for the largest California offshore platform, the port infrastructure requirements developed in **Section 6.4** are conservative. This results in an ideal port facility for offshore oil and gas decommissioning that could accommodate any chosen decommissioning strategy. In addition, the ideal port facility should accommodate all California platform sizes, will be in a location that best reduces offshore work and time spent offshore, minimize the distance from platform to port, and minimize the number of trips to and from the platform. Further, minimization of environmental impacts from decommissioning is an important factor that will need to be studied in more detail.

The locations of the offshore oil and gas platforms, in relation to the locations of the ports and recycling facilities, are shown in **Figure 21** below. M&N has not yet approached any California ports regarding interest in offshore oil and gas decommissioning, but this is an important next step in planning for the increasing decommissioning activity in the Pacific OCS region.

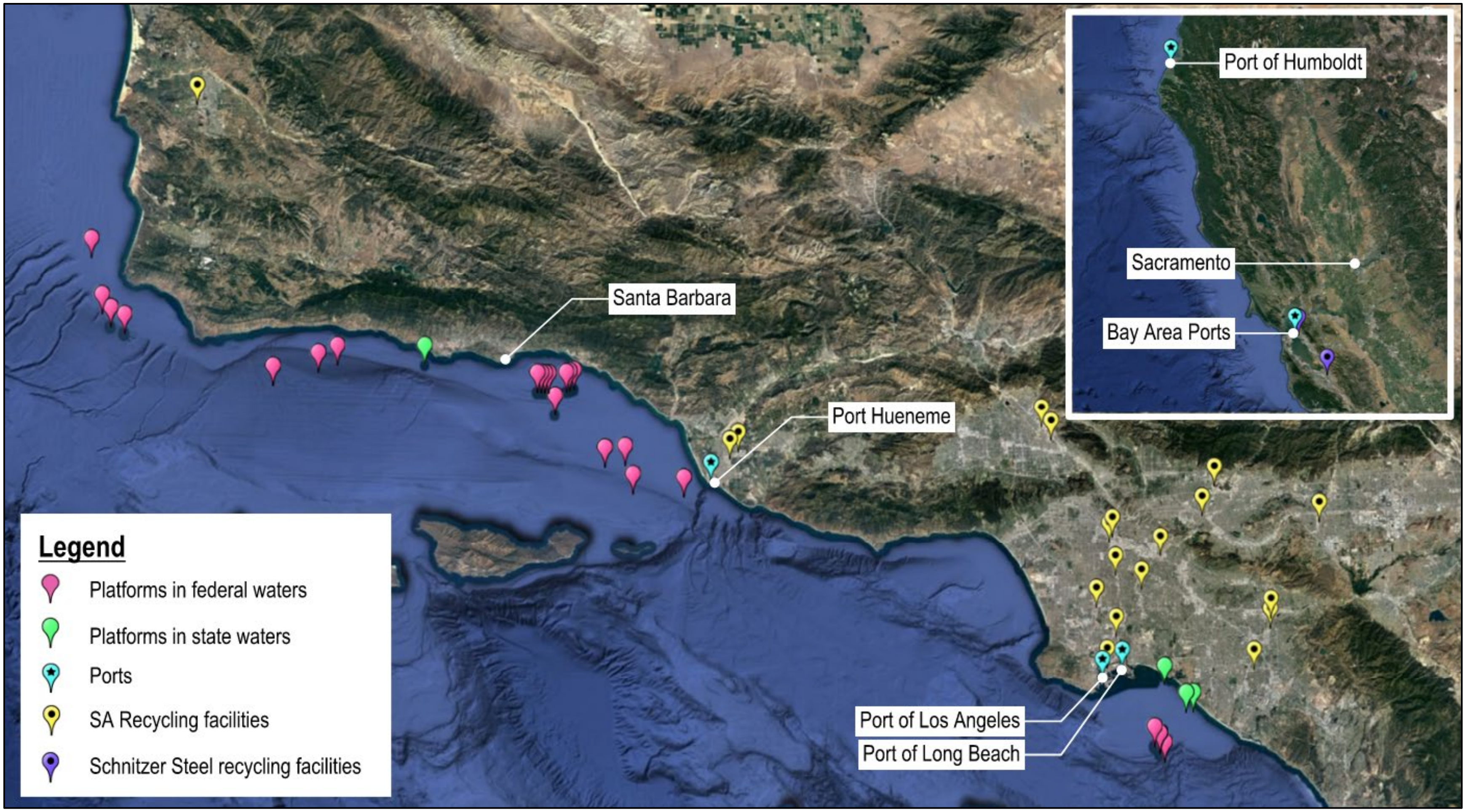

Figure 21. Locations of offshore oil & gas platforms, ports, and metal recycling facilities

Taking all port requirements specified in **Section 6.4** into account, an assessment of the California ports is summarized in **Table 18** below.

Table 18. Port assessment for offshore oil & gas decommissioning

Criteria	Humboldt Bay	Bay Area Ports	Central Coast	Port of Hueneme	Port of LA / LB	Port of San Diego
Channel Entrance Width	2	1	3	3	1	2
Distance to Oil & Gas Platforms	3	3	3	1	1	2
Air Draft Clearance	1	3	1	1	1	3
Proximity to Recycling Facilities	3	2	3	2	1	2
Available Terminal Acreage	1	1	3	3	1	2
Total Points	**10**	**10**	**13**	**10**	**5**	**11**

The point system used in **Table 18** ranks lower numbers better than higher ones (i.e., 1 is better than 2, 2 is better than 3, and so on). The legend for point values is as follows:

- Channel Entrance:
  - (1) Green: channel entrance is greater than twice the width of *Pioneering Spirit*
  - (2) Yellow: cannot accommodate *Pioneering Spirit*, but could accommodate the *Iron Lady* barge
  - (3) Red: channel entrance is too narrow for both *Pioneering Spirit* and *Iron Lady* barge
- Distance to Offshore Oil & Gas Platforms:
  - (1) Green: relatively short distance
  - (2) Yellow: fair distance
  - (3) Red: significant distance
- Air Draft Clearance:
  - (1) Green: no air draft restriction
  - (3) Red: air draft restriction(s)
- Proximity to Recycling Facilities:
  - (1) Green: close proximity to several recycling facilities
  - (2) Yellow: relatively close to a few recycling facilities
  - (3) Red: no recycling facilities in proximity
