FLOATING OFFSHORE WIND STUDY LITERATURE REVIEW

DRAFT

by the

OREGON
DEPARTMENT OF
ENERGY

January 2022

TABLE OF CONTENTS

Cover Image: mmastuura via Flickr Creative Commons

STATUTORY DIRECTION

Oregon House Bill 3375 (2021) requires the Department to conduct a literature review, gather stakeholder input, and submit a report to the legislature on the benefits and challenges of developing 3 gigawatts of floating offshore wind off Oregon's coast by 2030. Specifically:

1. "…conduct a literature review on the benefits and challenges of integrating up to three gigawatts of floating offshore wind energy into Oregon's electric grid by 2030."
2. "…gather input and consult with other interested or appropriate state, regional, and national entities, including but not limited to [see list of entities[i]], on the effects, including benefits and challenges, of integrating up to three gigawatts of floating offshore wind energy on reliability, state renewable energy goals, jobs, equity and resilience…"
3. "…hold no less than two public remote meetings with interested stakeholders to provide a summary of the literature review and consultation required by this section and to gather feedback from stakeholders on the benefits and challenges…"
4. "…provide a summary of the key findings from the literature review and consultation required by this section, including opportunities for future study and engagement, in a report and in the manner provided by ORS 192.245, to the appropriate interim committees of the Legislative Assemble no later than September 15, 2022."

ODOE STUDY

This draft literature review report serves as a response to the **first core component** of the legislatively-directed study described above. Given the timeline for implementation of the bill, it was not feasible to review every study and report about floating offshore wind. The Department focused the scope of its literature review on frequently cited and recent studies and reports related to the energy sector that reported quantitative and/or qualitative findings. Note that the Department does not have technical resources, nor a sufficient timeframe, to engage in separate technical analysis in this process that could either confirm or challenge the quantitative findings of existing studies and reports in this literature review.

This draft literature review identifies key topics and summarizes primary benefits and challenges relating to the deployment and grid interconnection of floating offshore wind off Oregon's coast. ODOE has structured the **second core component** of this process to gather input to focus on qualitative issues. This draft literature review helped to shape and inform the creation of prompting questions to which the agency is asking for public feedback through

---

[i] HB 3375 specifically lists the following entities: Oregon Department of Land Conservation and Development, Oregon Business Development Department, Oregon Department of Fish and Wildlife, Oregon Public Utility Commission, Northwest Power and Conservation Council, Bonneville Power Administration, Bureau of Ocean Energy Management National Renewable Energy Laboratory, Pacific Northwest National Laboratory, and United States Department of Defense.

ODOE's Comment Portal. The **third core component** of this process will involve convening public meetings to share information from the literature review, and to gather additional feedback from stakeholders on the benefits and challenges of integrating up to 3 gigawatts of floating offshore wind into Oregon's electric grid.

ODOE does not intend for the summary of the key topics identified from its literature review or themes from stakeholder feedback to convey an endorsement of findings by the Oregon Department of Energy or the State of Oregon – this will be made clear in the **fourth core component** of this process, the final report submitted to the Legislature by September 15, 2022.

With that background on the overall study process, ODOE invites stakeholders and the public to share additional studies, reports, articles, or other pieces of literature that were not included in the literature review. The agency asks for submissions through written comments in the online Comment Portal. It is important to this process that ODOE capture the variety of viewpoints and perspectives that Oregon stakeholders believe are important and relevant to the prospect of floating offshore wind off Oregon's coast.

INTRODUCTION

The timing of HB 3375 coincides with expanding efforts to increase clean energy across the world. As jurisdictions have generally increased commitments to reducing greenhouse gas emissions, and as certain jurisdictions have identified constraints to deploying vast scales of land-based wind and solar, markets for offshore wind have increased. Markets for offshore wind have grown considerably over the past 10 years, with total global installed capacity increasing from 3 GW in 2010 to 35.3 GW in 2020.[1] As deployments have risen, so has a wide range of literature on the benefits and challenges of offshore wind.

Broadly, there are two types of designs for offshore wind projects: **bottom-fixed offshore wind (BFOSW)** and **floating offshore wind (FOSW)** – note that this report will use these acronym descriptors going forward. In shallower waters less than 60 meters, BFOSW projects anchor wind towers directly to seafloors through a relatively mature design that's similar to how onshore wind towers are fixed directly to land. To reach into deeper waters of 60 meters or greater, FOSW projects affix wind towers to floating platforms that are anchored to seafloors with mooring lines – a design that's more complicated and still emerging.

Figure 1: Two types of offshore wind – BFOSW & FOSW

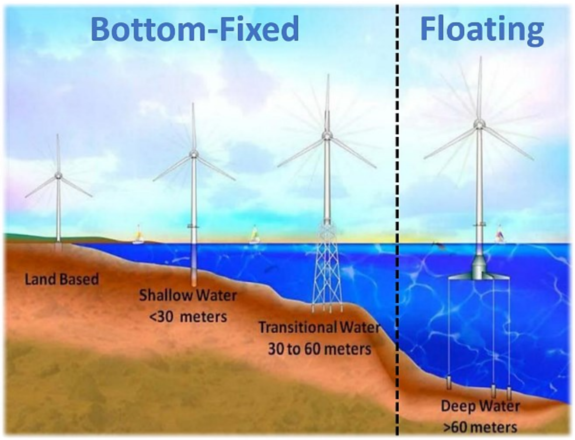


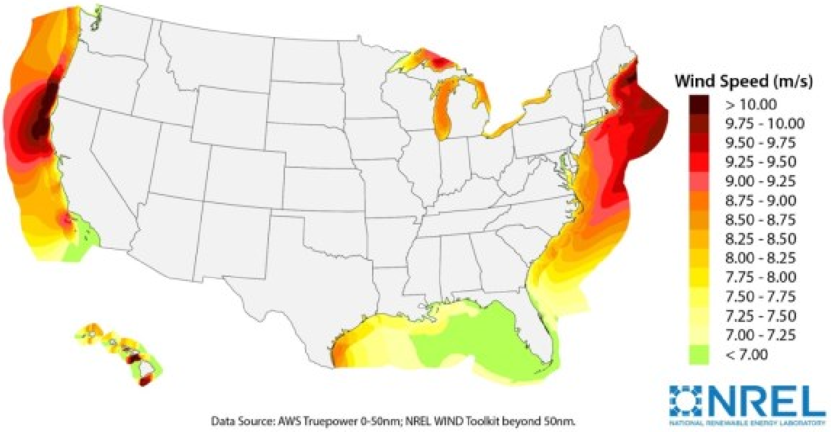
Figure *2*: Global Deployment of all three types of wind compiled from 2021 U.S. DOE and GWEC reports (see EN 3 and 4)

(3) Types of Wind	New Capacity Added in 2020	Cumulative Global Capacity as of 2020
Land-Based	~87 GW	~707 GW
Bottom-Fixed Offshore (**BFOSW**)	~6 GW	~35 GW Most in N. Europe, 0.042 in U.S.
Floating Offshore (**FOSW**)	~0.025 GW	~0.08 GW Single Largest Project = 50 MW

The BFOSW design is more mature and constitutes nearly all of the world's built and operational offshore wind capacity (over 99 percent). Various FOSW designs are still emerging and projects are more costly to deploy than BFOSW projects and other renewable energy technologies such as land-based wind and solar. For comparison, the estimated levelized cost of energy (LCOE)[ii] for FOSW projects deployed in different locations off Oregon's coast in 2022 range from $74 to $107/MWh,[2] and current average LCOEs for land-based wind and solar range from $26 to $50/MWh and $28 to $41/MWh,[3] respectively. Costs are a significant reason, but not the only reason, for why total global deployments of wind energy technologies as of 2020 were approximately 707 GW of land-based wind, 35 GW of BFOSW, and just 0.08 GW of FOSW.[4] [5] While the current costs of FOSW projects are a significant challenge facing their more widespread deployment, advancements in FOSW supply chains and technologies, such as larger turbines to achieve economies of scale, could lead to considerably lower costs. For example, the National Renewable Energy Lab (NREL) has estimated the LCOE for FOSW projects off Oregon's Southern Coast could drop to $51/MWh by 2032,[6] which is comparable to NREL reporting of low-end estimates of $50/MWh for global BFOSW projects in 2032.[7]

In the U.S., with the support of federal and state policies, BFOSW projects are being developed along the East Coast at relatively short distances from shore where ocean waters are shallow. As of September 2021, there are two operational BFOSW projects in the U.S.: the 30 MW Block Island Wind Farm off Rhode Island

Figure 3 Map of average offshore wind speeds around the U.S.



Data Source: AWS Truepower 0-50nm; NREL WIND Toolkit beyond 50nm.

