DOCKETED	
Docket Number:	17-MISC-01
Project Title:	California Offshore Renewable Energy
TN #:	242928
Document Title:	Guidehouse California Supply Chain Needs Summary Report
Description:	N/A
Filer:	susan fleming
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	5/4/2022 7:21:53 AM
Docketed Date:	5/4/2022

Guidehouse
Outwit Complexity

California Supply Chain Needs Summary

California Energy Commission

May 2, 2022

Disclaimers

This deliverable was prepared by Guidehouse Inc. for the sole use and benefit of, and pursuant to a client relationship exclusively with the California Energy Commission. Guidehouse's conclusions are the results of the exercise of its reasonable professional judgment. Use of this report by the reader for whatever purpose should not, and does not, absolve the reader from using due diligence in verifying the report's contents.

Accordingly, Guidehouse disclaims any contractual or other responsibility to others based on their access to or use of the deliverable. The work presented in this deliverable represents Guidehouse's professional judgement based on the information available at the time this report was prepared. Any forecasts contained in the publication reflect Guidehouse's current expectations based on available data. Market predictions and expectations are inherently uncertain and actual results may differ materially from those contained in the publication.

Acronyms

AB: Assembly Bill
BLS: Bureau of Labor Statistics
BOEM: Bureau of Ocean Energy Management
CA: California
CapEx: Capital Expenditure
CEC: California Energy Commission
CEJA: Clean Energy Jobs Act
CLCPA: Climate Leadership and Community Protection Act
COD: Commercial Operation Date
DTR: Disconnectable Turret for Renewables
EO: Executive Order
FOSW: Floating Offshore Wind
GW: Gigawatt
HB: House Bill
HMPE: High Modulus Polyethylene
HQ: Head Quarters
JEDI: Jobs and Economic Development Impact
kV: kilovolt
kW: Kilowatt
LCOE: Levelized Cost of Energy
MW: Megawatt
NJWP: New Jersey Wind Port
NREL: National Renewable Energy Laboratory
NYSERDA: New York State Energy Research & Development Authority
O&M: Operation and Maintenance
OEM: Original Equipment Manufacturer
OpEx: Operational Expenditure
OR: Oregon
OREC: Offshore Renewable Energy Certificate
OSW: Offshore Wind
PPA: Power Purchase Agreement
QC: Quality Check
R&D: Research and Development
RFP: Request for Proposal
RPS: Renewable Portfolio Standard
SB: Senate Bill
t/m^2: Ton per Meter Squared
TLP: Tension Leg Platform
TW: Terrawatt
US: United States
WA: Washington
WTIV: Wind Turbine Installation Vessels
XLPE: Cross Linked Polyethylene Cable

Background

Regulatory and Policy Background

- California's passage of Senate Bill 100 (De León, Chapter 312, Statutes of 2018) continues to change the landscape for clean energy development in the state by increasing demand for new clean energy generation sources, such as floating offshore wind (FOSW) energy.
- With the Biden Administration opening the Pacific Coast for offshore wind development, continuing the momentum of FOSW research is crucial for realizing the benefits of this newly available resource.
- Additionally, Assembly Bill 525 (Chiu, Chapter 231, Statutes of 2021) directs the California Energy Commission (CEC) to establish offshore wind planning goals for 2030 and 2045. A mature California supply chain is needed to help lower FOSW project risks and costs.

Development of OSW in California

While the FOSW industry is being developed in Europe and parts of the U.S., California-specific development and deployment will not only provide the ability to meet California's clean energy goals but can also strengthen the local manufacturing and supply chain, while providing economic benefits by creating jobs and utilizing local materials. **In an industry with an existing global supply chain, this project aims to identify California-specific supply chain and manufacturing opportunities to help achieve energy planning goals.**

Goals and Objectives

Goal

The goal of the report is to assess the needs and opportunities in the California FOSW supply chain using secondary research methodologies supplemented with limited primary research.

Objectives

The objectives of the report is to address prioritized questions from the CEC to inform FOSW deployment planning and future research and development by identifying:

- FOSW global targets and current project pipeline support informing California-specific FOSW planning.
- California manufacturing and supply chain needs and opportunity for existing California infrastructure.
- California workforce to support OSW manufacturing needs and opportunity for existing California workforce.
- How the East Coast supported development of an OSW supply chain to support deployment.

Image: Andrew Testa for the New York Times (Hywind Floating Wind Farm).

Methodology Overview

Duration of Research

Guidehouse conducted research between January 2022 through April 2022.

Approach & Method

Guidehouse relied on secondary research with limited supplemental primary research. The secondary research mainly consisted of the following:

- Literary review of academic research and reports (also included are other reports prepared by the private sector)
- Utilizing existing NREL model with data inputs from literary review
- International offshore wind database
- Case studies/reports about development of offshore wind on East Coast

The primary research mainly consisted of the following:

- Interviews with industry experts
- Reviewing procurement contracts (such as PPAs and ORECs) and other regulatory documents

Each section within the report has a high-level overview of methodology and approach specific to the research of that section.

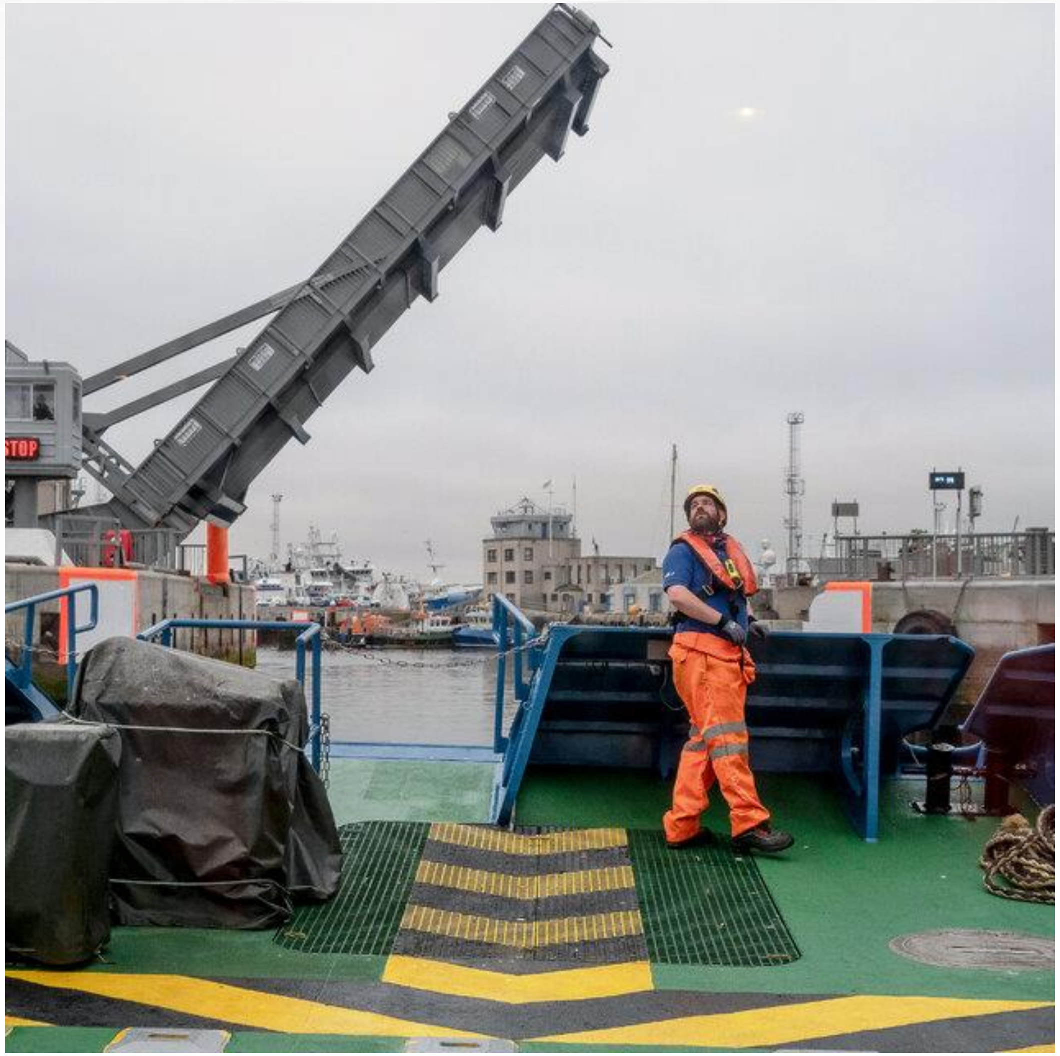


Image: Andrew Testa for the New York Times (Hywind Floating Wind Farm).

Illustration of Key Components for FOSW

The diagram summarizes the components of a semi-submersible platform OSW system.

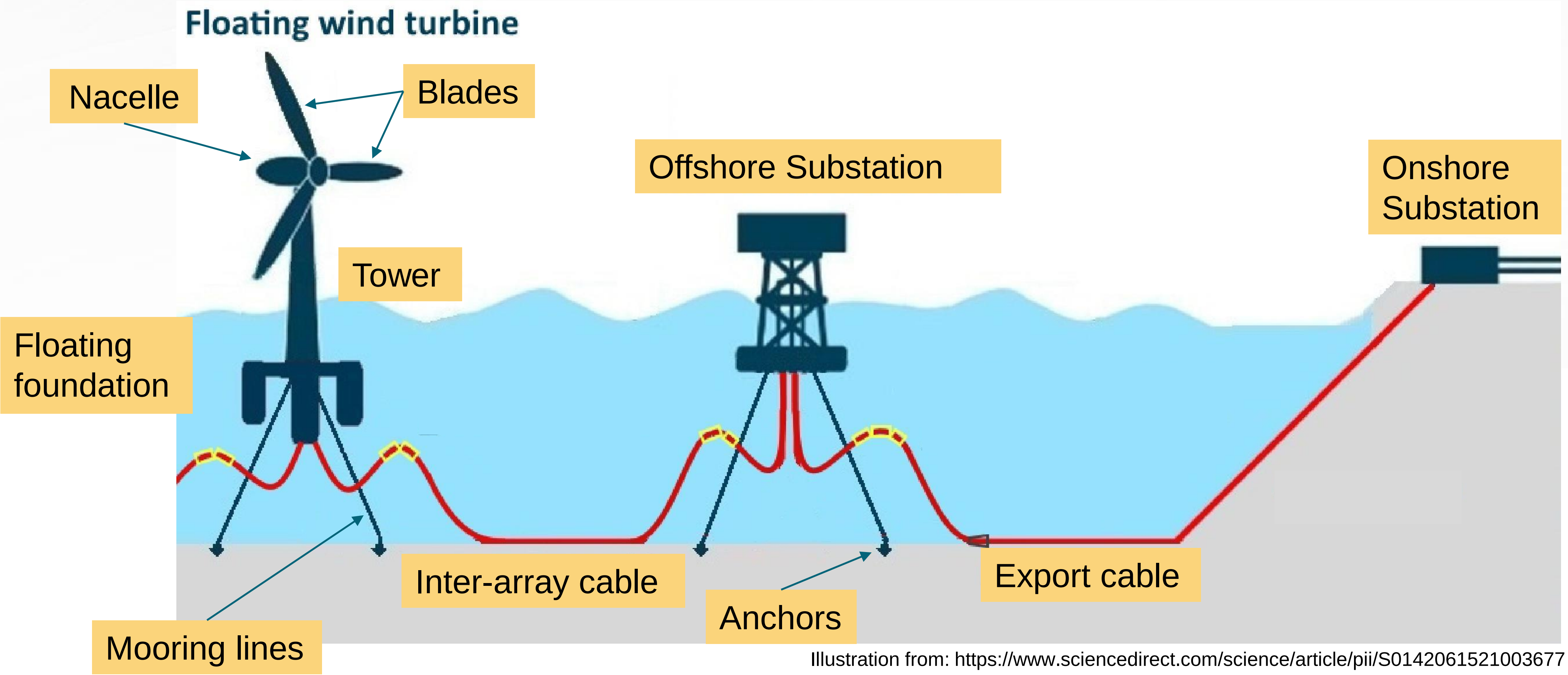


Illustration from: https://www.sciencedirect.com/science/article/pii/S0142061521003677

Material and Capital Inputs in the FOSW Supply Chain

The diagram summarizes the components of the OSW supply chain.

FOSW System components manufacturing

Development, planning, engineering

Tier 3 (raw material production)

- Concrete (for foundations)
- Steel (for foundations and other turbine components)
- Glass fiber reinforced plastic (for blades)
- Copper (for submarine cables, nacelle)
- Aluminum (for submarine cables)

Tier 2 (material fabrication)

- Steel fabrication and drawing (foundation, mooring, turbine)
- Steel casting (foundation and nacelle)
- Concrete casting (foundation components)
- Copper drawing (cables)
- Aluminum drawing (cables)

Tier 1 (parts production)

Highly standardized ports, vessels, cranes

See Vessels, heavy machines

Operations and Maintenance

See Vessels, Tier 2 material fabrication

Supporting manufacturing: vessels and cranes

Construction Vessels

- Jack-up barge/vessel
- Heavy lift vessel
- Tugboats
- Support vessels
- Cable laying vessel
- Diving support vessel
- Cargo barges
- Personnel transfer boats
- Safety boats

Pre Construction Vessels

- Survey vessels (geotechnical, geophysical, multi-purpose), some remotely operated

Pre Construction Vessels

- Survey vessels (geotechnical, geophysical, multi-purpose), some remotely operated

Operations and Maintenance Vessels

- Tailor–made O&M vessels

Cranes

- Highly specialized cranes

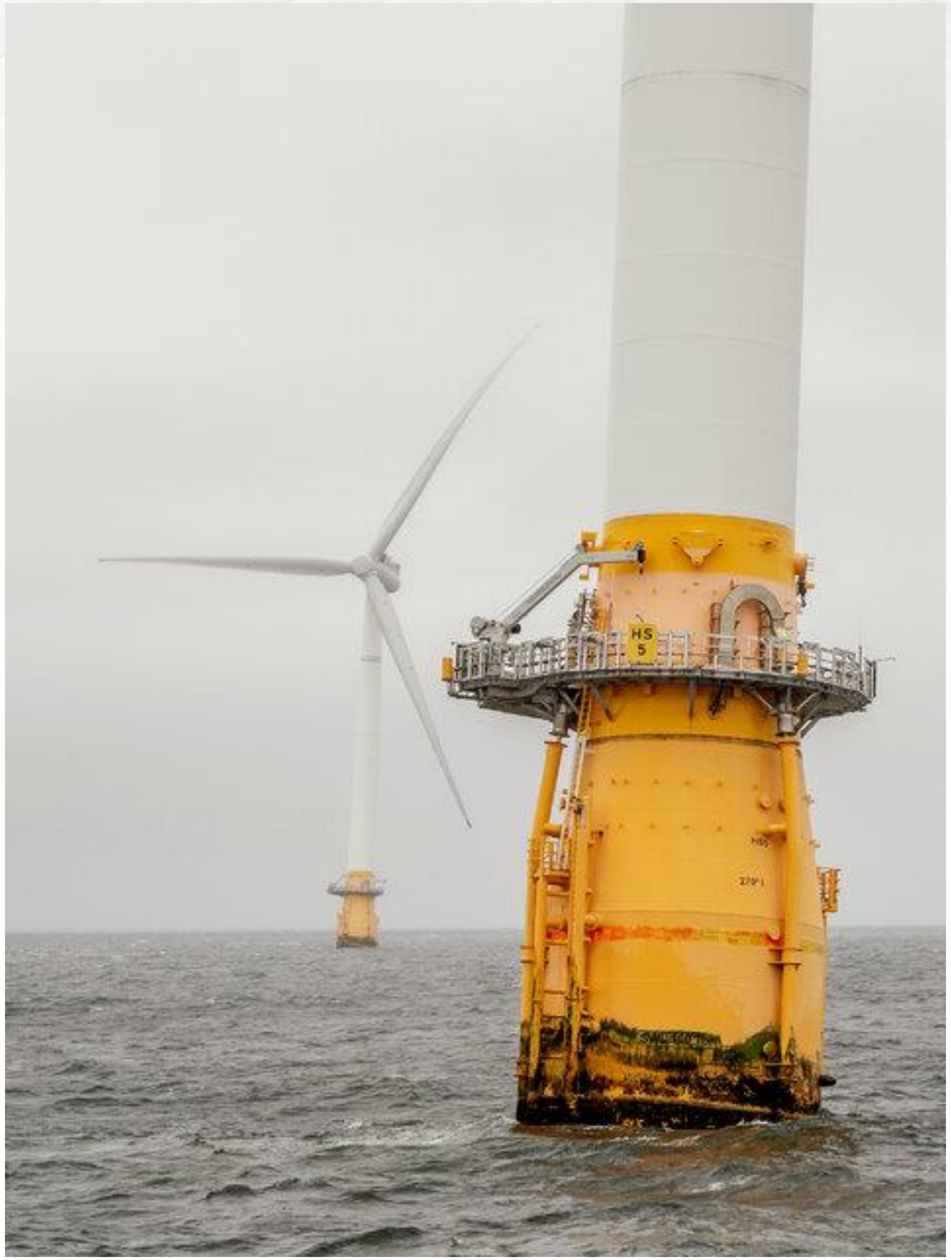


Image: Andrew Testa for the New York Times (Hywind Floating Wind Farm).

Table of Contents

Existing Offshore Wind Pipeline

International OSW Pipeline Summary

Research Question

What is the international pipeline for FOSW including what and when capacity are projected to come online? What technologies are being installed?

Research methodology

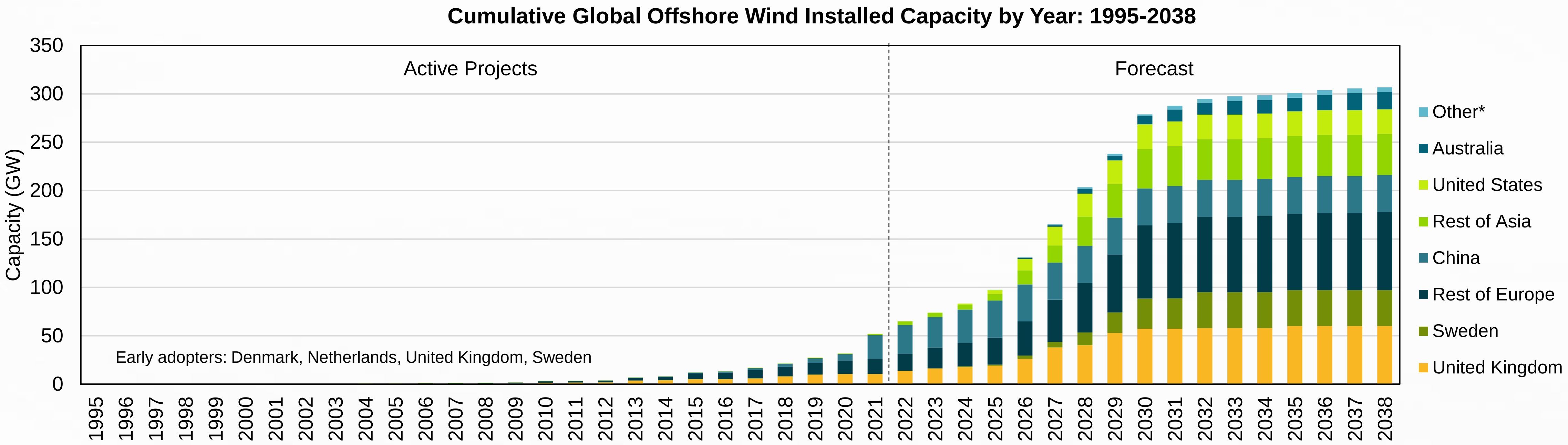
To answer these questions, Guidehouse utilized an international offshore wind database, which contains information on 2,514 global offshore wind farms and projects in over 53 countries. The database covers both existing and planned projects and lists a variety of statistics on each project, including capacity, technology type, manufacturer, developer, location, date of commissioning (actual or forecasted) and more. Guidehouse cleaned, formatted, analyzed, and drew conclusions from the database.

Conclusions

- Global installed FOSW capacity is expected to reach 40 GW by 2036.
- Most installed floating projects are using semi-submersible platforms, which also make up a majority of foundations for planned projects.
- Wind turbine unit capacity is expected to reach roughly 15 MW by 2036.

Guidehouse Outwit Complexity

Global Project Pipeline for OSW

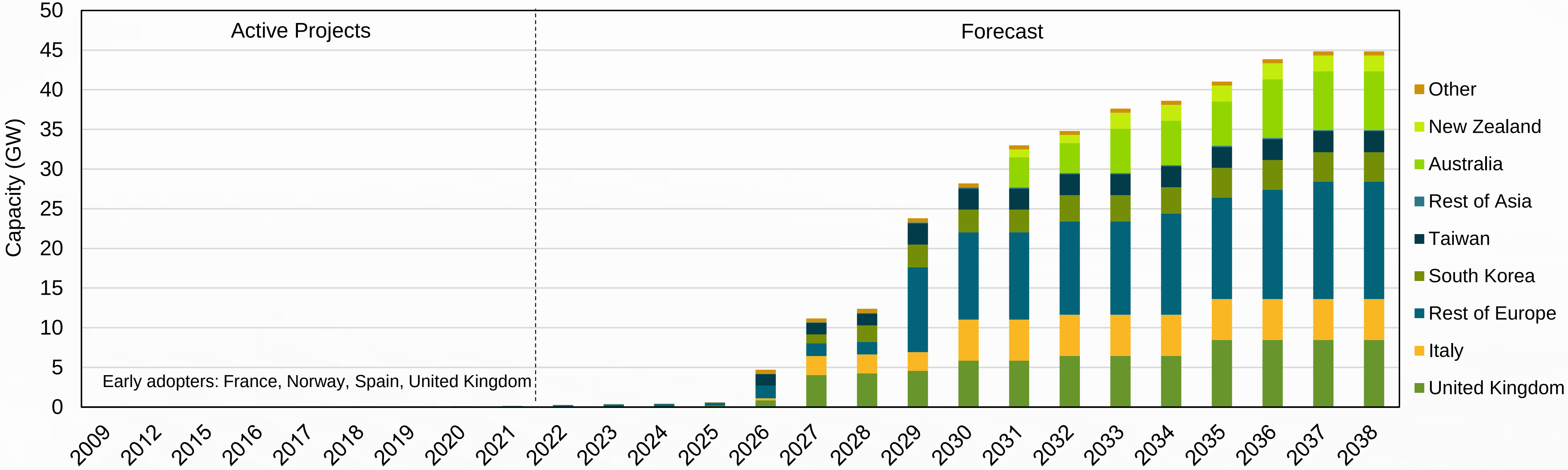


- "Active Projects" includes fully commissioned or partially generating projects. "Forecasted" includes projects of status early planning, consent application submitted, consent authorized, development, and pre-construction.
- Cancelled, decommissioned, dormant, and projects with failed submission were omitted from this plot, in addition to projects without a known date of commissioning.
- Some commission dates were estimated by Guidehouse based on a known consent application submission date and the average time from application to commissioning for projects with known commissioning dates.
- Note that the project pipeline doesn't necessarily align with regulatory targets.

**Included in Other: Bermuda, Brazil, Colombia, Saudi Arabia*

Global Project Pipeline for FOSW

Cumulative Global Floating Offshore Wind Installed Capacity by Year: 2009-2038



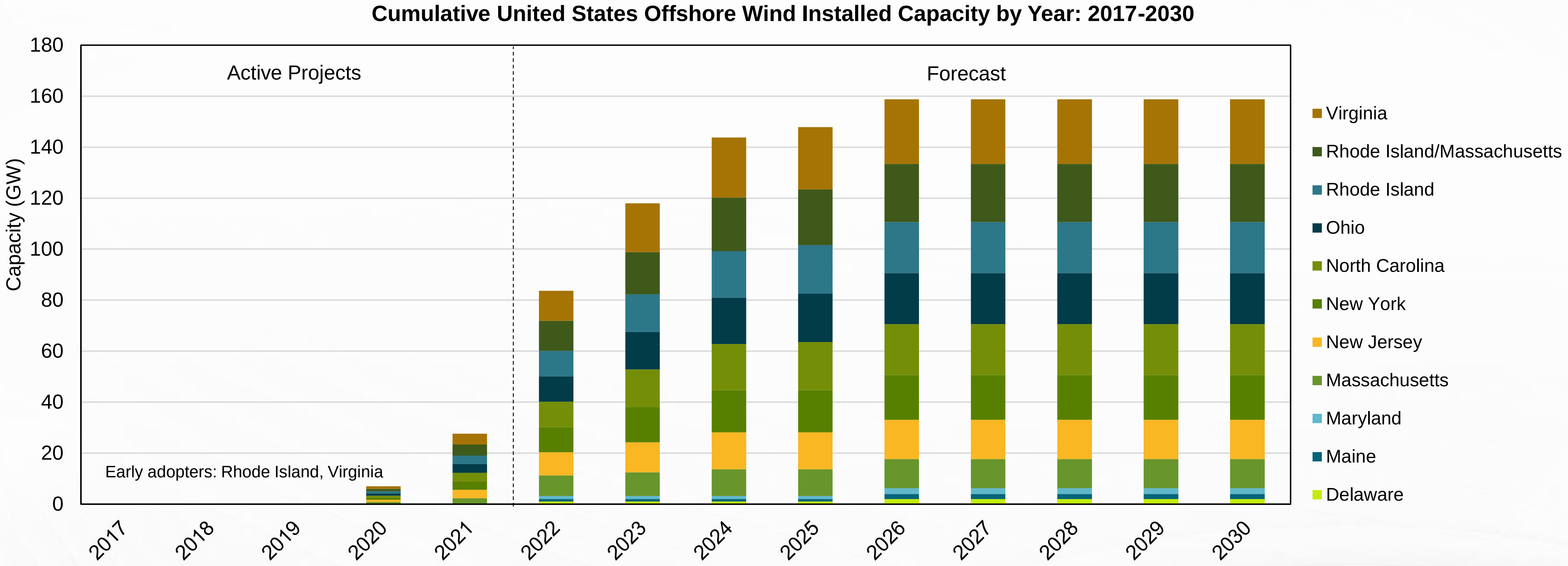
Included in Other: Saudi Arabia, United States. Years without capacity additions are omitted.

Average time from Consent Application Submission to Construction and Full Commissioning

Foundation Type	Average Application to Construction (Years)	Average Application to Commissioning (Years)
Floating	4.1	5.9
Fixed Bottom	5.5	7.1

Guidehouse Outwit Complexity

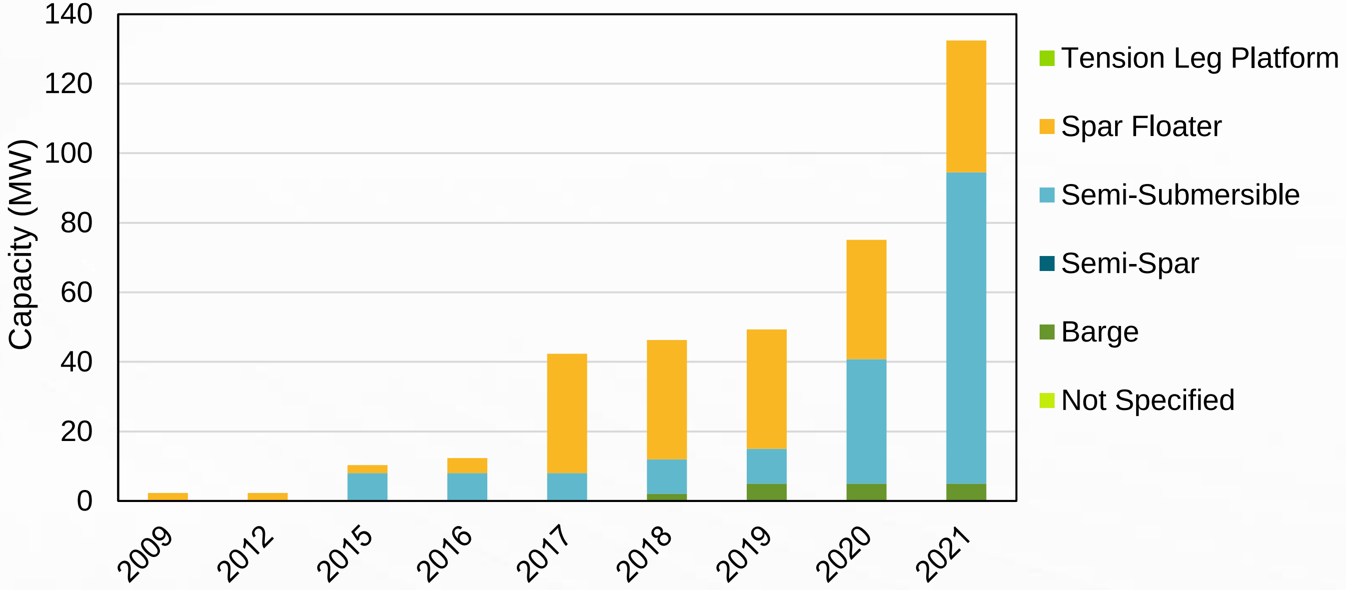
United States Project Pipeline for FOSW



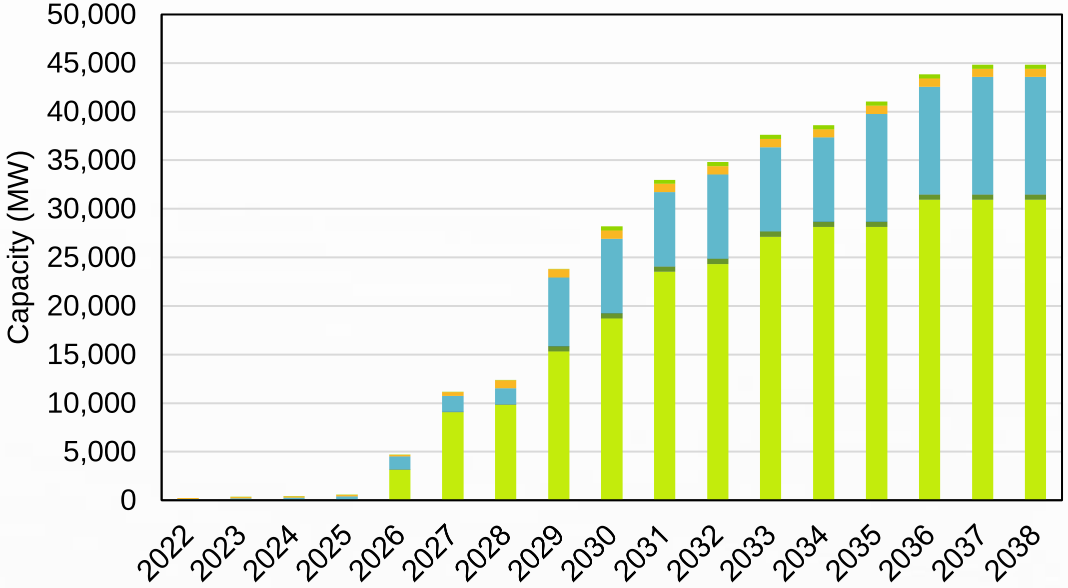
- The projects represented in this figure are almost entirely fixed-bottom. The only floating project is the Aqua Ventus in Maine, with a capacity of 12 MW by 2024.
- There are five other floating projects in the offshore database in the US, all are in the early stages of planning and have yet to submit a consent application. As such, Guidehouse was unable to estimate a potential date of commissioning, and these projects have been omitted.
- This analysis does not include potential capacity in BOEM Call Areas and there are currently no projects in the pipeline for California with the criteria explained above.

FOSW Project Foundations

Global FOSW Installed Capacity by Year and Foundation: Active Projects



Global FOSW Installed Capacity by Year and Foundation: Planned Projects

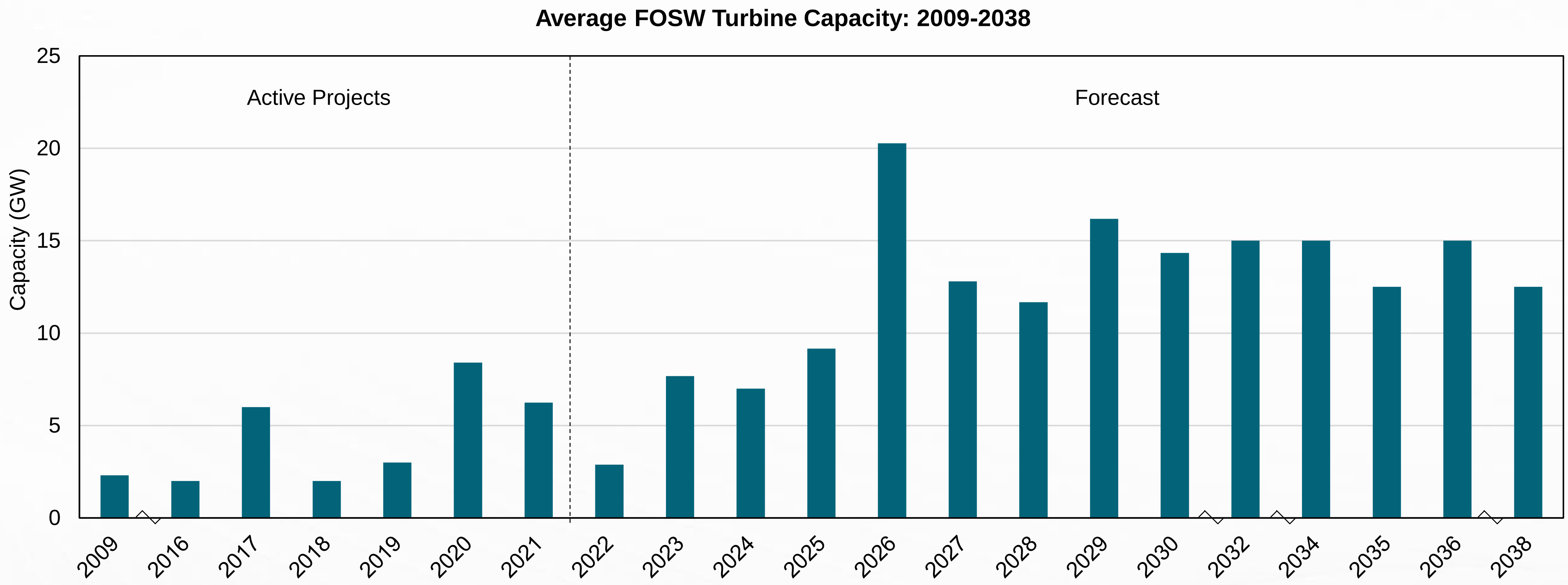


Project Status	Semi-Sub (MW)	Spar Floater (MW)	Barge (MW)	Semi-Spar (MW)	TLP (MW)	Not Specified (MW)
Active	89	38	5	--	--	20
Planned	25,448	2,451	2,430	2,049	60	138,367

While the plots above only show projects where dates of commissioning are known or can be estimated, this table contains additional projects without these values. As such, there are discrepancies between the table and plots.

Guidehouse Outwit Complexity

FOSW Turbine Capacity Trend



- These values are averaged from 95 projects in the database with commission years listed. Of these 95 projects, 24 lacked turbine capacity data. Years with insufficient data have been removed.
- While turbines are expected to average around 15 MW by 2032, technology advances could lead to turbines with higher nameplate capacities within this time period. The largest capacity forecasted for a single wind turbine in the database is 20 MW, located on a proposed wind farm in Sweden.

Regulatory Targets

Regulatory Targets Summary

Research Question

What are the total regulatory targets (GW) and peak/average annual installations (in GW and number of wind turbines) necessary to meet these total targets by US state and by country?

Research methodology

Guidehouse reviewed publicly available regulatory documents, research papers and databases to gather research. In this review, Guidehouse included the countries and US states with any project of any status in the offshore wind project pipeline (through the offshore database). Guidehouse then researched the respective country and US state government websites, news articles, and research papers to identify any specific OSW targets. To assess annual installations, if a country or US state does not already have OSW installed, then the first year of construction was determined through an assessment of the offshore database analyst opinion and Guidehouse subject matter expertise based on knowledge of other project timelines. To calculate the number of turbines installed, Guidehouse assumed a turbine will have a nameplate capacity of 15 MW (see FOSW Turbine Capacity).

Conclusions

The amount of supply chain capacity for manufacturing and services in the floating offshore wind development depends on the number of turbines that will be installed annually. Not all countries and US states have mandated targets set by the government on how much OSW to build. According to studies there is additional potential for OSW capacity outside of the targets set by governments. The type of regulatory target set varies and in Guidehouse's research, executive orders and legislative action is covered. However, other countries such as the Netherlands are building OSW with no targets but focusing on the availability to set up leases. Overall, based on the research conducted, in order to reach SB 100 and meet RPS targets with 10 GW of OSW by 2045, California would require many wind turbines and a robust supply chain.

Global OSW Capacity Targets

- Europe and Asia have more mature markets for offshore wind. However, there are emerging markets with much potential capacity worldwide.
- Capacity potential does not equal the target; however, the regulatory body will be evaluating what is a realistic target to based on potential capacity in country waters, technology maturity and supply chain maturity.
- China has a federal renewable generation target of 1.2TW in 2030 (wind, solar, biomass).

Summary of Data in Table:

- **Country:** Countries that have an OSW project in the pipeline and have a regulatory target.
- **OSW Target (GW):** the regulatory target to be met in the final year.
- **Final Target Year:** the year the regulatory target in the previous column is to be met.
- **Total Nameplate Capacity (GW, 2020):** total nameplate capacity by country in year 2020.
- **OSW Target as Percent of Total State Capacity**: OSW Target divided by the Total Country Capacity to show the magnitude of the country's goal.

Only countries with a project in the pipeline of any status are reviewed for OSW target.

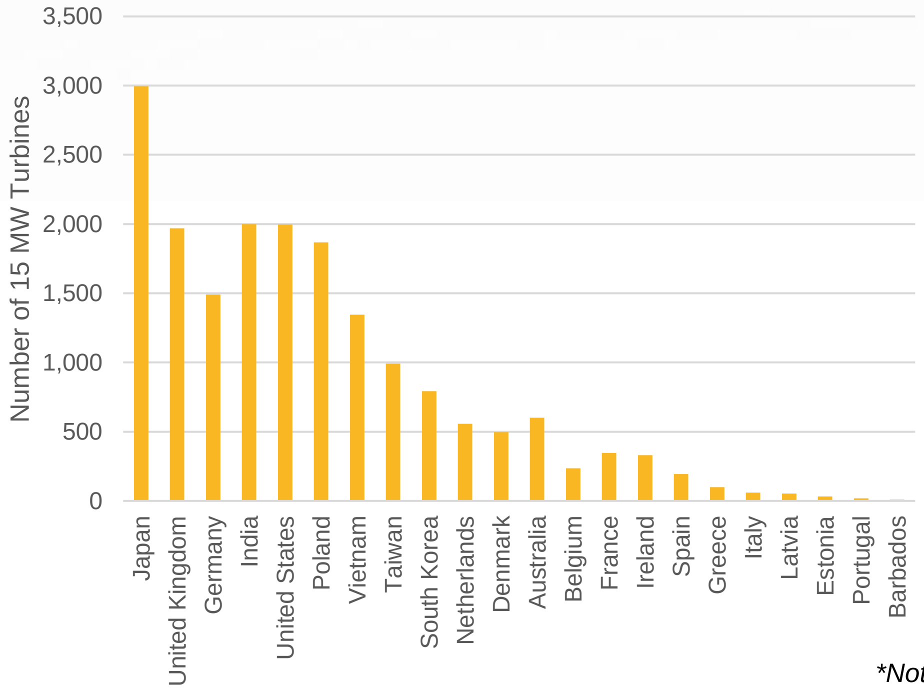
Country	OSW Target (GW)	Final Target Year	Total Country Capacity (GW, 2020)	OSW Target as Percent of Total Country Capacity (%)
Japan	45	2040	544.2	8%
United Kingdom*	40	2030	30.9	130%
Germany	30	2030	151.2	20%
India	30	2030	320.6	9%
United States**	30	2030	758.6	4%
Poland	28	2050	1889.6	1%
Vietnam	21	2045	79.0	27%
Taiwan	15	2035	103.0	15%
South Korea	12	2030	99.1	12%
Netherlands	11	2030	225.7	5%
Denmark	10	2030	67.0	15%
Australia**	9	2040	21.3	42%
Belgium	5.8	2030	125.1	5%
France	5.2	2028	33.2	16%
Ireland	5	2030	154.7	3%
Spain	3	2030	17.6	17%
Greece	1.5	2030	150.9	1%
Italy	0.9	2030	172.0	1%
Latvia	0.8	2030	4.1	20%
Estonia	0.5	2030	4.7	11%
Portugal	0.3	2030	29.1	1%
Barbados	0.15	2030	0.6	26%

United Kingdom also has a 1 GW **floating offshore wind target.*

***The goal for the United States is the federal goal while Australia's goal is specifically for the state of Victoria.*

Turbine Installations Required to Meet OSW Targets (by Country)

- Europe has the most commissioned OSW projects. Asia and North America are developing projects.
- Asia has most aggressive regulatory targets (around 120 GW), followed by Europe (around 130 GW).
- The list only includes OSW regulatory targets as mandated by the government. Other countries may have plans to set up OSW but no recognized target.