- Available Terminal Acreage:
  - (1) Green: has available terminal acreage or the ability to create terminal acreage
  - (2) Yellow: may have the required terminal acreage
  - (3) Red: no available terminal acreage

With the lowest number of total points ranked first and the highest number of total points ranked last, per **Table 18**, the Ports of Long Beach and Los Angeles are identified as the best potential port locations for offshore oil and gas decommissioning facilities. The ranking is as follows:

1. Port of Los Angeles / Port of Long Beach
2. Humboldt Bay / Bay Area Ports / Port of Hueneme
5. Port of San Diego
6. Central Coast

6.6 Recommendations / Synergies Between OSW and Offshore Oil and Gas Decommissioning

Based on the rankings that resulted from the assessment summarized in **Table 18**, locating offshore oil and gas decommissioning port facilities at the Port of Los Angeles and/or Port of Long Beach provides the shortest transit from platform locations, shortest transit to recycling facilities, and has the best potential for developing port infrastructure that reduces the cost of platform decommissioning.

When comparing port requirements for offshore oil and gas platform decommissioning and offshore wind development, it is evident that there are some synergies between the two, such as the required acreage and wharf loading criteria – refer to **Table 19**. However, the main difference between the two is draft at berth. Decommissioning offshore oil and gas platforms will likely require a grounding bed and shallow berth depth to ensure the barge and wharf are at the same level, while the offshore wind industry requires deeper water at the berth. This makes it difficult to have both activities located at the same port facility and share the same berth space. Furthermore, an offshore wind project may require the wharf and uplands area at a site with little to no interruptions to operations for multiple years at a time. Similarly, a decommissioned offshore oil and gas platform may be at a port facility for multiple years while being dismantled and recycled. Co-locating the two activities at the same port site would require one activity to be put on pause while the other is actively using the site, significantly increasing the timeline and cost for each activity. Therefore, these two activities could not occur simultaneously at the same port site. In addition, for offshore oil and gas decommissioning, the proximity to recycling facilities is an important factor for easy waterborne, road, or rail transport of recycled components, while this does not have to be considered for the offshore wind industry.