[ii] Levelized Cost of Energy (LCOE) – Is a measure of cost-effectiveness, and is often cited as a convenient summary measure of the overall cost competitiveness of different energy generating technologies allowing apples-to-apples comparisons. The metric ($/MWh) is a calculation of the total lifetime costs of an energy project (including capital and operating costs) divided by the project's lifetime electricity generation. LCOE does not include costs of associated projects that may be necessary for FOSW deployment and interconnection, such as upgrades to ports or the existing transmission grid, nor does it include the value of policy incentives, such as production or investment tax credits.

and the 12 MW Coastal Virginia Offshore Wind project.

Offshore wind has yet to be deployed along the West Coast, where opportunities for BFOSW projects are limited due to deeper waters that instead require FOSW projects. Yet, ocean areas adjacent to Oregon offer some of the highest quality offshore wind resources in the world, with an estimated technical potential of 62 GW.[8] While this resource potential is large, particularly in waters off Oregon's southern coast, and could offer energy and economic benefits to the state and possibly the larger western region of the U.S., there are also challenges facing its development, including: costs associated with floating platforms, port development, transmission constraints, and complex siting and permitting processes.

A vast body of literature exists on the benefits (e.g., supplying clean electricity) and challenges (e.g., costs and potential impacts to the ocean environment and its users) associated with the opportunity for increased deployment of FOSW. Most literature is quite recent and the body of literature is continuously expanding, with new research and studies rapidly emerging due to increased interest in the offshore wind market. Therefore, references to additional research and studies may be included as part of the final report to the legislature.

This draft literature review primarily examined the studies and reports listed below, in order of date of publication, on offshore wind generally, and with particular focus on FOSW:

1. Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii, BOEM, Mar. 2016
2. National Offshore Wind Strategy, U.S. DOE, Sept. 2016
3. Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios, NREL, May 2016
4. Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts in Oregon Coastal Counties from Two Future Scenarios, NREL, Jul. 2016
5. 2016 Offshore Wind Energy Resource Assessment for the U.S., NREL, Sept. 2017
6. 2018 Offshore Wind Technologies Market Report, U.S. DOE, 2018
7. The Economic Value of Offshore Wind Power in California, E3, Aug. 2019
8. Oregon Offshore Wind Site Feasibility and Cost Study, NREL, Oct. 2019
9. Exploring the Grid Value Potential of Offshore Wind Energy in Oregon, PNNL, May 2020
10. Potential Earthquake, Landslide, Tsunami and Geo-Hazards for the U.S. Offshore Pacific Wind Farms, BOEM/BSEE, May 2020
11. 2019 Cost of Wind Energy Review, NREL, Dec. 2020
12. Offshore Wind Transmission Study Comparison and Options, Levitan & Associates, Dec. 2020
13. California North Coast Offshore Wind Studies, Reports 1 – 24, Schatz Energy Research Center, Sept. to Dec. 2020
14. A Systematic Evaluation of Wind's Capacity Credit in the Western United States, Wind Energy, Feb. 2021
15. Global Wind Energy Report 2021, Global Wind Energy Council, Mar. 2021
16. Draft 2021 Northwest Power Plan, NWPCC, Sept. 2021
17. Offshore Wind Market Report: 2021 Edition, U.S. DOE, Aug. 2021

18. California’s Offshore Wind Electricity Opportunity, University of Southern California Schwarzenegger Institute for State and Global Policy, Aug. 2021
19. Climate Change Impacts on Wind Energy Generation in Ireland, Wind Energy, Aug. 2021
20. Floating Wind Joint Industry Project (JIP) Reports, Phase I - III Summary Reports, Carbon Trust, 2016 – Current
21. Updated Oregon Floating Offshore Wind Cost Modeling, NREL, Sept. 2021
22. Evaluating the Grid Impact of Oregon Offshore Wind, NREL, Oct. 2021
23. Offshore Wind to Green Hydrogen – Insights from Europe, CESA, Oct. 2021
24. Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning, BOEM, Jan. 2022

ODOE has identified relevant highlights and themes, and has distilled and synthesized key findings from the Department’s literature review on the topics in the following pages. Given the multi-faceted and rapidly evolving nature of literature on FOSW, and the limited real-world data and information on the technology, there may be some differences and inconsistencies across findings. For a more comprehensive understanding of the findings presented here, we encourage stakeholders to review the studies provided above.

OFFSHORE WIND TURBINE COST AND SIZE

Larger Size and More Electricity

Offshore wind turbines and their components (blades, towers, and nacelles — the box-like part housing the generating components) are generally larger than their onshore counterparts, meaning they have higher upfront costs but can generate more electricity. Lager turbines are possible because components can be transported by ships and barges, reducing transportation challenges that land-based wind components encounter, such as narrow roadways or tunnels.[9] These larger turbines can generate more electricity than smaller turbines, and studies have presumed FOSW individual turbine sizes are likely to increase from 8 MW in 2019 to 10 MW by 2022, 12 MW by 2027, and 15 MW by 2032.[10] For comparison, the largest land-based turbines in the U.S. approach 5 MW.[11]

Increasing Cost-Effectiveness

The trend of installing larger turbines is a primary driver for reductions in the LCOE ($/MWh) for FOSW projects.[12] The “Balance of System,” “Soft Cost,” and “O&M” costs in Figures 4 and 5 are relatively fixed for large FOSW projects. But as turbines increase in size and create more electricity per turbine, without adding proportionally to the capital cost, the cost of the output produced by the FOSW turbine ($/MWh) will decrease. This lowers the LCOE of FOSW projects and increases their cost-effectiveness. For example, as mentioned earlier, NREL has estimated LCOEs for FOSW projects in 2022 with 8 MW turbines off Oregon’s coast, sited at different locations from south-to-north, to range from $74/MWh-$107/MWh; but has estimated that these LCOEs could drop to a range of $51/MWh to $74/MWh by 2032 with 15 MW turbines and advancements in other FOSW component technologies, particularly floating platforms.[13]

Figure 4: Capital cost breakdown for a 2019 FOSW reference project (does not include capital costs for onshore upgrades to ports or the existing transmission grid). NREL, 2019 Cost of Wind Energy Review, https://www.nrel.gov/docs/fy21osti/78471.pdf

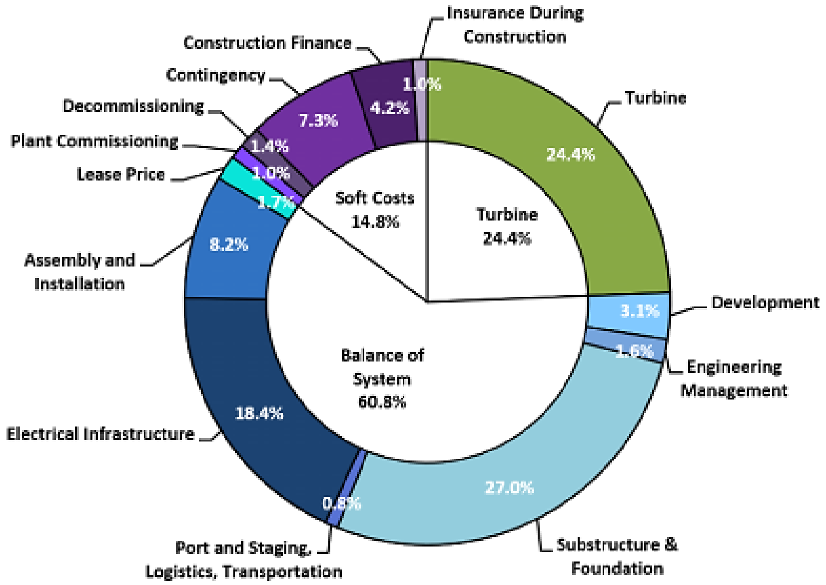
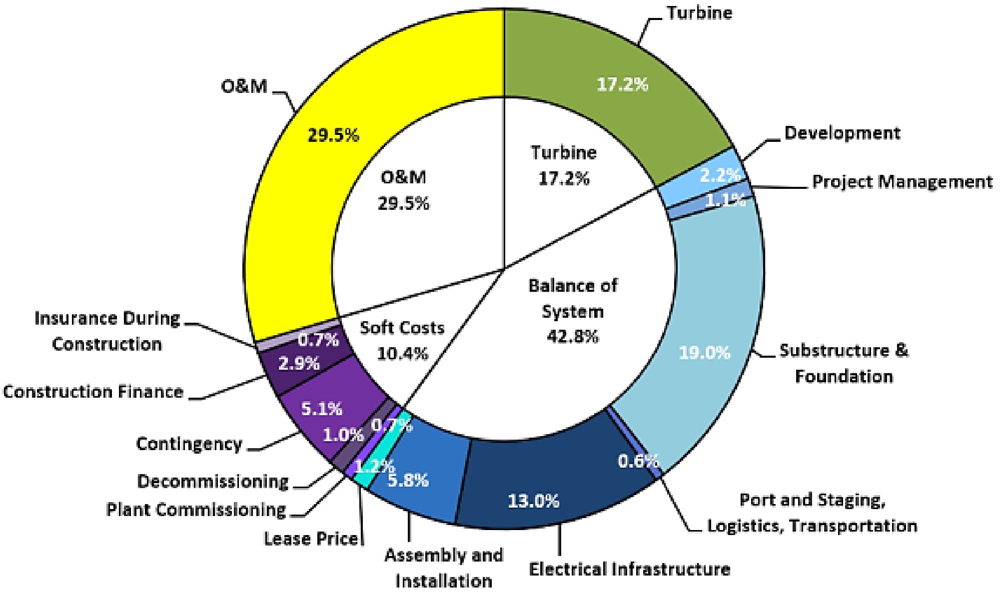