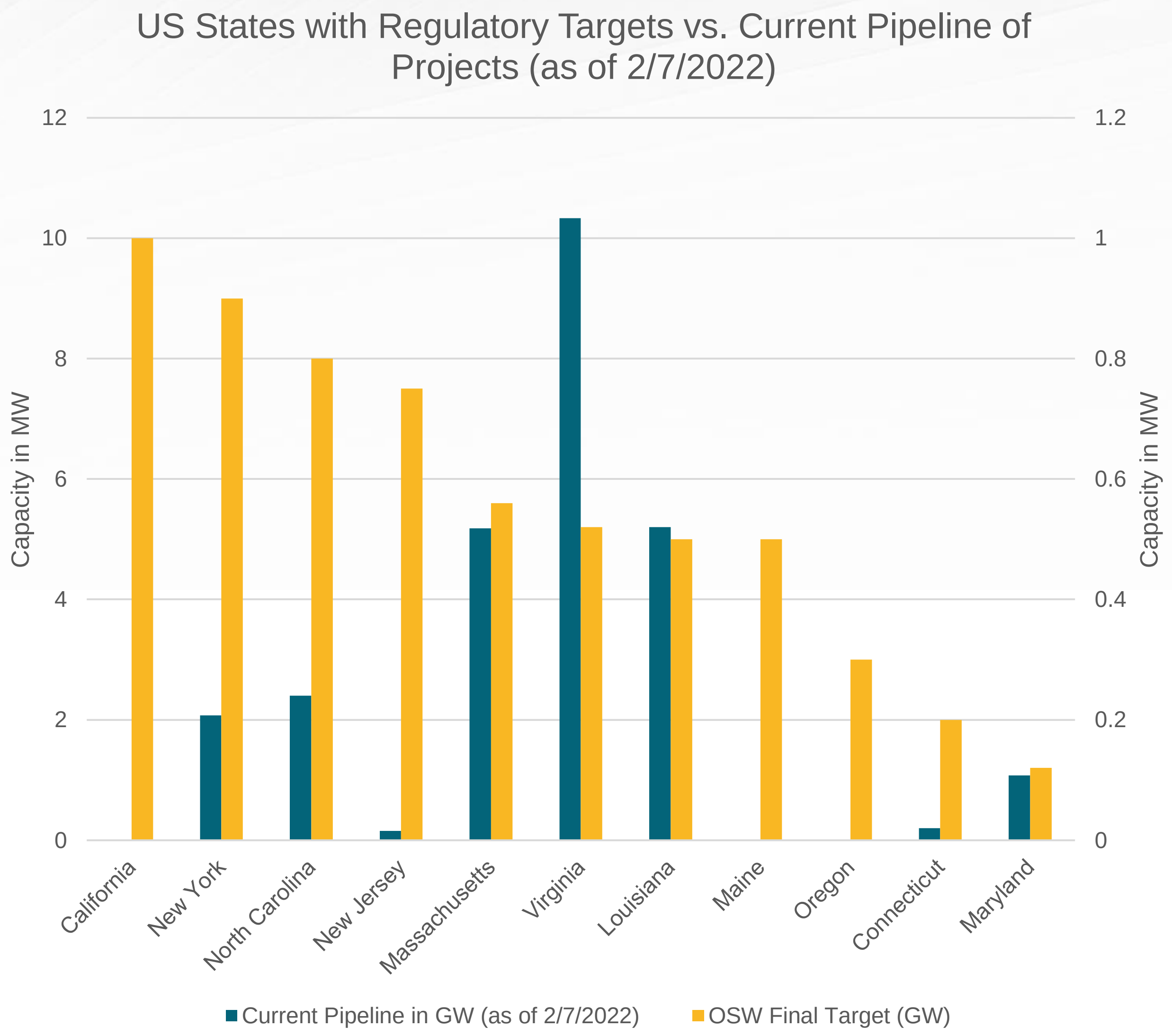
Country	Final Target Year	Estimated Start Date of OSW Installation***	Total # of Wind Turbines To Meet Target GW**	Avg. # of Wind Turbines/Year
Japan	2040	2022	2,995	166
Germany	2030	2022	1,969	246
India	2030	2022	1,490	186
United States**	2030	2028	2,000	1,000
Poland	2030	2022	1,997	250
Vietnam	2050	2024	1,867	72
Taiwan	2045	2022	1,345	58
South Korea	2035	2022	991	76
Netherlands	2030	2022	793	99
Denmark	2030	2022	557	70
Australia**	2030	2024	497	83
Belgium	2040	2022	600	33
France	2030	2026	236	59
Ireland	2028	2022	346	58
Spain	2030	2022	332	41
Greece	2030	2022	195	24
United Kingdom*	2030	2029	100	100
Italy	2030	2028	60	30
Latvia	2030	2029	53	53
Estonia	2030	2030	33	33
Portugal	2030	2029	18	18
Barbados	2030	2029	10	10

Note: United Kingdom has a 1 GW **floating offshore wind target., **Assuming 15 MW nameplate capacity per turbine.*
****Based on prior projects timeline, only for countries with no installed OSW (2022 if country already has projects).*

Guidehouse Outwit *Complexity*

US States: OSW Capacity Targets

US federal regulatory OSW target is 30 GW by 2030, current state targets combine to meet double the 2030 federal OSW target by 2045.



Only states with a project in the pipeline of any status are reviewed for OSW target.

State	OSW Capacity Final Target (GW)	Final Target Year	Total State Capacity in GW (2020)	Target as Percent of Total State Capacity
California*	10	2045	55.0	18.2%
New York	9	2035	34.6	26.0%
North Carolina	8	2040	22.1	36.2%
New Jersey	7.5	2035	15.8	47.4%
Massachusetts	5.6	2027	10.9	51.2%
Virginia	5.2	2034	16.2	32.2%
Louisiana	5	2035	21.1	23.7%
Maine	5	2030	3.8	131.5%
Oregon*	3	2030	10.9	27.4%
Connecticut	2	2030	8.0	24.9%
Maryland	1.2	2030	10.8	11.1%

**Note: CA and OR targets are based on planning studies (no official policy/goal).*
*'**As of March 2022, VA has 0.012 GW OSW capacity.*

Guidehouse Outwit *Complexity*

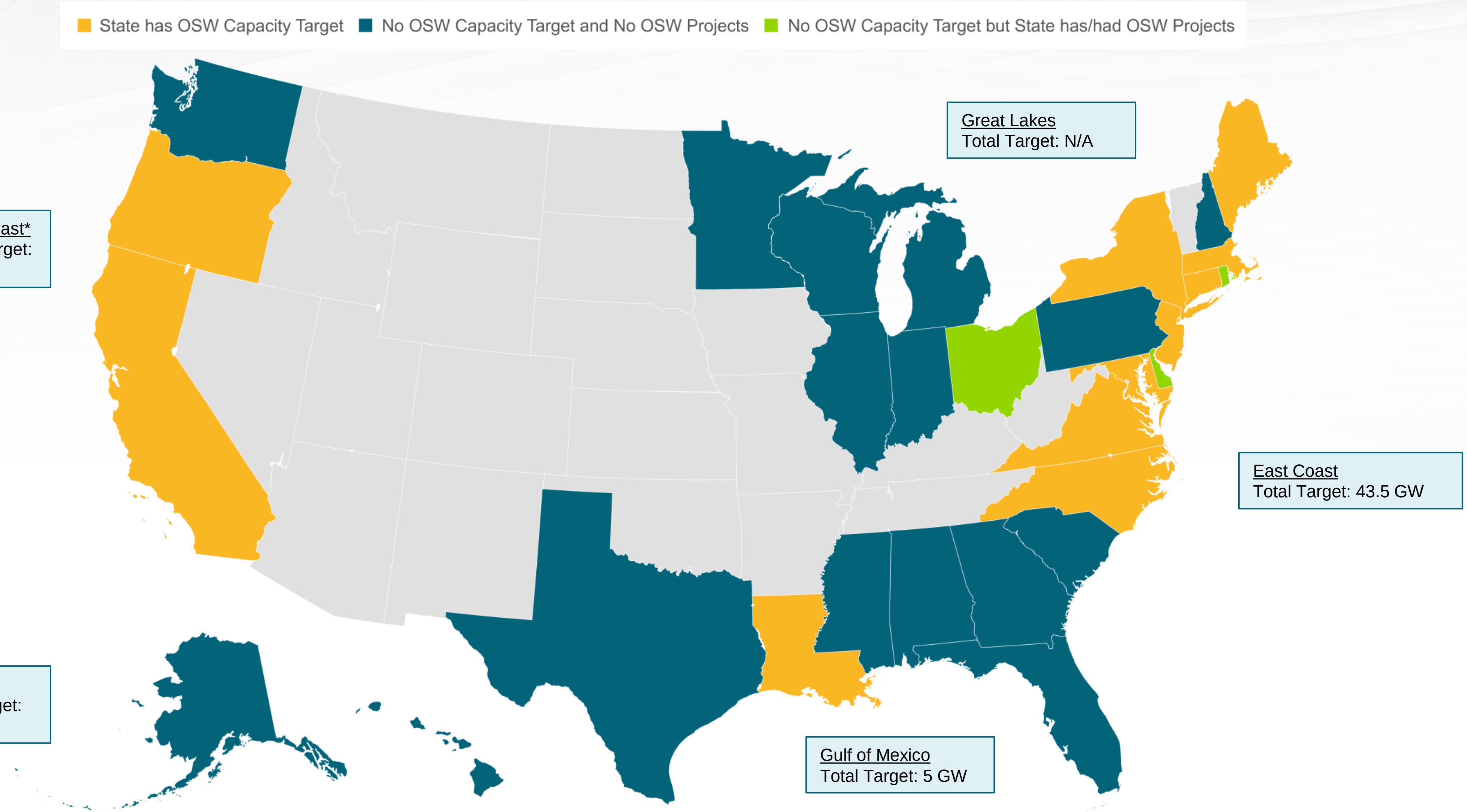
East Coast States: Capacity Goalsetting Process

State	Final Target (GW)	Final Target Year	Target Set By
Connecticut	2	2030	House Bill 715: An Act Concerning the Procurement of Energy Derived from Offshore Wind (Legislative)
Delaware	No target	No target	No target
Maine	5	2030	LD 1810: An Act to Implement the Recommendations of the Governor's Ocean Energy Task Force (Legislative)
Maryland	1.2	2030	Senate Bill 516: Clean Energy Jobs Act* (Legislative)
Massachusetts	5.6	2027	House Bill 4515: An Act Advancing Offshore Wind and Clean Energy** (Legislative)
New Jersey	7.5	2035	Assembly Bill 3723: An Act Concerning Clean Energy (Legislative), EO #92 (Executive)
New York	9	2035	Senate Bill S6599 (Legislative)
North Carolina	8	2040	Executive Order 218: Advancing North Carolina's Economic and Clean Energy Future with Offshore Wind (Executive)
Rhode Island	No target	No target	No target
Virginia	5.2	2034	House Bill 1526 (Legislative)

* Passed into law, but not signed by the Governor
** Not yet approved by the Governor

North Carolina and New Jersey are the only states to have an offshore wind capacity target set executively. Legislatively-set targets are set by laws, which are passed by the state legislature and, in most cases, signed into law by the governor. Executive orders are issued by governors; they are not laws but have the power to impose a course of action. Each governor has the opportunity to review executive orders of their predecessors, and they can rescind or continue them.

United States Regulatory Capacity Targets by State



Note: CA and OR targets are based on planning studies (no official policy/goal). States with access to water with potential for OSW reviewed.

Guidehouse Outwit Complexity

Regulatory Target & Existing OSW Project Pipeline

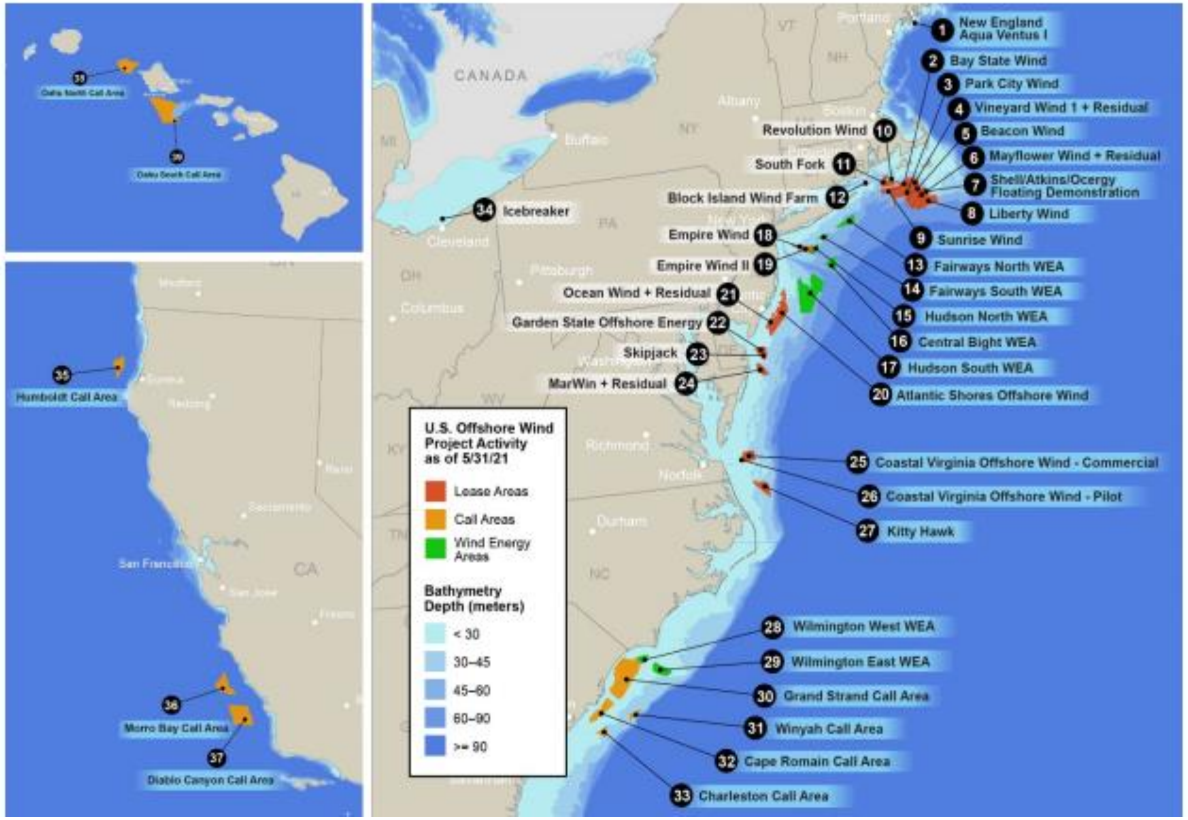
Total U.S. Project Pipeline Includes 28.7 GW of Capacity

- East Coast expected to host majority of projects with near term capacity.
- West Coast and Gulf of Mexico still developing and earlier in the development process.

Region	Total OSW Capacity Target (GW)	Current OSW Pipeline (GW)*
East Coast	43.5	28.6
Great Lakes	0	0.02
Gulf of Mexico	5	-
West Coast	13	-
Total	56.5	28.7

*Includes Concept/Early Planning, Consent Application Submitted, Consent Authorized, Fully Commissioned, Pre-Construction, as of February 2022. See Existing OSW Pipeline.

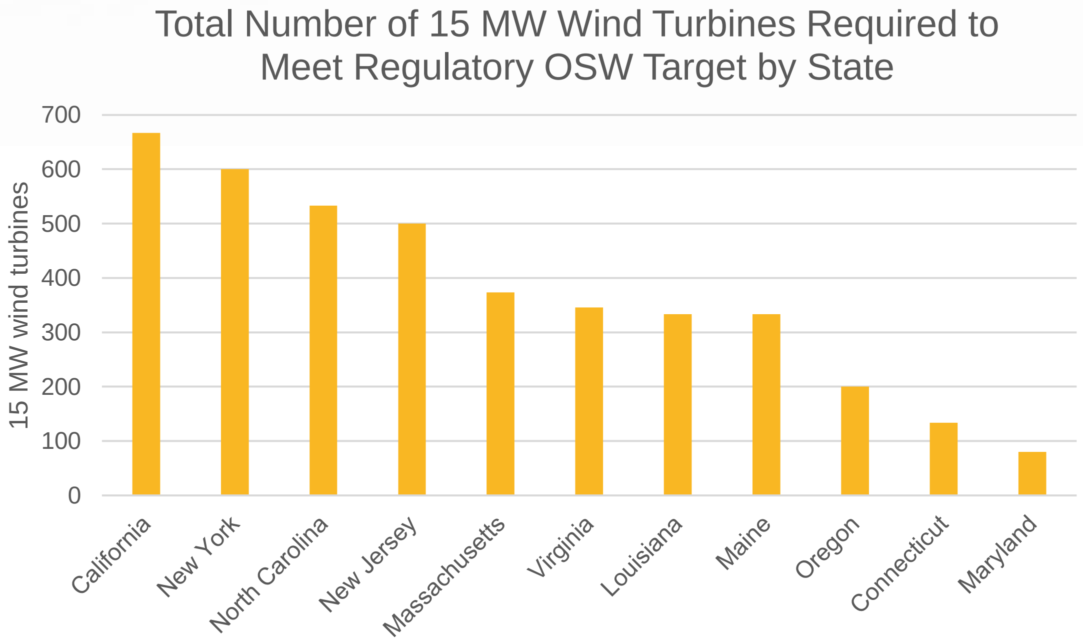
US Offshore Wind Call Areas as of May 2021



Map Source: US DOE – Offshore Wind Market Report: 2021 Edition

Turbine Installations Required to Meet OSW Targets (by State)

- Nine out of eleven states' OSW targets set through legislation. One is set by a Climate Action Plan, and one is set by Governor's Executive Order.
- West Coast projects will need to be floating projects while East Coast and Gulf of Mexico can install fixed bottom (where possible) combined with floating.



State	Number of Years to Meet Final Target***	Total # of Wind Turbines To Meet Target GW**	Avg. # of Wind Turbines/Year
California*	17	0.59	667
New York	11	0.82	600
North Carolina	12	0.67	533
New Jersey	11	0.68	500
Massachusetts	3	1.87	373
Virginia	6	0.86	346
Louisiana	3	1.67	333
Maine	2	2.50	333
Oregon*	1	3.00	200
Connecticut	2	1.00	133
Maryland	5	0.24	80

**Note: CA and OR targets are based on planning studies (no official policy/goal).*
***Assuming 15 MW nameplate capacity per turbine.*
****Based on project experience of when OSW will most realistically first be deployed. This is the expected first year of any OSW project being completed in the state.*

Ports and Vessels

Ports and Vessels Summary

Research Question

What are the critical characteristics of ports needed to meet offshore wind capacity targets in California? What ports in California or on the West Coast, if any, are ready to support floating offshore wind deployment? What types of vessels are needed for floating offshore wind in California? Which vessels are already available to serve FOSW deployment in California, and which vessels could jeopardize meeting offshore wind capacity targets in California?

Research methodology

Guidehouse reviewed literature and existing studies around ports and vessels for offshore wind fabrication, assembly, deployment, and installation to determine the critical characteristics of ports and vessels for offshore wind and assess the readiness level of ports and vessels for offshore wind deployment in California. Guidehouse also synthesized industry expert opinions on ports and vessels requirements and port readiness in California.

Conclusions

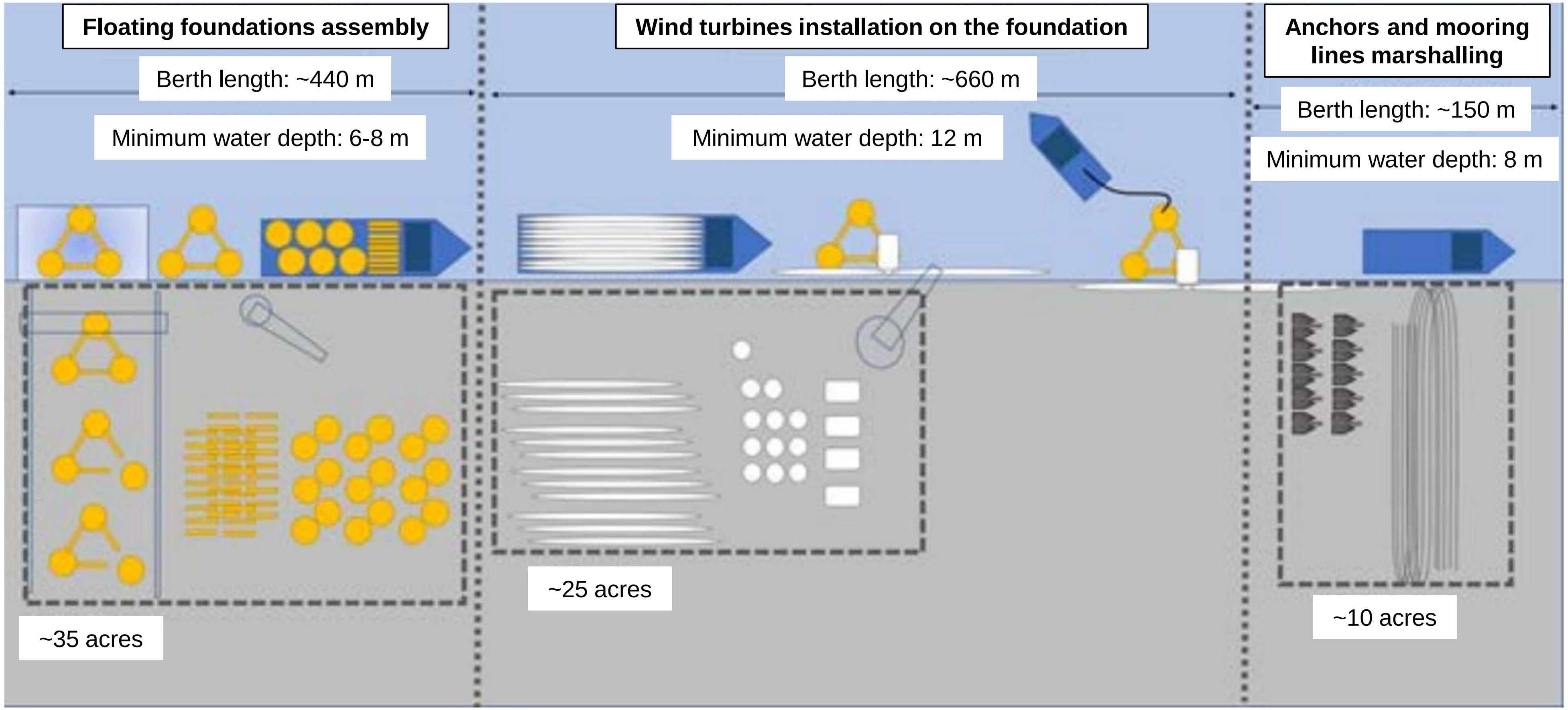
No port on the West Coast is currently ready to support commercial-scale floating wind energy deployment. Industry experts stressed that ports in California are not currently ready for offshore wind development and that port development needs to begin as soon as possible. Additionally, no Jones Act-compliant vessels currently exist in California to serve the offshore wind industry. Wind turbine installation vessels are not typically deployed for floating offshore wind. Of the types of vessels needed, service operating vessels and crew transfer vessels pose the biggest risk to FOSW deployment in California.

Key Port Characteristics

Characteristic	Details
Channel and berth depth	Floating foundations require a water depth of more than 12m to integrate wind turbines up to 10MW. As turbine capacity increases, depth requirements will increase as well. Barge and semi-submersible foundations have a shallower draft, whereas spar-buoy and tension leg platforms have a deeper draft.
Overhead air draft	Floating wind turbines are most likely to be assembled at the port (unlike fixed-bottom turbines, which are assembled at sea), so they require overhead air draft. Ports with air draft restrictions, such as bridges, will likely not be serviceable for floating offshore wind.
Storage, laydown, and staging area	Adequate portside area for storage (wet or dry), laydown, and staging of components. For 10MW turbines, about 12-16 hectare of space is needed.
Assembly area	For portside assembly, access to a high-capacity, deep-water dock is required. Portside assembly is also limited by the availability of cranes, space, draft, and carrying capacity.
Load-bearing capacity	The pre-assembly port storage area must accommodate a minimum surcharge load of 15 ton per square meter (t/m^2) as a uniform distributed load. Areas for heavy lifting crane operations must accommodate a minimum surcharge load of 30-40 t/m^2, and a maximum surcharge load of 50-80 t/m^2.
Quayside length	The total length where vessels may dock (divided into berths), and a key driver for foundation fabrication and assembly, wind turbine installation, and anchor/mooring marshalling. This is one of the most limiting parameters for offshore wind energy deployments, as quayside length costs can be quite high due to cross-industry competition.
Quayside area for manufacturing	As turbines get larger, it becomes more difficult to transport components by ground transportation. Portside facilities for component manufacturing can reduce logistics costs but require additional space. Concrete foundations, specifically, require a large quay area for fabrication.
Crane lifting capacity and height	Cranes will be required to lift around 600-1200 tons to install rotor-nacelle assemblies for 10-15MW turbines and will be required to reach hub heights of approximately 150 meters.

Activities and Minimum Port Requirements for Fabrication and Marshalling at a Floating Wind Port

Activities



Minimum Port Requirements

Parameter	Minimum Value
Draft (wind turbine installation)	12 m
Air draft	150 m
Laydown area (total)	70 acres
Quayside length	660 m
Bearing capacity	15 t/m^2

Illustration and table reproduced from: NREL's report on the Demand for a Domestic Offshore Wind Energy Supply Chain

West Coast Ports Assessment

Based on NREL's report on the Demand for a Domestic Offshore Wind Energy Supply Chain. See the report for more detailed characteristics of each port.

Port Name	State	Readiness level and requirements not met for FOSW deployment
Seattle	WA	Channel depth, bearing capacity
Astoria	OR	Laydown area, bearing capacity
Coos Bay	OR	Bearing capacity, quayside length
Humboldt Marine Terminal	CA	Channel depth
Morro Bay	CA	Laydown area, quayside length, berth/channel depth, bearing capacity
San Francisco	CA	Laydown area, bearing capacity, air draft
Oakland	CA	Bearing capacity, air draft
Richmond	CA	Bearing capacity, air draft
Benicia	CA	Bearing capacity, air draft
Hueneme	CA	Berth depth
Los Angeles	CA	High congestion
Long Beach	CA	High congestion
San Diego	CA	High congestion

Color legend
Green: Port meets all minimum requirements for FOSW deployment
Yellow: Port does not meet one minimum requirement but meets all others (with leniency if a port is close in some categories)
Red: Port does not meet two or more minimum requirements

The West Coast does not have any ports ready to support commercial-scale floating wind energy deployment. West Coast ports can be clustered into the following three groups:

- **High potential infrastructure readiness, but limited berth or laydown space for OSW:** Long Beach, Los Angeles, Seattle
- **Significant limitations that impact OSW development:** San Francisco Bay area ports, San Diego
- **Near offshore wind energy development areas, but lack adequate infrastructure:** Humboldt Bay, Hueneme, Morro Bay

Vessels Needed for Installation and O&M in California

Installation	Operations & Maintenance
• Cable laying vessels • Components mobilization vessels (roll-on/roll-off vessels) • Long haul tugs • Anchor handling vessels	• Inspection vessels • Service operating vessels • Crew transfer vessels • Heavy lift vessels • Long haul tugs

Jones Act Considerations

The Jones Act requires that only U.S.-built-and-operated ships can move goods between U.S. ports. In Rhode Island, the Block Island Wind Farm was built using foreign-flagged wind turbine installation vessels (WTIVs), with Jones Act-compliant feeder vessels bringing components from US ports to the installation site. In Virginia, Dominion Energy is currently investing in building the first Jones Act-compliant WTIV in the U.S.

While WTIVs are considered a major bottleneck for fixed-bottom offshore wind, WTIVs are not typically needed for floating offshore wind installation, as turbines will be mounted on the floating foundations at the port and floated out to the installation site. A Jones Act-compliant fleet exists for long haul tugs and anchor handling vessels, and cable laying vessels are currently exempt from the Jones Act. Interviewed experts stressed that the Jones Act is a barrier to offshore wind in California, particularly for service operating vessels and crew transfer vessels, but that the need for Jones Act compliance could present an opportunity for shipbuilding in California.

The following slide presents an evaluation of the risk different types of vessels pose to deployment of offshore wind in California, based on cost, demand, and availability of Jones Act-compliant vessels.

Vessels Needed for FOSW: Risk Evaluation

Based on NREL's report on the Demand for a Domestic Offshore Wind Energy Supply Chain. See the report for more details on each vessel type.

Vessel Type	Estimated Cost	Estimated Construction Time	# Existing	Risk Level
Cable laying vessel	$250 million	3 years	0	
Feeder barge/vessel	$150-200 million new; $10-20 million retrofit	Depends on design	20 jack-ups, 44 barges	
Service operating vessel	$50-100 million new; $10-50 million retrofit	2-3 years	0 (2 under construction)	
Lift vessels (for installation and O&M)	--	--	18	
Anchor handling vessel	--	--	Widely available	
Additional support vessels	--	--	Widely available	
Survey vessels	--	--	Widely available	
Dredging barge/vessel	--	--	Widely available	
Crew transfer vessel	$5-10 million	--	3, but similar widely available	
Tug	--	--	Widely available	

Color legend
Green: Vessel class is already widely available in the U.S. Costs and construction time are not estimated.
Yellow: Additional vessels will be required. New vessels are either relatively inexpensive to build (<$100M), have relatively low demand (1-2), can be European-flagged, or can be retrofits.
Red: Additional vessels will be required. New vessels are either relatively expensive (>$100M), have relatively high demand (>2), or are highly specialized designs that require new builds in the U.S.

Cable laying, feeder, and service operating vessels pose the biggest risk to floating offshore wind deployment in California. Wind turbine installation vessels (jack-up vessels) are not normally deployed for floating offshore wind, so they are not included on this slide.

Interview Insights: Ports and Vessels

- **Ports are a huge pinch point for offshore wind development in California**, as no existing California ports are currently ready for offshore wind. Port development needs to begin as soon as possible, and a purpose-built port may be necessary.
- **Different functions can be divided between multiple ports**: final assembly ports have many more requirements than supply chain ports, which feed up to final assembly ports. Supply chain ports are much easier to develop, as are operations and maintenance ports.
- California should **think of the West Coast as a region** and consider the role Oregon and Washington can play, especially for port space requirements. Coos Bay in Oregon is a promising candidate for port development.
- **Investment in ports** will attract project developers and component fabricators.
- It will be **difficult for ports to remain technology-agnostic** for different turbine foundation types.
- **A secure pipeline of projects is necessary** if a Jones Act-compliant vessel is to be built on the West Coast.

Major Offshore Wind Manufacturers

Major OSW Component Manufacturers

Research Question

Who are the global players that currently make turbines, towers, blades, floating platforms, mooring systems, inter-array cable manufacturers; where are they located; what U.S. or California presence do they have (if any)?

Research methodology

Guidehouse pulled manufacturing data for each relevant system component from an international offshore wind database ("offshore database"). Manufacturers were examined by quantifying and comparing the number of wind farms and cumulative OSW capacity with which their components are associated. After selecting the firms with the largest global market share, Guidehouse researched each company individually to find the locations of manufacturing facilities and determine whether each manufacturer has a U.S. and/or California presence.

For turbine manufacturers, Guidehouse excluded Chinese firms as historically these firms have not been able to enter the offshore wind markets beyond China. It is also worth noting that unless stated otherwise, this analysis focuses on *offshore* wind component manufacturers since the database focuses exclusively on offshore projects. For some components, there could be overlap between offshore and onshore manufacturers, although the component size will vary significantly. Our analysis assumes an average capacity of 15 MW for OSW turbines.

Conclusions

While several manufacturers with a large global market share have existing or planned manufacturing presence in the United States, none have OSW capable manufacturing facilities in California or elsewhere on the West Coast.

Assumptions and notes

Assumptions

- When analyzing manufacturers and wind farms in the offshore database, Guidehouse focused on projects that were fully commissioned as of April 2022. Projects that were planned or under construction were excluded from the analysis, as the manufacturing data was less clear.
- The capacity values and company presence information are not guaranteed to be correct. It is possible that errors in the database resulted in some farms and capacity being mistakenly attributed or not attributed to the correct manufacturer. Where possible, Guidehouse compared capacity statistics reported by companies and various public reports to the numbers calculated from the offshore database to ensure accuracy. However, this information is often not published by companies, especially for smaller components such as mooring, anchoring, and cabling, making this QC process unfeasible at times.

Notes on column definitions (example below)

- *Aggregate capacity* does **not** refer to the installed capacity of wind farms developed by the corresponding company in “Manufacturer name.” Rather, it refers to the MW a company's manufactured component have been used for, regardless of project developer. The same is true for the # of farms column.
- *Manufacturer home country* is the location of the company’s headquarters.
- *Presence in the U.S.* is defined as “Yes” if the company has some manufacturing capacity for this component in the U.S, and “No” otherwise. *Presence in California* is the same, but for California only. In many cases, Guidehouse was unable to determine this based on publicly available data, and these rows will accordingly say “Unclear.”
- *Merger notes* contains information on how mergers and acquisitions may have affected capacity, farms, and location information for a given firm. All subsidiaries and acquired companies have been combined into a single entry (the parent/acquiring company) where possible.

Manufacturer name	Aggregate capacity (MW)	# of farms	Manufacturer home country	Presence in the U.S.?	Presence in California?	Merger notes	Capacity & Location Notes
<company name>	X,XXX	XX	<country name>	Yes/No/ Unclear	Yes/No/ Unclear	<details on mergers>	<details on facility locations>

Manufacturers in California: Summary

For many offshore wind components, manufacturer presence in the U.S. is limited and located outside of California. The following list summarizes the information collected in this section of the report.

- **Blades:** 4 major firms with confirmed manufacturing capacity in the U.S., none in California.
- **Turbines:** 3 major firms with confirmed manufacturing capacity in the U.S., none in California.
- **Towers:** 2 major firms with planned manufacturing capacity in the U.S., although one is still planning its manufacturing facility and the other isn't confirmed to fabricate offshore towers. None in California.
- **Platforms:** 2 platform manufacturers/engineers with confirmed manufacturing capacity in the U.S. None in California.
- **Mooring:** Not enough data in the offshore database or publicly available to analyze wind-farm grade mooring. However, mooring and anchoring manufacturers that produce for other purposes do exist in California.
- **Cables:** 6 major firms with confirmed manufacturing capacity in the U.S., none in California.

Many firms do not publicly list the locations and details of their manufacturing facilities, and as such Guidehouse was unable to confirm U.S. and CA presence for these companies. This could be an area for more targeted research in the future.

Despite domestic content being relatively strong for larger components of land-based wind plants, the offshore wind supply chain is very limited, apart from some manufacturing of applicable electrical equipment and cabling. While several manufacturers have announced the intent to begin production at U.S. facilities in the coming years, there are no existing or planned facilities located on the West Coast.

Major OSW Manufacturers: Blades

During the research, there was limited availability of information, both public and from the offshore database, regarding blade manufacturing specifically for OSW. Since there is little differentiation in published material between onshore and offshore blade manufacturing capacity, the table below likely includes and favors onshore blade manufacturing, unlike other slides and components in this section that focus on offshore manufacturing capabilities more exclusively.

Manufacturer name	Aggregate capacity (MW)	# of farms	Manufacturer home country	Manufact. in the U.S.?	Manufact. in California?	Merger notes	Location Notes
General Electric	1,176	13	United States	Yes	No	Includes capacity from LM Wind Power, a company from Denmark which was purchased by GE in 2017 but has been making blades since 1978.	Production facility in North Dakota.
Siemens Gamesa Renewable Energy	Unknown	Unknown	Spain	Yes	No	Includes blades produced by Senvion, which was purchased by Siemens in 2019.	R&D Center in Boulder Colorado. Onshore blades factories in Kansas and Iowa. Service offices are in Colorado and Florida, although it's unclear what purpose they serve. Additionally, in 2021, Siemens Gamesa announced plans to construct a blades factory at the Portsmouth Marine Terminal in Virginia, $200 million investment.
Vestas	Unknown	Unknown	Denmark	Yes	No		Blade, nacelle, and tower production in Colorado.
Goldwind	Unknown	Unknown	China	No	No		Manufacturing plants in located in China. However, company official stated that they are investigating opportunities for Goldwind to participate in the local supply U.S. supply chain.
TPI Composites	Unknown	Unknown	United States	Yes	No		Announced plans to open a wind blade innovation center in Massachusetts That would support manufacturing facilities, also offers limited production capacity for offshore wind turbine blades.

Major OSW Manufacturers: Turbines

These companies in this list account for most of the global installed floating capacity. Siemens Gamesa, when combined with its subsidiary companies, dominates the industry. Chinese companies Envision and Goldwind are major manufacturers but have focused on developing turbines within their home country and thus are not listed in the table below.

Manufacturer name	Aggregate capacity (MW)	# of farms	Manufacturer home country	Manufact. in the U.S.?	Manufact. in California?	Merger notes	Location Notes
Siemens Gamesa Renewable Energy	19,155	105	Spain	Yes	No	Includes capacity of all subsidiaries and mergers, such as Senvion GmbH, which it acquired in 2019, as well as Adwen, formerly known as Areva, and Bonus, which it acquired in 2005.	R&D Center in Boulder Colorado. Factories in Iowa, Kansas, and Virginia. Service offices in Colorado and Florida.
Vestas Offshore Wind	7,622	53	Denmark	Yes	No	Contains all shares of joint venture with MHI, which Vestas acquired in 2020.	Blade, nacelle, and tower production in Colorado. Nacelle assembly facility announced at the New Jersey Wind Port.
General Electric	664	10	United States	Yes	No	GE acquired manufacturer Alstom in 2014.	Onshore wind turbine machine head/hubs assembly facility in Florida. Nacelle assembly facility announced at the Paulsboro Marine Terminal in NJ, partnering with Orsted. Turbine engineering office in South Carolina. HQ/engineering office in New York.

Major OSW Manufacturers: Towers

Guidehouse believes there should be additional capacity data included in this list, but during the research, there was limited availability of information, both public and from the offshore database. The summary of the available data on tower manufacturers globally offers a glimpse into the relative prevalence of manufacturers by region. Europe and China dominates tower manufacturing, with European firms taking the lead and representing roughly 60% of commissioned capacity in the data available, and Chinese firms constituting roughly 30%.

Manufacturer name	Aggregate capacity (MW)	# of farms	Manufacturer home country	Manufact. in the U.S.?	Manufact. in California?	Merger notes	Location Notes
Windar Renovables	2,318	11	Spain	No	No		Factories in Spain, India, Brazil, Mexico, Russia.
Ambau	2,273	11	Germany	No	No		Appears to focus on European offshore wind.
Welcon AS	1,346	4	Denmark	No	No		Appears to focus on European offshore wind.
Fuchuan Yifan New Energy Equipment	1,148	5	China	Unclear	Unclear		Insufficient data to determine office locations.
Jiangsu Haili Wind Power Equipment	849	3	China	Unclear	Unclear		Products are marketed throughout China. Most likely no presence in U.S. or CA.
CS WIND CORP	779	2	South Korea	No	No		Locations in China, Malaysia, Taiwan, Turkey, UK, Vietnam
Haizea Windgroup	752	1	Spain	No	No		Factories in Argentina and Spain.
Marmen, Welcon	Unknown	Unknown	France, Denmark	Yes	No		These companies announced the development of a tower manufacturing facility in the Port of Albany, New York, $350 million total investment
GRI Renewable Industries	Unknown	Unknown	Spain	Yes	No		Towers manufacturing center in Texas, but it's unclear if they're capable of producing offshore towers as well. Poised to supply offshore towers for Europe from a separate factory in the UK.

Major OSW Manufacturers: Floating Platforms

Due to the incipient nature of floating wind, there are no companies with substantial foundation production capabilities as most foundation designs are in earlier stages of development than other FOSW components. Most manufacturers are still testing designs in demonstration projects rather than supplying several units to the market. As such, the offshore database and additional secondary research done by Guidehouse had limited results. The table below, pulled directly from Wind Europe's September 2020 paper on ports, contains relevant information on foundation manufacturers. Neither of the U.S. manufacturers have facilities in CA.