Although the two activities cannot be at the same port site, they could be located within the same port, at separate and/or adjacent facilities with separate upland and berth space. Offshore wind development and offshore oil and gas decommissioning have similar business lines from a terminal equipment, operator, and vessel perspective, making it ideal to have the two facilities located within the same port.

Table 19. Comparison of offshore wind and offshore oil & gas decommissioning key criteria

Criteria	Offshore Wind (S&I Site)	Offshore Oil & Gas Decommissioning
Acreage, minimum	30 – 100 acres	35 – 75 acres
Wharf Length	1,500 ft	660 ft
Minimum Draft at Berth	38 ft	33 ft
Wharf Loading	> 6,000 psf	> 4,000 psf
Uplands / Yard Loading	> 2,000 – 3,000 psf	> 2,000 psf
Air Draft	No air draft restrictions allowed	No air draft restrictions allowed

6.7 Industrial Circular Economy: Energy Transition Facility – Ardersier Port, U.K.

An excellent example of an offshore wind development facility and an offshore oil and gas decommissioning facility working in tandem within the same port can be found at the Ardersier Port in Scotland, U.K. As shown in **Figure 22**, the two activities are placed next to one another, allowing each activity to have their own designated berth and upland area.

Over the next five (5) years, the following work will be completed for this port project (Fleschen 2021):

- Completion of major dredging and channel deepening
- Construction of an oil rig decommissioning facility
- Construction of a waste from energy recovery facility designed specifically to deal with special wastes
- Construction of a green steel plant powered by offshore wind and energy from waste
- Construction of a concrete production plant utilizing dredged sand from the port, by-products from the steel plant, and energy from the waste facility
- Construction of a dedicated floating wind hub for concrete floating wind foundation manufacturing

Figure 22. Ardersier Port site plan (Industrial Circular Economy 2021)

Once completed, the Ardersier Port will be Europe's first fully circular energy transition facility. This purpose-built facility uses the circular economy approach to decommission fossil-fueled energy assets and replace them with renewable energy infrastructure in an economically and environmentally beneficial way. This process is summarized in **Figure 23**.