Figure 5: Breakdown of component contribution to LCOE for a 2019 FOSW reference project operating for 25 years (costs for onshore upgrades to ports or the existing transmission grid are not a component of LCOE), https://www.nrel.gov/docs/fy21osti/78471.pdf



Footprint of 3 GW

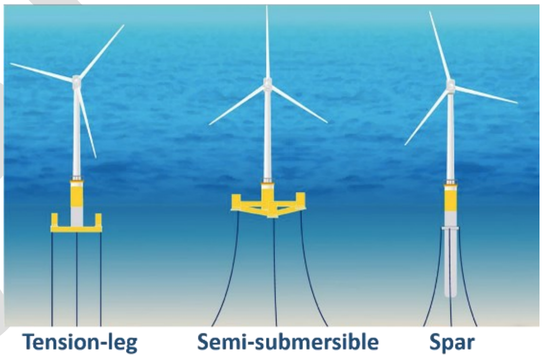
According to estimates from NREL and USDOE literature, which presume a power density for FOSW projects to be 3 MW per square kilometer (3 MW/km^2), 3 GW of FOSW off Oregon's coast could have a total ocean footprint of approximately 386 square miles.[14] For comparison, the entire ocean footprint of the total technical resource potential for FOSW off Oregon's coast could span over 7,000 square miles. This 3 GW footprint is a general estimation, as the actual footprint of a FOSW project will vary depending on the capacity per individual turbine and the spacing of individual turbines to optimize for wind wake losses and siting requirements. The total of 3 GW of FOSW could also be deployed across several individual footprints in different locations. For example, 1,000 MW (or 1 GW) deployed in three separate locations, each with an approximate footprint of about 130 square miles.

FLOATING PLATFORMS

Emerging Technologies

The floating platforms necessary to deploy offshore wind turbines in the deep ocean waters along Oregon's coast are emerging technologies that are still in the formative stages of development. Three archetypes of floating platform technologies have been deployed to date: spar platforms, semisubmersible platforms, and tension leg platforms. Different floating platform designs require different port water draft depths to enable their onshore fabrication and towing out to sea (draft depths indicate the minimum depth needed for floating platforms and ships to navigate safely). Spar technology requires the deepest water draft (~80m), with semisubmersible and tension leg platform requiring shallow water drafts (~20m and ~30m, respectively).[15] The largest installed FOSW project to date is the 50 MW Kincardine Wind Farm off the coast of Scotland, which was deployed from a deep-water port using spar technology.[iii] Oregon's shallower-water ports may make spar platforms less likely candidates for FOSW projects off Oregon's coast. Other FOSW projects have been installed using semisubmersible and tension leg platform designs, which could be more suitable for construction and tow-out from Oregon ports. Floating platform design continues to evolve. For example, different materials used in platform construction are being deployed. Many existing platform designs use steel, but a novel concrete semisubmersible platform will be a primary feature of what is poised to be the first U.S. FOSW project, an 11 MW pilot set for installation off the coast of Maine.[16]

Figure 6: Archetypes of floating platform technologies



[iii] The 50 MW Kincardine project was completed in August 2021 and is 9 miles offshore. It consists of five 9.525 MW turbines, along with a 2 MW demonstration turbine that's been operating since 2018.

Port Assembly & Maintenance

OSW final turbine assembly, commissioning, and major maintenance can occur at a port rather than in the open ocean. While BFOSW projects require specialized vessels and equipment for major construction and maintenance activities at sea, floating platforms enable many major construction and maintenance activities to occur a port facility. This has the potential for significant cost savings and risk reductions in the form of reduced marine operations during initial construction and installation, and during major maintenance activities post-installation. This potential for in-port construction, maintenance, and repair of FOSW components can mitigate the challenges of working in a wide range of weather conditions on the open ocean, as well as the need for specialized oceangoing equipment to perform these activities at sea in deeper water and more volatile conditions.[17]

Serial Fabrication

Serial fabrication of floating platforms in nearby ports can help achieve unit cost reductions through economies of scale.[18] Mass production of floating platforms is challenging because: 1) economically efficient designs for floating platforms are still emerging in general because floating platform designs are currently unique, and based on what type will be best suited for a specific FOSW project (e.g., semisubmersible, spar, tension leg, or a novel hybrid design); and 2) because serial fabrication requires a dedicated area for construction likely at or near a port. Serial fabrication of floating platforms at the same port that would assemble the tower to the floating platform would also decrease transportation costs of floating platforms and be the most economical. While Oregon has some ports that could be suitable for the fabrication and assembly of floating platforms – one study identified Coos Bay, Astoria, and Portland as having the potential to support these activities – some additional space may be necessary to create staging areas to support construction activities.[19] More information on the topic of port infrastructure follows below in the *Supporting Infrastructure* section.

Greater Depth & Distance

The use of floating platforms enables offshore wind projects to be developed at greater ocean depths, which also enables offshore wind to be deployed at greater distances from shore. This allows FOSW projects to be located where winds are stronger and more consistent, and visual impacts from shore are minimized. However, greater depths and distances from shore adds complexities and challenges to installation and maintenance activities, which increase the LCOE of FOSW projects. At depths of 1,300 meters, for example, studies found that construction challenges are more difficult to overcome based on present technology limits, and FOSW projects at this depth are not likely to be economically viable.[20]

Technology Resilience

Research on the resilience of floating platforms to natural hazards, especially their resilience to storms, tsunamis, and earthquakes, is incomplete and inconclusive. For example, with no data on how FOSW reacts in significant tsunamis or earthquakes, it is assumed that an earthquake of 8.0 or higher would result in a major failure of FOSW.[21]

SUPPORTING INFRASTRUCTURE

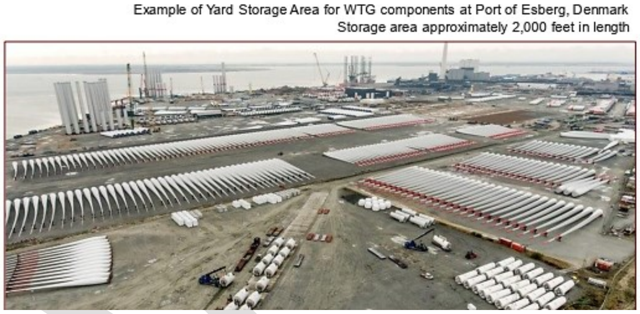
FOSW projects require ports and sea vessels to deliver, build, deploy, and maintain the projects.

Port Infrastructure

Construction, maintenance, and transport of FOSW components requires sufficient port infrastructure. The Bureau of Ocean Energy Management's port study in 2016[22] classified the ports required for the installation of FOSW into three categories: ports suitable for assembly, ports suitable for fabrication and construction, and ports suitable to support maintenance, troubleshooting, and repair of turbines once built. The following is a list of these different types of ports and features necessary to support FOSW:

- **Assembly Port (AP).** Supports final assembly of FOSW projects, including the assembly of towers and floating platforms; provides staging and storage areas; supports marine tow to installation location; and can potentially serve as a monitoring base to support cable-laying and mooring installation.

Illustration 1: Example storage yard for FOSW components



Example of Yard Storage Area for WTG components at Port of Esberg, Denmark
Storage area approximately 2,000 feet in length

- **Fabrication and Construction Port (FCP).** Supports construction, staging, and pre-assembly of FOSW project components; serves as transport hub for FOSW components and materials; supports fabrication of all wind turbine components – nacelle, blade, foundation, generator, hub, and cable.
- **Quick Reaction Port (QRP).** Located within two hours of ocean site where FOSW is installed and serves as the operations and pre-installation survey homeport. Supports crew transfers and minor maintenance and repairs. Helipad infrastructure may be necessary.
- **Cluster Port.** A cluster port would incorporate features from each of these three ports to provide synergies and optimizations that could be more efficient than relying on a network system of individual, specialized ports.