	Technology developer	Concept name	Country	Material	Part-scale demonstration	Full-scale demonstration	Pre-commercial deployment	Commercial deployment	Units installed and cumulative capacity (MW)
Semi-Submersible	Principle Power	WindFloat	US	Steel		2011	2019	2025	4 (27.2 MW)
	Naval Energies	Semi-submersible	France	Hybrid			2022	2025	
	Mitsubishi Heavy Industries	MHI 3 column V-shape	Japan	Steel		2016			1 (7 MW)
	Mitsui Eng. & Shipbuilding	Compact semi-sub	Japan	Steel		2013			1 (2 MW)
	GustoMSC	Tri-Floater	Netherlands	Steel		TBD			
	Aqua Ventus Maine	VolturnUS	US	Concrete		2022			
	SAIPEM	HexaFloat	Italy	Steel	2020	2022		2030	
	Nautilus	Nautilus	Spain	Hybrid		2021			
	Dolfines	TrussFloat	France	Steel		2022	2022	2025	1 (.17 MW)
	EOLINK	EOLINK	France	Hybrid		2022			1 (.2 MW)
	UoU, Mastek, Unison & SEHO	UOU 12-MW FOWT	South Korea	Steel	2020	2021		2025	
Barge	IDEOL	Damping Pool	France	Concrete		2018	2022	2025	2 (5MW)
	SAITEC	SATH	Spain	Concrete	2020	2021		2025	1 (.03 MW)
Spar-Buoy	Equinor	Hywind	Norway	Hybrid	2001	2009	2017	2024	6 (32.3 MW)
	Toda Corporation	TODA Hybrid spar	Japan	Hybrid		2016	2021		1 (2 MW)
	JMU	Advanced Spar	Japan	Steel		2016			1 (5 MW)
	Stiesdal	TetraSpar	Denmark	Steel		2020			
	SeaTwirl Engineering	SeaTwirl	Sweden	Hybrid		2020			1 (.3 MW)
	ESTEYCO	TELWIND	Spain	Concrete		TBD			
TLP	SBM Offshore & IFP Energies Nouvelles	Inclined-leg TLP	Netherlands & France	Steel			2021		
	GICON GmbH	GICON-SOF	Germany	Steel		TBD			
	Iberdrola	TLPWIND	Spain	Steel		TBD			
	X1WIND	X1WIND	Spain	Hybrid	2020	TBD			
	Hexicon	Hexicon	Sweden	Steel		2021		2025	
	FLOW Ocean	FLOW	Sweden	Steel		2021			

US based technology developer in light blue shaded cells.

Major OSW Manufacturers: Cables (Export + Inter Array)

Guidehouse was unable to QC the aggregate capacity for cable manufacturers from various sources. The reasons were that cable manufacturers do not typically list the projects or capacity in MW their cables have been associated with and usually do not work exclusively on offshore projects.

Manufacturer name	Aggregate capacity (MW)	# of farms	Manufacturer home country	Manufact. in the U.S.?	Manufact. in California?	Merger notes	Location Notes
Prysmian Group	9,435	37	Italy	Yes	No	Includes Germany company NSW, acquired in 2018, as well as Dutch company Draka, acquired in 2011.	Multiple manufacturing facilities in South Carolina.
JDR Cable Systems Ltd	8,826	23	United Kingdom	Yes	No		Service center in Houston that assembles, integrates, and tests cables. Offers management and engineering support to projects in the Gulf of Mexico.
Nexans	7,167	23	France	Yes	No	Contains German, French, and Norwegian sub-companies.	High-voltage cable facilities in South Carolina and Maryland. Service centers throughout U.S.
Ningbo Orient Wires & Cables	4,497	19	China	Unclear	Unclear		Offices in Ningbo, China and San Jose, CA, United States. No info on manufacturing.
Jiangsu Zhongtian Technology	4,312	21	China	Unclear	Unclear		Insufficient data to determine manufacturing locations, but company focus is China and East Asia -- U.S. and California manufacturing presence unlikely.
Qingdao Hanhe Cable Co	2,546	12	People's Republic of China	Unclear	Unclear		Insufficient data to determine manufacturing locations, but company focus is China and East Asia -- U.S. and California manufacturing presence unlikely.
Kerite, Marmon Group	N/A	N/A	America	Yes	No		Operational array cable manufacturing in Connecticut
Siemens Gamesa	N/A	N/A	Spain	Yes	No		OSW cable factories in Charleston, SC and Brayton Point, MA
Hellenic Cables	N/A	N/A	Greece	No	No		Production spread across Greece, Romania, and Bulgaria
LS Cable & System	N/A	N/A	South Korea	Yes	No		Presence appears to be limited to the East Coast. Major player in Europe and Asia.
NKT	N/A	N/A	Denmark	No	No		Manufacturing plants across Europe.
Sumimoto Electric	N/A	N/A	Japan	Unclear	Unclear		Several manufacturing plants through the U.S. and one in California, but it is unclear if these plants produce cables capable of serving wind farms or other products.

Manufacturing Needs and Current Manufacturing Capacity

Manufacturing Needs & Current CA Capacity

Research Question

To meet a given California capacity planning goal target, what is needed in terms of the number of each major component, size/type of component, raw materials to make them, and manufacturing processes to make them? How does this compare to existing manufacturing capacity in California, based on top-down statistical data?

Research methodology

To determine manufacturing needs, Guidehouse reviewed manufacturing and design reports for key FOSW turbine components, as well as manuals and websites from component manufacturers. Values are calculated for a 2 GW wind plant, based on Scenario 1 from the Workforce section (a tender for a 2 GW plant every 3 years). To quantify existing manufacturing capabilities, Guidehouse mapped all material and capital inputs that are part of the FOSW supply chain and used the U.S. Economic Census to identify the monetary value of various related industries. This dollar value was then converted to capacity through dimensional analysis. The research approach is discussed in more detail within the section.

Conclusions

Due to the specialized nature of many FOSW components, the existing manufacturing capacity is close to zero for most industries. This is especially true for steel production, fabrication, and casting; on the other hand, California has sufficient concrete manufacturing and production for FOSW needs. However, many adjacent industries or existing steel fabrication centers could be retooled or upgraded in order to produce FOSW systems.

Existing Manufacturing Capacity (CA): Research Approach

1. Mapping materials and capital inputs through the FOSW supply chain

Guidehouse mapped all value segments in the FOSW supply chain and identified the materials, services, and infrastructure used in each of the value segments. The result of the mapping provided a comprehensive view of the manufacturing capabilities involved in FOSW development and allowed for targeted research into California's existing manufacturing capacity. The result is the diagram summarizing the supply chain in the introduction of the report.

2. Connecting mapped inputs to data from the U.S. Economic Census

The U.S. Economic Census is performed every 5 years by the U.S. Census Bureau and provides industry-specific economic statistics at the statewide level. These statistics include # of firms, # of establishments, and total value of sales for each industry.

For each material and capital input found in step 1, Guidehouse found the corresponding industry in the Census Bureau for California. This allowed for analysis of the existing capacity of industries related to the future FOSW chain in California.

3. Dimensional analysis using U.S. Economic Census and research data

Because the U.S. Economic Census provided industry capacity in terms of total sales ($), some unit conversions and assumptions were needed to estimate each industry's ability to contribute to a potential 10 GW FOSW target. The dimensional analysis methodology Guidehouse applied is summarized on the following slide. This analysis was paired with secondary research and interviews with industry experts to draw conclusions on the manufacturing capacity in California.

Due to the specialized requirements for FOSW manufacturing, many processes, components, and materials lacked an exact match in the U.S. Economic census.

- If an industry in the Census represented a broader version of a specialized FOSW input, it was assumed the entire industry could be converted to develop the FOSW input, and the census data was used as-is to represent a rough upper bound on existing California manufacturing.
- If a corresponding industry to a FOSW input could not be found in the U.S. Economic census, or data within the census itself was missing, Guidehouse was unable to calculate statistics for every FOSW input identified in step 1. Where possible, these inputs were supplemented with analysis by Guidehouse subject matter experts as well as interviews and secondary research.

OSW Manufacturing Needs: Manufacturing Processes

The table summarizes the OSW manufacturing processes that are part of producing OSW system components.

Component	Process
Blades, nacelle housing	Molded glass fiber reinforced plastic (fiberglass); glass fiber laid out and epoxy pulled over with a vacuum pump
Nacelle frame	Front frame is casted steel; rear frame is formed and welded steel
Towers	Rolled/bent steel, welded flanges, bolted together during assembly
Floating foundations (steel, specifically for the TetraSpar)	Rolled/bent steel or steel plates + welding, bolted together during assembly
Floating foundations (concrete)	Reinforced steel is placed, formwork is erected, concrete is cast and cured; whole concrete structure can be cast sequentially or separate elements can be precast then assembled
Mooring lines (steel)	Steel bars heated, bent into chain links, and welded
Mooring lines (synthetic)	Parallel laid polyester sub-ropes, then laid parallel with a braided outer polyester jacket
Anchors (driven pile)	Rolled and welded steel tubes
Electrical cables	Small wires wound into a larger conducting core, then coated with insulation (e.g., cross-linked polyethylene), then encased with an extruded sheath (e.g., lead) and an outer layer of steel wiring

OSW Manufacturing Needs: Material Assumptions

Using SB 100 target of 10 GW between 2030 and 2045, assuming a 2 GW tender every 3 years consisting of 134 15 MW turbines. A 2 GW wind farm will need the following quantity of materials:

Component	Quantity (Total Length)	Material(s)	Unit Weight	Total Weight
Towers	134	Steel	860 tons/tower	115,300 tons
Blades	402	Fiberglass	65 tons/blade	26,130 tons
Nacelles	134	Copper, steel, fiberglass	700 tons/nacelle (full assembly)	93,800 tons (full assembly)
Floating foundations (semi-sub)	134	Steel or concrete	6,000 tons/structure (steel); 22,500 tons/structure (concrete)*	804,000 tons (steel); 3,015,000 tons (concrete)
Mooring lines	402**	Steel or synthetic rope (polyester or HMPE)	113 kg/m (steel); 26.5 kg/m (polyester)	146,000 tons (steel); 35,000 tons (polyester)
Anchors (driven piles)	402	Steel	200 tons/anchor	80,400 tons
Array cables (66kV, 630mm)	134*** (225,000 mi)	Three-core aluminum conductor, lead sheath	40.1 kg/m	9,030 tons
Export cables (220kV, 1000mm)	6**** (120 mi)	Three-core aluminum conductor, lead sheath	85.1 kg/m	16,450 tons

** Estimate of the weight of concrete foundations based on existing pilot projects*
*** Assuming 3 mooring lines per turbine, unit length of 3200m per line*
**** Assuming turbine spacing of 7 times rotor diameter, unit length of 1680m per cable*
***** Unit length of 20 miles based on distance to shore from BOEM assessments of Humboldt and Morro Bay*

Existing Manufacturing Capacity: Dimensional Analysis

Dimensional analysis using U.S. Economic Census and research data

Starting value

$$\frac{\text{Total annual industry sales (\$)}}{\text{Industry output unit price (\$)}} \rightarrow \frac{\text{Industry output units available}}{\text{Industry units per FOSW component}} \rightarrow \frac{\text{\# FOSW components the industry could build} \times \text{MW per FOSW system component}}{1000} \rightarrow \frac{\text{MW the industry could contribute to}}{1000} \rightarrow \frac{\text{California GW target} \div 15}{\text{GW the industry could contribute to}} \approx \text{\% of annual industry capacity a 10GW target would require}$$

Ending value

- **Total value of industry sales:** the annual value of shipments or sales of a particular industry in the 2017 Economic Census. *Source: 2017 Economic Census. Example: ready mix concrete industry valued at $3,180,338,000.*
- **Industry output unit price:** the value of a single unit of an industry's product. *Source: Guidehouse market research. Example: ready mix concrete is $62.5/ton*
- **Industry output units available:** the estimated number of units the industry would produce in a year. *Example: $3,180,338,000 / $62.5 = 50,885,408 tons of concrete*
- **Industry units per FOSW component:** the number of units required to produce the FOSW system component for which the industry is used. *Source: Guidehouse research and internal analysis. Example: 22,500 tons of concrete per floating turbine foundation.*
- **# FOSW components the industry could build:** the number of FOSW system components (such as blades, towers, cables, etc.) the industry could build given it's estimated annual capacity. *Example: 50,885,000 tons of concrete / 22,500 tons of concrete per foundation = 2,262 foundations*
- **MW per FOSW system component:** the number of MW a single FOSW system component supplied by the industry can support. *Source: Guidehouse research and internal analysis. Example: 15MW per foundation.*
- **MW the industry could contribute to:** The total capacity the industry can support in a year, given the number of components the industry can build and the MW that those components will enable. *Example: 2,262 foundations x 15 MW per foundation = 33,924 MW = 34 GW*
- **% of annual industry capacity a 10GW target would require:** The proportion of annual industry capacity that a 10GW target, annualized over 15 years, would require. *Example: 10 GW divided over 15 years = .667 GW per year. 0.667 GW / 34 GW = 2%.*

Existing Manufacturing Capacity (CA): Raw Materials (Tier 3)

Industry	# firms	# employees	% of industry capacity required	Notes
Concrete manufacturing	112	8,808	2%	Substantially more concrete in CA than would be required by target
Primary Steel manufacturing	0	0	--	There is no primary steel production in CA. Will need to import from U.S. or global market.
Glass fiber reinforced plastic	--	--	--	No corresponding industry in the U.S. Economic Census. Since blades are relatively easy to ship, look to U.S. or global market.
Copper production	--	--	--	No corresponding industry in the U.S. Economic Census. Since relatively little copper is used in the FOSW system, and it is easy to ship, look to U.S. or global market.
Aluminum production	--	--	--	Data unavailable. Not a major input to FOSW, could possibly be used as a substitute for copper. Look to U.S. or global market.

- Experts have expressed concerns about the economic viability of creating primary steel production in California or scaling/upgrading secondary fabrication capabilities, as this might represent a substantial investment in firms that would go obsolete after FOSW buildout is complete.
- The industry is still weighing whether it is best to use copper or aluminum as conductors. Aluminum might fatigue less than copper.

Existing Manufacturing Capacity (CA): Fabrication (Tier 2)

Industry	# firms	# employees	% of industry capacity required	Notes
Concrete product manufacturing	111	4,986	16%	Concrete products except block, pipes, and bricks.
Steel product fabrication	57	1,653	52%	Covers rolling and drawing of purchased steel, as well as steep pipe and tube manufacturing.
Steel investment casting	8	926	23%	For casting some of the nacelle parts.
Aluminum drawing	--	--	--	Guidehouse subject matter experts assume this will not be local content - small amounts of aluminum wire are relatively easy to ship. This is consistent with the JEDI model.
Copper drawing	--	--	--	Guidehouse subject matter experts assume this will not be local content - small amounts of copper wire are relatively easy to ship. This is consistent with the JEDI model.

- These statistics most likely represent the capabilities of industries adjacent to FOSW, but not necessarily able to produce the end products needed of FOSW systems. These industries will require upscaling or investment in equipment to convert to FOSW production. Example: existing steel rollers don't have the equipment to produce the steel large enough for monopiles, but a grant program could be used to purchase that equipment. These sorts of industry conversions have already been observed on the east cost.
- Experts mention that key elements of the manufacturing chain such as cable production, are already global and CA will be unable to capture. The extent of stimulated local content will depend on CA's priorities, policies, and requirements.

Existing Manufacturing Capacity (CA): Parts Production (Tier 1)

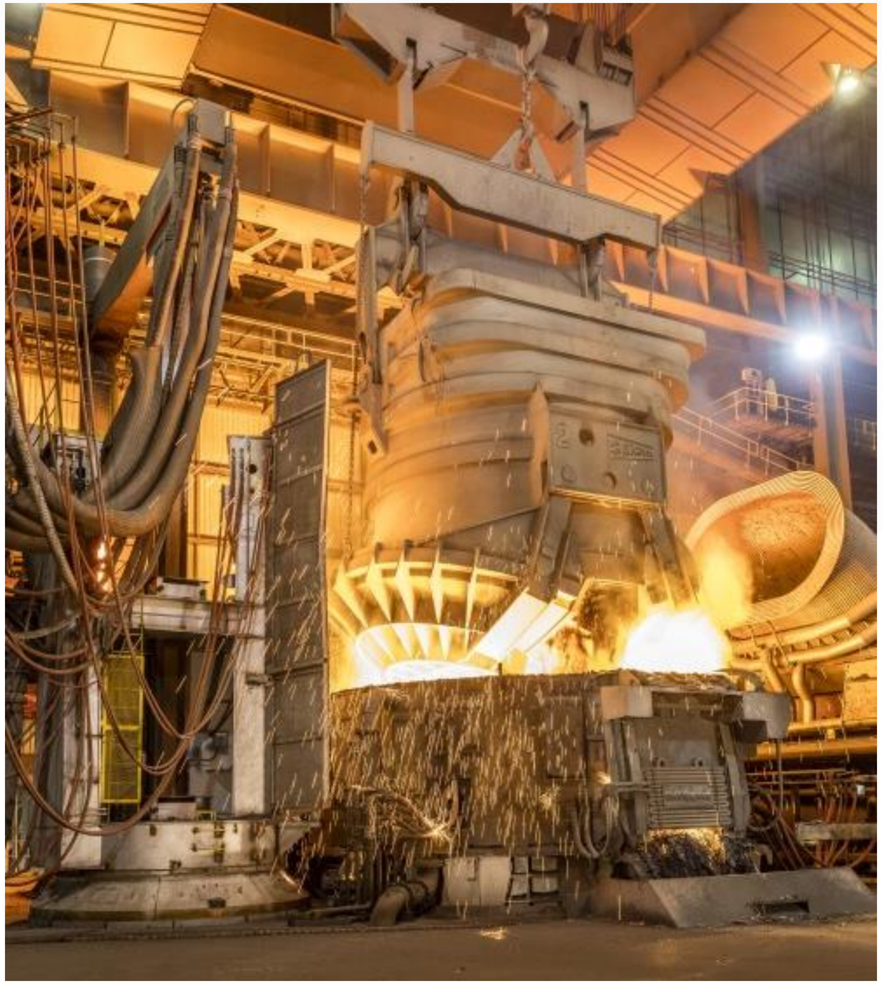
Industry	# firms	# employees	% of industry capacity required	Notes
Gear/transmission equipment assembly	26	1,136	78%	Use: Drivetrain component of nacelle module
Turbine generator set manufacturing	11	6,121	26%	Use: Overall nacelle assembly, as well as assembly for tower, generator, and blades
Shipbuilding and repairing	--	--	--	No corresponding industry in the U.S. Economic Census. Furthermore, there's a significant lack of Jones Act compliant vessels capable of installing FOSW in the United states.
Steel Wire Drawing	29	567	9%	Use: structural components of cables
Submarine cable production	--	--	--	No corresponding industry in the U.S. Economic Census.
Heavy lifting machinery	--	--	--	No corresponding industry in the U.S. Economic Census.
Onshore transportation	--	--	--	No corresponding industry in the U.S. Economic Census.

- The Jones Act is a federal law that bans non-US vessels from moving between US ports. California does not currently have any Jones Act compliant vessels capable of installing FOSW.
- Additionally, there is no port deep enough on the entire west coast to handle offshore platforms, combined with the weight of turbines. Most experts interviewed agreed there's a need to dredge and build an entirely new port, purpose-built for offshore wind.

Existing Manufacturing Capacity: Conclusion

Manufacturing in California

- The “% of industry capacity required” statistics represents the GW of FOSW an industry could supply as a percentage of a hypothetical 10 GW target, annualized over 15 years. This assumes that:
  - 1) the entirety of the industry can produce specialized materials and infrastructure applicable to the FOSW space, and
  - 2) the industry will be solely devoted to producing FOSW parts over a ten-year period.
- As such, **these numbers are likely to significantly overrepresent California’s manufacturing capacity and are not meant to indicate the exact capabilities of manufacturers**.
- Due to the specialized nature of many FOSW components, the existing capacity is more likely closer to zero for most industries, in absence of retooling or upgrading facilities.
- Limited available data prevented analysis for certain material inputs or manufacturing processes in the offshore wind supply chain.
- While Guidehouse focused only on manufacturing inputs directly related to the production, assembly, and installation of the FOSW system, there are many industries that would indirectly support offshore wind that might merit further research. For example, California has a many data and technology companies that could assist in turbine monitoring and O&M.



California Supply Chain Opportunities and Constraints

CA Supply Chain Constraints & Opportunities

Research Questions

- How does the supply chain support different technologies? Which technologies allow opportunity for local content?
- What existing technologies/components of FOSW platforms and turbines are the best fit for California and what are their workforce/port/supply chain implications and costs?
- What are current supply chain constraints and opportunities for fabrication, assembly, and deployment using existing facilities and future sites in California and the other west coast states?

Research methodology

To evaluate these questions concerning the ability of various components to utilize California’s supply chain, Guidehouse synthesized internal research on manufacturing and labor needs and existing capabilities, the presence and location of major manufacturers, and the opinions of interviewed experts.

Conclusions

Towers and foundations (especially designs that favor concrete) are the most favorable options for local production in California. Blades, mooring lines, anchors, and export/inter-array cables could be produced locally or imported based on California’s local content priorities. Nacelles would be the most difficult component for local supply chain utilization.

CA Supply Chain Opportunities Overview

Component	Input type	Input	Existing manufacturing/labor capacity in California	Capacity notes	Component manufacturer presence in U.S.	Component manufacturer presence in CA	Fit for local content
Towers	Material	Steel	No existing capacity	Would need to import steel from U.S. Market. Indiana, Ohio, Pennsylvania, Texas, and Alabama are largest steel producers -- could explore option sin these states. There is some steel product fabrication in CA, but retooling would likely be needed to fit specifications.	Yes	No	High
	Process	Steel product fabrication	Low				
	Process	Turbine generator set manufacturing	Low				
	Labor	Primary steel manufacturers	No existing capacity				
	Labor	Steel fabricators	Low				
Blades	Process	Turbine generator set manufacturing	Low	Blades are easier to ship than towers, although there still might be some logistical issues as their size increases.	Yes	No	Medium
	Material	Glass fibre reinforced plastic	N/A				
Nacelle	Material	Steel	No existing capacity	Would need to import steel from U.S. Market.	Yes	No	Low
	Process	Steel investment casting	Medium				
	Process	Turbine generator set manufacturing	Low				
	Process	Gear/transmission equipment assembly	Very low				

- **High:** It makes sense to produce the component locally. This can be due to an abundance of input industry, significant employment benefits, or logistic requirements that heavily favor local production.
- **Medium:** The component could be produced locally or imported based on California's priorities (usually, limited job creation vs. cheaper importation) and the pipeline/incentives for manufacturers.
- **Low:** Due to specialized subcomponents and industrial processes, or attractive options for importation, the component would be difficult to produce locally.

CA Supply Chain Opportunities Overview (cont.)

Component	Input type	Input	Existing manufacturing/labor capacity in California	Capacity notes	Component manufacturer presence in U.S.	Component manufacturer presence in CA	Fit for local content
Foundation	Material	Steel	No existing capacity	Same steel manufacturing and fabrication issues as listed previously.	Yes	No	High
	Material	Concrete	Very high				
	Process	Steel product fabrication	Low				
	Process	Concrete casting	Medium				
	Labor	Primary concrete manufacturers	Very high				
	Labor	Concrete product manufacturers	Very high				
	Labor	Primary steel manufacturers	No existing capacity				
	Labor	Steel fabricators	Low				
Mooring lines	Material	Steel**	No existing capacity	Same steel manufacturing and fabrication issues as listed previously.	Yes*	Yes*	Medium
	Process	Steel product fabrication	Low				
Anchors	Material	Steel	No existing capacity				
Inter-array cables	Material	Copper	N/A	Small amounts of copper and/or aluminum, or steel wires, are easy to import.	Yes	No	Medium
	Material	Aluminum	N/A				
	Process	Copper drawing	N/A				
	Process	Steel wire drawing	High				
	Process	Aluminum drawing	N/A				
High voltage export cables	Material	Copper	N/A	Small amounts of copper and/or aluminum, or steel wires, are easy to import.			
	Material	Aluminum	N/A				
	Process	Copper drawing	N/A				
	Process	Steel wire drawing	High				
	Process	Aluminum drawing	N/A				

*There is limited mooring and anchor manufacturing in California, but it is unclear whether these firms can produce lines and anchors to the specifications required by utility-scale floating wind farms.

**Synthetic mooring lines are also possible. With limited time Guidehouse focused on steel. Further research is needed to identify the ability of synthetic mooring lines to utilize California’s supply chain.

CA Supply Chain Opportunity: Towers

Opportunity for CA Local Content

As it stands, California's supply chain has a relatively low ability to support tower manufacturing. California would need to import steel from other states or the global market, as well as retool or upgrade existing steel fabrication facilities in order to manufacture towers. Still, industry experts interviewed by Guidehouse generally agreed that towers would be one of the more viable components to produce locally in California, citing the difficulty of shipping pre-fabricated towers across long distances, the large number of jobs that the fabrication process could create, and the fact that East Coast states are already importing steel and fabricating the towers locally in a similar way. The existence of a significant project pipeline or incentives for manufacturers and developers could attract a tower manufacturer to create a new factory in California, as there currently are none.

Potential Workforce Development

Potential to create a substantial number of jobs associated with steel fabrication and tower assembly. Examples of specific occupations: structural metal fabricators and fitters, first-line supervisors of production and operating workers, miscellaneous metal workers, industrial machinery installation and repair workers, welding, soldering, and brazing workers, engineering technicians, transportation storage and distribution, mechanical drafters.

Port Requirements

While the tower height for floating demonstration projects has typically been in the range of 60m-100m, the height of offshore wind towers is predicted to range from 100m-150m depending on turbine capacity. Guidehouse estimates a steel tower for a 15 MW turbine could weigh around 900 tons. Due to this size and weight, onshore transportation would be incredibly difficult. Tower production must be conducted at or near a port. Offshore transportation from one port to another is common, and the tower may be transported in 2 or 3 sections that are bolted together at the final assembly port or offshore. Additionally, there must be adequate room to store the towers until final system assembly and installation.

CA Supply Chain Opportunity: Blades

Opportunity for CA Local Content

While there are blade manufacturers located in the U.S., there are none in California, and it is unclear whether the primary material input (glass fiber reinforced plastic) or relevant workforces are currently available on the West Coast. Still, experts interviewed by Guidehouse generally agreed that it would be possible to manufacture blades in California despite there being fewer advantages compared to tower manufacturing. Compared to towers, blades could more easily (and possibly at a lower cost) be shipped from the U.S. or global market, and local production would not create as many jobs compared to manufacturing processes for other components.

Potential Workforce Development

Limited opportunity for job creation compared to other FOSW components. Examples of specific occupations: miscellaneous metal and plastic workers, industrial machinery installation and repair workers, transportation storage and distribution, hoist and winch operators, engineering technicians, mechanical drafters.

Port Requirements

While blade length for floating demonstration projects has typically been in the range of 40m-80m, larger offshore turbines have resulted in blades up to 115.5mm (for the Vestas V236-15.0 MW turbine.) Guidehouse estimates a blade for a 15MW turbine could weight around 65 tons. Because blades are usually somewhat shorter and significantly lighter than towers, it would be possible to ship them pre-constructed to the final assembly port through both onshore and offshore means. However, shipping via road transportation will become increasingly difficult as blade length increases, and the method of blade delivery is something that needs to be taken into consideration. If it is not possible to manufacture at the final assembly port, blades could be produced at other ports on the West Coast or overseas markets and transported on ships. Additionally, there must be adequate room to store the blades until final system assembly and installation.

CA Supply Chain Opportunity: Nacelle

Opportunity for CA Local Content

California currently lacks the primary material production (steel), infrastructure (steel investment casting), and workforce (turbine generator set manufacturing and gear/transmission equipment assembly) capabilities necessary for Nacelle production. Experts generally agreed that Nacelle assembly in California is not currently a viable investment, as nacelles are particularly complex and specialized compared to other FOSW components. However, manufacturers have occasionally opened nacelle assembly plants in new markets, so the main question is whether the incentive for manufacturers would be large enough.

Vestas has nacelle production capabilities in Colorado. Perhaps California could investigate onshore transportation of nacelles from this location.

Potential Workforce Development

Very limited. Guidehouse assumes nacelle manufacturing will not be local.

Port Requirements

While nacelles are substantially smaller than blades and towers, shipping via road transportation will become increasingly difficult as nacelle weight increases, and the method of delivery is something that needs to be taken into consideration. Guidehouse estimates that nacelles for 15MW turbines could weigh around 700 tons. Additionally, there must be adequate room to store the nacelles until final system assembly and installation.

CA Supply Chain Opportunity: Foundations

Opportunity for CA Local Content

Similar supply chain limitations to tower manufacturing: California would need to import steel and significantly upgrade and scale existing steel fabrication capabilities in order to produce components for steel foundations. However, thanks to California's high material and labor capacity for concrete and casted concrete production, foundation types and designs that use higher proportions of concrete, such as the barge, could more readily utilize the existing CA supply chain. Experts interviewed noted that large platform components could also come from the Gulf of Mexico due to existing oil & gas capabilities, but the end assembly of foundations must be done locally, as they are incredibly difficult to transport once assembled.

Potential workforce development

Potential to create a substantial number of jobs associated with steel fabrication, concrete production, and assembly. Could utilize and possibly create more jobs in the concrete space based on existing supply chain. Specific occupations: concrete manufacturers, concrete casters, structural metal fabricators and fitters, first-line supervisors of production and operating workers, miscellaneous metal workers, industrial machinery installation and repair workers, welding, soldering, and brazing workers, Engineering technicians, transportation storage and distribution, mechanical drafters

Port implications discussed on the following slide

CA Supply Chain Opportunity: Foundations

Port Requirements

- Different floaters can be built using steel, concrete or even in a hybrid configuration. This choice will affect some specific parts of the assembly process. In the case of steel, most of the operations will consist of plate cutting, bending, rolling, welding and applying an anti-corrosion coating. On the contrary, concrete structures require a large set-down and quay area to build the foundation by continuously pouring concrete into phases. The use of prefabricated concrete parts which only need to be assembled has been suggested to reduce quay area needed.
- Different foundation types require different drafts. Spar foundations have significantly larger drafts than barges, semi-subs, and TLPs. Thus, a port for spar deployment would require deeper waters (>100m) compared to 10-15m for other foundation types. The industry is also looking at using temporary buoyance modules attached to the foundations during transportation from the port to reduce the draught.
- Barge and semi-subs have a shallower draft and greater stability, making them suitable for onshore or quayside assembly of the wind turbine. Once the turbine is mounted on the floater it can be towed and installed to the mooring system. Spar has different processes – spar's deep draft makes it more suitable for horizontal transportation, and installation can take place at inshore deep-water location or at the offshore site. Potential methods for horizontal transportation are discussed in the innovations section.
- Lighter structures, such as TLP and semi-sub, can use cranes as a load-out method.
- O&M: In the case of semi-sub and barge, it might be cheaper to hook-off and tow back to port for repairs. For spars and TLPs, both onshore and offshore repairs are possible, but depend largely on the design of the mooring system and ability to stabilize the structure and vessel while performing repairs.
- The load-bearing capacity needed to support foundations, especially if assembled with other components, is extreme. Normal container ports or bulk commodity ports, with typical bearing capacities of ~2000 lbs/square foot, won't be sufficient. Experts interviewed by Guidehouse suggested that heavier FOSW components such as the foundation would require capacities up to 4000-6000 lbs/square foot.

CA Supply Chain Opportunity: Mooring & Anchors

Opportunity for CA Local Content

Similar supply chain limitations to tower and foundation manufacturing will apply to mooring production, as mooring lines and anchors are primarily composed of steel. Due to the relative ease at which these products can be shipped, experts recommend importing these products from U.S. or global market, despite the relatively low complexity of anchor and mooring products compared to other components such as Nacelles. There are some existing mooring and anchoring manufacturers in California, but their presence is limited, and it is unclear if they are capable of producing lines and anchors to the specifications required by wind farms. Still, their capacities could possibly be expanded. As such, mooring and anchor production could be produced locally for labor benefits or imported more cheaply, depending on California's priorities and incentives.

Workforce Implications

Not particularly labor intensive -- limited job creation. Examples of specific occupations: First-line supervisors of production and operating workers, miscellaneous metal workers, industrial machinery installation and repair workers, welding, soldering, and brazing workers

Port Requirements

Mooring lines and anchors would be much easier to ship and store than other components. There might not be any significant port-related issues, beyond ensuring adequate space to store the lines and anchors until installation.

CA Supply Chain Opportunity: Cables

Opportunity for CA Local Content

Despite limited mining and refinement capabilities in California, the small amounts of steel, aluminum or copper wire required for cable production could be cheaply and easily imported from the U.S. or global market. Experts interviewed by Guidehouse generally agreed that because cables are already a highly developed technology and not particularly labor intensive, they could easily be produced in California using these imported materials. Alternatively, cables could also be easily imported pre-assembled, and Guidehouse experts are generally not familiar with cable producers relocating to be closer to offshore wind developments. Similar to mooring lines and anchors, cables could be produced locally for potential labor benefits, or more cheaply imported, depending on priorities and incentives.

Workforce Implications

Not particularly labor intensive -- limited job creation. Examples of specific occupations: first-line supervisors of production and operating workers, electrical and electronics drafters, mechanical drafters, industrial machinery installation and repair workers, transportation, storage, and distribution, miscellaneous assemblers and fabricators.

Port Requirements

Cables would be much easier to ship and store than most other components. T There might not be any significant port-related issues, beyond ensuring adequate space to store the lines and anchors until installation.

CA Supply Chain Opportunity: General Insights

General local content insights from interviews

- Final assembly of FOSW components will most likely occur locally, as it's difficult and expensive to import pre- assembled turbines and foundations.
- Anything manufactured in California will probably be more expensive than manufacturing elsewhere and importing. As such, California should be ready to produce components at significant volume and capitalize on economies of scale.
- The degree of local content will ultimately be determined by California's priorities and incentives more than anything.
- The East coast is already purchasing steel from mills in other states and then fabricating in-state. This will likely be the case in California.
- Composed of roughly 8,000 components, it can be difficult to achieve local content from turbines. There are inherent challenges to getting higher up the local content curve towards raw materials and Tier 2/Tier 3 processes. Experts recommend ensuring Tier 1 manufacturers land in the state, as operations of local content are easier for them.
- If California opts for local content requirements and incentives, the definition of local content needs to be clearly described, as it can be ambiguous in a world of globalized manufacturing.

General port requirements

- Direct access to a high capacity and high depth water dock and navigation channels are required
- Must provide adequate staging and storage areas. Space will become a bigger issue, on land and in water, where heavy components might be stored in floating structures.
- Given current technology, a FOSW port couldn't be behind a bridge that impedes access to the open waters (for example, Oakland, CA.) See the innovation section for a design that could potentially negate this issue.

General cost implications discussed on the following slide

CA Supply Chain Opportunity: General Insights

Cost implications

- Most components do not necessarily need to be produced in port, but logistics costs will be reduced if the manufacturing facility is closer to the assembly area. Manufacturing and assembly can even take place in the same space to further reduce costs.
- On the other hand, developers and Guidehouse experts have all agreed that local manufacturing is likely to be more expensive than importing from states or countries with more mature supply chains and manufacturing capabilities.
- The cost of foundations is a major contributor to the total wind farm cost. Foundations would introduce lots of labor and would be expensive to ship.

CA Opportunity:
Use of Existing and Future Facilities/Sites

Phase / Infrastructure	Opportunities for buildout
Primary materials production	As the second-largest cement producing state in the U.S. (after Texas), California has a wealth of concrete manufacturing capacity. Existing producers will likely be able to ramp-up their production or expand facilities to meet the demand of the FOSW industry, especially if the pipeline is substantial and there are local content incentives or requirements.
Fabrication	For some components, it is advantageous or necessary to fabricate at or near the port, making the port and coastal space the crucial part of this question. Some exceptions are for the cabling, mooring/anchoring, and blades and nacelles to a lesser extent, which are more easily shipped. There are no known cable, blade, or nacelle manufacturers in California, but there are some mooring/chain/anchor manufacturers -- their capabilities could possibly be upgraded or expanded throughout CA. Otherwise, opportunities for using existing sites for component fabrication in California are limited. Washington and Oregon have even less fabrication capabilities than California. There are ports with shipbuilding capabilities across the west coast that could be useful in producing the vessels needed for FOSW deployment and maintenance. These include Coos Bay and Portland in Oregon, Shelton, Olympia, Seattle/Tacoma, Bremerton, Everett, Bellingham, Anacortes, and Port Angeles in Washington, and Oakland, Los Angeles, Long Beach, and San Diego in California.
Assembly & deployment	Assembly and deployment need to occur portside. There isn't much flexibility on this.

Ports discussed on the following slide

CA Opportunity:
Use of Existing and Future Facilities/Sites

Phase / Infrastructure	Opportunities for buildout
Ports	Most industry experts have agreed that there are no existing ports on the west coast deep enough to handle offshore platforms; once they are combined with the turbine, they would run aground at current port depths. While dredging existing ports could potentially fix this, many existing ports are also space constrained or behind bridges with insufficient air drafts for passage of turbine and foundation systems. Thus, a new port would have to be dredged. Guidehouse analyzed the following options: • **Diablo Canyon/Morro Bay:** The CA Central Coast is a hub of Marine, Air Force, and Navy Activity, who probably aren't interested in giving up their training territory for transmission developers. This could impede opportunity for port development. • **Humboldt:** There's no military objection in the north, which is an advantage. However, the area is sparsely populated, and some experts have expressed concerns about getting folks to move there for 15 years to work on projects. Would need to turn it into a "temporary work camp." Regardless, a $10.5 million grant for renovations and the Port of Humboldt Bay to support offshore wind activities was approved by the CEC in March of 2022. • **LA and Long Beach:** Although slightly more constrained than the north coast, there's coastal areas in LA and Long Beach with space for industrial activity. However, these areas are already busy with other shipping activities. FOSW would have to compete with these industries. • **San Diego:** Experts are concerned this would be too far away from potential BOEM Call Areas. • **Coos Bay:** In Oregon, so perhaps not as optimal for California developers, but there's adequate space for development and some experts interviewed by Guidehouse thought it was a favorable location. • **Hueneme:** Located closer to central coast call areas than LA/San Diego, but the port is space constrained, next to a Navy Base, and is currently heavily utilized for shipping by other industries.

Attracting FOSW supply chain manufacturing to California

Research Question

What incentives exist in California to attract supply chain manufacturing for FOSW components? How are economies of scale achieved with different capacity planning goals and what technology types could be used in California to fulfill those goals?

Research methodology

Guidehouse researched incentives in the state of California for manufacturers to evaluate the potential to attract supply chain manufacturing to the state. To gain a sense of how economies of scale could be achieved, Guidehouse synthesized research and interview insights from industry experts as to the pipeline of projects needed to spur investment in supply chain manufacturing in California, as well as other methods to drive investment in the OSW supply chain.

Conclusions

California has several tax credit, tax exclusion/exemption, and incentive programs for manufacturers that can be used to attract FOSW component manufacturers to California. California also has the Employment Training Panel, which can help fund training programs for companies that provide installation services, such as vessel and equipment operation, and operations and maintenance services. Industry experts agreed that a large volume of projects, guaranteed by a statewide goal, would drive investment in supply chain manufacturing and eventually drive costs down. Some interviewees also mentioned setting local content requirements and early state investment in infrastructure as ways to drive supply chain development.

Financial Incentives for Manufacturers in California

CAEATFA Sales and Use Tax Exclusion Program

The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) offers a sales and use tax exclusion to manufacturers that promote alternative energy and advanced transportation.

Capital Investment Incentive Program

Authorizes a local government to rebate a capital investment incentive amount to a manufacturer that is equal to the property taxes owed on the manufacturing property in excess of the first $150 million assessment for up to 15 years.

Employment Training Panel

Provides funding to employers to assist in upgrading the skills of their workers through training that leads to good paying, long-term jobs.

California Competes Tax Credit

Income tax credit for businesses that want to relocate to California or stay and grow in California. Businesses compete for over $180 million in tax credits through three application periods each year.

Partial Sales and Use Tax Exemption

Administered by the California Department of Tax and Fee Administration. Provides a sales tax exemption for purchase and leasing of machinery and manufacturing equipment.

For examples on financial incentives offered by East Coast states, see the East Coast Case Studies Section.

Tax credits, tax exclusions, and incentive programs can be used to attract FOSW component manufacturers to California. The Employment Training Panel can help fund training programs for companies that provide installation services, such as vessel and equipment operation, and operations and maintenance services.

A prior section of the report, California Supply Chain Opportunities and Constraints, covers the potential of developing a supply chain based on technology type and what is currently available in California.

Attracting Supply Chain Manufacturing to California: Interview Insights

Insights from interviewed manufacturers, developers, research institutes, and trade organizations on attracting supply chain manufacturing to California.