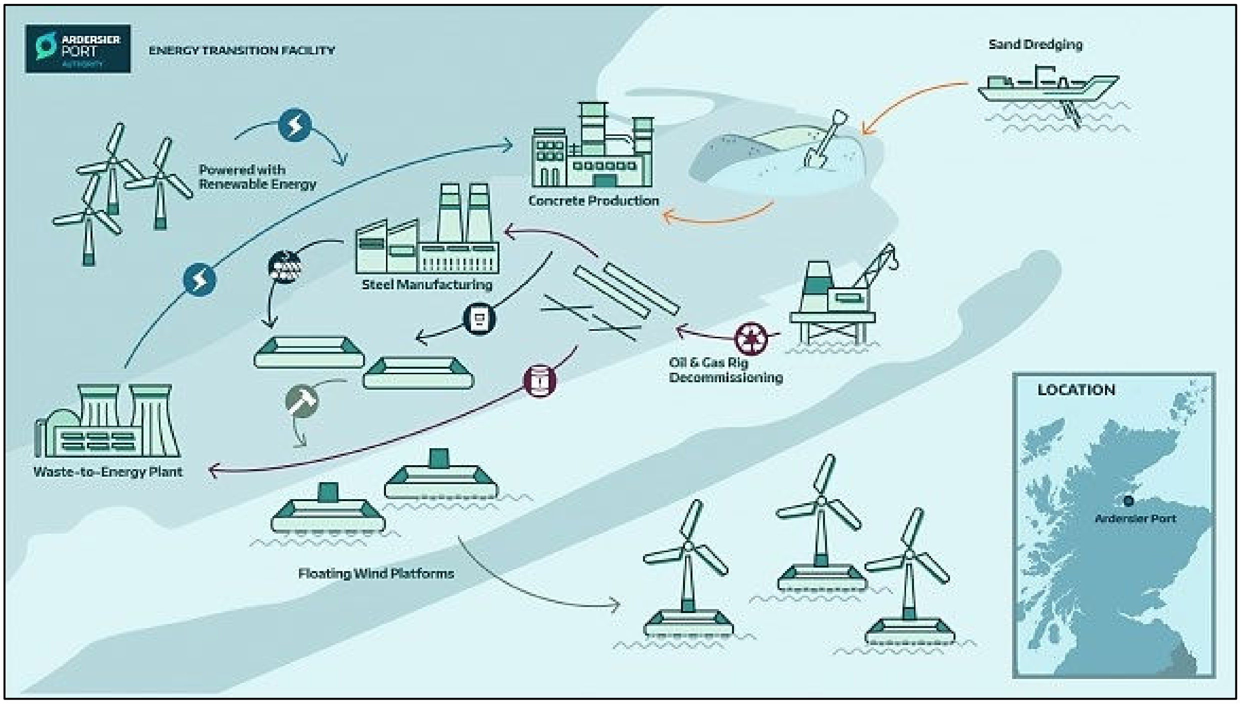

Figure 23. Ardersier Port fully circular energy transition facility (Industrial Circular Economy 2021)

7 Conclusion and Next Steps

The goals of this study were to:

1. Identify port requirements and deployment scenarios needed to support an offshore wind industry in California, concurrently with reasonably foreseeable OCS oil and gas decommissioning activities; and,
2. Assess physical, operational, and regulatory capabilities and constraints of port facilities and infrastructure.

Offshore Wind Port Needs

Section 2 documents the port requirements from the BOEM Port of Coos Bay study (Moffatt & Nichol 2022). **Section 3** identifies the various deployment scenarios for 2030 through 2050 and determines the number of required S&I and MF sites needed to meet those deployment scenarios. **Section 4** and **Section 5** discuss the port outreach that was conducted to identify the number and type of port sites that are potentially available for offshore wind development without displacing existing industries and uses.

In order to meet the medium deployment target of 1.5 GW/year to reach 25.5 GW by 2045, a minimum of three S&I sites are required. The existing California ports with the best capability to meet the offshore wind needs for S&I sites are the Ports of Humboldt, Los Angeles, and Long Beach. The Port of Humboldt is located close to the northern California WEA, while the Ports of Los Angeles and Long Beach are located closer to the central California WEA. Additionally, the Port of Humboldt is the only port in the state of California that is categorized as a good candidate site for all three categories of port uses (i.e., S&I, MF, and O&M). As such, it is a critical port for the development of offshore wind to meet the renewable energy goals set by the state, as well as critical to the feasibility of the northern California WEA development. Moreover, S&I sites are the limiting factor for offshore wind industry development as they have the least number of potential locations that could be improved to meet the offshore wind industry's needs.

Based on the results of this study, many port sites will need to be upgraded or developed for the offshore wind industry to meet the identified offshore wind deployment targets. Fortunately, per port outreach, many existing port sites were identified that could be used to meet these goals. This will require the use of multiple ports throughout the state. Purpose-built infrastructure for all selected sites will need to be planned, funded, permitted, designed, and constructed to meet the offshore wind industry requirements. These projects can take 3 – 5 years, from planning to finished construction, to complete.

The information gathered from this, and previous studies, will inform the next BOEM study titled *California Floating Offshore Wind Regional Ports Feasibility Analysis*, which will assess the feasibility of port upgrades and associated cost estimates and construction timelines. In addition, the AB 525 Strategic Plan, with support from the BOEM and CSLC studies, will include the following:

- Identify required port infrastructure improvements, including cost and schedule,
- Identify impacts to natural and cultural resources, including coastal resources, fisheries, and Native American and Indigenous peoples,
- Rank the recommended port sites,
- Determine workforce development needs, training, and strategy,
- Develop the seaport chapter for the AB 525 Strategic Plan due June 30, 2023.