Literature has identified potential ports in Oregon that could serve as an AP, FCP, or QRP:

- With upgrades, Coos Bay and Astoria have potential to serve as APs, FCPs, and QRPs.[23] These are the only ports directly on the Oregon coast that have been identified as a potential AP or FCP.[24]
- Ports along the Columbia River region, such as Portland, with access to the deep draft navigation channel of the Columbia River, existing infrastructure, a labor pool, and available land provide a good opportunity to serve as an FCP by supporting the fabrication and construction of FOSW components (with minor or major modifications to existing facilities based on component type). However, it is likely at least some new land development and marine terminal facilities would need to be built. In addition, the bridges crossing the Columbia River preclude Columbia River ports from serving as APs

due to air draft restrictions, and the river ports are located too far inland to serve as QRPs.[25]

Many ports located on the Oregon coast are intended for recreational use or for commercial fishing vessels, and do not meet the needs for FOSW development or as a quick-reaction port. These ports lack the permanent and floating crane infrastructure to facilitate the in-port FOSW assembly requirements needed for APs and FCPs. The limited number of existing options for these ports means some regions off the coast of Oregon with high FOSW resource value may not be within reasonable proximity to any suitable port. In these cases, FOSW development would also require building new infrastructure, or investigating the feasibility of a larger floating service vessel permanently moored near the FOSW installation site.

Illustration 3: Top to bottom, examples of 1) delivery vessel, 2) heavy lift vessel, 3) semisubmersible barges, 4) crane vessel. http://schatzcenter.org/pubs/2020-OSW-R19A.pdf

Sea Vessels

While construction of FOSW projects largely avoids the need for specialized sea vessels, some could be necessary to support installation and maintenance activities, such as the installation of mooring lines and power cables. Several types of specialized vessels are in short supply globally. Of the many different types of vessels capable of supporting offshore wind projects, the following is a short-list of specially designed sea vessels:

- **Component Delivery Vessels.** Consist of breakbulk carriers, cargo ships, and barges that transport wind turbine components.
- **Heavy Lift Vessels.** Designed to transport very large loads and may be used to deliver wind turbine components or FOSW platforms.
- **Semisubmersible Heavy Lift Vessels & Barges.** Designed to transport very large floating loads with semisubmersible capabilities for loading/unloading and may be used to deliver FOSW platforms.
- **Semisubmersible Dockside Barges.** Designed to lower floating platforms into the water and can be used to transport floating platforms.
- **Crane Vessels.** Designed for heaving lifts required for dockside float off and lifts required for ocean installation.

The availability of these and other vessels is further limited by the U.S. Jones Act, which requires flagged U.S. vessels for the transport of merchandise, such as wind turbine blades, between two *U.S. points*.[26] U.S. points are considered to include U.S. ports and ocean sites of FOSW projects. This means a FOSW component loaded in the U.S. at one point and transported to the ocean site of an offshore wind project must use vessels that are built in the U.S., registered in the U.S., and primarily crewed by Americans. While investments in U.S.-built vessels to support the offshore wind industry are being made, there are also questions surrounding whether the Act could cover construction activities at sea, not just transportation.[27] Major construction activities of FOSW projects are likely to occur at port, but if construction activities occurred at sea, they could require the use of U.S. flagged vessels for heavy lift installation activities — and there are currently no U.S. flagged heavy-lift vessels.

GENERATION IMPLICATIONS FOR THE ELECTRIC GRID

Oregon has significant offshore wind resources which, if developed, could provide large amounts of clean electricity to the grid to help achieve clean energy goals, and provide complementary generation that can support the reliability of the electric grid as more renewable and clean energy resources are brought online.

Figure 7 – Offshore wind resource adjacent to Oregon coast. Floating offshore wind resources are found at 60 meters or deeper, reflected by the green and purple portions, see EN 26.

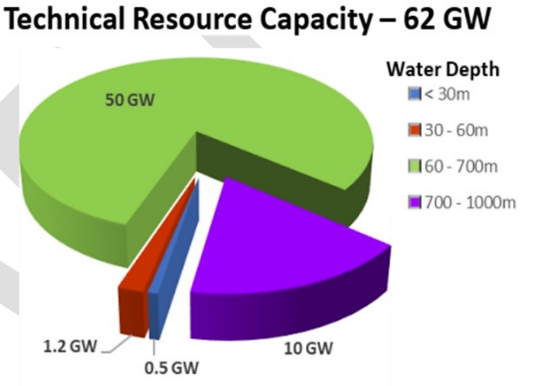
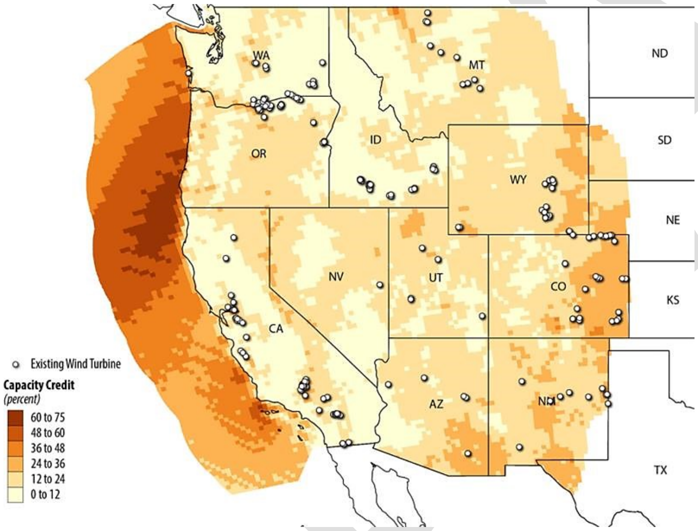


Figure 8: Capacity Credit values found in Jorgenson study, see EN 23.



Technical Resource Capacity

Research indicates that the winds off Oregon's coast are some of the strongest and most consistent in the world, with about 60 GW of estimated technical resource potential for FOSW development (e.g., in depths of 60 to 1000 meters).[28] For context, 60 GW is approximately equivalent to the total amount of currently installed capacity in the Pacific Northwest.[29] The consistent generation of offshore wind has been studied in terms of its capacity credit and its capacity factor,[iv] with one study calculating the capacity credit for

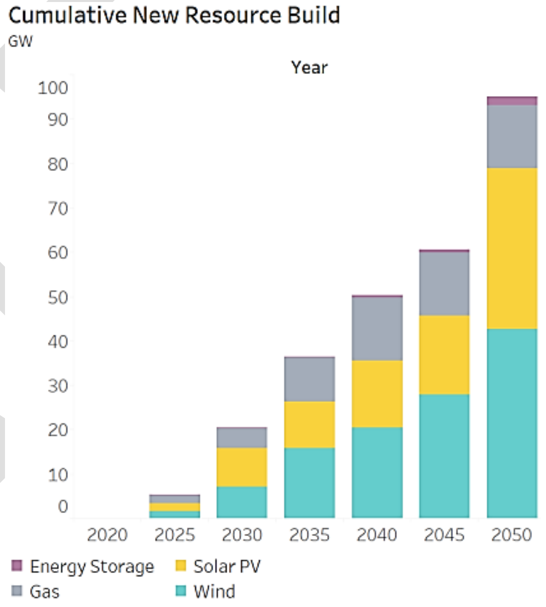
---

[iv] *Capacity credit* is a metric that calculates the percentage of a FOSW project's nameplate output that can contribute energy to the grid when energy is most needed, such as peak load hours. *Capacity factor* is a metric, expressed as a percentage, that compares the energy generated by a FOSW project during a time period to the energy that could have been generated by the project's nameplate output during the same time period, typically a year. While baseload resources with constant fuel supply approach 95 percent capacity factors, intermittent renewables only generate electricity when the fuel (e.g. wind or solar radiance) is available, and therefore have a much lower capacity factor. FOSW projects off Oregon's coats are expected to have average capacity factors ranging between around 40-55 percent.

offshore wind adjacent to Oregon's southern coast to be between 60-75 percent.[30] For comparison, the same study found the average capacity credit for the top performing sites for land-based wind (the top quartile) to be 20 percent. Another study found an average capacity factor for offshore wind adjacent to Oregon's southern coast to be over 50 percent.[31]

Achieving Clean Energy Goals

Figure 9: Findings from Evolved Energy Research indicating approximately 80 GW or new renewable resources by 2050 would result in a 96% clean regional grid, see EN 27.