Guaranteed pipeline of projects

Industry experts tended to agree that a guaranteed pipeline of projects, set by the state, would help attract supply chain manufacturing and offshore wind developers to California. Some experts pointed to the East Coast as an example of a pipeline of projects that could attract supply chain investments.

Local content requirements

Setting local content requirements can spur investment into a local supply chain and local workforce, because project developers will be required to use local manufacturing capabilities.

Early investments into infrastructure

State investment in infrastructure (ports, component manufacturing factories, offshore wind hubs) before leases are signed can attract manufacturers and developers to California.

Achieving economies of scale

Industry experts agreed that a large volume of projects, guaranteed by a statewide goal, would drive investment in supply chain manufacturing and eventually drive costs down. Some experts mentioned sharing workforce resources with neighboring states. Others mentioned the need to converge on a design for floating foundations to achieve economies of scale in foundation manufacturing.

Insights on market size needed to attract companies:

"The East Coast market is large enough and certain enough to attract investments from us"

"We recommend a state goal of 3GW by 2030, 1 GW/year afterwards, to reach 18GW in 2045."

"Massachusetts attracted a cable manufacturer with a pipeline of 2-5GW of work"

"It would take more than a 5GW pipeline for factories to become viable – more around 10GW"

Manufacturing and Workforce Gaps: Interview Insights

Manufacturing

- Lack of existing manufacturing facilities and long lead time to build new facilities.
- It will be a challenge for manufacturers to build components fast enough to meet project demand. Manufacturers in California tend to work on one thing at a time and are not accustomed to serial and batch component manufacturing, as will be required for offshore wind deployment.
- Dynamic cables are a big manufacturing gap, cables need to be rated for constant motion.
- Need to converge on a design for floating foundations, because different designs have different manufacturing and supply chain needs.

Workforce

- Need for skilled workforce, especially civil and electrical engineers and technicians
- Need for training/workforce development programs

Source: Daily Mail UK (Siemens AG)

Above photo and illustration show a 6 MW turbine.
The illustration shows the size comparison to an Airbus A380.
Highlights the need for space.

Guidehouse
Outwit *Complexity*

OSW Workforce Needs in California

OSW Workforce Needs in California

Research Question

What is the current need for a skilled and trained offshore wind workforce for different capacity planning goals and technology types?

Research methodology

Guidehouse used NREL's Jobs and Economic Development Impact (JEDI) tool to model the workforce needs for three planning goal scenarios. Default JEDI values were assumed to be accurate for floating and fixed-bottom wind turbines. Values for foundation, mooring systems, and inter-array cables were adjusted to floating-specific values.

Conclusions

Most jobs needed will be in component manufacturing and supply chain and support services, particularly for installation and development, ports and staging, onshore transmission, foundations, towers, and blades. The total workforce needed is approximately the same for all three scenarios, which reach 10 GW, 18 GW, and 20 GW by 2042, 2045, and 2050, respectively. Assuming a construction period of 5 years, the workforce requirements for the first scenario results in a slightly higher peak number of jobs and more layoffs and rehires during the scenario period compared to the other two scenarios, because two 2 GW projects would need to be constructed concurrently in Scenario 1, compared to one 5 GW project being constructed one at a time in Scenarios 2 and 3.

Skilled Workers Overview

The JEDI model breaks down jobs into three categories, which are each broken down into different components. This table gives an overview of the types of skilled workers that would be needed in each of the JEDI model output* categories and components.

	Component	Skilled Workers Needed	
Component Manufacturing, Supply Chain and Support Services	Ports and staging	• Tugboat operators • Components mobilization vessel operators	• Dockworkers
	Onshore transmission	• Heavy equipment operators • Electricians	• Lineworkers
	Foundation (steel)	• Steel workers (rolling, bending)	• Welders
	Foundation (concrete)	• Ready-mix concrete manufacturers	• Concrete casting workers
	Towers and blades	• Fiberglass molding workers	• Assembly workers
	Nacelle**	• Steel casting and forming	• Fiberglass molding workers
Installation and Development	Array and export cabling	• Cable layers • Cable laying vessel operators	• Deckhands
	Turbine	• Crane operators • Tugboat operators	• Millwrights • Deckhands
	Foundation	• Heavy lift vessel operators • Mooring system installers	• Anchor handling vessel operators • Deckhands
Operations and Maintenance	Technicians and management	• Maintenance/inspection, service operating, and crew transfer vessel operators • Heavy lift vessel operators	• Maintenance and repair technicians • Tugboat operators
	Supply chain/support services	• Supply vessel operators	

* Workers and skills included here are based on the categories of jobs output by the JEDI model. This is not an exhaustive list of jobs related to offshore wind farms.

** Nacelle manufacturing jobs cover a wide range of workers, including mechanical, electrical, and software engineering. This list focuses on manual labor jobs.

JEDI Model Assumptions

JEDI Model

The Jobs and Economic Development Impact (JEDI) model estimates the number of jobs and economic impacts to a local area that can reasonably be supported by a power plant, fuel production facility, or other project, based on user-entered project-specific data or default inputs (derived from industry norms).

Project Data Input	Assumption
Turbine capacity	15 MW
Foundation type	Semi-submersible
Site depth	800 m
Port to site distance	40 km
Anchor type	Suction pile
Mooring lines	3 per turbine
Cables	• Types: XLPE 1,000mm 220kV (export), XLPE 630mm 66kV (inter-array) • Each wind plant has its own high voltage transmission lines (not shared between plants)
Construction period	5 years
Turbine lifetime/Operating period	20-25 years

Notes:

- Local content inputs are based on previous Guidehouse project experience. It is the amount of local manufacturing & services used in the construction and O&M of the project.
- The JEDI model uses NREL's Offshore Renewables Balance of-System and Installation Tool (ORBIT). See https://www.nrel.gov/docs/fy20osti/77081.pdf for more information on the ORBIT model.

JEDI: Local Content Assumptions

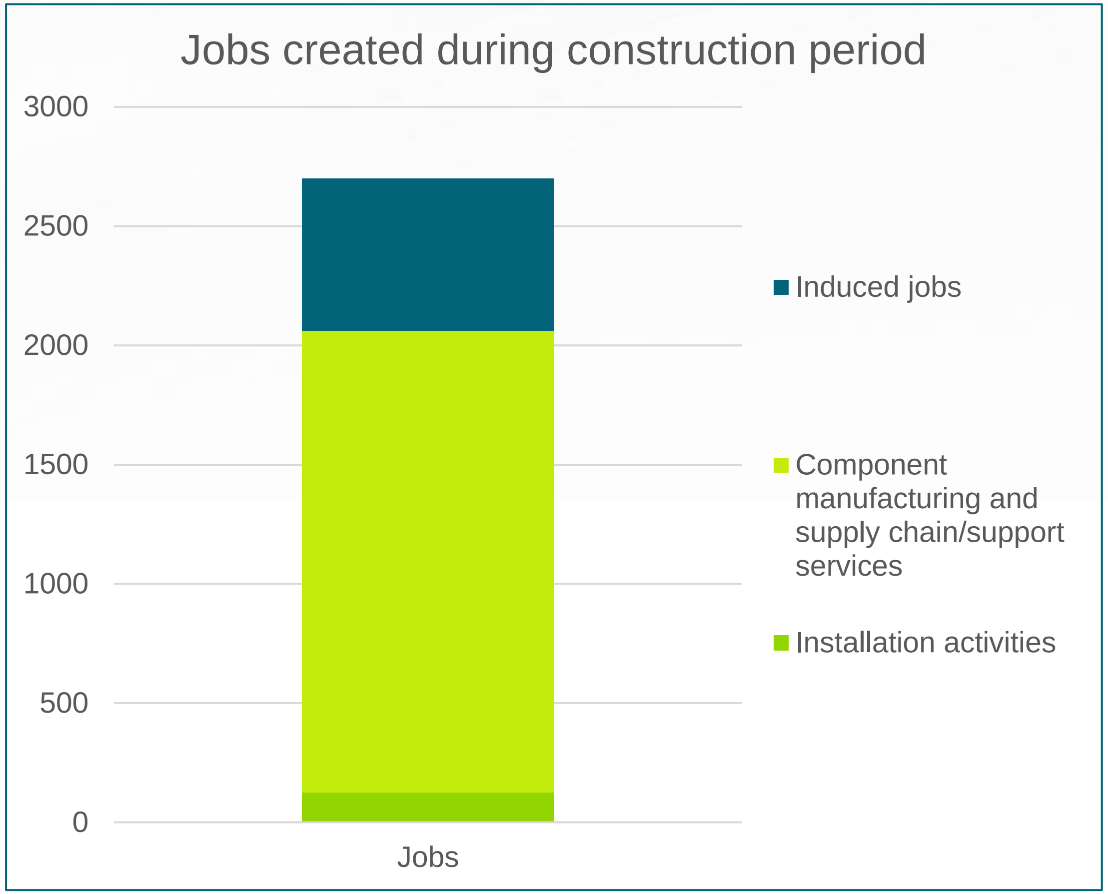
- Local content sets requirements for the percentage of cost spent on materials and labor within California.
- Local content assumptions are based on previous Guidehouse project experience as well as research on components that can be feasibly manufactured in California.
  - Components that are heavy and required in a large quantity, such as towers and blades, are likely to be produced locally.
  - Components that are highly specialized, such as nacelles, are likely to be imported.
- Local content percentages may increase over time as manufacturing capabilities and workforce mature within the state.
- **Defining local content is important to ensure economic development benefits local communities, developers and the supply chain.**

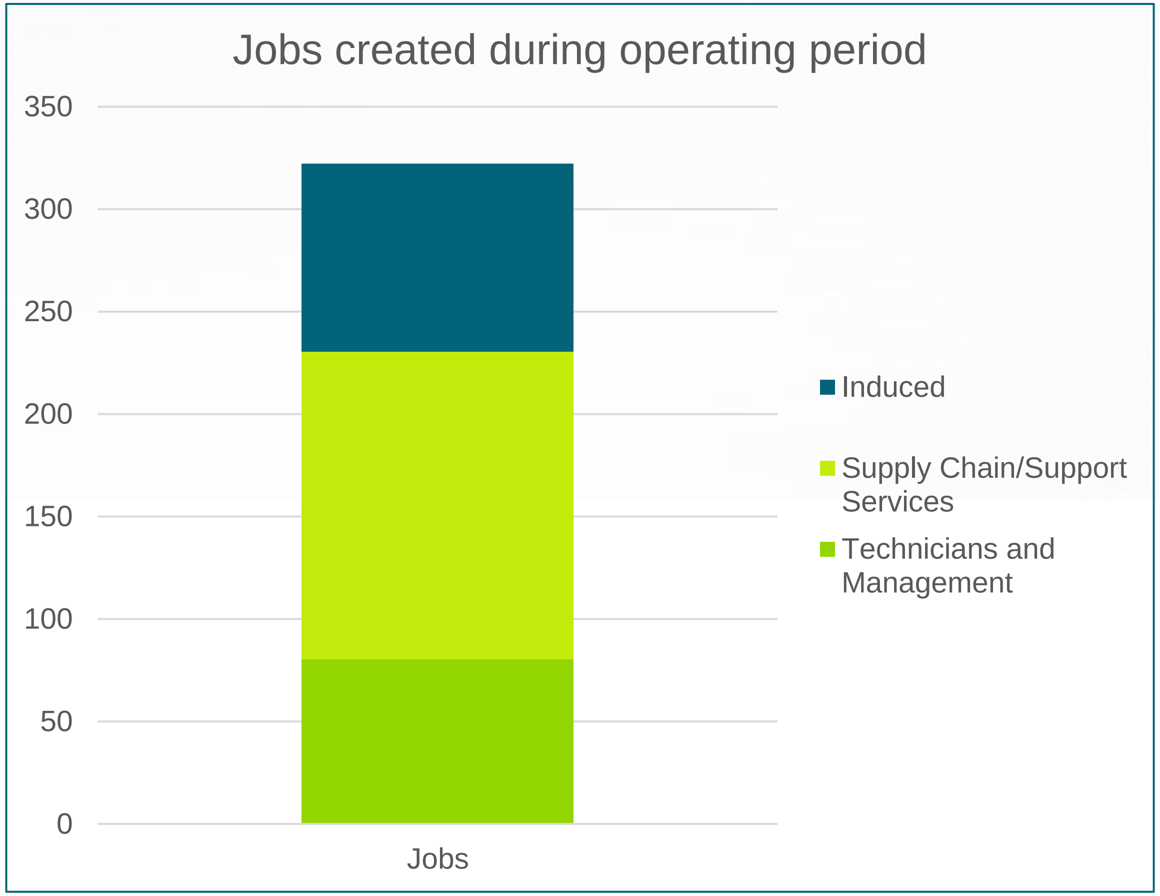
Local Content for Annual OpEx Category	Local Content
Total OpEx	
Maintenance	
Offshore Maintenance	
Technicians (Labor)	100%
Spare Parts	50%
Vessels	50%
Onshore Electric Maintenance	50%
Operations	
Operation, Management and General Administration	100%
Operating Facilities	21%
Environmental, Health, and Safety Monitoring	100%
Insurance	0%
Annual Leases and Fees	0%

Local Content for CapEx Category	Local Content
Turbine Component Costs (Materials and Labor)	
Nacelle/Drivetrain	0%
Blades	50%
Towers	50%
Other/Miscellaneous	0%
Balance of System Costs	
Substructure and Foundation (Materials and Labor)	
Monopile	0%
Scour Protection	0%
Spar	0%
Semisubmersible	20%
Mooring System	20%
Electrical Infrastructure Components (Materials and Labor for Array Cable and Export Cable Systems, Offshore Substation)	**0%**
Assembly and Installation (Vessel and Labor)	
Foundation	20%
Mooring System	0%
Turbine	50%
Array Cable	50%
Export Cable	50%
Offshore Substation	50%
Scour Protection	0%
Ports and Staging (Foundation, Mooring System, Turbine, Array Cable, Export Cable, Offshore Substation, Scour Protection)	**100%**
Development and Other Project Costs	
Site Auction Price	0%
BOEM Review	0%
Construction Operations Plan	50%
Design Install Plan	50%
Site Assessment Plan	50%
Site Assessment Activities	50%
Onshore Transmission	100%
Engineering and Management	
Construction Operations	50%
Soft Costs	
Commissioning	50%
Construction Finance	0%
Construction Insurance	0%
Contingency	0%
Decommissioning	50%
Other/Miscellaneous	50%

High Level Construction and O&M jobs in California

Assuming a 2 GW system, these two charts show the types of jobs created during the construction and operation period.

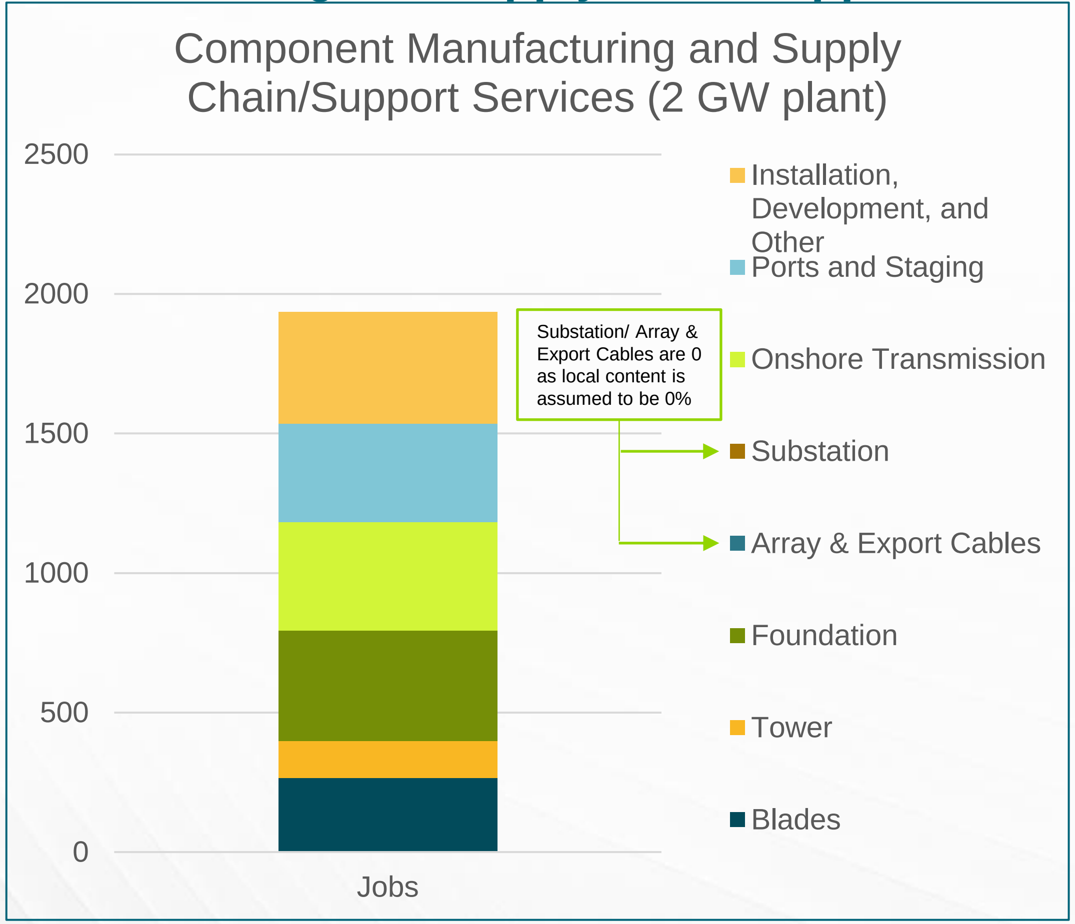


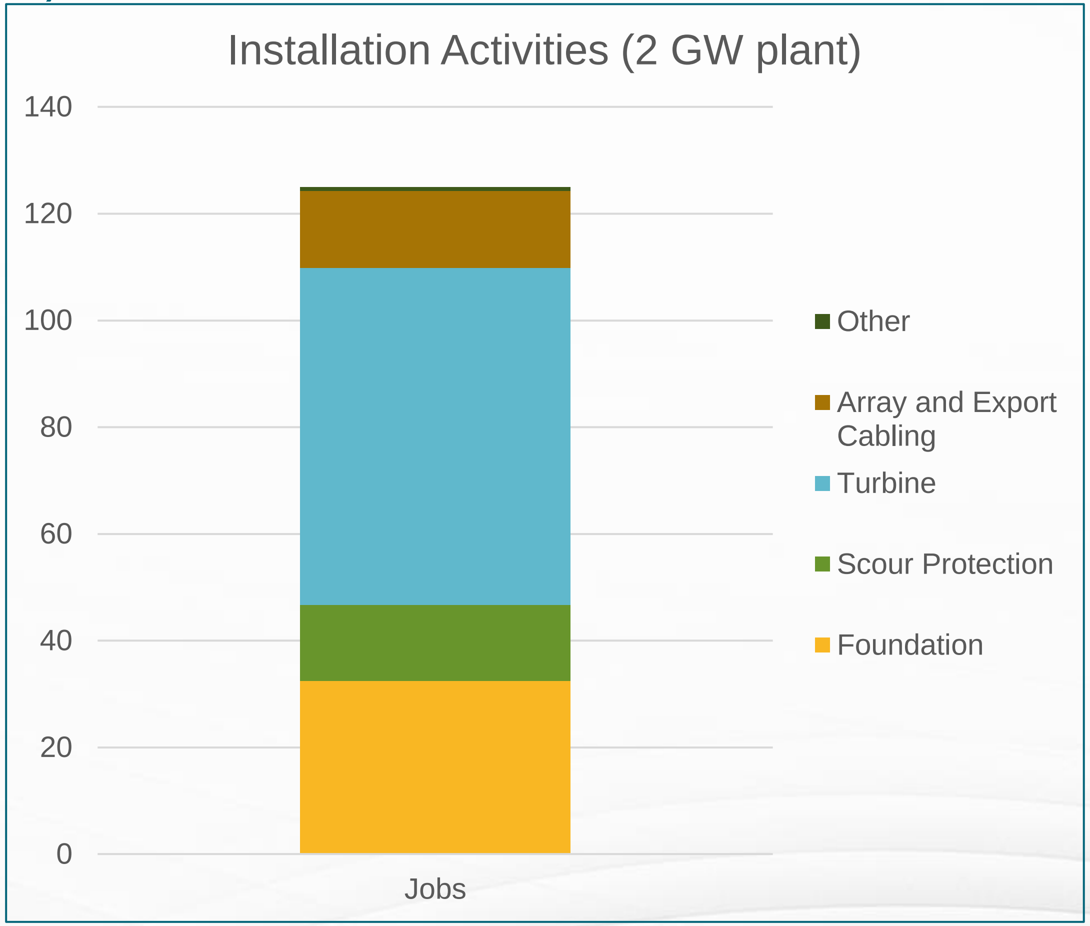


Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years.

Specific Types of Manufacturing and Installation Jobs

Assuming a 2 GW system, these two charts show the detailed job types created for component manufacturing and supply chain/support services, and installation activities.

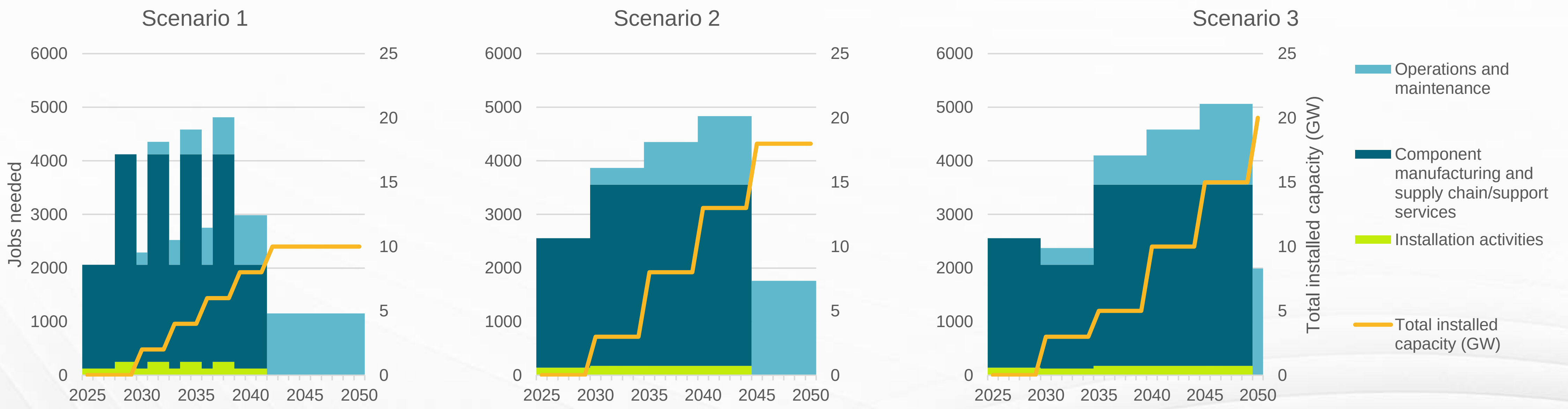




Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years.

Job Needs for Capacity Planning Goal Scenarios – Summary

	Final OSW Capacity Goal	OSW Capacity Installation Timeline	Source
Scenario 1	10 GW by 2045	2 GW by 2030, 2 GW every 3 years thereafter to reach 10 GW in 2042	SB 100 scenario (Guidehouse interpretation)
Scenario 2	18 GW by 2045	3 GW by 2030, 5 GW every 5 years thereafter, up to 18 GW in 2045	AB 525 workshop stakeholder comments
Scenario 3	20 GW by 2050	3 GW by 2030, 10 GW by 2040, 20 GW by 2050	AB 525 workshop stakeholder comments



Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years, after which GW will be in service. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years. Charts represent total employment in each year, not new jobs added each year. Charts exclude induced jobs.

Job Needs for Capacity Planning Goal: Scenario 1

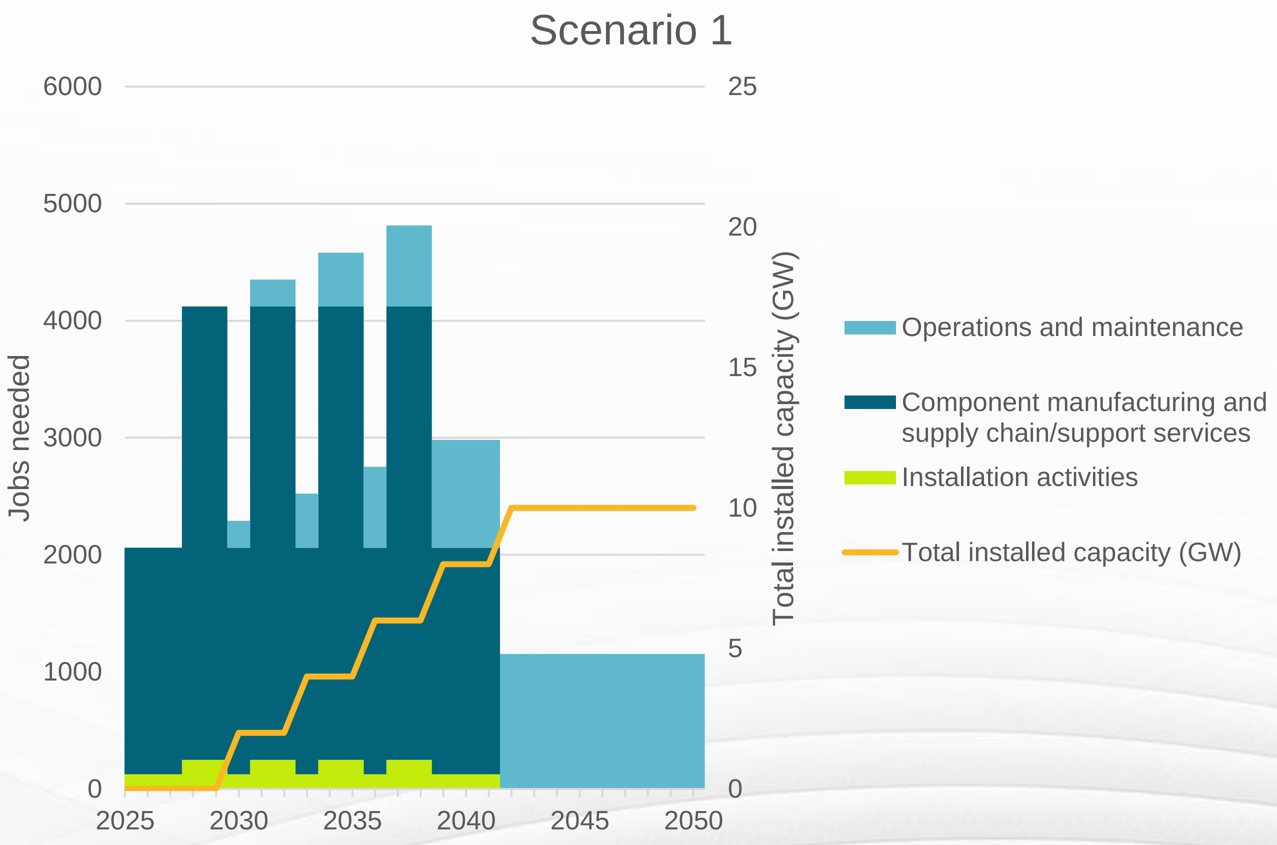
JEDI Model output for meeting Scenario 1 of the capacity planning goals.

Final OSW Capacity Goal	OSW Capacity Installation Timeline	Source
10 GW by 2045	2 GW by 2030, 2 GW every 3 years thereafter to reach 10 GW in 2042	SB 100 scenario (Guidehouse interpretation)

Years*	Installation	Component Manufacturing & Supply Chain	O&M
2025–2028	125	1936	0
2028–2030	250	3872	0
2030–2033	250	3872	231
2033–2036	250	3872	461
2036–2039	250	3872	692
2039–2042	250	3872	922
2042–2050	0	0	1153

** Note that year intervals are not consistent for Scenario 1.*

Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years, after which GW will be in service. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years. Charts represent total employment in each year, not new jobs added each year. Charts exclude induced jobs.



Guidehouse Outwit Complexity

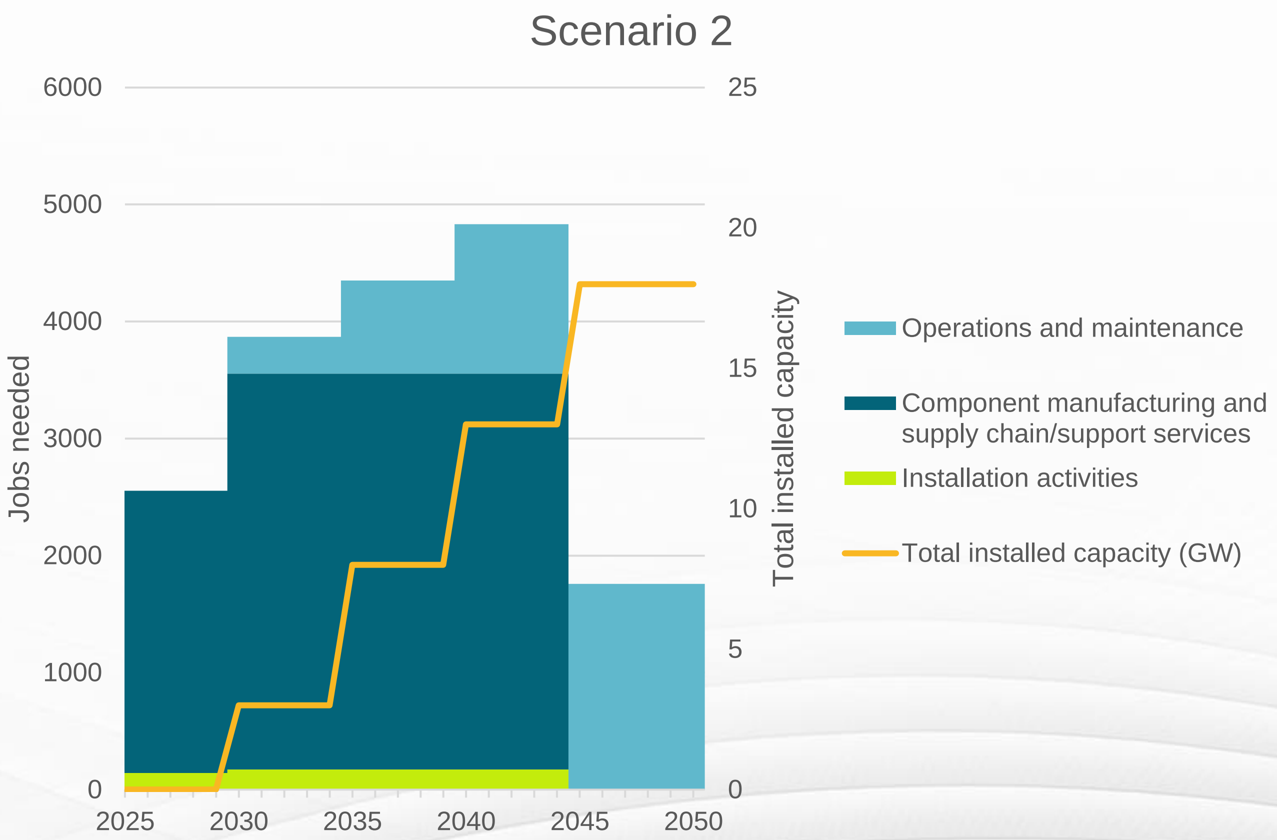
Job Needs for Capacity Planning Goal: Scenario 2

JEDI Model output for meeting Scenario 2 of the capacity planning goals.

Final OSW Capacity Goal	OSW Capacity Installation Timeline	Source
18 GW by 2045	3 GW by 2030, 5 GW every 5 years thereafter, up to 18 GW in 2045	AB 525 workshop stakeholder comments

Years	Installation	Component Manufacturing & Supply Chain	O&M
2025–2030	141	2413	0
2030–2035	173	3382	314
2035–2040	173	3382	796
2040–2045	173	3382	1277
2045–2050	0	0	1759
2050–2050	0	0	1759

Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years, after which GW will be in service. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years. Charts represent total employment in each year, not new jobs added each year. Charts exclude induced jobs.



Guidehouse Outwit Complexity

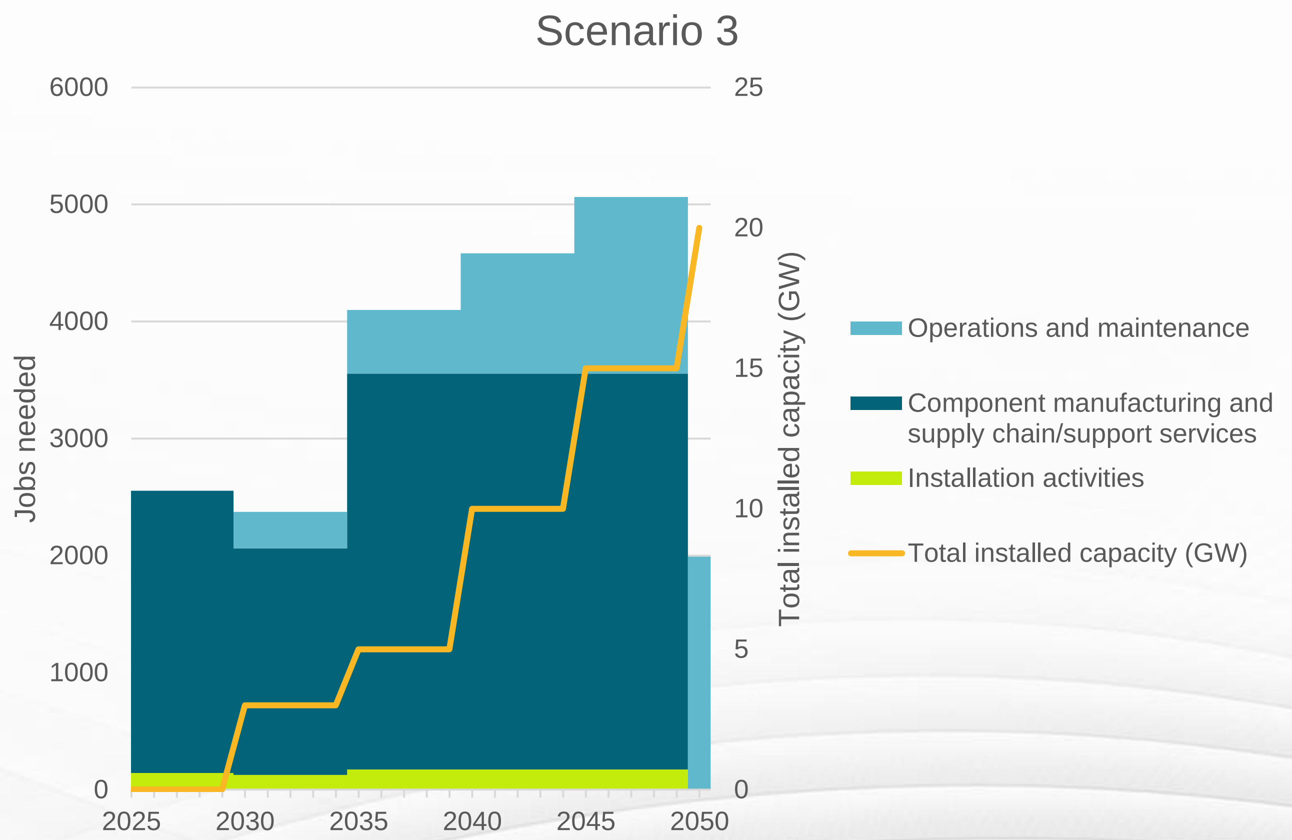
Job Needs for Capacity Planning Goal: Scenario 3

JEDI Model output for meeting Scenario 3 of the capacity planning goals.

Final OSW Capacity Goal	OSW Capacity Installation Timeline	Source
20 GW by 2050	3 GW by 2030, 10 GW by 2040, 20 GW by 2050	AB 525 workshop stakeholder comments

Years	Installation	Component Manufacturing & Supply Chain	O&M
2025–2030	141	2413	0
2030–2035	125	1936	314
2035–2040	173	3382	544
2040–2045	173	3382	1026
2045–2050	173	3382	1508
2050–2050	0	0	1990

Jobs in component manufacturing and supply chain/support services and installation activities are expected to be spread over the construction period of 5 years, after which GW will be in service. Operations and maintenance jobs are expected to last the lifetime of the wind turbines, 20-25 years. Charts represent total employment in each year, not new jobs added each year. Charts exclude induced jobs.



Existing California Workforce

Existing California Workforce Summary

Research Question

What is the current workforce in California that is applicable to offshore wind? What is a high-level estimate of needs for additional workforce?

Research methodology

To understand California's current labor landscape, Guidehouse compared the relevant occupations from a NYSERDA offshore wind study to CA-specific values from the US Bureau of Labor Statistics (BLS), and mapped materials requirements to industries in the U.S. Economic Census. Guidehouse then compared outputs from NREL's Jobs and Economic Development Impact (JEDI) tool to existing employment numbers for industries applicable to the offshore wind supply chain from the BLS and U.S. Economic Census.

Conclusions

A variety of labor related to the FOSW supply chain already exists in California. For most component production, supply chain/support services, installation and development activities, and operations and maintenance activities, the workforce needed to meet California's OSW goal is less than 10% of the available workforce. However, the labor categories are relatively broad and the portion of the workforce with skills applicable to OSW is likely to be small. Additionally, California FOSW will have to compete with onshore and offshore wind developments across the US, as well as other intra-state industries, for specialized laborers.

Skilled Workers Overview

The JEDI model breaks down jobs into three categories, which are each broken down into different components. This table gives an overview of the types of skilled workers that would be needed in each of the JEDI model output* categories and components.

	Component	Skilled Workers Needed	
Component Manufacturing, Supply Chain and Support Services	Ports and staging	• Tugboat operators • Components mobilization vessel operators	• Dockworkers
	Onshore transmission	• Heavy equipment operators • Electricians	• Lineworkers
	Foundation (steel)	• Steel workers (rolling, bending)	• Welders
	Foundation (concrete)	• Ready-mix concrete manufacturers	• Concrete casting workers
	Towers and blades	• Fiberglass molding workers	• Assembly workers
	Nacelle**	• Steel casting and forming	• Fiberglass molding workers
Installation and Development	Array and export cabling	• Cable layers • Cable laying vessel operators	• Deckhands
	Turbine	• Crane operators • Tugboat operators	• Millwrights • Deckhands
	Foundation	• Heavy lift vessel operators • Mooring system installers	• Anchor handling vessel operators • Deckhands
Operations and Maintenance	Technicians and management	• Maintenance/inspection, service operating, and crew transfer vessel operators • Heavy lift vessel operators	• Maintenance and repair technicians • Tugboat operators
	Supply chain/support services	• Supply vessel operators	

* Workers and skills included here are based on the categories of jobs output by the JEDI model. This is not an exhaustive list of jobs related to offshore wind farms.

** Nacelle manufacturing jobs cover a wide range of workers, including mechanical, electrical, and software engineering. This list focuses on manual labor jobs.

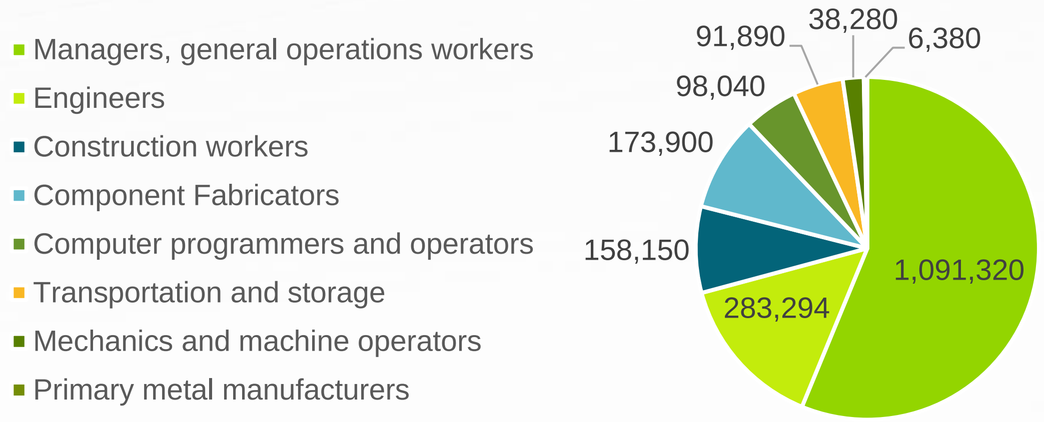
Approach & Introduction to OSW Workforce

The NYSERDA report *U.S. Job Creation in Offshore Wind* contains lists of occupations required for each step in the offshore wind supply chain (development, manufacturing, assembly, operation, etc.)

Using this report, Guidehouse consolidated a list of occupations relevant to floating offshore wind development, and then found CA specific employment numbers from the Bureau of Labor Statistics for each occupation.