Synergies Between OSW and Offshore Oil and Gas Decommissioning

There are some synergies between the offshore wind industry and the offshore oil and gas decommissioning industry. These synergies include similar business lines from a terminal equipment, operator, and vessel perspective, making it ideal to have the two facilities located within the same port. However, they cannot be located at the same port site as both need designated berth and upland space for long periods of time. The Port of Los Angeles and Port of Long Beach were identified to be the ideal locations for offshore oil and gas platform decommissioning due to proximity to the offshore oil and gas platforms, recycling facilities, potentially available port sites, no air draft restrictions, and wide entrance and navigation channels. An important next step in planning for the increasing decommissioning activity in the Pacific OCS region is to conduct outreach with the identified ports to determine interest and suitability for offshore oil and gas decommissioning.

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List of Relevant Literature

The following lists the information and data gathered from a range of offshore wind industry, offshore oil and gas decommissioning, and government sources to provide a baseline of best available information on offshore wind, decommissioning activities, and ports.

Offshore Wind Literature

Bureau of Ocean Energy Management (BOEM):

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- Floating Offshore Wind in California: Gross Potential for Jobs and Economic Impacts from Two Future Scenarios [NREL] (BOEM 2016-029)
- Floating Offshore Wind Turbine Development Assessment: Final Report and Technical Summary [ABSG Consulting Inc.] (BOEM 2021-030)
- Port of Coos Bay Port Infrastructure Assessment for Offshore Wind Development [Moffatt & Nichol] (BOEM 2022-073)
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- Presentation BOEM California Leasing Update – 10-6-22 (BOEM 2022)

California Energy Commission (CEC):

- AB 525 Goals – Resources Considered (as of March 3, 2022), March 10, 2022 (CEC 2022)
- Commission Report – Offshore Wind Energy Development off of California Coast, August 1, 2022, CEC-800-2022-001-REV (CEC 2022)
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California State Lands Commission (CSLC):

- Alternative Port Assessment to Support Offshore Wind Feasibility Assessment Report [Moffatt & Nichol] (CSLC, Unpublished Report)

National Renewable Energy Laboratory (NREL):

- 2014-2014 Offshore Wind Technologies Market Report (NREL 2015)
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- California Offshore Wind: Workforce Impacts and Grid Integration (UC Berkeley Labor Center 2019)
- California's Offshore Wind Electricity Opportunity (USC Schwarzenegger 2021)
- Economic Impact of Offshore Wind Farm Development on the Central Coast of California (Cal Poly SLO 2021)
- Scenarios for Offshore Wind Power Production for Central California Call Areas (Cal Poly SLO 2020)
- Supply Chain Contracting Forecast for U.S. Offshore Wind Power – The Updated and Expanded 2021 Edition (The Special Initiative on Offshore Wind 2021)

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Bureau of Ocean Energy Management (BOEM):

- Air Emissions Associated with Decommissioning Operations for Pacific Outer Continental Shelf Oil and Gas Platforms Volume 1: Final Report [MRS Environmental, Inc.] (BOEM 2019)
- Environmental Setting of the Southern California OCS Planning Area [Argonne National Laboratory] (BOEM 2019)
- Environmental Studies Program, Studies Development Plan 2021-2022 (BOEM 2020)
- FAQ: Decommissioning and Rigs to Reefs in the Pacific Ocean (BOEM 2017)
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- Oil and Gas Leasing on the Outer Continental Shelf (BOEM)
- Santa Clara Unit (Platforms Grace and Gail) Conductor Removal Program Environmental Assessment (BOEM 2021)
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- Decommissioning Cost Update for Pacific OCS Region Facilities Volume 1 [InterAct PMTI] (BSEE 2020)
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U.S. Department of the Interior (DOI)

DOI protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

BOEM’s mission is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.