Oregon, California, and Washington have established 100 percent clean electricity goals, necessitating utility investments in resources that do not emit greenhouse gases.[32] Meanwhile, in the Pacific Northwest alone, 2.6 GW (2,600 MW) of coal-fired electricity generation is scheduled to be retired by the end of 2028, electrification for economy-wide decarbonization is projected to increase loads, and investments in renewable resources such as solar and onshore wind are increasing.[33] Several studies point to the need for dozens of gigawatts of clean electricity generation to support decarbonization in Oregon and the Pacific Northwest. A recent economy-wide decarbonization study for the Pacific Northwest – decarbonizing electricity supplies and accounting for increased electrification of the transportation and building sectors – showed the region could be 96 percent clean by 2050 if the region added approximately 80 GW of new renewable resources.[34] Meanwhile, a separate study indicates Oregon could achieve 100 percent decarbonization of its 2050 economy-wide energy demand if approximately 35 GW of new renewable resources were added to the western grid from 2020 through 2050.[35] This includes a projection for 20 GW of FOSW interconnected to the Oregon grid between 2035 and 2050. While these two studies offer very different projections for the amount of generation needed to achieve decarbonization, both demonstrate significant need for deployment of clean energy.

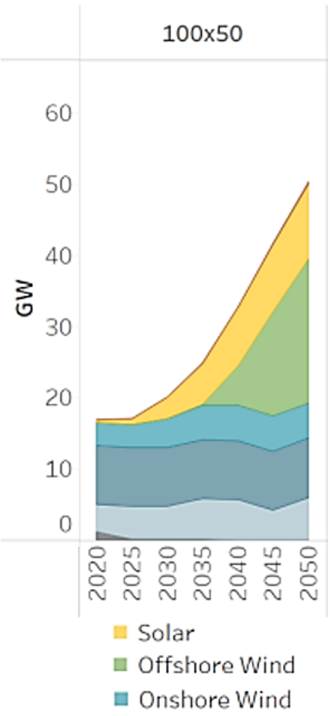


Figure 10: Findings from Evolved Energy Research indicating 35 GW of new renewable resources added to the Western grid by 2050, including addition of 20 GW of FOSW interconnected to Oregon's grid, would result in Oregon achieving 100 percent economy-wide decarbonization, see EN 28.

Complementary Generation

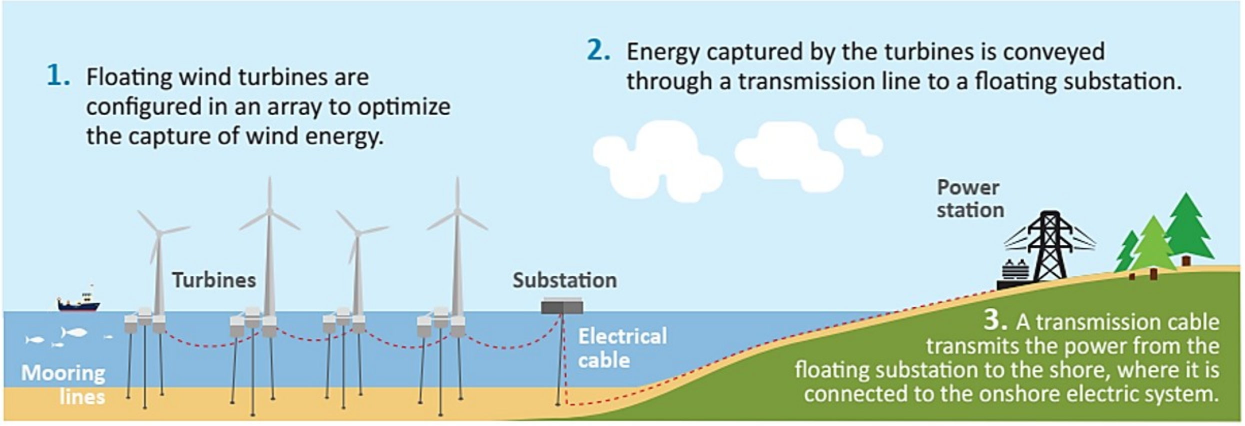
The literature also shows FOSW can provide the grid with clean energy at times that are complementary to other clean generation resources that are variable in their generation output, such as solar, onshore wind, and hydropower.[36] Offshore wind tends to be more consistent in generation output, and is available at times of the day and during seasons of the year when the sun is not always shining, when onshore wind is not always blowing, and when hydropower may be constrained. To the extent FOSW offers generating output that complements the output pattern of other clean resources, it can help improve the reliability of a clean mix of generation to meet the load demands of the power grid across a variety of timeframes and seasons.

TRANSMISSION IMPLICATIONS FOR THE ELECTRIC GRID

FOSW development has the potential to provide a variety of benefits related to the transmission grid. FOSW has the potential to diversify power supplies to coastal areas thereby enhancing grid reliability and community energy resilience. In addition, FOSW has the potential to re-balance and optimize regional onshore transmission flows, which could help mitigate existing onshore transmission constraints.

Any FOSW project will require the installation of new ocean-based transmission lines and substations, as well as upgrades to land-based transmission lines and substations. The scale of transmission infrastructure development needed is dependent on the amount of FOSW capacity installed. Larger FOSW projects generally would require correspondingly larger amounts of new offshore transmission infrastructure, as well as larger amounts of new or upgraded onshore transmission infrastructure. However, to the extent multiple FOSW projects can make use of common transmission infrastructure, as larger amounts of FOSW capacity are planned for deployment, opportunities to optimize the scale and configuration of new offshore and onshore transmission infrastructure are likely to increase.

Figure 11: Offshore and onshore transmission infrastructure necessary for FOSW - https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022



Offshore Transmission Infrastructure

Different scales and distributions of FOSW deployment can lead to different configurations of offshore transmission infrastructure. All configurations require low voltage gathering lines that connect individual turbines before feeding into an offshore substation. There are at least two different configurations that could be used when developing offshore wind transmission infrastructure:

- **HVAC Radial Export Cable Configuration.** With this configuration, an offshore substation steps up the alternating current (AC) voltage from low to high before the electricity is transmitted across a high-voltage AC (HVAC) export cable to the mainland transmission infrastructure.[37] Offshore export cables are laid in a trench on the seafloor, where deep sea canyons and seismic activity can pose challenges to route selection and increase installation costs.[38] Natural and cultural resources can be affected by installation of an export cable and could change the route of the cable to mitigate impacts. Some routes may also require horizontal directional drilling to pass the cable through the continental shelf and up to the point of interconnection with mainland transmission infrastructure – which can add to project costs.[39]
- **HVDC Subsea Backbone Transmission Configuration**. This configuration includes a high-voltage direct current (HVDC) subsea backbone transmission line. Backbone HVDC lines have been deployed worldwide both on land and at sea.[40] They are particularly useful in transmitting large amounts of power over long distances because DC lines have lower line losses than AC lines and transmit electricity more efficiently. This configuration uses a subsea HVDC line that could span a long distance in the north-to-south direction parallel to the coast, and enable multiple FOSW projects to tie into the line as they are developed, supporting more opportunities for the FOSW project development and enabling economies of scale.[41] While it would also reduce the need for individual export cables at each project, thus reducing potential effects on environmental, natural, and cultural resources caused by each of these lines, the tradeoff is the environmental,

natural, and cultural resources impacts of the north-to-south HVDC line.[42] In addition, this type of configuration could consolidate the use of onshore transmission lines and substations, which could lower the overall onshore environmental footprint.

This design would require HVDC converter stations to convert the generated AC power to DC. While technology is advancing, to date, there are no existing *floating* HVDC converter stations.[43] Some BFOSW projects use an HVDC configuration, but in these instances the converter stations are also bottom-fixed. Studies beyond the concept of a floating HVDC design are inconclusive, and while the industry is planning for this type of configuration in the future, additional technological advancements could be needed for this design to be viable configuration for FOSW.[44]

The cost for building an HVDC line is also a significant hurdle. A conceptual assessment for a nearshore, approximately 250-mile, 500-kV HVDC subsea cable project from Humboldt Bay to San Francisco had a very rough cost estimate of at least $2 billion.[45] For comparison, a land-based transmission project of similar scale, the approximately 300-mile, 500-kV AC Boardman to Hemingway project, is estimated to cost about $1 billion.[46]

Onshore Transmission Infrastructure

There is a limited amount of FOSW generation capacity that can be connected to Oregon's existing coastal onshore transmission infrastructure without significant upgrades. As shown in Figure 12, the coastal grid has been designed to supply relatively small communities with small loads with electricity delivered from large inland generating resources located east of the Coast Range. This limits the total amount of FOSW generation that can be added at different points along the coastal transmission grid.[47] However, interconnecting FOSW has the potential to bolster the overall reliability of the onshore transmission system by diversifying coastal power supplies and adding voltage stability to the grid.[48]