There were 57 total occupations, which have been aggregated into the 8 categories in this figure.

California 2020 Employment by Occupation Category



1,941,254 total employed

An example of occupations included in the categories above:

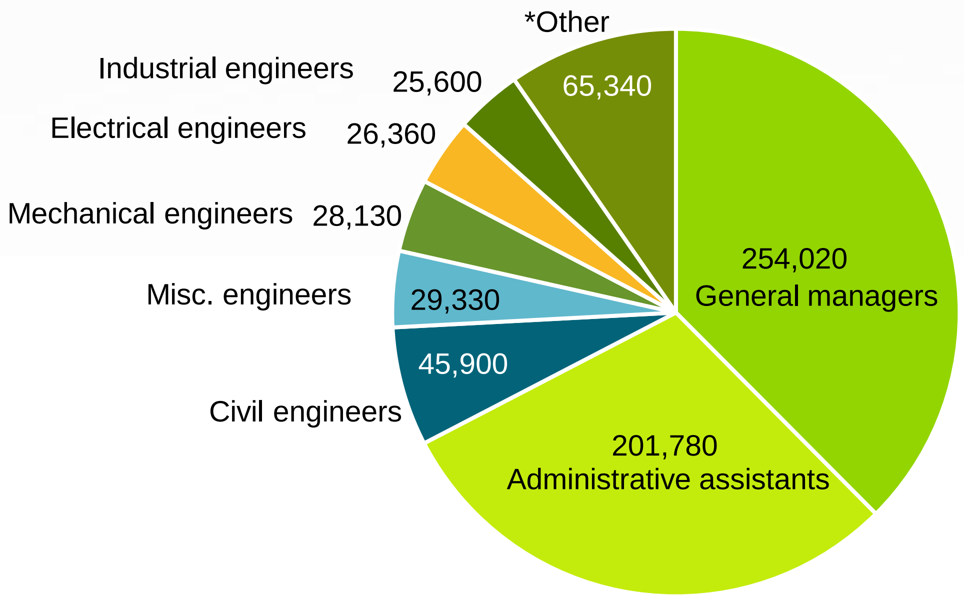
- *Managers, operations workers*: general managers, purchasing managers, assistants, public relations/fundraisers, inspectors, accountants
- *Engineers*: Civil engineers, industrial engineers, health and safety engineers, mechanical engineers, electrical engineers, ship engineers
- *Construction workers*: construction laborers, first-line supervisors of construction trades and workers
- *Component fabricators:* machine assemblers, structural metal fitters, electrical drafters, welding and brazing, cement masons, chemical processors
- *Computer Programmers and operators:* computer control programmers, operators, computer and information system managers
- *Transportation and storage:* industrial truck and tractor operators, transportation, storage, and distribution managers
- *Mechanics and machine operators*: Miscellaneous installation and repair, crane operators, construction operators, ship operators, hoist operators
- *Primary metal manufacturers:* metal furnace operators, tenders, pourers, casters, mining machine operators, metal/plastic workers

Existing Workforce in California: Development & Parts Production

The occupation categories below are also pulled from NYSERDA's *U.S. Job Creation in Offshore Wind.* California employment numbers are from the Bureau of Labor Statistics in 2020.

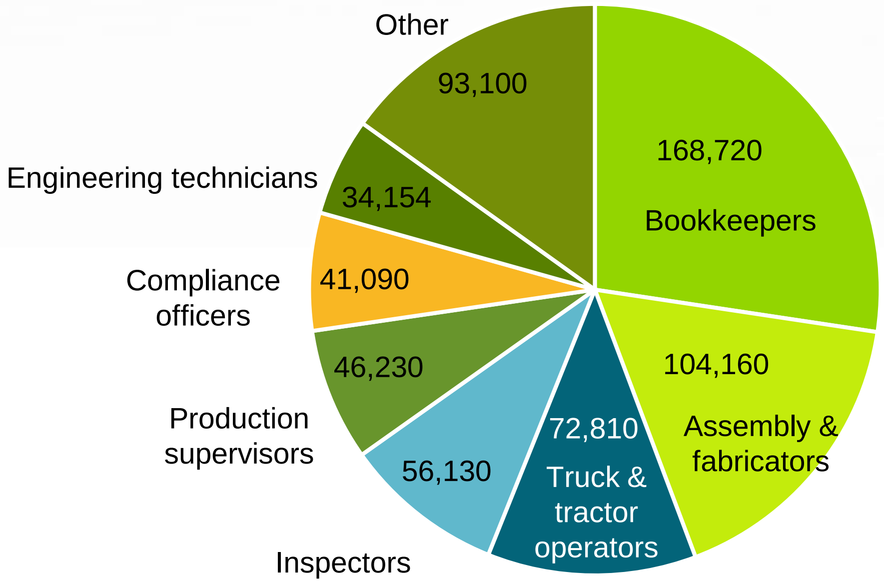
It is important to note that the labor statistics here and on the previous slide represent individuals that are already employed in California , not a readily available labor pool. California FOSW will have to compete with offshore projects in other states, as well as other industries within California, for highly specialized laborers that might not be represented in these broad categories. Additionally, the relative prevalence of occupations in these charts is not reflective of the number of workers needed for a FOSW project.

Development (676,460 total currently employed)



Included in other: electronics engineers, public relations and fundraising managers, purchasing managers, misc. electronic equipment, health and safety engineers.

Parts Production (616,394 total currently employed)



Included in other: industrial machinery installers and repairers, transportation and storage, computer control programmers, metal fabricators, mechanical drafters, chemical processors, electrical drafters, mining machine operators, misc. metal workers, welding and brazing workers, engine assemblers, hoist operators, painting workers, metal furnace operators

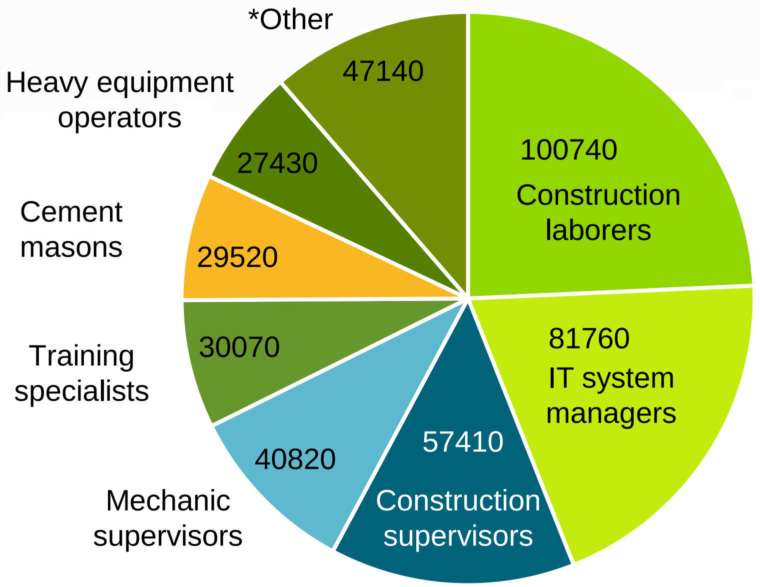
Guidehouse Outwit *Complexity*

Existing labor in California: Installation and Operations & Maintenance

The occupation categories below are also pulled from NYSERDA's *U.S. Job Creation in Offshore Wind.* California employment numbers are from the Bureau of Labor Statistics in 2020.

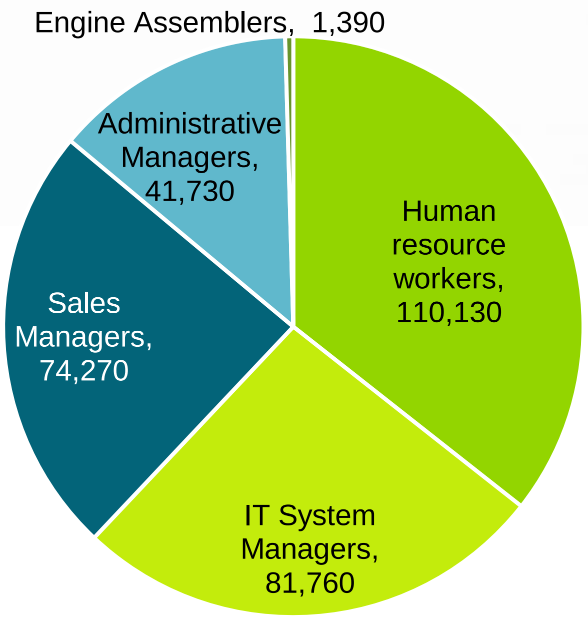
It is important to note that the labor statistics here and on the previous slide represent individuals that are already employed in California , not a readily available labor pool. California FOSW will have to compete with offshore projects in other states, as well as other industries within California, for highly specialized laborers that might not be represented in these broad categories. Additionally, the relative prevalence of occupations in these charts is not reflective of the number of workers needed for a FOSW project.

Installation (412,190 total currently employed)



**Included in other: maintenance workers, structural iron and steel workers, surveying and mapping technicians, miscellaneous plants and system operators, cranes and tower operators, millwrights, iron and rebar workers, ship and boat captains and operators, wind turbine service technicians, ship engineers*

Operations & Maintenance (309,280 total currently employed)



Format of Subsequent Analysis Results

- The tables on the following slides discuss each tier of manufacturing (1 through 3) and compare the current occupation levels in California industries with the amount needed to manufacture enough infrastructure to meet a 10 GW by 2045
- Tables are to be interpreted as follows:

Industry	Applicable JEDI component(s)	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Manufacturing	Component 1	X,XXX	YYY	Z%	

Current California employment in this specific industry

“0” means there is a matching industry in the U.S. Economic Census, but no employees in California, while “--” means there is no matching industry in the U.S. Economic Census.

Number of jobs needed are based on the JEDI outputs for a 2 GW plant.

Jobs needed can be satisfied through new jobs in an industry/occupation, or through a portion of the industry converting to working on OSW.

The maximum percentage of the existing workforce that would be required to work on OSW component manufacturing, supply chain, support services, installation and development, or operations and maintenance, **assuming the entire jobs need output from JEDI is applicable for specific industries/occupations.**

Existing Workforce in California: Raw Materials (Tier 3)

Industry	Applicable JEDI component(s)	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Concrete manufacturing	Foundation	8,808	395	4.5%	Number of jobs needed is a relatively small percentage of the existing workforce.
Primary Steel manufacturing	Tower, Nacelle, Foundation	0	528	--	There is no primary steel production in CA. Will need to import from U.S. or global market.
Glass fiber reinforced plastic	Nacelle, Blades	--	266	--	No corresponding industry in the U.S. Economic Census. JEDI output likely refers to T2 or T1 manufacturing.
Copper production	Nacelle, Array & Export Cables, Substation, Onshore Transmission	--	0	--	No corresponding industry in the Economic Census.
Aluminum production	Array & Export Cables	--	0	--	Data unavailable. Not a major input to FOSW, could possibly be used as a substitute for copper. Look to U.S. or global market.

- The number of concrete manufacturing jobs needed to support floating foundation manufacturing is a relatively small percentage of the entire industry workforce, but not all employees within the category may have the skills necessary for floating offshore wind specifically.
- Raw materials for glass fiber reinforced plastic (fiberglass), copper, and aluminum are unlikely to be sourced locally in California, so no local workforce is needed.

Existing Workforce in California: Fabrication (Tier 2)

Industry	Applicable JEDI component(s)	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Concrete product manufacturing	Foundation	4,986	395	7.9%	
Steel product fabrication	Tower, Nacelle, Foundation	1,653	528	32%	
Steel investment casting	Nacelle	926	0	0%	Nacelles are expected to be produced outside of California.
Aluminum drawing	Array & Export Cables	--	0	--	Guidehouse subject matter experts assume this will not be local content. This is consistent with the JEDI model.
Copper drawing	Array & Export Cables, Nacelle, Substation, Onshore Transmission	--	389	--	Guidehouse subject matter experts assume this will not be local content. Job need output for applicable JEDI components encompasses aspects of manufacturing other than copper.

- The number of concrete manufacturing jobs needed to support floating foundation manufacturing is a relatively small percentage of the entire industry workforce, but not all employees within the category may have the skills necessary for floating offshore wind specifically.
- A significant percentage of the steel product fabrication workforce would be needed to fabricate towers, foundations, and (to a lesser extent) nacelle components, but the capabilities of this workforce may only be adjacent to the FOSW industry.

Existing Workforce in California: Parts Production (Tier 1)

Industry	Applicable JEDI component(s)	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Gear/transmission equipment assembly	Nacelle	1,136	0	0%	Nacelles are expected to be produced outside of California.
Turbine generator set manufacturing	Nacelle, Blades, Tower	6,121	398	6.5%	Use: Overall nacelle assembly, as well as assembly for tower, generator, and blades
Steel Wire Drawing	Array & Export Cables	567	0	0%	Use: Structural component of array and export cables, but JEDI model assumes no local cable production.
Submarine cable production	Array & Export Cables	--	0	--	No corresponding industry in the U.S. Economic Census.
Heavy lifting machinery	Installation, Development, and Other	--	401	--	No corresponding industry in the U.S. Economic Census.
Onshore transportation	Installation, Development, and Other	--	401	--	No corresponding industry in the U.S. Economic Census.

- The number of turbine generator set manufacturing jobs needed to support floating foundation manufacturing is a relatively small percentage of the entire industry workforce, but this category encompasses steam, hydraulic, and gas turbines, in addition to wind turbines. The portion of this workforce with skills applicable to wind turbines may be small.

Existing workforce in California: Installation & Development

BLS occupation	Applicable JEDI component(s)	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Captains, Mates, and Pilots of Water Vessels	Foundation, Turbine, Array and Export Cabling	1,450	110	7.6%	The BLS occupation encompasses ships and water vessels, such as tugboats and ferryboats
Cranes and Tower Operators	Turbine, Foundation	2,970	96	3.2%	
Millwrights	Turbine	2,700	14	0.52%	

- Components in JEDI outputs that do not match with an occupation in BLS are Scour Protection (not relevant to CA offshore wind) and Other (very small # of employees, not specific enough to match with BLS).
- The number of vessel operation jobs needed to support floating foundation manufacturing is a relatively small percentage of the entire industry workforce, but the specific vessels needed for offshore wind installation (jack-up, cable laying, and heavy lift vessels) may or may not be represented within the BLS occupation statistic.

Existing workforce in California: Operations & Maintenance

BLS occupation	Applicable JEDI occupation	# existing employees	# of jobs needed (JEDI output)	max % of industry workforce required	Notes
Captains, Mates, and Pilots of Water Vessels	Supply Chain/Support Services	1,450	150	10%	BLS occupation is shared between O&M and Installation and Development (previous slide).
Cranes and Tower Operators	Technicians and Management	2,970	80	2.7%	BLS occupation is shared between O&M and Installation and Development (previous slide).
Wind Turbine Service Technicians	Technicians and Management	610	80	13%	

- There are shared occupations between the Operations and Maintenance and Installation and Development (previous slide) existing workforce, which means the maximum % of industry workforce required should be summed between the two slides, giving an actual maximum % of industry workforce required of 17.6% for Captains, Mates, and Pilots of Water Vessels, and 5.9% for Cranes and Tower Operators

Procurement Models and Cost Trends

East Coast: Offshore Wind Procurement

Research Question

What are the cost curves and Power Purchasing Agreement (PPA) prices observed on the East Coast of the United States? How are these projected to change as capacity increases over time?

Research methodology

Guidehouse reviewed research publications, public PPA and Offshore Renewable Energy Certificates (OREC) contracts, and various regulatory documents to gather the PPA/OREC prices for any current or past project on the East Coast in the United States to respond to the first part of the research question. For the second part of the research question, Guidehouse reviewed published research to better understand the direction of cost curves as the installed capacity of OSW increases in the future in the United States.

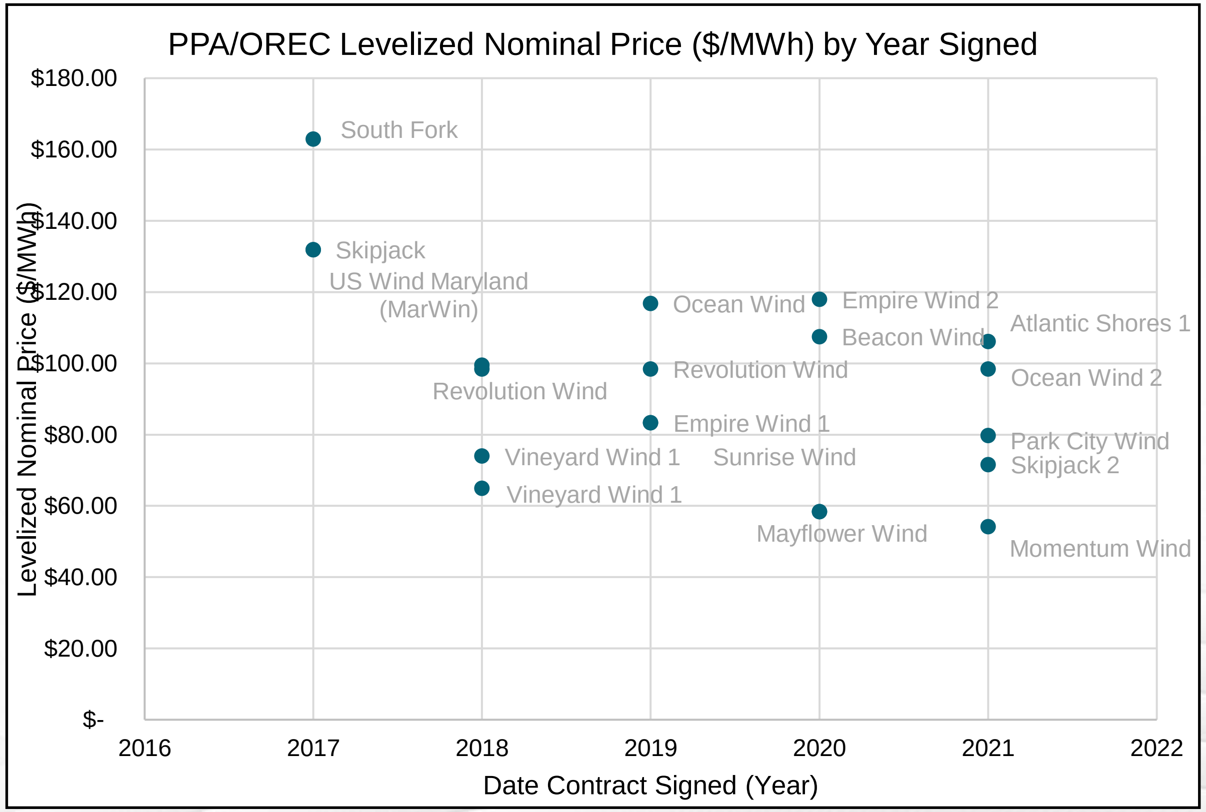
Conclusions

The cost of offshore wind is decreasing as the industry matures, both for fixed-bottom and floating offshore wind. There are 19 commercial scale projects on the East Coast, all fixed-bottom platform, which are illustrating a correlation between time and a decrease in prices. There are differences in the cost components for fixed-bottom and floating offshore wind, mainly due to the platform components, and there are different drivers for cost. However, the floating offshore wind industry can leverage much of what the fixed-bottom wind industry has done and learned already, including a more mature supply chain. The US currently only has floating offshore wind demonstration projects, but studies show that the levelized cost of energy ($/MWh) will fall over time in California due to technology innovation, development of a supply chain and larger turbine size.

PPA/ORECs for East Coast OSW Procurements

To ensure lower risk for the developer and/or owner of the asset and make the project more “bankable,” an offtake agreement is often used. This offtake agreement is a contract between the buyer and seller of energy. The off-taker agrees to procure all or a substantial output from the facility and provides a predictable revenue stream to support project financing. There are two contract types that support the offtake agreement and include project specifics, the $/MWh price, and the duration in which the contract is binding. The **Power Purchase Agreement (PPA)** and **Offshore Renewable Energy Certificates (OREC)** have been the two most common types of procurement mechanisms used by East Coast states to incentivize OSW to meet regulatory targets.

- PPAs and ORECs provide a fixed price for the generation of the projects as this could otherwise be highly variable if the generating plant participates in the wholesale market, and thereby creates financial certainty for the project after it is deployed.
- PPAs and ORECs are awarded through a competitive bidding process, including price and other criteria like environmental factors or economic development in the area.
- Several developers are deploying their projects in the waters of another state than the state which is part of their offtake agreement. This is due to the developers seeing the most favorable PPAs and other offtake options with the highest value of offshore wind.
- **Outside of PPAs and ORECs**, there is full utility ownership, such as the case with CVOW Commercial Project in Virginia. In this case, the utility, Dominion, has full ownership of the offshore wind project.
- **Note:** It is challenging to compare prices from these long-term contracts as each project has different parameters, regulatory and/or tax environment and other factors.

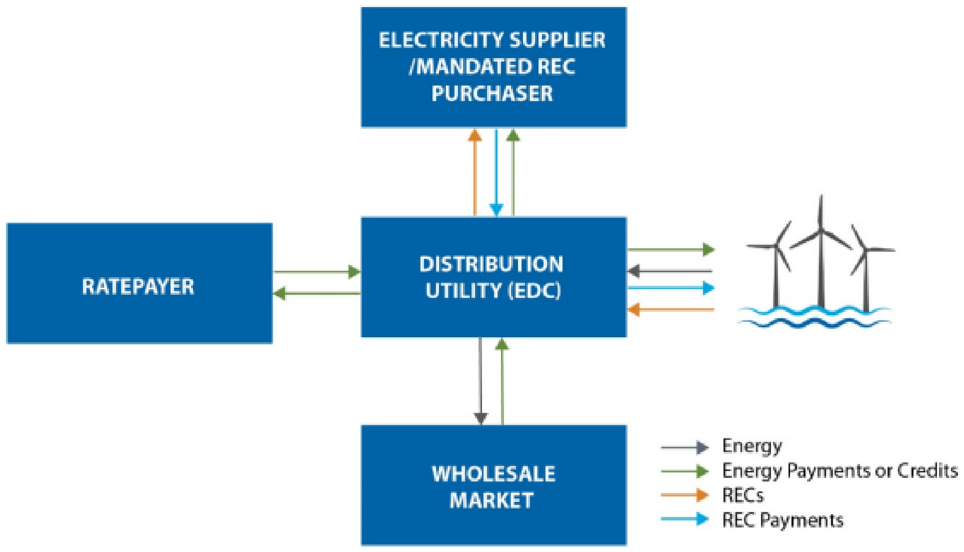


Not including demonstration projects.

PPA Scheme for Projects on the East Coast

PPAs are standardized long-term contractual agreements for the purchase of power from a specific renewable energy generator (i.e., the seller) to a purchaser of electricity (i.e., the buyer).

- The OSW generator contracts its energy, energy services (such as capacity) and/or associated environmental attributes at a specified price to a third party (usually the electric distribution company) and injects its power into a specified grid. Under the PPA structure used in these states, the developer receives a predetermined payment for its generation, regardless of the price that generation sells for in the wholesale market.
- The PPA does not include payments for capacity and ancillary services, and these can be provided from the OSW generator directly to the wholesale market, bypassing the PPA. There is some risk of revenue uncertainty to the OSW generator since capacity and ancillary services are not included in the PPA price.
- The PPA governs the payment, delivery, and performance terms between the generator and the counterparty (i.e., electric distribution company).
- **Ratepayers pay for the generation through charges on their distribution utility bill.**
- This structure provides revenue certainty for the developer and an ability to obtain lower-cost financing compared to a merchant structure or a Fixed-Premium OREC structure.



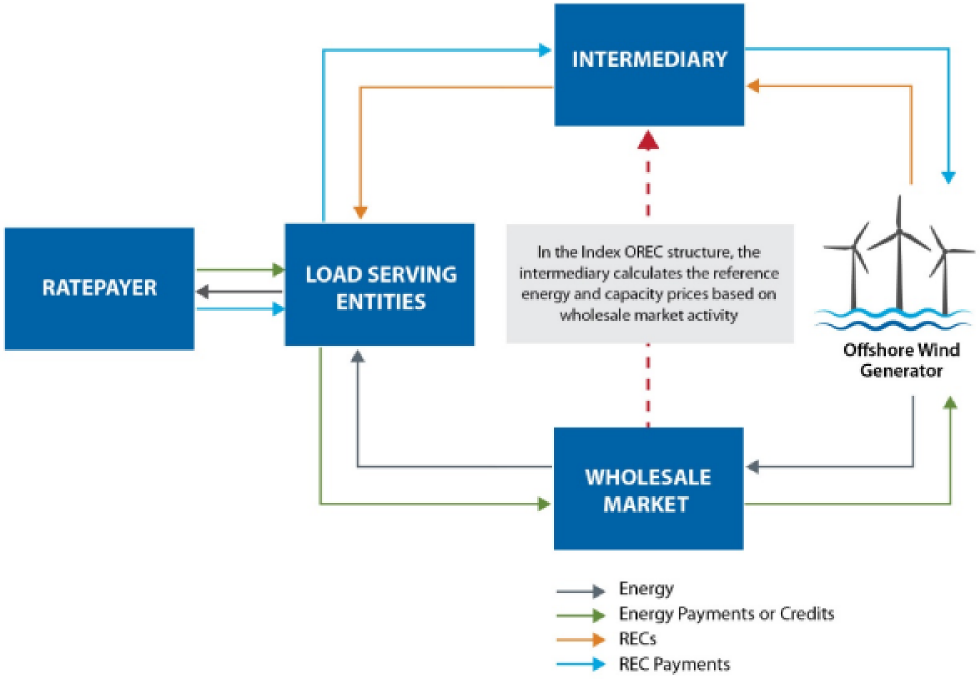
Generic PPA scheme (NREL, Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States, 2020)

Massachusetts, Rhode Island, and Connecticut have mandated utilities to enter into power purchase agreements (PPAs) with offshore wind generators for a specified nameplate capacity.

OREC Scheme for Projects on the US East Coast

ORECs represent the environmental attributes of one megawatt-hour of electric generation from an offshore wind project and are used to comply with state offshore wind-specific renewables portfolio standard provisions

- Depending on the state, ORECs may be the same as RECs in that they do not include the energy, capacity, ancillary services and environmental attributes. However, Maryland distinguishes ORECs from RECs in that ORECs include these components (HB 226). If an OREC includes the additional components, then the project will have more revenue certainty to a project developer than a REC-only procurement.
- The entity which ends up with the ORECs/RECs varies by state. Generally, it has been that the ORECs/RECs remain with the renewable energy generator, however, Maryland set up a process to transfer the OREC revenue from the generator to the state's electric supplier as the generator would sell the energy, capacity and ancillary services directly into the wholesale market.
- Generally, as mentioned above, the generator would sell the energy into the wholesale market and the ORECs to an intermediary (such as a distribution utility, state agency, or escrow account). The ORECs would then be sold to electricity suppliers.
- ORECs are not tied directly to compensation to wholesale market prices.
- **Ratepayers pay the OREC costs through charges on their utility bill.**



Generic OREC scheme (NREL, Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States, 2020)

ORECs appeared in New Jersey in the late 2000's and have subsequently been adopted in Maryland and New York.

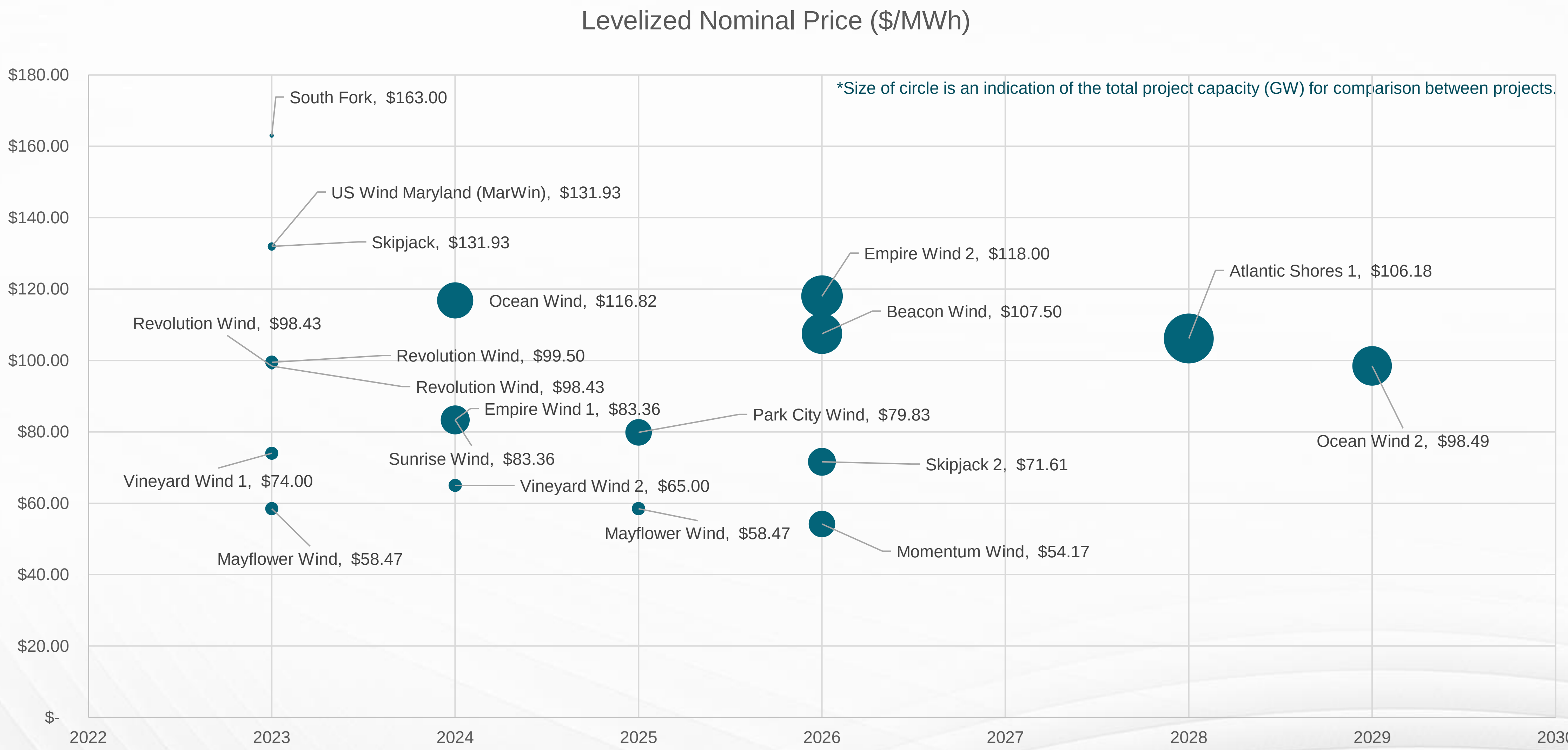
19 OSW Projects (current & proposed) on U.S. East Coast

Project	Foundation (Fixed-bottom or floating)	Year Signed	Size (MW)	Duration (Years)	Offtake State	Contract type	Levelized Nominal Price ($/MWh)	Power Delivery	Power Purchaser
Skipjack	Fixed-Bottom	2017	120	20	MD	OREC	$131.93	2023	Exelon
South Fork	Fixed-Bottom	2017	130	20	NY	PPA	$163.00	2023	Long Island Power Authority
US Wind Maryland (MarWin)	Fixed-Bottom	2017	248	20	MD	OREC	$131.93	2023	Exelon
Revolution Wind	Fixed-Bottom	2018	400	20	RI	PPA	$99.50	2023	Eversource, UIL
Revolution Wind	Fixed-Bottom	2018	200	20	CT	PPA	$98.43	2023	Eversource, UIL
Vineyard Wind 1	Fixed-Bottom	2018	400	20	MA	PPA	$74.00	2023	National Grid, Eversource, Unitil
Vineyard Wind 2	Fixed-Bottom	2018	400	20	MA	PPA	$65.00	2024	National Grid, Eversource, Unitil
Empire Wind 1	Fixed-Bottom	2019	816	25	NY	OREC	$83.36	2024	New York Independent System Operator
Ocean Wind	Fixed-Bottom	2019	1,100	20	NJ	OREC	$116.82	2024	MD Utilities
Revolution Wind	Fixed-Bottom	2019	104	20	CT	PPA	$98.43	2023	National Grid
Sunrise Wind	Fixed-Bottom	2019	880	25	NY	OREC	$83.36	2024	New York Utilities
Mayflower Wind	Fixed-Bottom	2020	400	20	MA	PPA	$58.47	2023	National Grid, Eversource, Unitil
Mayflower Wind	Fixed-Bottom	2020	404	20	MA	PPA	$58.47	2025	National Grid, Eversource, Unitil
Empire Wind 2	Fixed-Bottom	2020	1,260	25	NY	OREC	$118.00	2026	New York Utilities
Beacon Wind	Unspecified	2020	1,230	25	NY	OREC	$107.50	2026	New York Utilities
Atlantic Shores 1	Fixed-Bottom	2021	1,510	20	NJ	OREC	$106.18	2028	MD Utilities
Park City Wind	Fixed-Bottom	2021	804	20	CT	PPA	$79.83	2025	Eversource, UIL
Momentum Wind	Fixed-Bottom	2021	808	20	MD	OREC	$54.17	2026	Distribution Utilities
Ocean Wind 2	Fixed-Bottom	2021	1,200	20	NJ	OREC	$98.49	2029	MD Utilities
Skipjack 2	Fixed-Bottom	2021	846	20	MD	OREC	$71.61	2026	Distribution Utilities
Commonwealth Wind	Fixed-Bottom	Negotiating	1,200	N/A	MA	PPA	N/A	N/A	N/A
CVOW Commercial	Fixed-Bottom	Negotiating	2,640	N/A	VA	Utility-Owned	N/A	2026	N/A

Levelized price: amount a developer needs to recover on a $/MWh basis to pay off its initial investment and satisfy its revenue requirements the contract duration.

Not including demonstration projects.

19 OSW Contracts on U.S. East Coast



Levelized price: amount a developer needs to recover on a $/MWh basis to pay off its initial investment and satisfy its revenue requirements the contract duration.

Not including demonstration projects.

Components of Energy Cost: Offshore Wind Projects

Floating vs. Fixed-Bottom Offshore Wind

The commercial PPAs/OREC contracts in the US exist only for fixed-bottom OSW projects on the East Coast. There are a few differences between the cost components of fixed-bottom and floating wind structures, which can be seen in the charts on the right. These differences are important to consider when evaluating floating offshore wind structures in California as compared to fixed-bottom structures on the East Coast.

- The main difference between the cost components of floating and fixed-bottom offshore wind is within the substructure and the foundation of the platform. The charts on the right assume the fixed-bottom project has a monopile type foundation while the floating project has a semisubmersible platform.
- When comparing 8 MW units, NREL's analysis found that the fixed-bottom project substructure cost is about a quarter of that for a floating substructure.
- O&M and Soft Cost categories do not depend on whether the project is fixed-bottom or floating. The costs are instead related to the project size. Floating wind would therefore cost more due to the larger project cost due to the substructure.
- Water depth and distance from shore are the main factors that drive price for both fixed-bottom and floating offshore wind projects.
- The fixed-bottom offshore wind market is more evolved and there may be additional cost efficiencies found as more floating offshore wind projects are deployed.

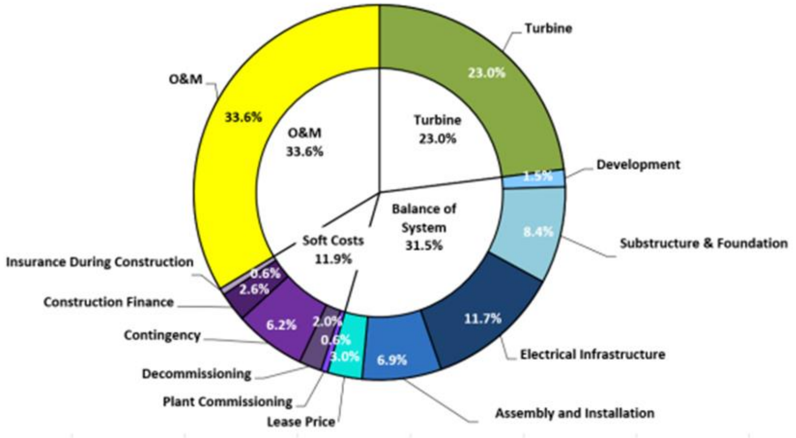


Figure ES2. Component-level LCOE contribution for the 2020 fixed-bottom offshore wind reference project operating for 25 years

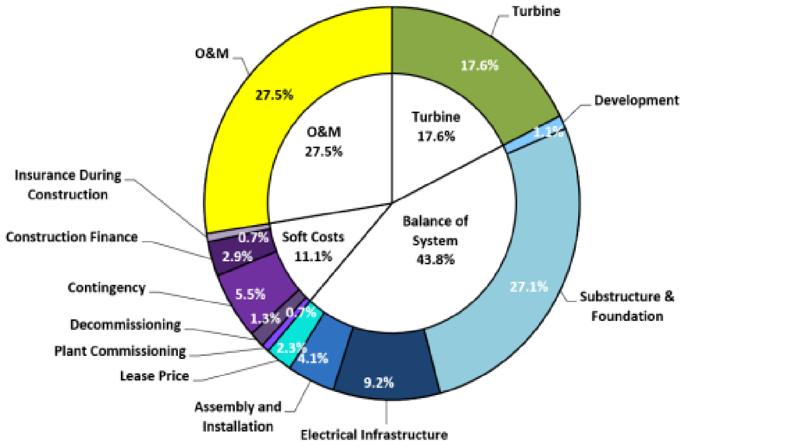


Figure ES3. Component-level LCOE contribution for the 2020 floating offshore wind reference project operating for 25 years

Charts taken from NREL's Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States, 2020.

OSW Energy Price Projections: Fixed-Bottom

All commercial wind farms on the East Coast are fixed-bottom (as of April 2022)

Levelized Cost of Energy (LCOE) is the cost of the energy project over the full lifetime divided by the amount of energy the project produces. The LCOE is used by energy developers to understand price of a power plant. The LCOE is not fully comparable to a PPA or OREC price, however, studying LCOE over a certain amount of time uncovers important insights in the trends for future energy costs of offshore wind.

Factors Driving Lower Costs in Fixed-Bottom OSW (NREL)

- Site characteristics
- Regulatory and market environment
- Calculation methods
- Assumptions about financing
- Technology and market maturity

Trends in Fixed-Bottom Offshore Wind

- Fixed-bottom offshore wind has already seen declines in cost. Studies show that globally there are reductions of between 28-51% in LCOE of fixed-bottom OSW projects between 2014 to 2020. The chart to the right illustrates various results of studies that forecast the continued decrease in LCOE for fixed-bottom offshore wind.

Decline in Fixed-Bottom Offshore Wind energy cost as the technology matures could foreshadow a similar trend in Floating Offshore Wind. However, it is important to understand differences in factors driving costs.

Global LCOE Estimates for fixed-bottom offshore wind

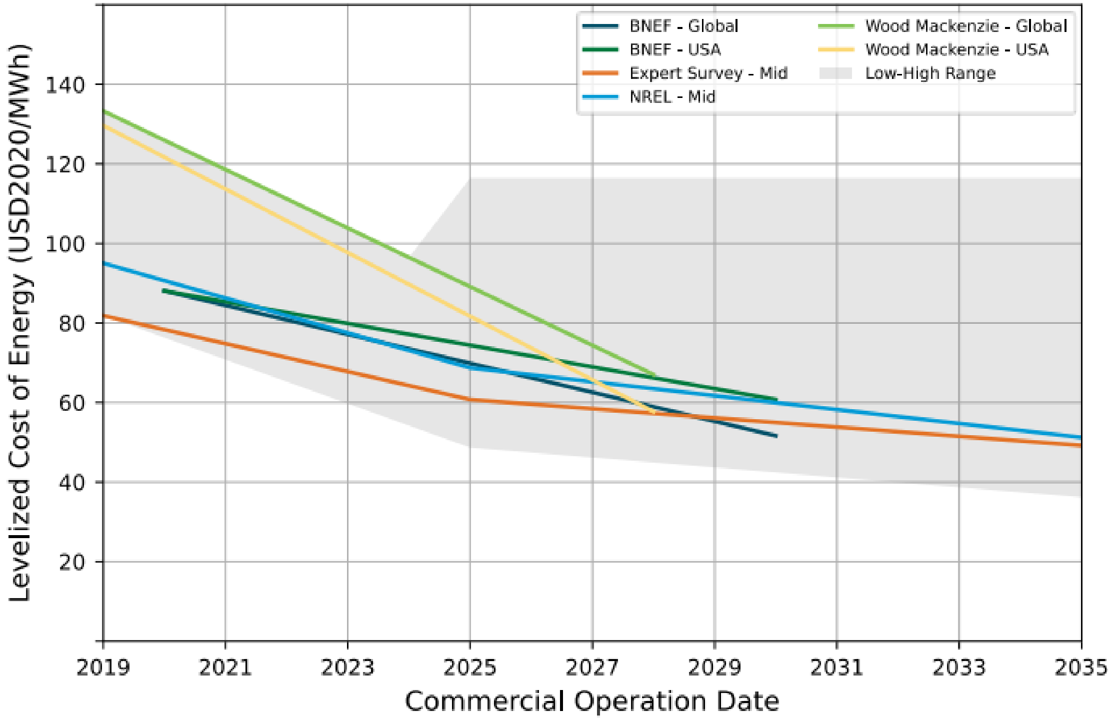


Chart from NREL's Offshore Wind Market Report: 2021 Edition.

OSW Energy Price Projections: Floating

The floating wind industry is still maturing

The LCOE estimates, globally, for offshore wind are projected to decrease from approximately $160/MWh in 2020 to $60-105/MWh in 2030 through research done by various institutions. The declining in LCOE is due to commercialization of floating wind power plants and the incorporation of learnings as the floating wind industry matures.

Key Factors Driving Lower Costs in Floating OSW (NREL)

- Experience from fixed-bottom offshore wind projects.
- Leveraging existing supply chains.
- Optimizing floating structures using lighter components and increased modularity.
- Reducing the number and complexity of steps constructing the project at sea.
- Automating production and fabrication of floating platforms.
- Higher wind speeds to increase capacity factor outweigh the higher O&M and installations costs due to being further off the coast with harsher meteorological conditions.
- Regulatory and market maturity, including tax credits.

Floating Offshore Wind – Demonstration Projects in Maine

- Two projects, Aqua Ventus and Maine Research Array. Aqua Ventus set up a PPA with Central Maine Power.
- Concrete semi-submersible hull platforms.

Global LCOE Estimates for floating offshore wind

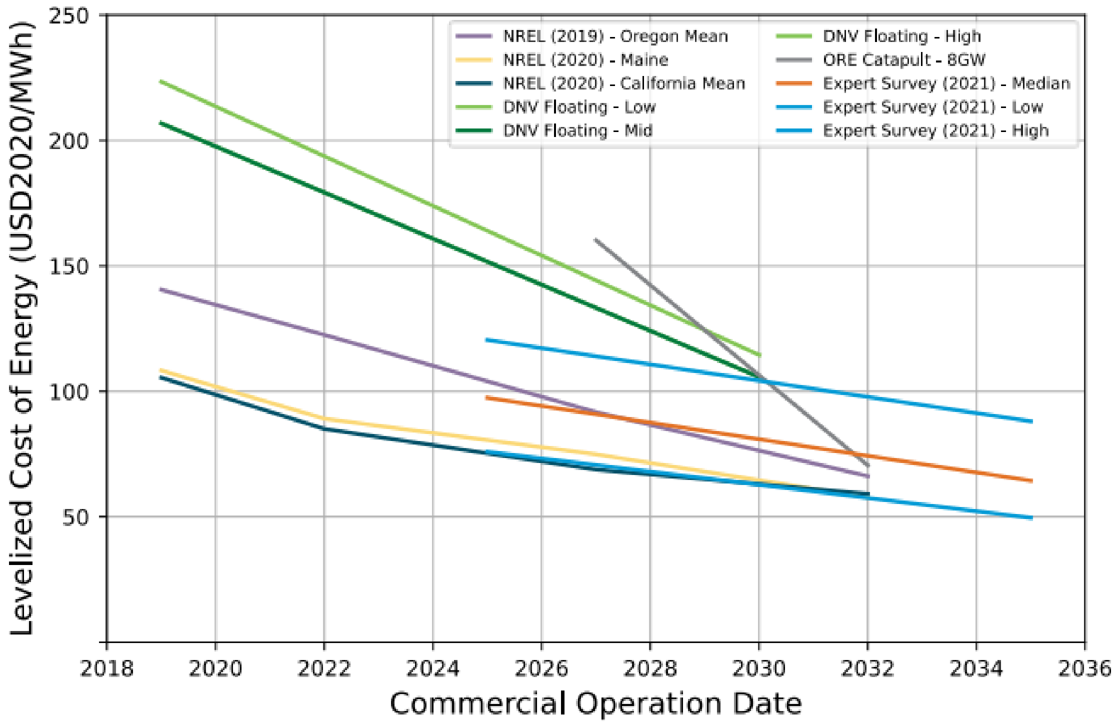


Chart from NREL's Offshore Wind Market Report: 2021 Edition.

OSW Energy Price Projections: California

Costs for California floating OSW are projected to decline.

Between 2019 and 2032, the LCOE of the five study areas is estimated to decline by 44% on average, reaching levels of $53–$64/MWh by 2032. This can be seen in the chart on the bottom right side. The decline in cost is driven by increased turbine size, more mature supply chain, and technology innovation. The power plant capacity rating, 1 GW, is held constant in the chart.

Study Highlights Drivers Contributing to Lower LCOE in CA for FOSW

- Turbine size increasing will offset costs as more energy can be produced (turbine rated power increases from 10 MW in 2022 to 15 MW in 2032).
- Maturing fixed-bottom supply chain as many floating components use the same supply chain.
- Technology innovation through demonstration projects on the east coast and globally will increase the efficiency and drive down costs of the components used.
- Financing structures and terms (PPAs, ORECs, etc.) have been developed and California is able to learn from other types of agreements that have been executed.
- Learning from experience with OSW operations and development practices.

Variations in LCOE between the different study sites was mainly due to wind speed, export cable length, distance to port and water depth.

- Morro Bay, with the deepest water and the farthest distance to port and cables, results in the highest LCOE.
- Higher wind speeds are a key factor for lower LCOE for the northern study areas, such as Del Norte, Cape Mendocino and Humboldt.
- Humboldt and Morro Bay are the current two call areas in development by the BOEM.

LCOE Estimates for floating offshore wind, California

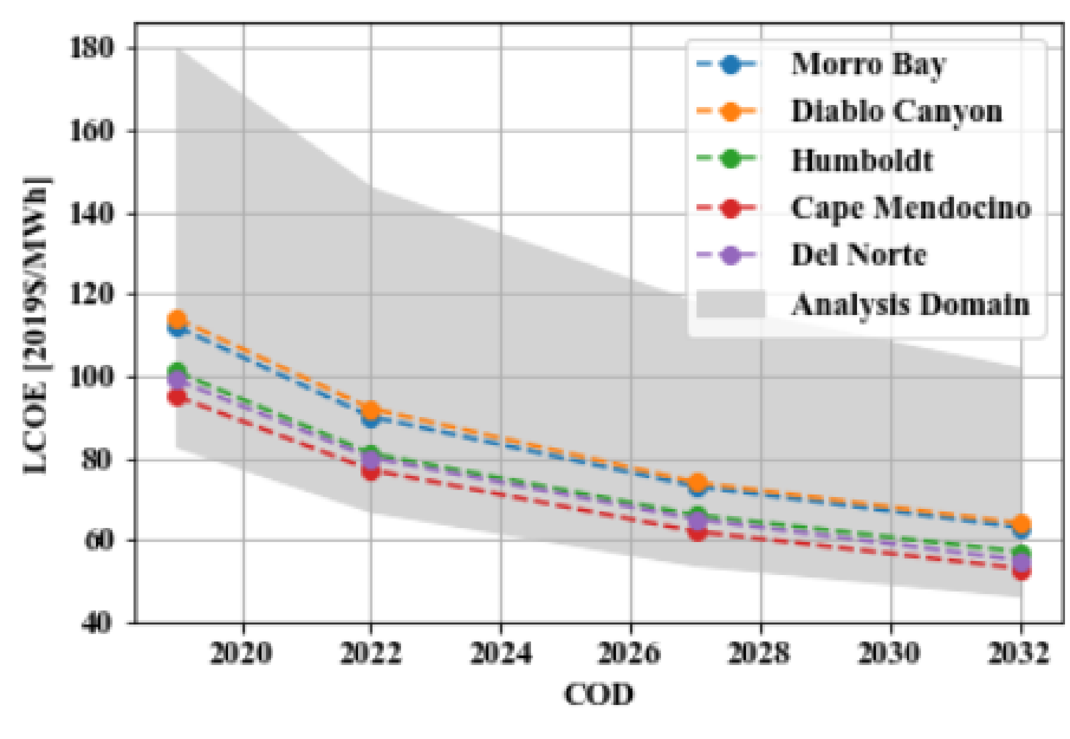


Chart from NREL's Cost of Floating Offshore Wind Energy in California between 2019 and 2032.

Guidehouse Outwit Complexity

East Coast: Infrastructure, Workforce, and Supply Chain Development

East Coast: Infrastructure, Workforce, and Supply Chain Development Summary

Research Question

How have East Coast states approached supply chain, workforce, and supporting infrastructure development through the offshore wind procurement process? What costs are included in procurement contracts? What other methods have been used to help finance supply chain development and the infrastructure to prepare for offshore wind?

Research methodology

Guidehouse reviewed solicitation documents and requests for proposals from East Coast states to understand the supply chain, workforce, ports, and infrastructure development elements required or considered in the procurement process. Guidehouse also reviewed proposals and procurement contracts from winning projects to understand the economic and workforce development efforts that project developers committed to and compared the extent to which states have developed or planned development in supply chain, workforce, ports, and infrastructure. Guidehouse only evaluated states with OSW projects in the pipeline.

Conclusions

Out of the nine East Coast states assessed, there are varying degrees of the procurement process for the preparation of OSW development. The six states with prior solicitations requested or required applicants to provide plans for engaging and/or training the local workforce as well as ensuring to a certain degree the net benefit of the project to the state. Several states, such as MA, NY and NJ, also included supply chain and infrastructure development elements in their solicitations. The OSW landscape is still emerging in the US, and states supporting the development of local supply chain and infrastructure early on are establishing themselves as players in the supply chain going forward. Note that all East Coast projects so far have been fixed-bottom.

Overview of East Coast Targets & Procurement

State	Final Target (GW)	Final Target Year	Target Set By	Policy Instrument for Procurement	Development Elements in Solicitations
Connecticut	2	2030	HB 7156 (Legislative)	Fixed-rate PPA	Workforce
Maine	5	2030	LD 1810 (Legislative)	No solicitations	No solicitations
Maryland	1.2	2030	CEJA (Legislative)	Fixed-rate ORECs	Workforce
Massachusetts*	5.6	2027	H4515 (Legislative)	Fixed-rate PPA	Workforce, supply chain, infrastructure, ports
New Jersey	7.5	2035	AB 3723 (Legislative), EO #92 (Executive)	Fixed-rate ORECs	Workforce, supply chain, infrastructure, ports
New York	9	2035	S6599 (Legislative)	Index ORECs	Workforce, supply chain, infrastructure, ports
North Carolina	8	2040	EO 218 (Executive)	No solicitations	No solicitations
Rhode Island	No target	No target	No target	Fixed-rate PPA	Workforce, supply chain, infrastructure
Virginia	5.2	2034	HB 1526 (Legislative)	Utility-owned	No solicitations (utility-owned project)

*Massachusetts currently has a target of 4 GW by 2027 through An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy. The 5.6 GW target is pending.

Comparison of East Coast States' Development Efforts

State	Policy Instrument for Procurement	Development Elements in Recent Solicitations	Awarded Project(s)' Development Efforts	States' Methods to Drive Development Outside of Solicitations
Connecticut	Fixed-rate PPA	Workforce	Development of Bridgeport Harbor and local supply chain; local construction	No OSW specific efforts
Maine	Solicitation for pilot project only	Solicitation for pilot project only	Pilot project only	Maine Offshore Wind Supply Chain registry to connect state-based companies with project developers (BNOW-affiliated)
Maryland	Fixed-rate ORECs	Workforce	Ports; steel fabrication; monopile, subsea cable, and turbine tower manufacturing	Competitive grant programs for supply chain and workforce development
Massachusetts	Fixed-rate PPA	Workforce, supply chain, infrastructure, ports	Local supply chain strategy; port upgrades; infrastructure improvements; workforce development	Tax incentives to spur in-state revenue and local employment creation; grant funding for ports investment and workforce development
New Jersey	Fixed-rate ORECs	Workforce, supply chain, infrastructure, ports	Building nacelle assembly facilities at the NJWP; foundation manufacturing at the Port of Paulsboro	Tax credits for investment in OSW-specific facilities; grant competitions for workforce development programs, NJ Offshore Wind Supply Chain Registry (BNOW-affiliated)
New York	Index ORECs	Workforce, supply chain, infrastructure, ports	Port infrastructure development: tower manufacturing facility, staging and assembly facility; workforce development	Proposed public funding for OSW supply chain development; funding for OSW training institute
North Carolina	N/A	Lease to be held on May 11, 2022, through BOEM	No projects	North Carolina Offshore Wind Supply Chain Registry (not affiliated with BNOW)
Rhode Island	Fixed-rate PPA	Workforce, supply chain, infrastructure (shared with Massachusetts' 83C RFP)	Local port improvements; investment in OSW education and supply chain development	Supply chain development program; OSW education programs
Virginia	Utility-owned	No solicitations (utility-owned project)	Construction of Jones Act-compliant wind turbine installation vessel and crew transfer vessel; workforce development	Grant to recruit OSW companies to the region and identify opportunities for existing VA businesses to participate in the OSW supply chain

Detailed Development Efforts: Connecticut

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
2 GW by 2030	HB 7156 (Legislative)	Fixed-Rate PPA	Workforce	No OSW specific efforts

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Bidders must include plans for use of skilled labor, "including, but not limited to, for any construction and manufacturing components of the proposal including any outreach, hiring and referral systems…that are affiliated with an apprenticeship program registered with the Connecticut State Apprenticeship Council".

Outside of solicitations: No offshore wind-specific efforts.

Plan for Port of New London, CT, https://revolution-wind.com/state-pier.

Awarded Projects and Year Awarded

Revolution Wind (2018), Park City Wind (2020)

Awarded projects' supply chain development efforts

- Revolution Wind committed to investing $15 million in the Port of New London to allow for local construction, and plan to use a CT-based boat builder to construct one of the project's crew transfer vessels. *Outside of this contract, the Port of New London will support the Sunrise Wind and South Fork Wind projects.*
- Park City Wind includes an estimated $890 million in direct economic development in CT, including Bridgeport Harbor and the local supply chain.

Ratepayer Impact

- All revenues, except capacity market revenue, are passed through to the ratepayers. The generator may keep the revenue received from the forward capacity market.
- Transmission included in PPA bid and the seller covers the interconnection costs to the transmission or distribution system.

Detailed Development Efforts: Maine

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
5 GW by 2030	LD 1810 (Legislative)	PPA	N/A (pilot project only)	Maine Offshore Wind Supply Chain Connect (BNOW-affiliated)

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: N/A (pilot project only)

Outside of solicitations: Maine Offshore Wind Supply Chain Connect profile with the Business Network for Offshore Wind (BNOW)'s Supply Chain Connect registry. The registry aims to match offshore wind project investors with state-based partners and suppliers.

Awarded Projects and Year Awarded

Aqua Ventus (2014, pilot project)

Awarded projects' supply chain development efforts

N/A (pilot project only)

Ratepayer Impact

- PPA agreement with Central Maine Power and ratepayer impact is the cost of energy. $100 million investment from private sector.

VolturnUS, 1:8 scale of a 6 MW wind turbine near Maine. VolturnUS was built at U Maine. It is the first grid connected offshore wind turbine in the US. (https://composites.umaine.edu/research/volturnus/)

Detailed Development Efforts: Maryland

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
1.2 GW by 2030	CEJA (Legislative)	Fixed-Rate ORECs	Workforce	Competitive grant funding for workforce and supply chain development

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Applications should include (1) plan for engaging small businesses; (2) plan for compliance with the Minority Business Enterprise Program for construction, manufacturing, and maintenance phases; (3) plan for the use of skilled labor, especially for construction and manufacturing components of the projects, including outreach, hiring, or referral systems that are affiliated with registered apprenticeship programs

Outside of solicitations: $2.6 million in competitive grant funding for FY 2022 for supply chain and workforce development programs: Maryland Offshore Wind Capital Expenditure Program ($1.6 million) and Maryland Offshore Wind Workforce Training Program ($1.2 million)

Awarded Projects and Year Awarded

MarWin (2017), Skipjack (2017), Skipjack 2 (2021), Momentum Wind (2021)

Awarded projects' supply chain development efforts

Maryland's total offshore wind market (Round 1 and Round 2 projects) will support MD's offshore wind supply chain, resulting in at least $1.5B of in-state expenditures including the following investments:

- $40M for port infrastructure
- $76M for steel fabrication
- $150M for monopile foundation manufacturing
- $140M for subsea cable manufacturing, and
- $100M+ for turbine tower manufacturing

Ratepayer Impact

- All energy and capacity revenues from the wholesale market are returned as pass-through costs from the generator to the ratepayers. Generator receives OREC payment.
- Project must prove net benefit to state.
- Maryland set a rate impact cap and an OREC price cap in the Offshore Wind Energy Act of 2013. Maryland decreased the rate impact cap to be lower starting in 2020.

Detailed Development Efforts: Massachusetts

State OSW Target	Target Mechanism	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
5.6 GW by 2027	H4515 (Legislative)	Fixed-Rate PPA	Workforce, supply chain, ports, infrastructure	Tax incentives to spur in-state revenue and local employment creation; grant funding for ports investment and workforce development

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Qualitative evaluation factors of proposals include: (1) demonstrated ability and commitment to create and foster short- and long-term employment and economic development in the Commonwealth; (2) investment in supply chain improvements to support the offshore wind industry; (3) investment in workforce development to support the offshore wind industry; and (4) utilization and investment in port facilities and infrastructure during project development, construction, and operation and maintenance

Outside of solicitations: Offshore Wind Industry Investment Fund to spur in-state revenue and local employment creation by OSW companies and organizations; Anticipated $50M in state funding for the Massachusetts Offshore Wind Industry Port Investment Challenge; Previously awarded $4M through three rounds of the MA Offshore Wind Workforce Development Grants Program

Awarded Projects and Year Awarded

Vineyard Wind 1 & 2 (2018), Mayflower Wind (2019)

Awarded projects' supply chain development efforts

- Vineyard Wind: $10M for infrastructure and supply chain development; $2M for Windward Workforce program to recruit and train MA residents; contract with New Bedford Marine Commerce Terminal for construction/deployment of OSW turbines
- Mayflower Wind: adopting a local-first supply chain strategy, investing in port upgrades and infrastructure improvements; partnering with MA institutions for workforce development; partnering with European OSW contractor to train regional workforce

Ratepayer Impact

- All revenues, except capacity market revenue, are passed through to the ratepayers. The generator may keep the revenue received from the forward capacity market.
- The levelized price of a project is capped at the price of previous projects ($/MWh). Although not applied in the 2019 solicitation.
- Transmission construction costs included in the PPA price, paid by ratepayers.

Detailed Development Efforts: New Jersey

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
7.5 GW by 2035	AB 3723 (Legislative), EO #92 (Executive)	Fixed-Rate ORECs	Workforce, supply chain, ports, infrastructure	Tax credits for investment in OSW-specific facilities; grant competitions for workforce development programs, NJ Offshore Wind Supply Chain Registry (BNOW-affiliated)

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Applicants' Economic Development plan should include: plans to use offshore wind infrastructure already planned for NJ, i.e., the New Jersey Wind Port; how their project's supply chain plan will help make NJ a hub for offshore wind, including construction, operations, project development, R&D, and innovation; specific contributions to the development of a long-term and sustainable supply chain for offshore wind manufacturing, R&D, and services; how they would engage or integrate efforts with WIND Institute efforts related to workforce development and innovation.

Outside of solicitations: Offshore Wind Tax Credit Program provides reimbursement for capital investments in OSW industry-specific facilities located in NJ; grant competitions for workforce development (Wind Turbine Technician Training Grant Challenge and New Jersey Offshore Wind Safety Training Challenge, which have both been awarded); NJ Offshore Wind Supply Chain Registry (like Maine).

Awarded Projects and Year Awarded

Ocean Wind (2019), Atlantic Shores (2021), Ocean Wind II (2021)

Awarded projects' supply chain development efforts

Both Atlantic Shores and Ocean Wind II projects committed to building new nacelle assembly facilities at the New Jersey Wind Port and utilizing the foundation manufacturing facility at the Port of Paulsboro.

Ratepayer Impact

- OREC $/MWh includes all generation-related costs, paid for by rate payers.
- Any revenues the generator makes in the wholesale market is returned to the ratepayers to offset the costs.
- Project must demonstrate net-economic benefits to the state to be approved.

Detailed Development Efforts: New York

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
9 GW by 2035	CLCPA S6599 (Legislative)	Index ORECs	Workforce, supply chain, ports, infrastructure	Proposed public funding for OSW supply chain development; funding for OSW training institute

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Proposers must provide a Jobs and Workforce Plan, which gives an overall approach and demonstrate a commitment to engaging New York's union workforce and identifies opportunities for collaborating, developing, or investing in partnerships with NY State OSW workforce training efforts currently underway. Proposers must agree to provide NY companies with the opportunity to provide goods and services. Incremental Economic Benefits are also evaluated, which include expenditures and jobs specifically associated with development and construction of an Investment Plan Supply Chain Facility (port, manufacturing, or supply chain infrastructure) receiving NY State Funding. Expenditures that can enable New York based manufacturers and suppliers' participation in the regional OSW industry as early as possible will be awarded additional scoring credit.

Outside of solicitations: $500 million of proposed public funding in New York for port improvements or manufacturing of nacelles, blades, or cables, and targeting existing small and medium suppliers in NY; $20 million to establish the Offshore Wind Training Institute.

Awarded Projects and Year Awarded

South Fork (2017, PPA), Empire Wind 1 (2019), Sunrise Wind (2019), Empire Wind 2 (2021), Beacon Wind (2021)

Awarded projects' supply chain development efforts

Empire Wind 2 and Beacon Wind will support $644 million in funding for port infrastructure, including: $357 million for offshore wind tower manufacturing facility (Port of Albany), over $287 million for an OSW staging and assembly facility (South Brooklyn Marine Terminal), and $47 million in workforce development and just access funding.

Ratepayer Impact

- Confidential price benchmark cap during solicitations, if a project's levelized net OREC cost is higher then the project is not eligible.
- Interconnection and transmission costs are included in the contract and passed on to ratepayers.
- NYSERDA's contracts protect ratepayers against cost overruns, and these would be incurred by the project developers who bear upfront capital and risks throughout construction.

Detailed Development Efforts: North Carolina

State	State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
North Carolina	8 GW by 2040	EO 218 (Executive)	No OSW procurements	No solicitations	North Carolina Offshore Wind Supply Chain Registry

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: N/A
Outside of solicitations: North Carolina Offshore Wind Supply Chain Registry (run by the NC Department of Commerce, not BNOW-affiliated)

Awarded Projects and Year Awarded

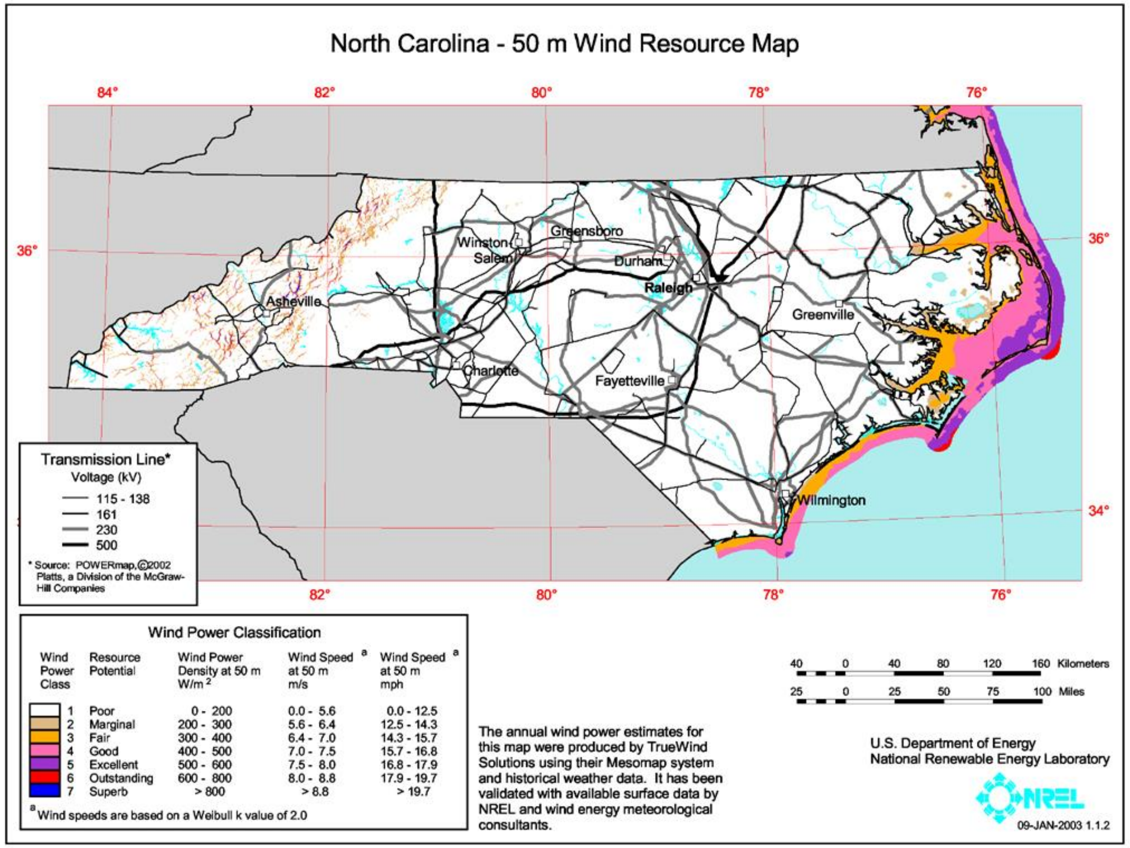
First BOEM lease area auctions to take place on May 11, 2022.

Awarded projects' supply chain development efforts

No projects awarded by the State

Ratepayer Impact

No projects awarded by the State



North Carolina potential capacity for offshore wind. Study by NREL.

Guidehouse Outwit Complexity

Detailed Development Efforts: Rhode Island

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
No target*	No target	Fixed-Rate PPA	Workforce, supply chain, infrastructure	Supply chain development program; OSW education programs

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: Solicitation for Revolution Wind was in collaboration with Massachusetts' 83C RFP. Qualitative evaluation criteria included Economic Benefits: demonstrated ability to create and foster employment and economic development in the Commonwealth such as leases for water-side facilities, capital investment, local manufacturing or outfitting project such as turbine foundations, or use of local suppliers and service providers.

Outside of solicitations: State funding for BNOW's READY 4 OFFSHORE WIND supply chain education program; career pathway training system, WindWinRI, develops educational programs for primary, secondary, and post-secondary students; Qualified Jobs Incentive Tax Credit provides tax credits for businesses to expand their workforce in Rhode Island or relocate jobs from out of state and has been awarded to Boston Energy to bring Wind Turbine Technician and Administrative Staff jobs to Rhode Island.

*Rhode Island has a 100% renewable goal by 2030 (Executive Order, 20-01).

Awarded Projects and Year Awarded

Block Island (2014), Revolution Wind (2019)

Awarded projects' supply chain development efforts

Revolution Wind developers Ørsted and Eversource are investing $40M in RI for local port improvements, including making ProvPort a major construction hub for Revolution Wind, and targeting Quonset for the long-term operations center. Ørsted and Eversource also investing $4.5M in offshore wind education ($3M) and supply chain development ($1.5M).

Ratepayer Impact

- PPA cost for the energy are passed on the utility ratepayers.
- If the generator participates in the capacity market, they keep their revenues as the PPA does not include capacity. However, any other type of revenue is passed on to the ratepayers.
- Project must prove net benefits to the state and the ratepayers.
- Seller pays for transmission up until the point of delivery, then the costs are covered by the buyer.

Detailed Development Efforts: Virginia

State OSW Target	Target Set By	Procurement Contract Type	Development Elements in Solicitations	Development Elements outside of Solicitations
5.2 GW by 2034	HB 1526 (Legislative)	N/A (Utility-owned)	No solicitations (Utility-owned project)	Grant to recruit OSW companies to the region and identify opportunities for existing VA businesses to participate in the OSW supply chain

Development Elements in Detail (supply chain, infrastructure, workforce, or ports)

Included in solicitations: N/A (utility-owned)

Outside of solicitations: Virginia Clean Economy Act of 2020 states that "in constructing any such [offshore wind generation] facility… the utility shall develop and submit a plan to the Commission for review that includes the following considerations: (i) options for utilizing local workers; (ii) the economic development benefits of the project for the Commonwealth, including capital investments and job creation; (iii) consultation with the Commonwealth's Chief Workforce Development Officer, the Chief Diversity, Equity, and Inclusion Officer, and the Virginia Economic Development Partnership, on opportunities to advance the Commonwealth's workforce and economic development goals, including furtherance of apprenticeship and other workforce training programs"

Awarded Projects and Year Awarded

Coastal Virginia Offshore Wind (owned by Dominion Energy)

Awarded projects' supply chain development efforts

Dominion Energy is investing in the construction of 2 Jones Act-compliant vessels: one for installation of the turbines, and another for the transportation of 150-person installation crews. Dominion is also investing in offshore wind workforce development, partnering with K-12 educators, community colleges, colleges and universities, and trade unions. Dominion will use the Portsmouth Marine Terminal as a staging and pre-assembly area for foundations and turbines.

Ratepayer Impact

- Dominion will recover the costs of the projects from its customers under traditional utility cost-of-service regulation.

Potential for Regional Collaboration on West Coast

Many industry experts highlighted opportunity for regional collaboration among West Coast states. While the East Coast has more regional proximity, the West Coast may benefit from a broader network of industries, ports, academic institutions and more. This slide includes interview insights on the topic of regional collaboration and examples of regional collaboration on the East Coast.

Examples of Regional Collaboration on East Coast

- **Partnerships:** North Carolina, Maryland and Virginia created the Southeast and MidAtlantic Regional Transformative Partnership for Offshore Wind Energy Resources (SMARTPOWER) with the intent to "promote, develop, and expand offshore wind energy generation and the accompanying industry supply chain and workforce" in the region.
- **Coalition:** In 2021, governors from nine U.S states requested President Biden to prioritize OSW development in the US.* This is an example of how states can come together to promote a shared agenda.
- **Partnerships:** New York, New Jersey and the BOEM have a shared vision of OSW and will meet quarterly to discuss current and future developments, including a focus on supply chain. This working group also intends to set up best practices and guidance to drive domestic supply chain development and ensure that OSW development benefits underserved, disadvantaged and overburdened communities. The policies and standards these efforts produce can then be used as a model for other states. The NY Bight OSW lease area is off the coast of New York and New Jersey.
- **Research:** Clean Energy States Alliances (CESA) collaborated with Massachusetts, Rhode Island and New York in 2015 to "explore the potential for mutual action to develop OSW at the scale necessary to reduce costs by achieving economies of scale and establishing a regional supply chain." CESA provides a summary in 2018, here.
- **Solicitations:** Rhode Island and Connecticut have participated in Massachusetts's solicitations previously.
- **Ports:** Port of New London in Connecticut is intended to be used to assemble nacelle for projects tied to other states, such as New York's South Fork.

Benefits of Collaboration: Interview Insights

Guidehouse summaries of the interviews with industry experts and not verbatim.

- Definition of local content at the regional level would allow for regional collaboration with WA and OR around supply chain development.
- Globalization presents a significant challenge of where the money should go for local content accounting. Often, companies are multi-national.
- If you have a regional supply chain, including all of the West coast, then you have an opportunity for a broader workforce, academic collaboration, ports that can collaborate. The key is to have communication between the states/stakeholder groups.
- Opportunity to create a partnership between West Coast ports. Different ports could have different specialties.

*CT, MA, MD, ME, NH, NJ, NY, RI, and VA

Summary of East Coast Development Efforts

Nine East Coast states were assessed at varying stages of OSW development. Of these, the six states that have had solicitations have requested or required applicants to provide plans for engaging the local workforce and/or ensuring net economic benefit to the state via investments in supply chain, infrastructure, and port development. States that are supporting the development of local supply chain and infrastructure early on are establishing themselves as key players in the supply chain going forward.

Elements as Part of Solicitations

States that have had solicitations for offshore wind projects have included different elements in their procurement processes to encourage supply chain, infrastructure, and workforce development. All states that have had a solicitation have requested or required applicants to provide plans for engaging and/or training local workforce. Several states (MA, NJ, and NY) also included supply chain, infrastructure, and port development elements in their solicitations.

Elements Not Included as Part of Solicitations

States have also employed efforts outside of the procurement process to drive supply chain, infrastructure, and workforce development. These include competitive grant funding for workforce development programs, tax incentives to encourage companies to do business in-state or participate in the offshore wind industry, funding for supply chain, infrastructure, and ports development, and supply chain registries to connect local companies with project developers and investors.

Results of East Coast Development Efforts

States achieved a variety of commitments and investments in supply chain, infrastructure, and workforce, no matter the level of efforts to drive development in and outside of the procurement process. For example, Connecticut only included workforce in its recent solicitation and had no OSW-specific development efforts, but Revolution Wind and Park City Wind both committed to investing in local port development, local supply chain, and use of local labor. Awarded projects in Maryland, New Jersey, and New York notably committed to investments in component manufacturing and assembly facilities. The utility-owned Coastal Virginia Offshore Wind project is unique in investing in the construction of 2 Jones Act-compliant vessels for installation of turbines and crew-transfer.

Note that all East Coast projects so far have been fixed-bottom in commercial projects.

Innovations

Innovations summary

Research Question

What are the most promising technology innovations that can use materials produced in California or other West Coast states to manufacture major wind energy components, vessels, or otherwise improve the case for FOSW in the Pacific?

Research methodology

Guidehouse created a list of relevant innovations from interviewees, internal subject matter experts, and offshore wind research and development initiatives, then conducted further research on each.

Conclusions

Several innovations exist that could potentially be leveraged to address crucial obstacles to FOSW deployment, or otherwise improve the business case for FOSW. While some of these innovations have examples of existing commercial applications, many are still in the early stages of design.

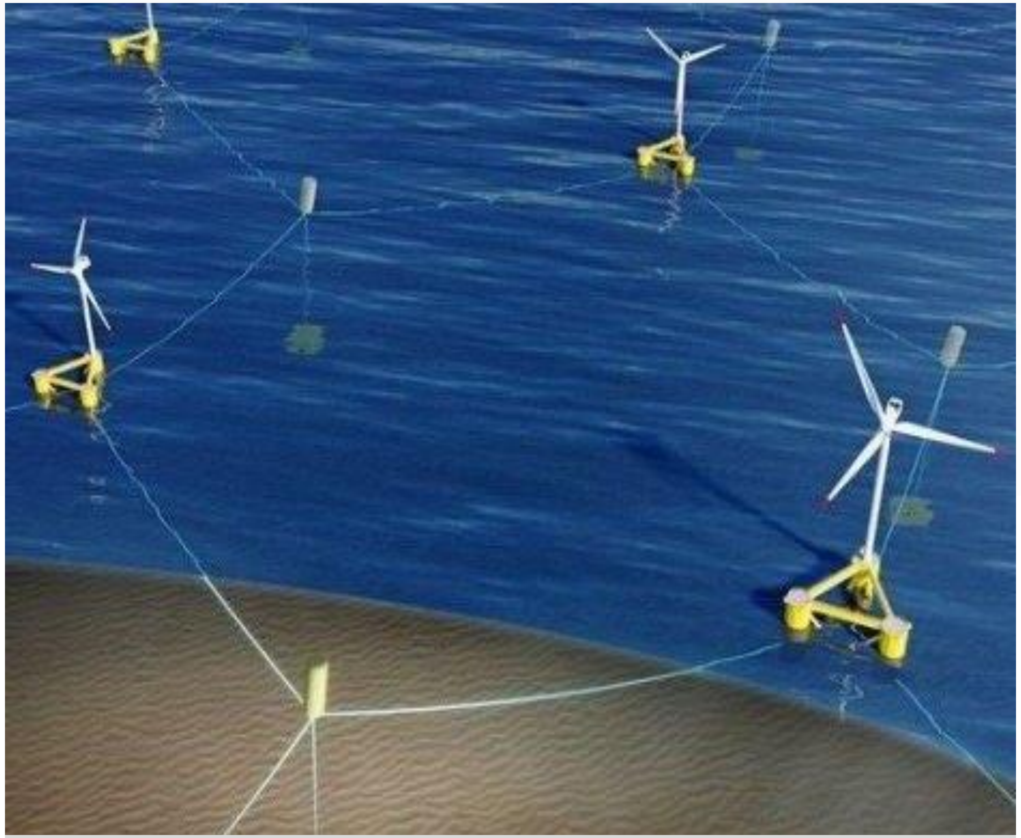
Shared Mooring and Anchor Systems

Description

- As floating turbines and foundations mature, and farms are considered at larger scale in deeper waters, the cost share of moorings of the total CAPEX may increase
- To decrease mooring costs, moorings could be shared between turbines, using interconnecting mooring lines between adjacent platforms and possibly connecting multiple mooring lines to the same anchor. For example, two turbines would have a total of 4 moorings rather than six, resulting in a more integrated web.
- For example: French oil and gas company TotalEnergies, alongside Equinor and Norwegian engineering company Semar, are developing a honeycomb-shaped mooring array system where each mooring point is tethered to three turbines in an interlinked array (see visual on the right).
- Shared mooring and anchor systems are a relatively new development, and concepts have only been independently developed with no academic consensus formed on which methods to pursue commercially.

Possible benefits

- Reduce total length of mooring line, number of anchors, footprint on seabed.
- Reduce peak loads on turbine structure and mooring system.
- Reduce mooring component costs by up to 50% compared to traditional mooring.



TotalEnergies Honeymooring, courtesy of the Maritime Executive

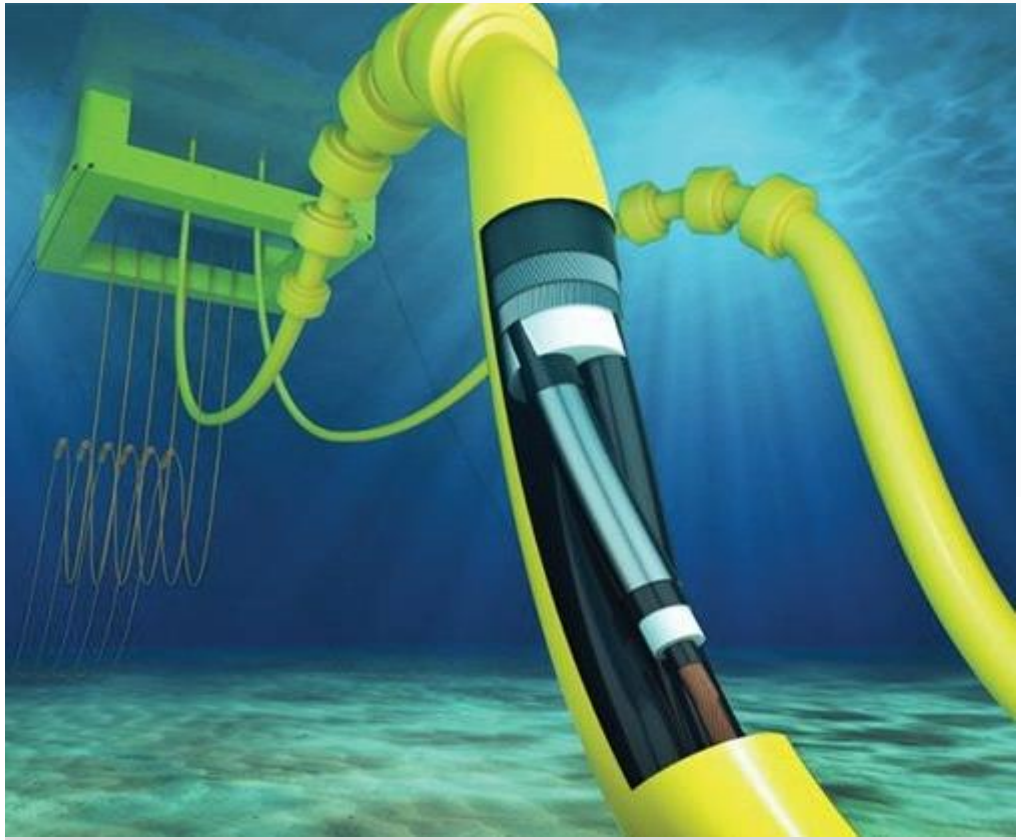
Dynamic Cables

Description

- While typical transmission cables are not designed with wave motion in mind, dynamic cables are able to withstand a lifetime of constant movement. As such, dynamic cables are a natural fit for deep-water FOSW projects, especially for the section of cable that rises from the sea floor to the platform.
- Dynamic cables could be used for both export and inter-array cables
- The offshore oil and gas industry has been successfully using cable and umbilical technologies in deep-water environments for many years now. FOSW can draw on this experience, but cables will need to operate at higher voltages than before in order to transmit all the energy as turbines grow larger and larger.
- Examples:
  - In 2019, NKT deployed the world's first commercial application of a dynamic cable to supply electricity to an oil & gas platform. The link consisted of mostly static cable on the seabed, with the portion rising to the platform being dynamic.
  - In 2021, Nexans was awarded a contract to supply a deep-water dynamic cable from an Australian Chevron facility. Nexans believes the project will be a strategic reference for future projects in offshore wind.