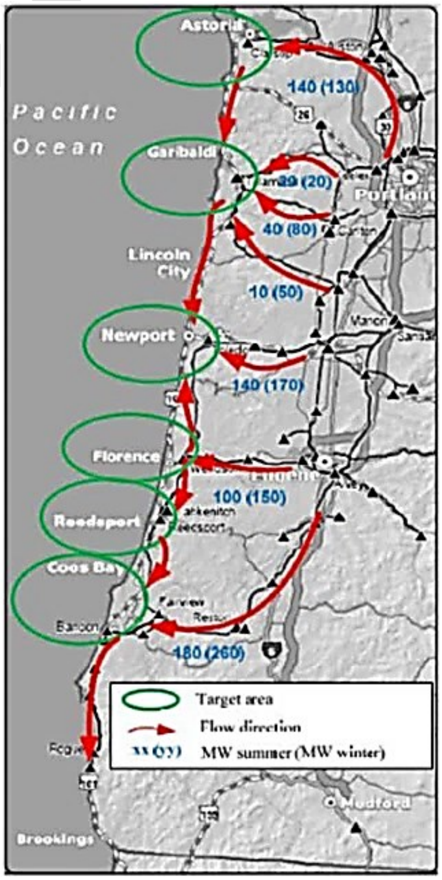
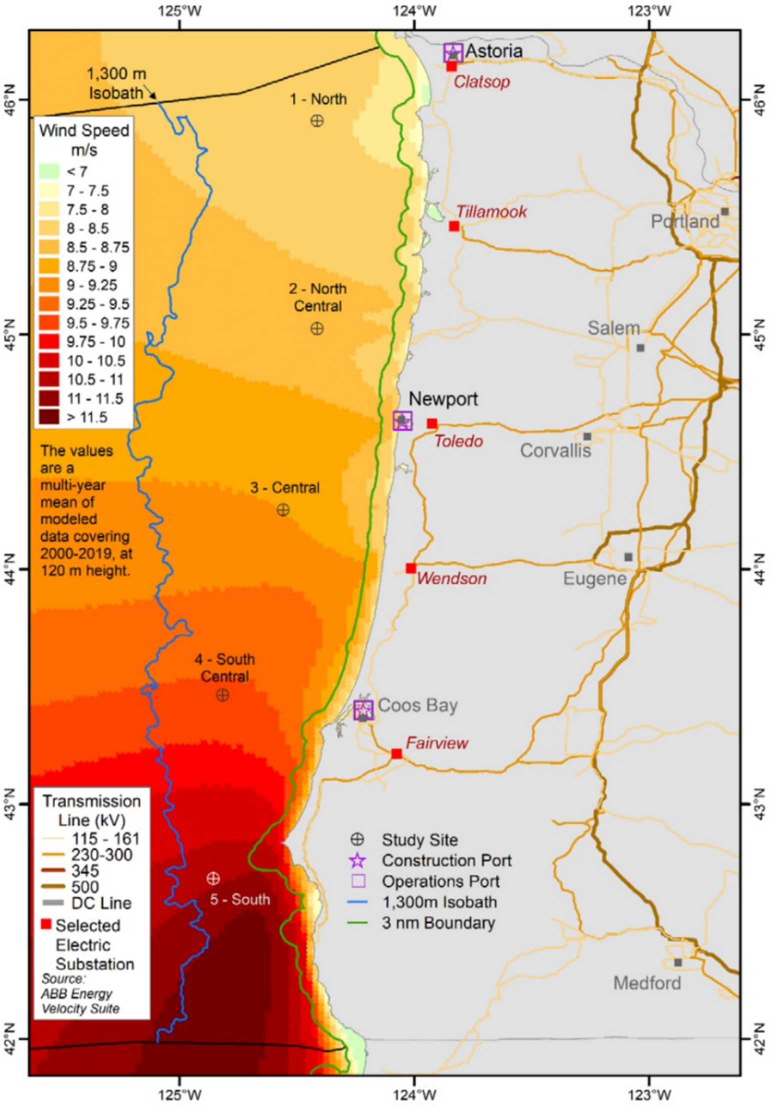


Figure 12: Map to right showing design of the coastal grid and how electricity is supplied from inland generating resources east of the Coastal Range. https://www.nrel.gov/docs/fy20osti/74597.pdf

Transmission Capacity

Two recent studies by Pacific Northwest National Laboratories (2020)[49] and the National Renewable Energy Laboratory (2021)[50] identified existing transmission capacity across the Coast Range as the most significant challenge to integrating more than about 2 GW of FOSW capacity into Oregon's grid. Without significant upgrades to existing transmission, additional large amounts of the FOSW generation would be at risk of curtailment (i.e., shutting down generation from FOSW turbines due to a lack of transmission capacity). In both studies, the 2 GW was split across multiple interconnection points – four coastal substations in the PNNL study and five in the NREL study. In the NREL study, five substations located along the entire length of the existing Oregon coastal transmission system, from Astoria to Coos Bay, were required to integrate the 2 GW of FOSW generation without significant and costly transmission system upgrades. The studies did not explore the additional costs of potential onshore transmission upgrades.

Figure 13: Map showing five substations analyzed for points of interconnection in the 2021 NREL transmission study for Oregon FOSW. https://www.nrel.gov/docs/fy22osti/81244.pdf

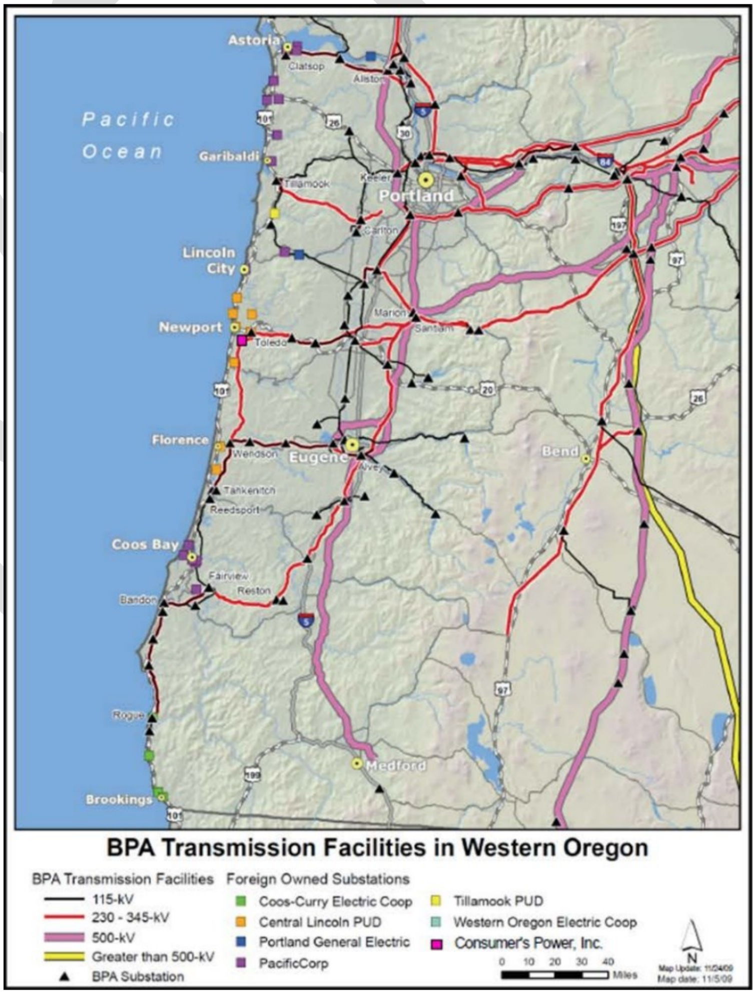


Transmission Planning

Transmission planning for upgrades or new lines associated with a FOSW project could occur at the local, regional, and federal level, depending on the where a transmission project will be located, who owns the line, the length of the new line, and the extent of a transmission project's impacts. The Pacific Northwest regional transmission grid consists of multiple transmission lines and networks that are owned and operated by many individual transmission providers. Some are operated entirely within a specific state while others cross state lines. The Bonneville Power Administration owns and operates approximately 75 percent of the transmission line miles in the Pacific Northwest, and is the primary owner and operator of transmission serving the Oregon Coast.[51] Because FOSW projects will necessitate new offshore and onshore transmission infrastructure, BPA and other transmission owners and operators would play a significant role in transmission planning for the potential development of FOSW.

- **Local Transmission Planning.** If a FOSW project proposes an interconnection to the coastal transmission system, the transmission entity that owns the point of interconnection must analyze the ability of the existing transmission infrastructure to integrate the proposed amount of electricity generation without creating reliability or safety impacts to the grid. In Oregon, owners of coastal transmission that could serve as points of interconnection for FOSW projects include BPA, PacifiCorp, and Coos-Curry Electric Cooperative. If the capacity of existing transmission infrastructure cannot accommodate the proposed injection of additional generation capacity, the transmission owner will require upgrades to address the transmission capacity constraints, which must be paid for by the FOSW project. Significant upgrades to a transmission provider's system can become part of that transmission entity's local transmission plan.