Possible benefits

- Dynamic cables are better suited to experience the fatigue caused by more than 100 million wave-induced bending motions over a 30-year time frame.



An example of dynamic cables, courtesy of Nexans

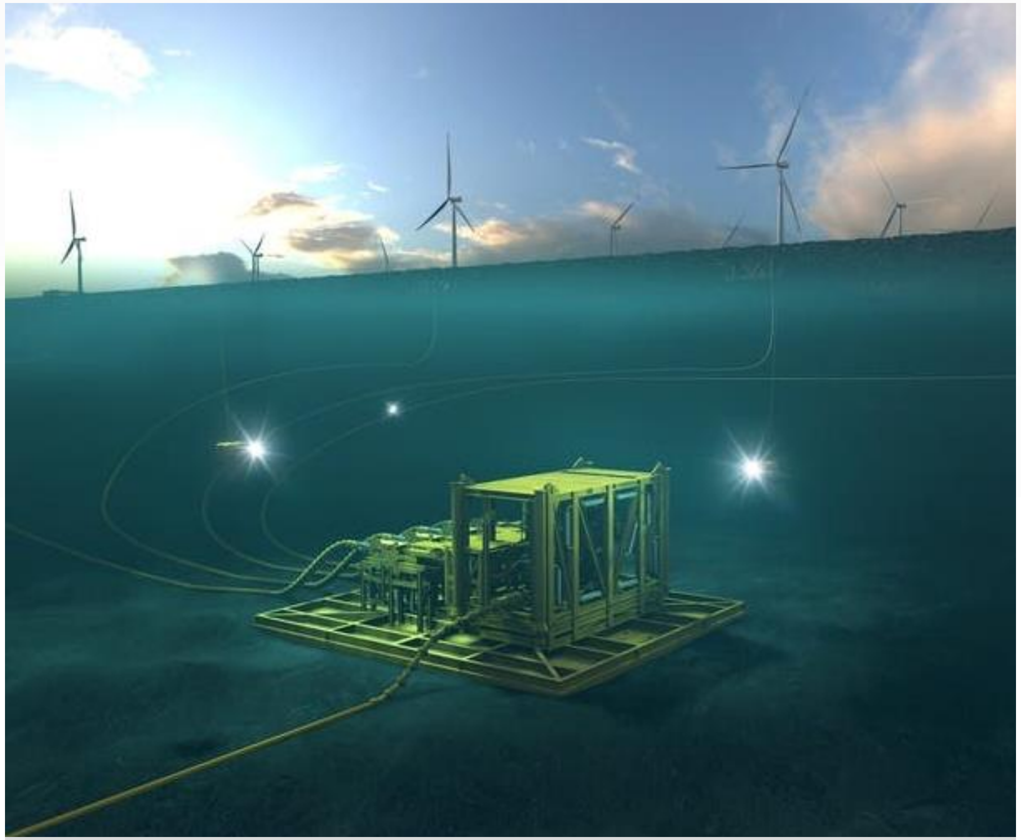
Underwater Substations

Description

- In 2021, developer Aker Offshore Wind announced plans to deploy an underwater substation if its bid for a lease area in Scotland is successful.
- Aker's project was not selected in the ScotWind licensing program. It is unclear whether Aker will pursue the deployment of the underwater substation elsewhere.
- Aker appears to be the only firm suggesting to move substations underwater. This technology is not yet commercially viable.
- Floating substations are also a very novel technology, so the concept of an underwater substation is not as unorthodox as it might seem.

Possible benefits

- Benefits, according to Akker Offshore Wind:
  - Seawater could be used as a natural cooling system
  - Reliability would be increased through more stable temperatures, fewer components, and no rotating parts, as water cools the substation.
  - Operational costs could come down through reduced maintenance and material use.
- However, there are also some challenges worth noting:
  - Attaching a substation to the seafloor might make it more vulnerable to seismic activity, compared to a floating counterpart.
  - Installation and maintenance might be more difficult underwater. Underwater operations would require specialized equipment and training.



A depiction of the Aker underwater substation design

Fabrication Automation

Description

- Automating various manufacturing processes could increase supply chain efficiency, especially for labor-intensive processes. However, automation will also reduce the quantity and change the types of jobs created by FOSW development.
- Most automation innovation seems to be focused on blade manufacturing. Two examples:
  - NREL recently began prototyping and validating blade finishing technologies using a 3m arm equipped with devices that perform various finishing operations, as well as using 3D imaging to capture the geometry of the blade surface and program robot movements.
  - Dutch company TebuloRobotics recently demonstrated an autonomous mobile robot capable of precision blade coating. This is still in an early stage of development, and company officials hope it can be utilized in other manufacturing stages as well.
- There are existing automation solutions available for welding tower and foundation pieces together. Further automation and innovation might still be possible.

Possible benefits

- Reducing production costs
- Decreasing the time needed for manufacturing
- Improving product quality and general workplace safety
- Ultimately increasing the volume of components produced in a given timeframe

A blade manufacturing robot from NREL

Data Collection, Analysis, Predictive Modeling

Description

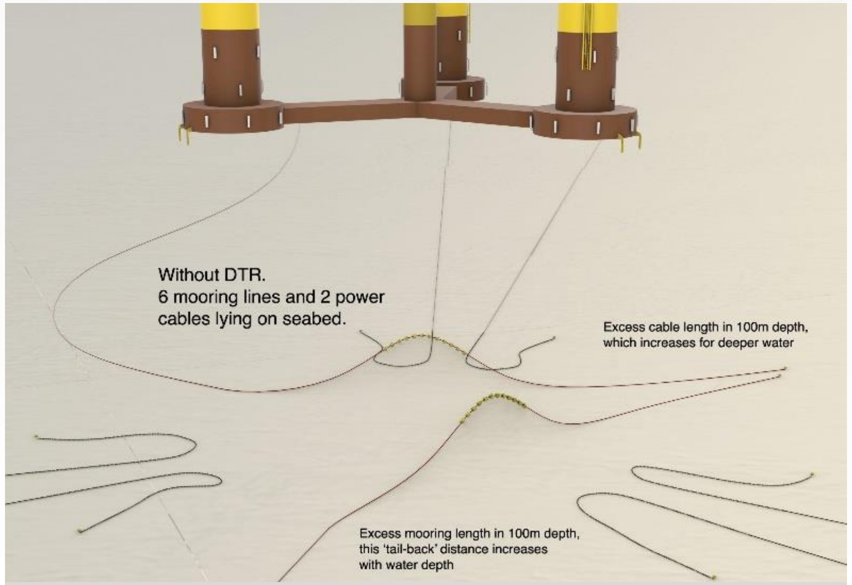
- Companies are beginning to utilize advanced data sensing and analysis, which could offer a variety of benefits. At a broad level, this usually entails the placement of sensors on different system components, which can provide real-time data streams of component conditions and inform asset management decisions.
- One example is Proserv's smart cable monitoring solution, ECG, by deploying sensors through the farm, the system enables automated condition monitoring.
- A similar example is the concept of a digital twin, a virtual representation of the FOSW system that serves as a real-time digital counterpart. This is also achieved through a combination of sensors and modeling. The digital twin is supplied with data and insights from the physical counterpart and can be used to test different weather/load scenarios, monitor component conditions, and more.
  - GE is currently developing wind digital twin capabilities.
  - Akselos and Lamprell utilized digital twin simulation capabilities to test design alternatives against thousands of scenarios, ultimately reducing the steel weight and associated foundation costs by 30%.

Possible benefits

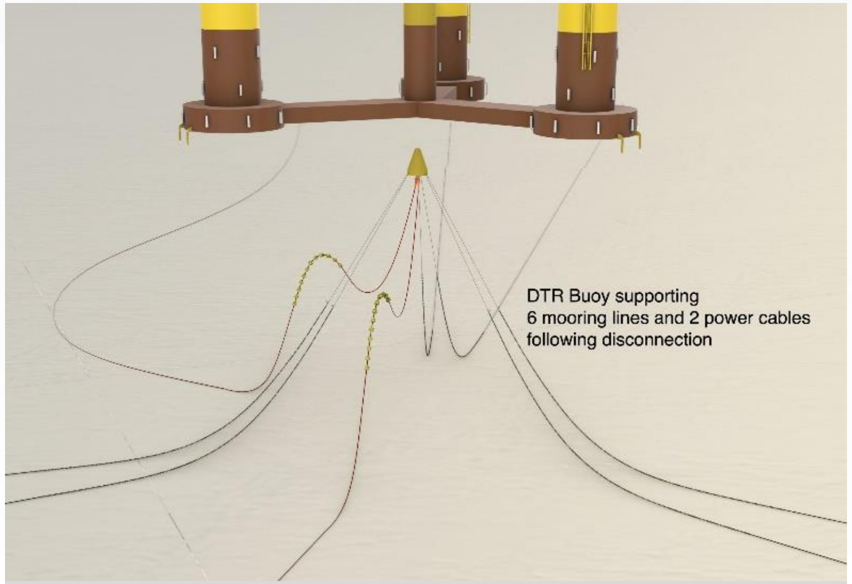
- Detecting small anomalies in performance before problems arise.
- Maximizing power transmission.
- Reducing component failures and maintenance/vessel costs.
- Optimizing component and system design.

Image courtesy of GE

Quick Mooring Connection and Disconnection



Connection without DTR. Courtesy of SBT.



Connection with DTR. Courtesy of SBT.

Possible benefits

SBT states that the DTR achieves major benefits such as:

- Avoiding major costs and risks of storing lines and cables on the seabed, which is traditionally a technical issue for deep water sites.
- Shortening the time to first power by allowing safe cable installation well in advance of turbine arrival.
- Potentially allowing power to flow through an inter-array string when the FOWT is off-station by coupling cables together inside the buoy.

Description

- Rather than storing mooring lines and power cables on the seafloor prior to foundation and turbine installation or during maintenance, SBT's design, termed the Disconnectable Turret for Renewables (DTR), holds the lines and cables in a safe configuration below the system when not connected.
- SBT estimates CAPEX reductions somewhere in the range of $1-2 million, and approximately double for OPEX, leading to significant LCOE and commercial risk reduction.
- SBT released this video that demonstrates the operation of the DTR for both connection and disconnection.

Horizontal Turbine Assembly and Transport

Description

- Many ports in CA are blocked by overhead constraints, namely bridges or airports. Guidehouse identified two firms currently designing systems that would allow for the horizontal assembly or transportation of floating wind turbines prior to installation, which would negate this air draft problem.
- Aikido Technologies, a spin-out of Otherlab, is developing a platform design that would allow for the turbine to be assembled and transported horizontally, and once the port constraint is cleared, to use a ballasting technique to self-upend the turbine to make it vertical. This is done by filling and removing foundation columns with water. Aikido's design claims to also reduce space and equipment required for assembly at the port, enabling up to five times the assembly capabilities than with traditional designs. This is achieved by pinning components together rather than welding, allowing platforms to fold and save space.
- Nautica Windpower's SEALIFT design operates similarly, as it can be fully assembled quayside in a nearly horizontal position and leaves the port under tug assist. It can then traverse beneath bridges and through shallow waterways.

Possible benefits

- Enables the use of ports behind bridges or other draft constraints.
- More efficient use of port space for assembly.
- Reduction of capital and operating costs.

Nautica Windpower's SEALIFT design

Insights from OSW Industry Interviews

Guidehouse asked industry experts for their thoughts on innovations that would be worth further investigation, and many of those ideas were included in this section on Innovation. However, some suggestions were not specific to FOSW, or related less to a specific innovation and more to a general topic that could use further research. The more general innovation topics are:

- A few industry experts highlighted a need for innovations that address the end of life for turbine systems. This could include the recycling or reuse of blades, as there are currently limited uses of leftover carbon fiber and fiberglass. This problem is not specific to FOSW and will need to be tackled by the entire wind industry.
    - One example is Siemens Gamesa Renewable Energy (SGRE) RecycleableBlade. According to SGRE, their design utilizes a new type of resin that makes it possible to efficiently separate it from the other components at the end of the blade's working life. This allows the materials to be recycled for new applications.
- In addition to using specific innovations that utilize data, such as digital twin or smart cable monitoring, experts noted that California's existing expertise with technology and data analysis could be leveraged to improve the permitting process through more robust data analytics and acquisition – perhaps improving sensing and survey work.
- 3D Concrete printing has been cited as a way to potentially reduce capital costs for land-based towers. Printing solutions are being developed by RCAM Technologies, University of California, Irvine, as well as GE.
- Finally, one expert discussed eliminating sulfur hexafluoride from switchgears, and using synthetic ester oil as opposed to mineral oil in transformers, in order to improve the environmental impact of the industry. However, these innovations are not specific to floating wind.

The list of innovations in this section is not exhaustive. As the industry matures and a steadier pipeline of projects is secured, further innovations will likely be researched. Research and development initiatives, such as the Floating Wind Joint Industry Project between Carbon Trust and 17 leading international offshore wind developers, are good sources of information for current and future innovations.

Guidehouse
Outwit *Complexity*

Findings from Pilot Studies in Japan

Pilot Program Summary

Research Question

What floating wind pilots have been done in Japan? Which have done well, and why?

Research methodology

Guidehouse reviewed project development documents, news articles, academic papers, reports, and press releases from a variety of sources to understand the details and outcomes of three separate pilot programs in Japan. By analyzing these projects, Guidehouse developed four conclusions applicable to floating offshore wind in California.

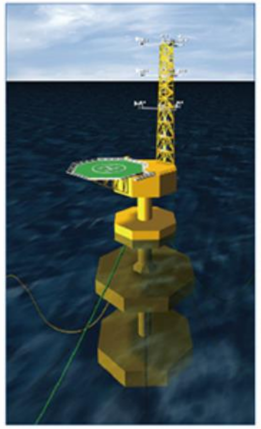
Conclusions

Three pilot programs were conducted in the capacity range of 2-7MW from 2013 to 2018. Five total turbines were built.

- Achieving consistent availability and high-capacity factors is crucial to project financial viability.
- Deploying proven technology can minimize operational problems that limit capacity factor.
- Differences in carbon content and local manufacturing capabilities can lead to advantages and disadvantages between concrete and steel platforms, despite similar performance.
- Actively engaging with local stakeholders, especially the fishing industry, is key to social acceptance of floating windfarm developments.

Pilot Programs: Fukushima Forward

Floating Substation



Compact Semi-Sub (2MW)

Advanced Spar (2MW)

V-shape Semi-sub (7MW)

Project overview

- Completed over three distinct phases, Fukushima Forward was the first FOSW demonstration in Asia and sought to establish a general business model for FOSW.
- The 7 MW and 5 MW unit had difficulty producing energy amidst maintenance issues*, and as a result all turbines were eventually decommissioned due to low income and high O&M costs.

2013: 2 MW Semi-Sub

Developed by Marubeni Corporation. Tech. developed by Mitsui Engineering & Shipbuilding. Decommissioned in 2021.

- An early concern was how to protect the steel structure from excessive corrosion. Marubeni eventually settled on an epoxy-based coating pigmented with aluminum by AzkoNobel.
- Best performance of the three turbines, with an average capacity factor of 34%.
- Project initially faced strong opposition from local fishery operators. Social acceptance was eventually gained with hopes the turbines would revitalize local economy with tourism. Engagement with local stakeholders was crucial to the project.

2015: 7 MW Semi-Sub

Developed by Marubeni Corporation. Technology developed by Mitsubishi Heavy Industries. Decommissioned in 2020.

- This unit was built around a unique hydraulics-powered technology known as digital displacement transmission rather than more common direct-drive or geared drivetrains. This led to several operating problems and high maintenance costs.
- Maintenance issues led to the least electricity production of all three turbines, with an average capacity factor of just 2%. For new turbines in this period, roughly 30% was expected.

2016: 5 MW Spar

Developed by Marubeni Corporation. Technology developed by Japan Marine United. Decommissioned in 2020.

- This unit managed an average capacity factor of 12%, significantly below the expected 30%.
- Despite the satisfactory performance of the 2 MW unit, project costs eventually overwhelmed a revenue stream stifled by low availability.
- The Japanese Wind Power Association stated that the technical issues, and resulting decommissioning, should be seen in the context of using new-made prototypes rather than more reliable commercial wind turbines.

**Mechanical issues were isolated to the turbines. There were no reports of problems with the floating platforms themselves.*

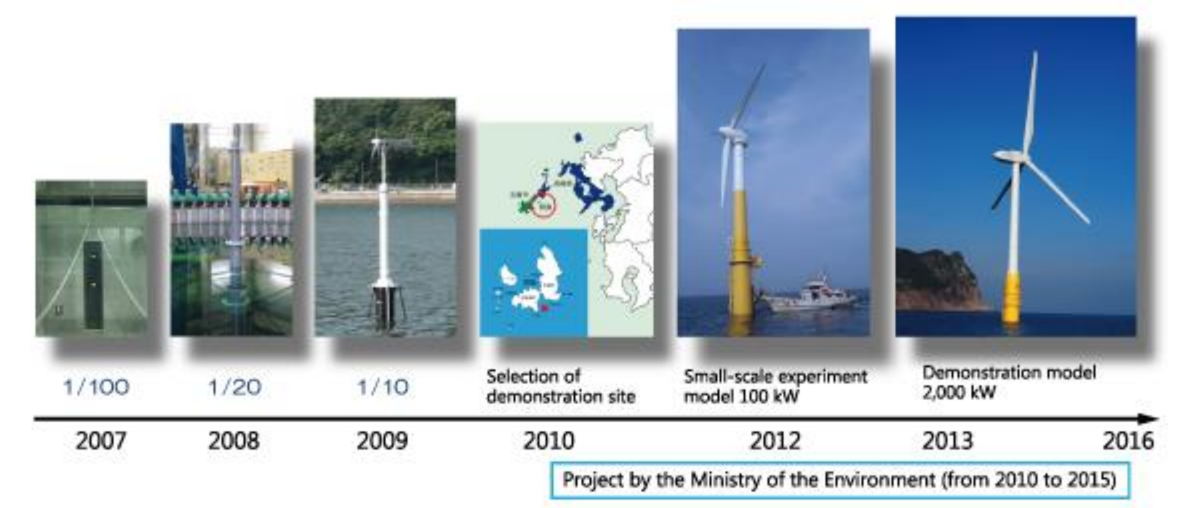
Pilot Programs: Kabashima/Sakiyama

Project Overview

- Project and technology were developed by the Toda Corporation in collaboration with Kyushu university over the course of a decade. Research began in 2007 on a model at 1/100 scale, and incrementally larger projects were tested over the years.
- In 2012, a 100kw turbine model, a similar design to the final 2MW version, was installed on the site. This unit experience a severe typhoon and emerged “unscathed” and was considered a success. Movement patterns were recorded and compared to simulations.
- The final 2MW spar demonstration began operation in 2013. Unlike Forward Fukushima, there was no floating substation – power was transmitted directly to shore through the inter-array cable attached to the turbine.

2016 Relocation to Fukue

- After development and testing off the Goto Kabashima coast, the turbine was reinstalled near Fukue island for commercial operation.
- Prior to installation, a cable was installed that allowed all generated electricity to be transmitted to shore, whereas at the previous location only 35% of full capacity could be exported.
- The turbine has maintained commercial viability and continues to operate off the coast of the Fukue islands.



- *Project and technology developer: Toda Corporation*
- *Platform technology: Hybrid spar*
- *Turbine Capacity: 2MW*
- *Operating since 2013*

Pilot Programs: IDEOL Kitakyushu Demo

Project overview

- The New Energy and Industrial Technology Development Organization (NEDO) selected tech developer IDEOL to design two foundations (one steel and the other concrete). This 3MW turbine is a demonstrator for their steel design. The concrete design was deployed in France around the same time.
- After installation, the demonstrator faced three super-typhoons successfully, showing the promise of IDEOL's barge design. Project was considered a success.

- *Project developer: IDEOL & Hitachi Zosen*
- *Technology developer: IDEOL*
- *Platform technology: Steel barge*
- *Turbine Capacity: 3MW*
- *Operating since 2018*

Concrete vs. Steel

- As part of the design process, IDEOL studied the differences in concrete and steel hulls. A summary of the 2016 paper's results can be found in the table below.
- IDEOL found that steel and concrete are equivalent in terms of performance. The main criteria that might lead to choosing a material are the availability of local manufacturing capabilities, construction sites, and carbon content target.

Material	Hull Weight	Carbon Content*	Cost	Construction	Performance & O&M
Concrete	8,250 t	2422 tCO2	Twice as cheap as steel hulls. Concrete structures are less affected by steel supply volatility and other constituents are more stable in price.	Main challenge is their weight. Must be at least partially built on a quay/barge, and possibly finished offshore, depending on the port.	Will crack in most stressed areas. As such, necessary to incorporate thick, pre-stressed walls.** O&M advantage after 20 years.
Steel	2,200 t	4719 tCO2	Up to twice as expensive as concrete. Due to the volatility of global steel market, construction costs can quickly fluctuate +/-25%	Similar to ship construction. Can be built in a shipyard or steel construction shop. Typically built by assembling panels and welding together.	Fully watertight. Similar O&M up to 20 years, after which concrete might be advantageous, according to IDEOL.

**This is the average of the worst- and best-case scenarios in the IDEOL report. Worst case uses new materials, while best case incorporates recycling. This is for fabrication and does not include emissions during installation.*
***Pre-stressed concrete is produced by compressing and tensioning the structure with high-strength tendons in order to improve its performance.*

Pilot Programs: Conclusions

1. Concrete and Steel

Barge hulls primarily based on either Steel or Concrete have been proven commercially viable. IDEOL's Kitakyushu barge, primarily based on steel, and the concrete counterpart in France have both been deployed successfully. According to IDEOL's research, the decision to focus on concrete or steel should stem from the availability of local manufacturing capabilities, construction sites, ports, and carbon content target.

While steel and concrete platforms have similar performance, differences in carbon content, cost, and local manufacturing capabilities can lead to advantages and disadvantages between the materials.

2. Achieving consistent availability

Achieving a high-capacity factor was crucial to ensuring the commercial viability of projects. Low availability was cited as the primary reason for the decommissioning of the 7 MW and 5 MW turbines in the Fukushima Forward demonstration, which achieved 2% and 12% average capacity factors respectively. Around 30% was expected. The Kabashima/Sakiyama and IDEOL Kitakyushu projects have thus far achieved a better output of energy and have been commercially successful thus far.

California developments should make capacity factor a priority in project design considerations.

Guidehouse Outwit Complexity

Pilot Programs: Conclusions (Continued)

3. Deploying proven technology

While the aim of pilot projects is to test unproven technology, using technology with some demonstrated viability was key to avoiding expensive maintenance and ensuring high availability.

- The Fukushima Forward project utilized “new-made prototypes, not commercial wind turbines” with unique design choices, such as a digital displacement transmission rather than direct-drive or geared drivetrains (which are more commonly used in turbines). As a result, the 5 MW turbine and 7 MW turbine especially were “riddled” with operating problems, which contributed to the low availabilities.
- On the other hand, before constructing the full 2 MW demonstration, The Kabashima project deployed a 100kW turbine that was otherwise identical. This provided the developers with a chance to examine the platform and turbine’s performance, collect data, and compare to numerical models, which could have contributed to the successful deployment of the 2 MW model.
- The IDEOL project was their second demonstrator, a near identical barge being successfully commissioned successfully in France beforehand.

Using technology that has either been tested at the project site or proven commercially viable in previous demonstrations can prevent unexpected operational problems for California FOSW

4. Engaging with local stakeholders

Both the Fukushima Forward and Kabashima projects emphasized the importance of engaging with local stakeholders in early stages of development. Active communication with fishery operators around the development was crucial to mitigate opposition, as they argued that dragnets and other equipment used in trawling could get caught on the undersea cables. The developer had regular meetings with fishers, performed fish catch testing and other field research. In the case of Fukushima, acceptance eventually came with the expectation that the turbines would vitalize these regions by becoming tourist attractions, among other reasons.

Future FOSW developments in California would do well to proactively reach out to stakeholders, especially the fishing industry in BOEM call zones, to encourage social acceptance

Pilot Programs: Detailed Comparison

Project Name	First Power	Project Dev.	Technology Dev.	Technology	Turbine MW	Turbine OEM	Water Depth	Cap. Factor	Status	Foundation Details	Turbine details	Mooring
Fukushima Forward Phase 1	2013	Marubeni corporation	Mitsui Engineering & Shipbuilding	Semi-Sub	2 MW	Hitachi	120m	34%	Decommissioned (2021)	Compact semi-sub, width 58m, total column length 32m of which 16m was submerged	hub height 60m, blade length 40m, rotor diameter 80m, cut out wind speed 25m/s, cut in wind speed 13m/s, RPM 11.1-19.6	6 chains catenary. Nippon Steel & Sumitomo Metal.
Fukushima Forward Phase 2	2015	Marubeni corporation	Mitsubishi Heavy Industries	V-Shape Semi-Sub	7 MW	Mitsubishi	120m	2%	Decommissioned (2020)	32m depth, 17m draft, 85m length, 150m width	Hub height 105m rotor diameter 167m, cut in wind speed 15m/s, cut out wind speed 21m/s, RPM 10.3	8 pieces catenary. Nippon Steel & Sumitomo Metal.
Fukushima Forward Phase 3	2016	Marubeni Corporation	Japan Marine United	Spar	5 MW	Hitachi	120m	12%	Decommissioned (2020)	48m depth, 33m draft, 59m length, 51m width	hub height 105m, tower height 88.8m, rotor diameter 167m, spart length 60m, connection tower and foundation height 12m	6 chains catenary, Nippon Steel & Sumitomo Metal.
Kabashima / Sakiyama	2013 / 2016	Toda Corporation	Toda Corporation	Spar	2 MW	Hitachi/Subaru	N/A	N/A	Operating	Steel with pre-stressed concrete. total length 172m, total weight including turbine 3,400t	80m rotor diameter	Steel chain mooring, 3 chains catenary, attached to drag anchors
IDEOL Kitakyushu Demo	2018	IDEOL & Hitachi Zosen	IDEOL	Damping Pool Barge	3 MW	Aerodyn	55m	N/A	Operating	Steel with pre-stressed concrete. total length 172m, total weight including turbine 3,400t	SCD 3MW, 122m turbine height, 72m hub height, 100m rotor diameter	N/A

Guidehouse Outwit Complexity

Seismic Requirements

Seismicity Summary

Research Question

What are the existing seismic requirements and recommendations for floating offshore structures? What adaptations could be made to reduce seismic vulnerability of floating systems in California?

Research methodology

To answer this question, Guidehouse reviewed existing standards and practices, academic papers, and government reports related to seismic effects on floating offshore systems.

Conclusions

The relevant standards, recommended practices, as well as system design and siting guidelines are summarized in this section. Based on our research, it does not appear there is any specific need for the CEC to directly assist with technology investment to address potential seismic issues in California FOSW**.** Adaptations will likely be site-specific and based on further seabed and soil studies.

Seismicity: Geohazard Overview

The subduction of the Gorda and Juan de Fuca plates off the coast of northern California, coupled with the San Andreas Fault Zone, lead to high levels of seismic activity in all California call areas. As a result, there are four distinct geohazards that can affect wind farms off the California coast. These are worth considering when designing FOSW system components.

Earthquakes

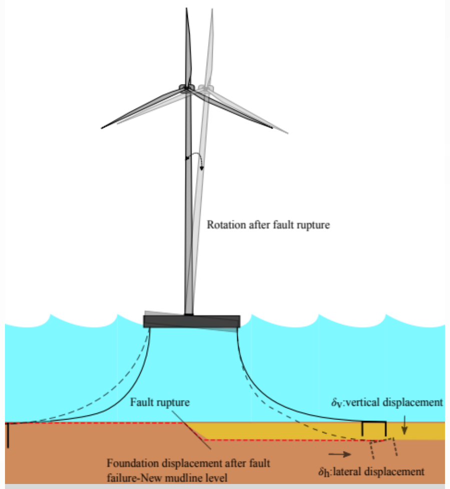
- Earthquake motion affects the anchors and mooring, which transmit seismic motion to the floater. This effect is mitigated by low mass of the cables and damping effects of the water.
- Tension leg platforms will have a higher response to seismic motion and are more sensitive to vertical ground motion than horizontal ground motion.
- Large fault movements can lead to cable or anchor ruptures. Legs can be subjected to additional or less tension depending on relative displacement (see figures to the right).

Tsunamis

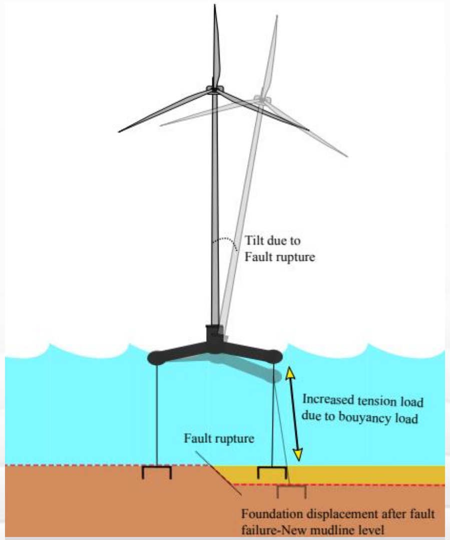
- Wave loads from tsunamis can lead to structural fatigue, reducing system durability.
- In deep waters tsunami wave crests are usually too small to be noticed by ships. Effects of tsunamis are minimized when a floating structure is set at a depth of at least 40m to 50m.

Landslides and liquefaction

- Shallow sea floor gas and gas hydrates off the coast of northern California reduce sediment strength and increase the possibility of slope instability.
- Underwater landslides can randomly occur in earthquakes with magnitudes smaller than 5.0, and more commonly occur with those over 5.0. They can also be induced by remote quakes.
- Landslides can also occur as a result of liquefaction, where soil begins to act as a fluid.
- Landslides can generate potentially hazardous tsunamis and produce long run-out turbidity currents that break cable networks.



Effect of fault rupture on a floating offshore wind turbine with a catenary mooring system



Effect of fault rupture on a floating offshore wind turbine supported by a tension leg platform

Existing Seismic Standards and Recommended Practices

Due to the limited number of existing floating offshore wind farms constructed, mandatory standards for the seismic design of floating systems, or holistic guidelines for their certification, are not available. However, there are some recommended practices and guidelines*, as well as relevant sections of codes from the oil & gas industry.

2021: DNVGL-RP-0585, Seismic Design of Wind Power Plants

- In August of 2021, DNV published the world's first recommended practice to "minimize cost, warranty, and liability risks and optimize wind power plant design for seismic conditions in emerging wind power markets."
- This recommended practice is meant to provide principles and technical recommendations for the seismic design of wind power plants, as well as supplement existing DNV standards for turbine design which did not focus on seismicity.

2020: ABS Guide for Building/Classing Floating Offshore Wind Turbines

- In 2020 the American Bureau of Shipping created a guide containing criteria for the design, construction, installation, and survey of floating offshore turbines. There is a short section on seismicity.
- Rather than cover specific design criteria or potential adaptations, the guide briefly recommends types of site-specific data that can be considered when establishing an area's seismicity, as well as the different geohazards a site can encounter.

2017: ISO 19901-2:2017, Offshore Seismic Design Procedures

- In 2017, ISO released standard 19901-2:2017, "Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria." These seismic design procedure requirements focused on fixed steel and concrete offshore structures. Effects of seismic events on floating structures are briefly discussed.

**Note: Recommended practices are documents prepared by professional groups or committees indicating good engineering practices which are optional in nature. Standards are similar but contain mandatory requirements. The use of the term "recommendations" on this slide is not an endorsement made by Guidehouse.*

Existing Seismic Standards and Recommended Practices (continued)

2016-18: DNVGL-ST-0119 and DNVGL-ST-0437

- Prior to the release of DNVGL-RP-0585, DNV released two other relevant standards. Neither of these focused extensively on seismicity.
  - **2018, DNVGL-ST-0437:** Loads and Site Conditions for Wind Turbines. This standard briefly discusses how to perform dynamic response analysis for seismic loads, not specific to floating. The standard does not provide any details of seismic design criteria.
  - **2016, DNVGL-ST-0119:** Floating Wind Turbine Structures. This standard contains two paragraphs that recommend assessment of seismic data for developments in seismically active regions. The standard does not provide any seismic design criteria details.

2014: API RP 2EQ, Seismic Design Procedures and Criteria for Offshore Structures

- In 2014, API released four new recommended practice documents relating to offshore platforms, including *RP 2EQ, 1st Edition, Seismic Design Procedures and Criteria for Offshore Structures*. RP 2EQ contained requirements for defining design procedures and criteria for earthquake-resistant fixed offshore structures and discussed the effects of seismic events on floating structures.

2007: NORSOK N-003: Actions and Action Effects

- This 2007 standard was developed by stakeholders in the Norwegian petroleum industry and focuses on fixed and floating structures in the North Sea. As such, content might be less relevant to the Pacific Coast.
- There is a two-page section that discusses the basis for a seismic and soil assessment and describes the structural action effects of an earthquake on soil and bedrock.

**Note: Recommended practices are documents prepared by professional groups or committees indicating good engineering practices which are optional in nature. Standards are similar but contain mandatory requirements. The use of the term "recommendations" on this slide is not an endorsement made by Guidehouse.*

Seismic & Geo-Hazard Considerations: System Design

Guidehouse reviewed the publicly available data on these recommended practices and guides, as well as academic papers and government reports, to summarize seismicity design and siting recommendations for California.

Subsea Transmission Cables

- Subsea cables are the most vulnerable part of the FOSW system.
- Experts recommend:
  - Burying 80% of the cable between depths of 1 to 2 meters using plowing or jetting methods.
  - Protecting the rest of the exposed cable with concrete mattresses or rock dumps
  - Using copper to sheath cables since it is more resistant to fatigue than traditional sheathing materials.
  - Avoiding direct fault areas and creating monitoring and emergency response plans for seismic activity.
  - Providing sufficient length to the cable if areas of strong seismicity cannot be avoided.
  - Building a secondary cable with a backup route for important cables.

Anchoring System

- Vulnerable to scouring if not protected. To prevent seabed erosion, secure the base of the anchors with sandbags, grout-filled bags, stone bags, or artificial seaweeds.
- The most common adaptation is placing crushed rocks around the cable and anchors; however, this should not exceed a height of 2m.
- If a drag anchors are buried at a depth of 10-15m, no scour protection is required.

Tsunamis and Liquefaction

- Tsunami loads can be mitigated by locating floating structures in depths of at least 40m to 50m.
- A structure should be set in a position in which it is not likely to be attacked by a transverse wave.*
- Consider soil composition and liquefaction when determining burial depth close to the shore. Sandy soils are more vulnerable to liquefaction.

Catenary Mooring Systems

- Catenary mooring systems are less impacted by earthquakes because of the small stiffness of the mooring. They are less vulnerable to ground shaking and are applicable to high seismic regions.
- The dynamic tension caused by the earthquake causes all three translational motions (surge, sway and heave) for taut-line mooring, but only heave motions for catenary systems.

TLP Mooring Systems

- The vertical component of seismic factor (causing heave) should be considered a crucial aspect for FOWT design as it is directly added to the tendon pretension.
- Avoiding direct faults is crucial (see Geohazard Review slide).
- It is important to pay close attention to existing best practices when determining pile uplift capacity**, the weight of gravity anchors, and mooring line pretension.

**A moving wave that oscillates in perpendicular direction to the direction of the wave*
***Pile uplift capacity refers to the resistance of a pile from being pulled from the ground.*

Seismic Considerations: General/Siting

General Considerations

- Many of the standards and recommended practices discussed encourage structural stress testing to ensure platforms and turbines don't exceed various stresses, which differ for each document's version of the test.
- All documents suggest not only considering the effects of earthquakes, tsunamis, landslides, and liquefaction on floating system components, but also the interactions between these geohazards themselves and amidst other loads such as gravity, buoyancy, and hydrostatic pressure.
- While there are no specific data to categorize earthquake damage to floating wind facility structures, it has been assumed by BOEM that there would be damage causing partial structural failure to a wind farm above Richter 5.0 and major structural damage at Richter 7.0.
- Most of the guides strongly recommend that system design is determined by a site-specific assessment of:

Historical seismology data	Bathymetry data	Fault conditions	Soil condition and it's liquefaction or mud failure
Erosion around the mooring	Tsunami frequency	Peak ground acceleration	Any other relevant tectonic conditions

Site Selection Process

- For selecting suitable sites for FOWT, several factors should be considered to evaluate potential effects in the environment and possible socio-economic impacts.
- The Bureau of Ocean Energy Management recommends the following steps to selecting a suitable site location in relation to geohazards:
    1. **Data collection:** data encompassing oceanographic and atmospheric parameters such as ocean currents, temperatures, wind statistics, and wave spectra, as well as geotechnical data on subsurface conditions should be collected.
    2. **Exclusion Criteria:** a set of exclusion criteria should be considered in order to determine unsuitable areas for FOWT siting. Some exclusion criteria, such as military areas, maritime traffic, exploration and exploitation of hydrocarbons or minerals, environmental protected areas, and heritage areas, were already considered during the selection of the BOEM Call Areas. However, there are other factors that could potentially disqualify an area from being a potential site for floating offshore wind development.
    3. **Evaluation Criteria:** after eliminating areas based on exclusion criteria, other factors need to be analyzed before sites are finalized. See the following slide for criteria recommended by BOEM and various other researchers.
    4. **Finalizing locations:** after evaluating collected data for eligible areas, selection can be finalized by maximize or minimizing relevant evaluation criteria.

BOEM Evaluation Criteria

The following tables contain floating offshore wind farm site evaluation criteria from BOEM's report *Potential Earthquake, Landslide, Tsunami, and Geo-Hazards for the U.S. Offshore Pacific Wind Farms* as discussed in the previous slide.

Category	Evaluation Criteria	Objective
Met-ocean Data	Wind velocity	Maximize
	Water depth	Minimize
	Wave conditions	Minimize
	Marine currents	Minimize
	Temperature	Minimize
Viability	Technical feasibility	Maximize
	Sufficient study times	Maximize
Proximity to Facilities	Distance from shore	Minimize
	Distance to local electrical grid	Minimize
	Distance from coastal facilities	Minimize
	Distance from residential areas	Maximize
	Distance from maritime routes	Maximize
	Distance from underwater lines	Maximize
	Distance to marine recreational activities	Maximize
	Distance from airport	Maximize

Category	Evaluation Criteria	Objective
Marine Environment	Distance from protected areas	Maximize
	Proximity to migratory birds’ paths	Maximize
	Proximity to migratory marine life paths	Maximize
Techno-economic data	Area of the territory	Maximize
	Proximity to electric demand	Maximize
	Population served	Maximize
	Multiple competing resources	Minimize
Local geology*	**Submarine slope failure**	**Minimize**
	Sea floor rupture	**Minimize**
	Rough sea floor	**Minimize**
	Seabed scouring	**Minimize**
	Seismic activity	**Minimize**
	Liquefaction potential	**Minimize**
	Lateral spread potential	**Minimize**
	Slope of seabed	**Minimize**
	Coral reefs	**Minimize**

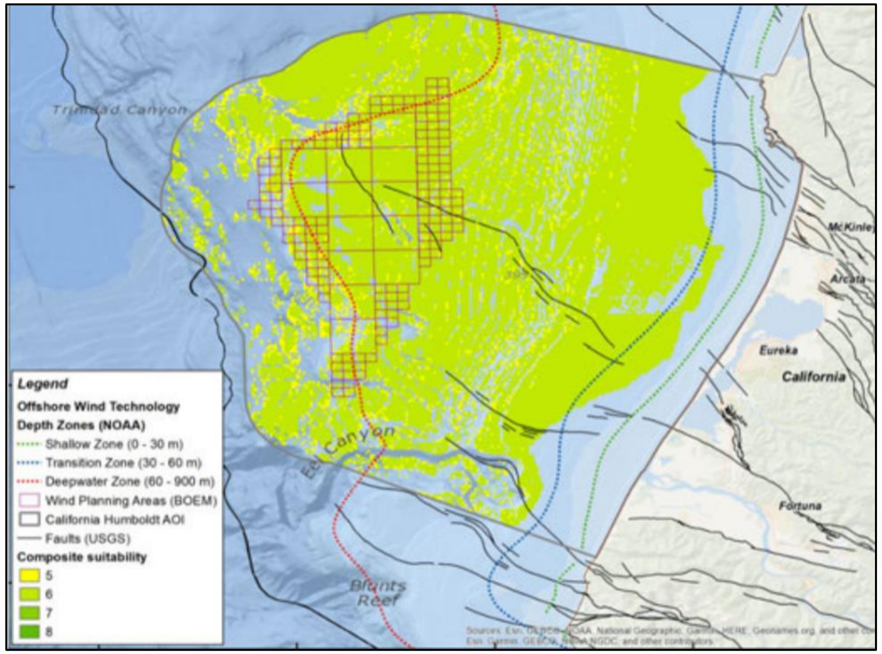
*Evaluation criteria related to seismicity

Site Analysis: California Humboldt

Suitability Analysis

Using ArcGIS and the criteria mentioned previously, BOEM conducted a quantitative suitability analysis on the California Humboldt call area with the following results:

- The northern part of the call area is more suitable for turbine installation, as faults are avoided, and the soil is muddy and preferable.
- Slope gradient data is poor in this study area, although it does not appear to be a serious issue.
- Earthquake events are very frequent in this area, and the report contains some specific spots that could be excluded based on a model that is weighted towards seismicity.
- Areas of coarse-grained sand, hard ground, and higher slope are absent.
- The entire Humboldt area has high peak ground acceleration, which indicate a high intensity of movement during earthquake ground shaking.