Figure 14: Oregon Transmission Infrastructure, BPA and others



- **Regional & Interregional Transmission Planning.** The Federal Energy Regulatory Commission (FERC) requires regional transmission planning that identifies and evaluates transmission needs driven by: 1) reliability requirements, 2) economic considerations, or 3) public policy requirements.[v] While several Pacific Northwest entities assess transmission as part of their regional planning efforts, NorthernGrid is a transmission planning association that facilitates regional transmission planning for FERC compliance in the Pacific Northwest. They aggregate local transmission plans from the region's transmission entities (i.e., NorthernGrid members). They pull local transmission plans together to assess impacts to regional reliability and to evaluate whether alternative transmission solutions could

---

[v] As required by FERC Order 1000

meet the needs of the region more efficiently or cost-effectively than solutions identified by individual transmission entities in their local transmission plans.[52]

Transmission developers that are not NorthernGrid members can also propose regional or interregional transmission projects[vi] to NorthernGrid.[53] If a regional or interregional transmission project for a large capacity FOSW project (or multiple FOSW projects with a large aggregate capacity) were proposed off Oregon's coast it would be analyzed by NorthernGrid. A new regional or interregional offshore and/or onshore transmission project could have the potential to help optimize the integration of FOSW into Oregon's grid. The analysis would evaluate whether it could meet the needs of the region more efficiently or cost-effectively, either by itself or in combination with other regional projects, compared to the region's baseline transmission projects identified in the local transmission plans of NorthernGrid's members.[54]

Grid Reliability & Resilience

FOSW projects have the potential to provide local reliability and resilience benefits to coastal communities, in addition to broader state-wide and regional reliability benefits.

- **Local Reliability**. Coastal communities are more at risk for power disruptions due to their geographic isolation from the overall electric grid, and the fact that there is no existing large-scale electricity generation west of Oregon's Coast Range.[55] Coastal electricity customers largely rely on supplies of electricity delivered to them via the small number of transmission lines crossing the Coast Range, leaving the coast with few supply options when one of these lines is disrupted.[56] All transmission lines can be affected by winter storms or summer wildfires, but when a line extending to the coast is disrupted, coastal communities can face risks of diminished power quality (i.e., brown-outs) or even power outages. FOSW could provide generation for the Oregon coast that would bolster reliability for communities west of the Coast Range.[57]
- **State-Wide and Regional Reliability.** As noted, FOSW could also help bolster state and regional electricity system reliability by providing the grid with clean energy at times when other clean resources aren't generating. Oregon's electric systems are also part of a larger, interconnected interregional grid that ties in-state and out-of-state electric

RELIABILITY

A reliable power system, at any point in time, requires the amount of electricity generated and delivered to customers to be in balance with the amount of electricity consumed by customers. Achieving this balance occurs through planning activities and system management protocols designed to meet established reliability standards. A reliable power system is designed to minimize power loss disruptions as a result of a sudden disturbance or unanticipated failures of system elements.

[vi] Interregional projects connect two planning regions and regional projects occur within a planning region.

systems together, and transmission constraints or failures in one area of the state can lead to transmission constraints and failures in other areas. To the extent FOSW generation could help reduce existing transmission constraints throughout the state and inter-regionally, FOSW may also improve the reliability of state, regional, and interregional transmission systems.[58]

- **State-Wide and Regional Reliability.** As noted before, FOSW could also help bolster state and regional electricity system reliability by providing the grid with clean energy at times when other clean resources aren't generating. Oregon's electric systems are also part of a larger, interconnected interregional grid that ties in-state and out-of-state electric systems together, and transmission constraints or failures in one area of the state can lead to transmission constraints and failures in other areas. To the extent FOSW generation could help reduce existing transmission constraints throughout the state and inter-regionally, FOSW may also improve the reliability of state, regional, and interregional transmission systems.[59]
- **Local Resilience.** A supply of FOSW generation could also help improve energy resilience for coastal customers by diversifying power supplies. It could provide an alternate supply of electricity for coastal communities surrounding a point of interconnection to withstand a non-routine severe disruption for a long period of time (i.e., a resilience event).[60] A resilience event (such as a large earthquake) could cause a failure of one of the major east-to-west transmission lines crossing the Coast Range, or one of the major coastal north-to-south transmission lines that are critical to keeping the lights on for coastal customers. FOSW could also potentially provide resilience value to other coastal communities further from the points of interconnection depending on the location of the major transmission line failure.

RESILIENCE

Power system resilience is a concept separate and distinct from power system reliability. Resilience is the ability of power systems to withstand and rapidly restore power delivery to customers following non-routine disruptions of severe impact or duration. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. For example, Oregon is within the Cascadia Subduction Zone and an earthquake is a type of resilience event that could affect Oregon's power systems, particularly those along the coast.

OFFTAKERS – POWER SYSTEMS AND MARKETS

Costs play a significant role in finding a buyer, or an "offtaker," for the generation supplied by a FOSW project. Cost competition from a diverse set of generation technologies is a significant challenge facing the deployment of FOSW. It is therefore important to understand and assess the landscape of potential offtakers and the energy markets in which they can participate.

There are a variety of ways to offtake electricity from a FOSW project. Regardless of the ownership structure, FOSW generation could be sold via a long-term Power Purchase Agreement or sold in shorter timeframes via wholesale energy markets. Some examples include:

- A utility or a combination of utilities making direct investments to own a project and use its output to serve customer loads;
- An independent power producer investing in and owning a project to sell its output to utilities or other consumers;
- A private business investing in and owning a FOSW project to use its output for meeting its own, typically industrial-scale, electricity needs; or
- A combination of the entities above could share in the ownership and output of a FOSW project to serve their individual needs.

Oregon Utilities as Offtakers

Investor-owned utilities are required by the Oregon Public Utility Commission to engage in long-term resource planning – through integrated resource plans (IRPs) – to determine what resources they will use to meet current and future load. Oregon's consumer-owned utilities, with some exceptions (e.g., Eugene Water & Electric Board, Emerald PUD, and others that create their own IRPs), largely meet their electricity needs with hydropower supplied by the Bonneville Power Administration and do not engage in power purchase agreements with other entities. IRPs use sophisticated modeling and vetting of assumptions in a public process to forecast the demand for energy over a 20-year period. Once demand is understood, the IRP process identifies the least-cost, least-risk combination of energy resources to meet demand across all timeframes (e.g., hours, days, months, seasons, and years). To date, no Oregon utilities have identified FOSW in their long-term resource plans as a potential cost-effective and least-risk resource to meet expected energy demand.[61] [62] FOSW is not currently a cost-effective purchase for Oregon utilities. However, HB 2021 (2021) requires Portland General Electric and PacifiCorp to submit "clean energy plans" to the PUC that reduce GHG emissions and meet clean energy targets over time – 80 percent by 2030, 90 percent by 2035, and 100 percent by 2040.[63] This requirement could lead to the inclusion of FOSW for analysis in future IRPs to meet the clean energy targets if the cost of FOSW become competitive.

Wholesale Energy Markets of the Pacific Northwest

The higher costs associated with the technology, port upgrades, and transmission needs for FOSW will be a significant barrier for FOSW to compete in the Pacific Northwest's low-cost wholesale energy market. FOSW projects could be sold through the Pacific Northwest's decentralized wholesale energy market through individual bi-lateral contracts between utilities and generation owners. The Pacific Northwest's abundant supply of low-cost hydropower, an increasing supply of low-cost solar and onshore wind, and existing natural gas power plants have led to some of the lowest wholesale electricity prices in the country. For example, average hourly wholesale power prices in 2021 ranged from $17 to $30/MWh.[64] Low wholesale electricity prices make it more difficult to find an offtaker for FOSW generation that is relatively more expensive – for example, the 2022 LCOE for a FOSW off Oregon's southern coast is estimated to be $74/MWh.[65]

California Energy Market

Offtakers for FOSW generated off Oregon's coast could include utilities operating in other states, particularly California, where their commitment to 100 percent clean electricity by 2045 combined with a more centralized market, planning process, and higher overall energy prices may have more influence on FOSW development in the near term. In addition to individual utilities in California engaging in long-term integrated resource planning, the California Public Utilities Commission also conducts a long-term integrated resource plan for the entire state – which informs the IRPs of individual utilities and other load serving entities. The CPUC modeled FOSW in its 2019-20 state-wide IRP as a sensitivity analysis only, meaning FOSW was not selected as a least-cost resource in the final IRP.[66] This analysis explored the tradeoffs between FOSW and out-of-state onshore wind, including the costs of transmission upgrades necessary to deliver energy from these resources into California. The result was that the CPUC intends to further examine future steps needed to support the development of FOSW.[67]

One of the next steps involves the California Independent System Operator. CAISO is responsible for transmission planning informed by the CPUC's integrated resource plan. CPUC has developed an offshore wind policy-driven sensitivity portfolio that identifies a significant amount of FOSW capacity for the planning year 2031,[68] which feeds into CAISO's power flow study, deliverability assessment, and production cost modeling for its 2021-22 transmission planning. In addition to assessing the transmission needs for this sensitivity portfolio, CPUC also asked CAISO to conduct an "outlook" assessment to accommodate additional FOSW capacity through 2045.[69] The goals of these planning exercises are to refine the transmission capacity and cost input assumptions that inform CPUC's future IRP modeling, and to ensure any transmission development to accommodate early FOSW resources is not undersized and built to allow future FOSW development. Results of CAISO's 2021-22 transmission planning analysis will inform CPUC's next IRP cycle, which will provide more information about the near and longer-term cost-effectiveness for California utilities to procure FOSW. Another driver in California is AB 525, a law the state passed in 2021,[70] which requires the California Energy Commission to plan for offshore wind development and is discussed in more detail below.