Humboldt California Composite Suitability Map

Depth, Soil, and Further Study

The extent of the publicly available bathymetry data lacks detail and a better resolution is required to derive more precise conclusions. Based on the existing bathymetry data, depth ranges from 500m-1000m, and all types of FOWT will have adequate draft to be deployed.

The use of a driven pile anchoring system might be feasible due to the versatility of soil types. More analysis and data collection are needed to determine accurate soil condition and appropriate anchorage type.

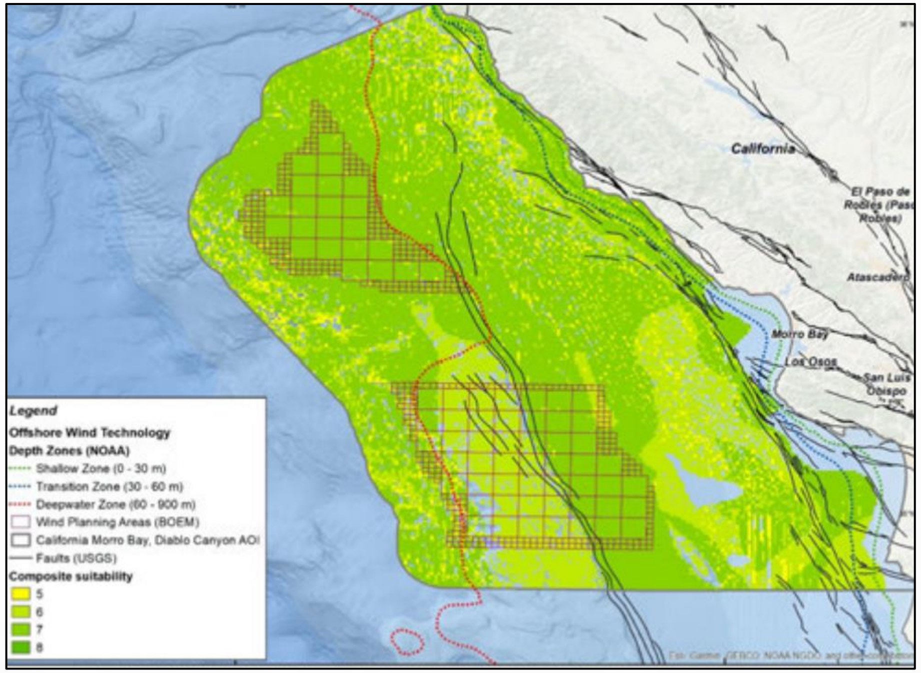
Based on these results, the Humboldt area is largely a favorable area for placement of FOSW, though heavily prone to seismicity, and the least suitable block among all 6 west coast regions studied by BOEM in relation to ground acceleration.

Site Analysis: Morro Bay and Diablo Canyon

Suitability Analysis

Using ArcGIS and the criteria mentioned previously, BOEM conducted a quantitative suitability analysis on the Morro Bay and Diablo Canyon call area with the following results:

- Slope gradient does not appear to be a serious issue
- Seismicity is more of an issue in the shallower waters away from proposed call areas
- Based on lower peak ground acceleration and other geohazard considerations, Morro Bay is preferable to Diablo Canyon, and the east side of Diablo Canyon is more suitable than the west side. On the east side, the bulk of the seabed is likely to be mud.
- There are some areas of exposed bedrock or slump, as well as higher slope areas, with absent or reduced suitability.
- Peak ground acceleration values are lower (between 9 and 25), making this more favorable than the California Humboldt call area.



Morro Bay and Diablo Canyon California Composite Suitability Map

Depth, Soil, and Further Study

The depths of the Central California Call Area are adequate for all foundation types, as the depths of Diablo Canyon are between 500m to 1,000m and the depths of Morro Bay range from 900m to 1,200m, respectively.

Very little slope and soil information is available for this area, and site-specific seabed sampling is recommended for siting of anchorage, mooring, and cable burial. Based on available data at the time of the study, a dedicated survey and soil sampling was recommended before development.

Morro Bay and Diablo Canyon are largely favorable for placement of FOSW. The nearshore areas close to Morro Bay and San Luis Obispo Bay are unfavorable. Due to faults and risk of liquefaction, the center shows lower suitability than the other parts of the region.

Seismicity: Conclusion

While there is a need for further seabed and soil studies in the BOEM California call areas, there are recommended practices published and technology solutions available. The developer will need to evaluate the appropriate technology solution based on site specific information.

Based on the research, there is no specific need for the CEC to directly assist with technology investment to address potential seismic issues in California FOSW.

Your Guides

Amul Sathe
Director
amul.sathe@guidehouse.com

Bruce Hamilton
Director
bruce.hamilton@guidehouse.com

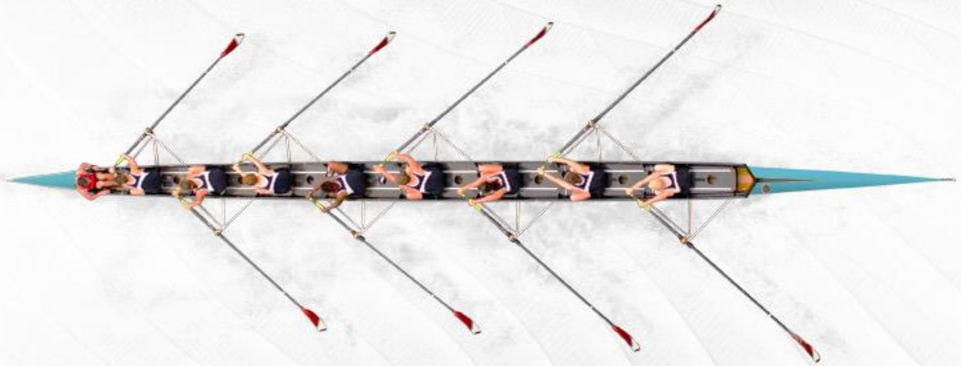
Bob Prinsen
Associate Director
bob.prinsen@guidehouse.com

Tom James
Senior Consultant
tjames@guidehouse.com

Claire Huang
Consultant
chuang@guidehouse.com

Michael Quiroz
Consultant
mquiroz@guidehouse.com

Johanna Fors (Project Manager)
Managing Consultant
jfors@guidehouse.com



Guidehouse
Outwit *Complexity*

End Notes: Regulatory Targets

1. Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860). U.S. Energy Information Administration, 2021. https://www.eia.gov/electricity/data/state/.
2. Offshore Wind Market Report: 2021 Edition. U.S. Department of Energy, 2021. https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf.
3. Statistical Profiles. International Renewable Energy Agency, 2021. https://www.irena.org/Statistics/Statistical-Profiles.
4. China's Achievements, New Goals and New Measures for Nationally Determined Contribution (Unofficial Translation). UNFCCC. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/China%20First/China%E2%80%99s%20Achievements,%20New%20Goals%20and%20New%20Measures%20for%20Nationally%20Determined%20Contributions.pdf.

End Notes: Regulatory Targets (US State)

State	Target Source	Reg. Mechanism	Proposed/ Approved	Target Type	Source
California	SB 100, AB 525	Legislative	Proposed	Path to RPS Goals	AB 525, (https://leginfo.legislature.ca.gov/faces/billVotesClient.xhtml?bill_id=202120220AB525). 2. 2021 SB 100 Joint Agency Report, (https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity).
Connecticut	HB 7156	Legislative	Approved	Capacity Target	HB 7156, (https://www.cga.ct.gov/2019/act/pa/pdf/2019PA-00071-R00HB-07156-PA.pdf).
Louisiana	Climate Action Plan	Regulatory	Approved	Capacity Target	https://gov.louisiana.gov/assets/docs/CCI-Task-force/CAP/Climate_Action_Plan_FINAL_3.pdf
Maine	LD 1810	Legislative	Approved	Capacity Target	LD 1810, (http://www.mainelegislature.org/legis/bills/bills_124th/chapters/PUBLIC615.asp).
Maryland	CEJA	Legislative	Approved	Capacity Target	CEJA, (https://energy.maryland.gov/Pages/Info/renewable/offshorewind.aspx).
Massachusetts	H4515	Legislative	Approved	Capacity Target	House Bill No 4515, (https://trackbill.com/bill/massachusetts-house-bill-4515-an-act-advancing-offshore-wind-and-clean-energy/2235638/)
New Jersey	AB 3723	Legislative	Approved	Capacity Target	AB 3723, (https://legiscan.com/NJ/text/A3723/id/1808963).
New York	CLCPA S6599	Legislative	Approved	Capacity Target	SB S6599, (https://www.nysenate.gov/legislation/bills/2019/s6599).
North Carolina	EO 218	Executive Order	Approved	Capacity Target	EO 218, (https://governor.nc.gov/media/2438/open).
Oregon	HB 3375	Legislative	Proposed	Path to RPS Goals	HB 3375, (https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/HB3375).
Virginia	HB 1526	Legislative	Approved	Capacity Target	HB 1526, (https://lis.virginia.gov/cgi-bin/legp604.exe?201+ful+CHAP1193).

End Notes: Regulatory Targets (Country)

Country	Note	Source
Japan	10 GW by 2030	Japan plans to install up to 45 GW of offshore wind power by 2040, Reuters (https://www.reuters.com/article/us-japan-windpower/japan-plans-to-install-up-to-45-gw-of-offshore-wind-power-by-2040-idUSKBN28P0C6).
United Kingdom		GWEC Global Wind Report 2021. https://www.great.gov.uk/international/content/investment/sectors/offshore-wind/
Germany	40 GW by 2035, 70 GW by 2045	New German Government to speed up wind energy expansion, (https://windeurope.org/newsroom/news/new-german-government-to-speed-up-wind-energy-expansion/).
India	F. No. 225/3/20218-Wind	Government Offshore Wind information, (https://mnre.gov.in/wind/offshore-wind/). Office Memorandum, (https://mnre.gov.in/img/documents/uploads/42f765854e204d72bb36b46c9e0c4cfa.pdf).
United States	Exec. Order No. 14,008, 86 F.R. § 7619 (2021)	Executive Order Press Release, (https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/).
Poland		Wind Europe - Poland adopts historic offshore wind act (https://windeurope.org/newsroom/news/poland-adopts-historic-offshore-wind-act/)
Vietnam	2 by 2030, 9 by 2035, 15 by 2040, 21 by 2045	PDP8, Vietnam government plan (https://energytracker.asia/the-proposed-vietnam-pdp8-update-and-the-risks-from-the-coal-pivot/#:~:text=Vietnam's%20PDP8%20Draft%20and%20the%20Proposed%20Update&text=In%20a%20nutshell%2C%20the%20plan,coal%2Dfired%20capacity%20by%202030.&text=This%20plan%20sacrifices%208%20GW,from%20the%20base%20case%20scenario.)
Taiwan	Offshore wind targets are 5.7GW by 2025 with an additional 15GW by 2035	GWEC Global Wind Report 2021.
South Korea		GWEC Global Wind Report 2021.
Netherlands	35 - 75 GW by 2050	Netherlands Integrated National Energy and Climate Plan, (https://energy.ec.europa.eu/system/files/2020-03/nl_final_necp_main_en_0.pdf) Netherlands govt page about Offshore Wind, (https://www.government.nl/topics/renewable-energy/offshore-wind-energy#:~:text=Wind%20energy%20targets,Energy%20Agreement%20for%20Sustainable%20Growth.)
Denmark		Denmark's Final NECP (https://energy.ec.europa.eu/system/files/2020-01/dk_final_necp_main_en_0.pdf)
Australia	Only state of Victoria has set a target.	https://www.energy.vic.gov.au/renewable-energy/offshore-wind
Belgium	Adding an extra area for the production of offshore wind	Belgian govt website, Economy page (https://economie.fgov.be/en/themes/energy/belgian-offshore-wind-energy) Belgian Offshore Platform (non profit association of investors and owners of wind farms in belgium, advocates for offshore wind).
France	Assuming goal is cumulative of already existing capacity	Integrated National Energy and Climate Plan for France (https://energy.ec.europa.eu/system/files/2020-09/fr_final_necp_main_en_0.pdf), March 2020)
Ireland		Ireland's National Energy & Climate Plan (https://energy.ec.europa.eu/system/files/2020-08/ie_final_necp_main_en_0.pdf).
Spain		Ecological Transition and the Demographic Challenge (MITECO)
Greece	1.5 GW by 2030	Minister of Environment and Energy Kostas Skrekas said the goal is to develop 1.5 GW by 2030 (https://balkangreenenergynews.com/greece-targets-1-5-gw-in-offshore-wind-by-2030-who-is-in-race/)
Italy	300 by 2025, 900 by 2030	Italy's National Energy & Climate Plan (https://energy.ec.europa.eu/system/files/2020-02/it_final_necp_main_en_0.pdf).
Latvia		Latvia could have 15 GW installed in offshore wind energy (https://balticwind.eu/andris-vanags-latvia-could-have-15-gw-installed-in-offshore-wind-energy-but-many-steps-need-to-be-taken/) Ministry of Economics, Republic of Latvia, National Energy and Climate Plan for 2021-2030 (https://www.em.gov.lv/en/national-energy-and-climate-plan-2021-2030?utm_source=https%3A%2F%2Fwww.google.com%2F)
Estonia		Republic of Estonia, Ministry of Economic Affairs and Communications (https://www.mkm.ee/en/news/innovative-estonian-latvian-joint-offshore-wind-farm-project-sets-sail)
Portugal		Portugal NECP, December 2019 (https://energy.ec.europa.eu/system/files/2020-06/pt_final_necp_main_en_0.pdf)
Barbados	Energy mix - 2030 scenario	Barbados National Energy Policy (BNEP 2019 - 2030) Implementation Plan (http://www.smartenergybarbados.com/wp-content/uploads/2021/03/Implementation-Plan-for-Barbados-National-Energy-Policy-VIEW.pdf)

End Notes: Ports and Vessels

1. Ports: a key enabler for the floating offshore wind sector. Wind Europe, 2020. https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/.
2. Cost of Floating Offshore Wind using New England Aqua Ventus Semi Sub Concrete Semisubmersible Technology. NREL, 2020. https://www.nrel.gov/docs/fy20osti/75618.pdf.
3. Floating Offshore Wind: Market and Technology Review. The Carbon Trust, 2015. https://www.carbontrust.com/resources/floating-offshore-wind-market-technology-review.
4. Jones Act Compliance Strategies for US Offshore Wind Construction. Morgan Lewis, 2021. https://www.morganlewis.com/pubs/2021/12/jones-act-compliance-strategies-for-us-offshore-wind-construction.
5. The Demand for a Domestic Offshore Wind Energy Supply Chain. NREL, March 2022. https://www.nrel.gov/docs/fy22osti/81602.pdf.

End Notes: Major Offshore Wind Manufacturers

1. ***Wind Trade and Manufacturing, a Deep Dive.* Bloomberg NEF, February 2021.** https://csis-website-prod.s3.amazonaws.com/s3fs-public/Wind%20Case%20Study%20-%20BloombergNEF.pdf?dgmuM67K1ezPpLIUi5pGZrZ2CwDNlMPX.
2. ***Wind Energy: Supply Chain Deep Dive Assessment*. U.S. Department of Energy, February 2022.** https://www.energy.gov/sites/default/files/2022-02/Wind%20Supply%20Chain%20Report%20-%20Final%202.25.22.pdf
3. ***GWEC releases Global Wind Turbine Supplier Ranking for 2020*. GWEC, March 2021.** https://gwec.net/gwec-releases-global-wind-turbine-supplier-ranking-for-2020/
4. **LM Wind Power Group:** https://www.lmwindpower.com/en/about/locations
5. **Vestas:** https://www.vestas.com/en/about/our-locations/production
6. **Siemens Gamesa:** https://electrek.co/2021/10/25/siemens-gamesa-us-first-offshore-wind-blade-factory/ & https://www.siemensgamesa.com/about-us/location-finder#NorthAmerica
7. **Goldwind:** https://www.goldwindamericas.com/news/recharge-news-chinas-goldwind-poised-north-america-breakthrough
8. **TPI Composites:** https://www.tpicomposites.com/ & https://www.reliableplant.com/Read/26279/TPI-Composites-innovation-center
9. **GE:** https://www.ge.com/renewableenergy/about-us/locations
10. **BARD:** https://second.wiki/wiki/bard_engineering
11. **Doosan:** https://www.doosanenerbility.com/en/network/global_network
12. **ADWEN:** https://www.linkedin.com/company/adwen-offshore
13. **Hyundai:** https://english.hhi.co.kr/contact/network01
14. **DeWind:** https://www.linkedin.com/company/dewind-co/about/
15. **Windar:** https://windar-renovables.com/en/location/ & https://windar-renovables.com/en/the-total-capacity-of-the-towers-supplied-by-wrs-towers-exceeded-1000-mw/
16. **Ambau:** https://www.linkedin.com/company/ambau-gmbh/about/
17. **Welcon:** https://www.welcon.dk/
18. **Jiangsu:** https://www.bloomberg.com/profile/company/1849513D:CH
19. **CS Wind:** http://www.cswind.com/eng/?page=company%7Clocation%7Ccswind_global
20. **Haizea:** https://haizeawindgroup.com/en/inicio-haizea-wind-group-english/
21. **Wind Europe, September 2020. Ports: a key enabler for the floating offshore wind sector.** https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/
22. **JDR:** https://www.jdrcables.com/about/global-locations/
23. **Nexans:** https://www.nexans.com/company/Locations.html
24. **Ningbo**: http://www.orient-cables.com/contact.html
25. **Prysmian:** https://www.prysmiangroup.com/en/company/global-presence
26. **Qingdao:** https://www.linkedin.com/company/qingdao-hanhe-cable-co.-ltd/about/

Guidehouse Outwit *Complexity*

End Notes: Manufacturing Needs & Current Capacity

Manufacturing Needs

1. Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine. IEA Wind, 2020. https://www.nrel.gov/docs/fy20osti/75698.pdf.
2. Ports: a key enabler for the floating offshore wind sector. Wind Europe, 2020. https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/.
3. XLPE Submarine Cable Systems: Attachment to XLPE Land Cable Systems – User's Guide. ABB. https://new.abb.com/docs/default-source/ewea-doc/xlpe-submarine-cable-systems-2gm5007.pdf.
4. Economic Potential of Industrializing Floating Wind Turbine Foundations. ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering, 2018. https://www.researchgate.net/publication/327873044_Economic_Potential_of_Industrializing_Floating_Wind_Turbine_Foundations.
5. Design and comparative analysis of alternative mooring systems for floating wind turbines in shallow water with emphasis on ultimate limit state design. Xu et al., 2021. https://www.sciencedirect.com/science/article/pii/S0029801820312841.
6. Mooring Chain & Anchor Chain. Daihan Anchor Chain Mfg. Co., Ltd. http://www.dhac.co.kr/m42.php.
7. Manufacturing a Subsea Cable. JDR Cable Systems. https://www.jdrcables.com/manufacturing-subsea-cable/.
8. CABRAL 512®. Lankhorst Offshore. https://www.lankhorstoffshore.com/products/cabral-512.
9. Concrete Support Structures for Offshore Wind Turbines: Current Status, Challenges, and Future Trends. Mathern et al., 2021. https://www.mdpi.com/1996-1073/14/7/1995/pdf.
10. Nacelles | How are they manufactured? Wind Power Engineering & Development, 2015. https://www.windpowerengineering.com/how-is-a-nacelle-manufactured/.

Current Manufacturing Capacity

1. U.S. Job Creation in Offshore Wind: A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind. BVG Associates Limited, NYSERDA, 2017. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/US-job-creation-in-offshore-wind.ashx.
2. May 2020 State Occupational Employment and Wage Estimates, California. Bureau of Labor Statistics, 2022. https://www.bls.gov/oes/current/oes_ca.htm.
3. United States Economic Census. United States Census Bureau, 2017. https://www.census.gov/programs-surveys/economic-census.html.

End Notes: California Supply Chain Opportunities and Constraints

1. *Made In America: Primary Metal Products.* Adji Fatou Diagne, Office of the Chief Economist. https://www.commerce.gov/sites/default/files/migrated/reports/made-in-america-primary-metal-products.pdf

2. *Ports: a key enabler for the floating offshore wind sector.* Wind Europe, 2020. https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/

3. *Floating Foundations: A Game Changer For Offshore Wind Power.* IRENA, 2016. *https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Offshore_Wind_Floating_Foundations_2016.pdf*

4. *Port and Shipyard Requirements for the Installation of Floating Offshore Wind Turbines.* Royal Institution of Naval Architects, London Branch Technical Meeting, 2021. https://www.youtube.com/watch?v=JLv8oZ2Ypdc

5. *Floating offshore wind turbines port requirements for construction.* AP Crowle, PR Thies, SAGE journals. https://journals.sagepub.com/doi/full/10.1177/14750902221078425

6. *2017 Washington State Marine Ports and Navigation Plan.* Washington State Department of Transportation, 2017. https://wsdot.wa.gov/sites/default/files/2021-10/Freight-Plan-AppendixB-MarinePortsNavigationPlan.pdf

7. *State Approves $10.5 Million to Prepare the Port of Humboldt Bay for Offshore Wind.* California Energy Commission, 2022. https://www.energy.ca.gov/news/2022-03/state-approves-105-million-prepare-port-humboldt-bay-offshore-wind

End Notes: California Supply Chain Opportunities and Constraints

1. CAEATFA Sales and Use Tax Exclusion Program, https://www.treasurer.ca.gov/caeatfa/ste/index.asp.
2. California Competes Tax Credit, https://business.ca.gov/california-competes-tax-credit/.
3. Partial Sales and Use Tax Exemption, https://www.cdtfa.ca.gov/industry/manufacturing-exemptions.htm.
4. Capital Investment Incentive Program, https://static.business.ca.gov/wp-content/uploads/2020/02/Capital-Investment-Incentive-Program-2019-Report.pdf.
5. Employment Training Panel, https://etp.ca.gov/.
6. *The massive 75m wind turbine blades (each the size of an Airbus A380) coming to the Essex coast in 2014.* UK Daily Mail, 2012. https://www.dailymail.co.uk/sciencetech/article-2181963/Wind-power-gets-massive-Worlds-biggest-air-turbines--twice-width-Airbus--erected-Essex-coast-2014-Siemens-Dong.html

End Notes: Workforce Needs

1. *Offshore wind turbine operations and maintenance: A state-of-the-art review.* Renewable and Sustainable Energy Reviews, 2021. https://www.sciencedirect.com/science/article/abs/pii/S1364032121001805

2. Jobs & Economic Development Impacts Model. NREL. https://www.nrel.gov/analysis/jedi/about.html

3. AB 525 Workshop Docket Log. California Energy Commission, 2022. https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-MISC-01
    - Stakeholder comments for Scenario 2: ACP, Avangrid
    - Stakeholder comments for Scenario 3: Offshore Wind California

End Notes: Existing Workforce in California

1. *U.S. Job Creation in Offshore Wind: A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind.* BVG Associates Limited, NYSERDA, 2017.
2. *May 2020 State Occupational Employment and Wage Estimates, California.* Bureau of Labor Statistics, 2022.

End Notes: Procurement Models and Cost Trends

1. Offshore Wind Market Report: 2021 Edition. U.S. Department of Energy, 2021. https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf.
2. Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States. NREL, 2020. https://www.nrel.gov/docs/fy20osti/76079.pdf .
3. The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032. NREL, 2020. https://www.nrel.gov/docs/fy21osti/77384.pdf.
4. As Vineyard Wind Gets Go Ahead, Long-Term Costs for Consumers Remain Cloudy. The Connecticut Examiner, 2021. https://ctexaminer.com/2021/05/11/as-vineyard-wind-gets-go-ahead-long-term-costs-for-consumers-remain-cloudy/.
5. 2020 Offshore Wind Solicitation. NYSERDA, 2020. https://www.nyserda.ny.gov/All-Programs/Offshore-Wind/Focus-Areas/Offshore-Wind-Solicitations/2020-Solicitation
6. PPA and OREC contracts:
    1. Atlantic Shores Offshore Wind Project 1: https://www.pjm.com/-/media/planning/services-requests/atlantic-shores-offshore-wind-project-1.ashx
    2. Skipjack Offshore Energy: https://www.psc.state.md.us/wp-content/uploads/Order-No.-90011-Case-No.-9666-Order-Granting-Offshore-Wind-Renewable-Energy-Credits.pdf, https://www.psc.state.md.us/wp-content/uploads/Order-No.-88192-Case-No.-9431-Offshore-Wind.pdf
    3. Ocean Wind 2: https://nj.gov/bpu/bpu/pdf/boardorders/2021/20210630/ORDER%20Solicitation%202%20Board%20Order%20-%20OW2%20B.pdf
    4. Virginia Energy Regulatory Updates (December 2021): https://reisingergooch.com/virginia-energy-regulatory-updates-december/
    5. Massachusetts 83C III Bid: https://macleanenergy.com/2021/12/17/the-distribution-companies-and-department-of-energy-resources-have-completed-the-evaluation-of-83c-iii-bids-received/
    6. Atlantic Shores 1: https://nj.gov/bpu/bpu/pdf/boardorders/2021/20210630/ORDER%20Solicitation%202%20Board%20Order%20-%20ASOW%20C.pdf
    7. South Fork Wind Farm: https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BAE4EC5A6-6F16-4F26-A83F-B00BB09D35E9%7D#:~:text=The%20price%20for%20the%2090,per%20year%20for%2020%20years
    8. Vineyard Wind: https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/9676766

End Notes: Procurement Models and Cost Trends

1. GWEC Global Wind Report 2022, Global Wind Energy Council, 2022, https://gwec.net/wp-content/uploads/2022/03/GWEC-GLOBAL-WIND-REPORT-2022.pdf.
2. Stehly, Tyler and Patrick Duffy. 2021. 2020 Cost of Wind Energy Review. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-81209. https://www.nrel.gov/docs/fy22osti/81209.pdf.
3. Beiter, Philipp, Walter Musial, Patrick Duffy, Aubryn Cooperman, Matt Shields, Donna Heimiller, and Mike Optis. 2020. The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-77384. https://www.nrel.gov/docs/fy21osti/77384.pdf.

End Notes: East Coast: Infrastructure, Workforce, and Supply Chain Development

- Beiter, Philipp, Jenny Heeter, Paul Spitsen, David Riley. 2020. Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-76079. https://www.nrel.gov/docs/fy20osti/76079.pdf
- Embracing the Potential of Offshore Wind in Connecticut, Chamber of Commerce – Connecticut, 2021, https://chamberect.com/wp-content/uploads/2021/12/CT-OSW-Strategic-Study-Final-12.22.21_reduced1.pdf
- A Shared Vision on the Development of an Offshore Wind Supply Chain, BOEM, BOEM, New York, New Jersey – Shared Vision on the Development of an Offshore Wind Supply Chain.
- Northeast Wind Resource Center - A Roadmap for Multi-State Cooperation on Offshore Wind Development, CESA, 2015, https://www.cesa.org/projects/northeast-wind-resource-center/a-roadmap-for-multi-state-cooperation-on-offshore-wind-development/.

End Notes: East Coast: Infrastructure, Workforce, and Supply Chain Development (by State)

Connecticut

- House Bill No. 7156, An Act Concerning the Procurement of Energy Derived From Offshore Wind (State of CT, January 2019)
- DEEP-Selected Power Purchase Agreement for 804 MW Offshore Wind Project Filed with PURA (CT DEEP press release, May 2020)

Maine

- Diamond Offshore Wind, RWE Renewables join the University of Maine to lead development of Maine floating offshore wind demonstration project
- Maine Offshore Wind Supply Chain Connect

Maryland

- Code of Maryland Regulations: Title 20 Public Service Commission, Subtitle 61 Renewable Energy Portfolio Standard Program, Chapter 06 Offshore Wind (COMAR 20.61.06)
- Offshore Wind Energy in Maryland (Maryland Energy Administration)
- Maryland Offshore Wind Capital Expenditure Program – FY 2022 (Maryland Energy Administration)
- Maryland Offshore Wind Workforce Training Program – FY 2022 (Maryland Energy Administration)

Massachusetts

- 83C III Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects (Massachusetts Department of Energy Resources, May 2021)
- Bids into 83C II Request for Proposals, including Mayflower Wind's bid
- Vineyard Wind commitment to Massachusetts supply chain and workforce development
- Baker seeks $100m for offshore wind port infrastructure (CommonWealth Magazine, July 2021)
- Massachusetts Proposal to Support Offshore Wind Industry Development, Additional Offshore Wind Projects, Transmission, and Energy Storage (JD Supra, January 2022)
- Notice of Intent: Massachusetts Offshore Wind Industry Ports Investment Challenge (MassCEC)
- Massachusetts Offshore Wind Workforce Development Grants Program

New Jersey

- New Jersey Offshore Wind Second Solicitation Award Fact Sheet
- New Jersey Offshore Wind Solicitation #2 Solicitation Guidance Document (New Jersey Board of Public Utilities, September 2020)
- New Jersey Economic Development Authority – Programs and Incentives for Offshore Wind
- NJ Govt Website - Summary of OSW Goal

New York

- 2022 Purchase of Offshore Wind Renewable Energy Certificates Request for Proposals (NYSERDA, 2022)
- New York Jobs and Workforce Plan
- 2020 Offshore Wind Solicitation (Closed)
- $500 Million New York State Offshore Wind Supply Chain Funding Roll Out Factsheet
- Fact Sheet - Offshore Wind Contracts and Phase One Report

North Carolina

- North Carolina Offshore Wind Industry (North Carolina Department of Commerce)

Rhode Island

- Rhode Island Regulators Approve Revolution Wind Power Contract (Ørsted press release, May 2019)
- Governor Announces $4.5 Million Investment by Ørsted, Eversource to Grow Rhode Island's Offshore Wind Workforce and Supply Chain (RI government press release, April 2019)
- 83C Request for Proposals for Long-Term Contracts for Offshore Wind Energy Projects (Massachusetts Department of Energy Resources, June 2017)
- Revolution Wind Project Proposal (Deepwater Wind, December 2017)
- Rhode Island Funds READY 4 OFFSHORE WIND Initiative (NA Wind Power, April 2019)
- WindWinRI
- Rhode Island Commerce Qualified Jobs Incentive Tax Credit

Virginia

- Virginia Clean Economy Act of 2020
- Potential Impact of the Development of the Offshore Wind Industry on Hampton Roads and Virginia (Magnum Economics, September 2020)
- Coastal Virginia Offshore Wind – Educators

End Notes: Innovations

1. *Comparison of pilot-scale floating offshore wind farms with shared moorings.* Patrick Connolly, Matthew Hall, 2019. Ocean Engineering. https://www.sciencedirect.com/science/article/abs/pii/S0029801818316238
2. *Optimizing Shared Mooring and Anchoring Strength for Floating Offshore Wind Turbine Arrays.* Michael C Devin, 2019. Oregon State University. https://static1.squarespace.com/static/5aa9f94e5ffd209c73921fa3/t/5d14f7ae808f79000106a4c7/1561655219399/DevinMichaelC2019.pdf
3. *New Mooring Design Could Cut Costs of Floating Offshore Wind.* The Maritime Executive, 2022. https://www.maritime-executive.com/article/new-mooring-design-could-cut-costs-of-floating-offshore-wind.
4. *High Voltage Dynamic Cables: Designed to last a lifetime of constant movement.* NKT, 2022. https://www.nkt.com/products-solutions/high-voltage-cable-solutions/high-voltage-offshore-solutions/high-voltage-dynamic-cables
5. *World's first dynamic HV cable system.* NKT. https://nkt.widen.net/content/2vouvyxair/pdf/Gja-Brochure_v5_low.pdf?u=gj0n1y
6. *For subsea power cables, offshore wind industry can benefit from oil and gas experience.* Maxime Toulotte, 2021. Offshore. https://www.offshore-mag.com/renewable-energy/article/14214348/nexans-for-subsea-power-cables-offshore-wind-industry-can-benefit-from-oil-and-gas-experience
7. *Nexans' groundbreaking deep-water high voltage dynamic cable selected for Jansz-Io Compression project, paving the way for future offshore innovation.* Nexans, 2021. https://www.nexans.com/newsroom/news/details/2021/10/nexans-groundbreaking-deep-water-high-voltage-dynamic-cable-selected-jansz-io-compression-project.html
8. *Connection: Delivering clean renewable energy to coastal communities.* Principle Power, 2022. https://www.principlepower.com/windfloat/advantage/connection
9. *Engaging Autopilot: NREL Explores Automation To Build Better Blades, Lower Costs, and Transform Wind Technology Manufacturing.* NREL, 2021. https://www.nrel.gov/news/program/2021/automation-wind-manufacturing.html
10. *Exclusive: Robot trial looks to speed up production for large wind turbine blades.* Eize de Vries, 2021. Windpower Monthly. https://www.tebulorobotics.com/exclusive-robot-trial-looks-to-speed-up-production-for-large-wind-turbine-blades/
11. *PEMA welding automation for offshore wind tower and foundation manufacturing.* PEMA Welding Automation, 2022. https://pemamek.com/us/welding-solutions/wind-energy/offshore-wind-tower-and-foundation-manufacturing/
12. *ECG™ Holistic Cable Monitoring System.* Proserv, 2022. https://www.proserv.com/business-units/renewables/ecg-holistic-cable-monitoring/
13. *BUILDING A DIGITAL TWIN, BOLSTERING THE POWER OF A WIND TURBINE.* GE, 2022. https://www.ge.com/renewableenergy/stories/improving-wind-power-with-digital-twin-turbines
14. *Digital twin technology improves offshore wind jacket design.* Offshore, 2021. https://www.offshore-mag.com/renewable-energy/article/14206660/digital-twin-technology-improves-offshore-wind-jacket-design
15. *Offshore Wind Solutions: DTR (Disconnectable turret for Renewables).* SBT Energy, 2021. https://sbt-energy.com/wp-content/uploads/2021/09/SBT-Energy-DTR-Brochure-Rev-3.1-HR.pdf
16. *Innovating To Grow The Floating Offshore Wind Industry.* Nautica Windpower, 2022. https://www.nauticawindpower.com/
17. RecyclableBlade: Taking responsibility. Blade by blade. Siemens Gamesa Renewable Energy, 2021. https://www.siemensgamesa.com/-/media/siemensgamesa/downloads/en/sustainability/environment/siemens-gamesa-recycablelblade-infographic-en.pdf

End Notes: Findings from Pilot Studies in Japan

1. Katrin Radtke, *Setback for Japanese Offshore Wind Efforts*. Windfair, 2018. https://w3.windfair.net/wind-energy/news/29116-wind-turbine-floater-japan-coast-capacity-factor-yield-turbine-lower
2. Annette Bossler, *Japan's Floating Offshore Wind Projects.* Main(e) International Consulting LLC, 2014. https://www.ormanagerconference.com/wp-content/uploads/2014/06/Bossler.pdf
3. *Japan's Offshore Wind Projects: An Overview.* Main(e) International Consulting LLC, 2013. https://cdn.website-editor.net/073319e35fa34e6189750e64c2e99060/files/uploaded/Japan%252BFloating%252BOffshore%252BPoster%252BUpdate%252BOct%252B28%252B2013.pdf
4. Bridget Randall-Smith, *Japan's floating trio to be decommissioned next year.* 4C Offshore, 2020. https://www.4coffshore.com/news/japan27s-floating-trio-to-be-decommissioned-next-year-nid20670.html
5. Darius Snieckus in Aberdeen, *Fukushima Forward floating turbine 'to be decommissioned'.* Recharge News, 2018. https://www.rechargenews.com/wind/fukushima-forward-floating-turbine-to-be-decommissioned/2-1-462750
6. *Fukushima Forward Pamphlet 1.* Fukushima Offshore Wind Consortium. http://www.fukushima-forward.jp/pdf/pamphlet3.pdf
7. *Fukushima Forward Construction of Phase II Pamphlet.* Fukushima Offshore Wind Consortium. http://www.fukushima-forward.jp/pdf/pamphlet7en.pdf

End Notes: Findings from Pilot Studies in Japan

1. Tomoaki Utsunomiya, *Floating Offshore Wind Turbines in Goto Islands, Nagasaki, Japan.* Kyushu University, 2019. https://link.springer.com/chapter/10.1007/978-981-13-8743-2_20
2. *Sakiyama 2MW Floating Offshore Wind Turbine.* Toda Corporation. https://www.toda.co.jp/business/ecology/special/pdf/sakiyama2mw_e.pdf
3. *BW Ideol and ENEOS Will Work to Develop Japan's Offshore Wind Industry.* The Maritime Executive, 2021. https://www.maritime-executive.com/article/bw-ideol-and-eneos-will-work-to-develop-japan-s-offshore-wind-industry
4. *Ideol's Floating Wind Turbine Off Japan Officially Inaugurated After Months at Sea.* Kerogen Capital, 2019. https://kerogencap.com/news/ideols-floating-wind-turbine-off-japan-officially-inaugurated-after-months-at-sea/
5. *BW Ideol's Second Demonstrator Hibiki.* BW Ideol. https://www.bw-ideol.com/en/japanese-demonstrator
6. Thomas Choisnet, *Initial Comparison of Concrete and Steel Hulls in the Case of IDEOL's Square Ring Floating Substructure.* BW Ideol, 2016. https://www.bw-ideol.com/sites/default/files/inline-files/A-2-3_WWEC_2016_Thomas_Choisnet.pdf

End Notes: Seismic Requirements

1. Subhamoy Bhattacharya et al., *Seismic Design of Offshore Wind Turbines: Good, Bad and Unknowns.* Multidisciplinary Digital Publishing Institute, 2021. https://www.mdpi.com/1996-1073/14/12/3496

2. Dr. Tayebeh Tajalli Bakhsh et al., *Potential Earthquake, Landslide, Tsunami, and Geo-Hazards for the U.S. Offshore Pacific Wind Farms.* BOEM, 2020. https://www.rpsgroup.com/media/5565/potential-earthquake-landslide-tsunami-and-geohazards-for-the-us-offshore-pacific-wind-farms.pdf
3. *DNV-RP-0585 Seismic design of wind power plants, Edition 2021-08.* DNV, 2021. https://www.dnv.com/energy/standards-guidelines/dnv-rp-0585-seismic-design-of-wind-power-plants.html
4. *Guide for Building and Classing Floating Offshore Wind Turbines.* American Bureau of Shipping, 2020. https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/offshore/195_fowti/fowt-guide-july20.pdf
5. *ISO 19901-2:2017 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 2: Seismic design procedures and criteria.* ISO, 2017. https://www.iso.org/standard/61142.html

6. *DNVGL-ST-0119: Floating Wind Turbine Structures.* DNV, 2018. https://rules.dnv.com/docs/pdf/DNV/ST/2018-07/DNVGL-ST-0119.pdf

7. *DNVGL-ST-0437: Loads and site conditions for wind turbines.* DNV, 2016. https://www.dnv.com/energy/standards-guidelines/dnv-st-0437-loads-and-site-conditions-for-wind-turbines.html

8. *API RP2EQ – Seismic Design Procedures and Criteria for Offshore Structures*. API, 2010. https://onepetro.org/OTCONF/proceedings-abstract/10OTC/All-10OTC/OTC-21047-MS/36362

9. *NORSOK N-003:2017 Actions and action effects.* Standards Norway, 2017. https://www.standard.no/en/sectors/energi-og-klima/petroleum/norsok-standard-categories/n-structural/n-0032/