Renewable Hydrogen Offtakers

Similar to other potential offtakers, a business or utility interested in producing renewable hydrogen from renewable electricity would survey its options for procuring the least-cost renewable energy necessary to meet its needs. Renewable hydrogen is produced by the electro-chemical process of electrolysis, which passes electricity generated by renewable energy technologies (e.g., solar or wind) through water to release hydrogen molecules. The process inputs are renewable electricity and water, and the process outputs are separate streams of hydrogen and oxygen gas.

RENEWABLE HYDROGEN

The Oregon Department of Energy is conducting a renewable hydrogen study, due to the Legislature by September 15, 2022. Learn more: https://www.oregon.gov/energy/energy-oregon/Pages/rh2.aspx

Today, nearly all hydrogen is produced from a thermal process that reforms non-renewable natural gas, creating carbon dioxide as a byproduct. Currently, hydrogen is most commonly used in industrial processes such as the manufacturing of ammonia for fertilizer production, and the refinement of crude oil into gasoline and diesel fuels. There is significant worldwide interest in future development of a renewable hydrogen market – which holds promise to help decarbonize heavy industrial manufacturing sectors and heavy transportation sectors (e.g., heavy freight, marine, and air transportation).

As previously discussed, a challenge facing FOSW projects off the coast of Oregon is the limited capacity of existing transmission infrastructure. Larger capacities of FOSW projects that could be contemplated for interconnecting to Oregon's onshore grid (i.e., up to 3 GW or more), would either require significant upgrades to transmission infrastructure or result in significant amounts of curtailed generation.[vii] Curtailment of electricity that could be generated, but isn't because of a constraint in the transmission system (i.e., limited capacities of transmission of distribution system infrastructure) or a lack of load, can be detrimental to the economics of a FOSW project and could prevent development.

Studies focused on the European offshore wind market note the potential for renewable hydrogen production to serve as an offtaker of FOSW generation to reduce the need for FOSW curtailment and help reduce greenhouse gas emissions from other sectors, such as transportation.[71] In addition, renewable hydrogen has the potential to provide resilience benefits to communities during power outages through the use of fuel-cells to convert stored hydrogen back to electricity. Costs associated with the use of renewable hydrogen to produce electricity are high, and there is not sufficient data to show if or when it may be cost-effective to supply electricity to the power grid. Ultimately, the viability of a renewable hydrogen offtaker for FOSW generation would depend on the cost and benefits of producing renewable hydrogen from FOSW generation, relative to the costs and benefits of producing renewable hydrogen from other sources of renewable energy (e.g., hydro, solar, and/or onshore wind), and the relative costs and benefits of transmission infrastructure upgrades necessary to ensure minimal levels of curtailment.

OREGON INTERESTS

Oregon has many policy interests relating to the potential benefits and challenges of FOSW, including state policies directed at clean energy development, local economic development, equity, and energy resilience – all of which FOSW has the potential to benefit. Oregon also has state policies directed at engagement with tribal and local governments, which help the state

---

[vii] Curtailment – Curtailment of generation can occur when there are constraints in delivery systems (transmission and/or distribution infrastructure) or lack of load.

gather feedback on how FOSW could benefit state policy goals, and how FOSW could navigate siting and permitting complexities.

Clean and Renewable Energy Policies

FOSW is a renewable electricity generation resource that emits no greenhouse gases, and could help Oregon achieve its renewable energy, clean energy, and greenhouse gas emission reduction goals.

- **Greenhouse Gas Emissions Targets.** The electricity sector accounts for about 30 percent of the state's emissions. In 2007, the Oregon Legislature passed HB 3543, which set a greenhouse gas emission reduction target of 75 percent below 1990 levels by 2050. In 2020, Governor Brown issued Executive Order 20-04, which established a new GHG emission reduction goal for the state of 45 percent below 1990 emission levels by 2035, and 80 percent by 2050.
- **Renewable Portfolio Standard.** The Oregon Renewable Energy Act of 2007 (SB 838) established a standard of 25 percent renewable energy by 2025. In 2016, the Oregon Legislature passed SB 1547, updating the Oregon Renewable Portfolio Standard (RPS) law requiring Oregon's largest utilities to achieve at least 50 percent renewable electricity resources by 2040.
- **Oregon 100% Clean Energy Law.** Enacted into law in 2021, HB 2021 committed Oregon's largest investor-owned utilities and its electricity service suppliers to reduce their greenhouse gas emissions 80 percent by 2030, 90 percent by 2035, and 100 percent by 2040, effectively providing Oregon customers with 100 percent clean electricity by 2040. The law also restricts the state from approving new or amended permits for greenhouse gas-emitting energy facilities that use fossil fuels.

New clean energy projects, including FOSW projects interconnecting directly into Oregon's coastal grid, can help Oregon, as well as other states, achieve their clean energy commitments. Oregon utilities or Electricity Service Suppliers could use purchases of electricity generated by a FOSW project to comply with Oregon's RPS or the Clean Energy law. A utility or load serving entity from another state could also purchase electricity generated from a FOSW project interconnected directly to Oregon's coastal grid to supply clean energy to out-of-state customers and help meet clean and renewable energy policies enacted by other states.

Equity, Resilience, and Local Economic Development

Oregon HB 2021 also has provisions tied to renewable energy that aim to strengthen equity, resilience, and local job development for Oregon communities. For example, the law created the Community Renewable Energy Grant program with $50 million to fund planning or development of community renewable energy projects (<20 MW) that promote resilience and support environmental justice communities. The law also requires the construction of large renewable energy and storage projects (≥ 10 MW) to document and meet specific labor standards.

Tribal and Local Government Engagement

Offshore wind has the potential to affect coastal communities, ocean users, the environment, and cultural resources. The planning, installation, and decommissioning of FOSW projects and components necessary for their installation, such as offshore and onshore transmission equipment and infrastructure, must meet the approval criteria of several local, state, tribal, and federal jurisdictional processes. Tribal and local government engagement is an important aspect of these project review processes, providing opportunities for coastal and tribal communities to participate and provide input on specific projects. For example, Part Two of Oregon's extensive Territorial Sea Plan includes a "mandatory consultation process, as necessary, among local governments, the Governor, and state agencies on major ocean-development activities or actions" (ORS 196.465(2)(f)) and requirements for state agencies to promote positive tribal and state agency relations through coordination and engagement (ORS 182.162-168).

In addition, the Bureau of Ocean Energy Management (BOEM) and the State of Oregon are committed to offshore wind energy planning with meaningful and effective data gathering and engagement to inform potential decisions about lease areas of the outer continental shelf for the potential development of FOSW projects. BOEM and Oregon's Department of Land Conservation (DLCD) have held 75 meetings to date with local governments, tribes, coastal communities, ocean users, and environmental organizations. DLCD and BOEM developed an Oregon Offshore Wind Mapping Tool (OROWindMap) within the West Coast Ocean Data Portal to provide public access to the best available data to inform the planning process for offshore wind energy leasing in federal waters off of Oregon. BOEM, in particular, as a federal agency has formal consultation requirements with Tribes in accordance with treaties and federal law for its activities and decision-making related to planning and leasing.

Table 1 below is a snapshot from the Data Gathering and Engagement Summary Report for Oregon Offshore Wind Energy Planning issued by BOEM on January 14, 2022.[72] The draft of this summary report was provided to the BOEM-Oregon Intergovernmental Renewable Energy Task Force for review and discussion at the Task Force virtual meeting on October 21, 2021. The final report incorporates feedback from the October 2021 meeting, subsequent written feedback from Task Force members, and 15 additional meetings held through December 2021.

Table 1 Snapshot from BOEM's Data Gathering and Engagement Summary Report (Jan. 2022)

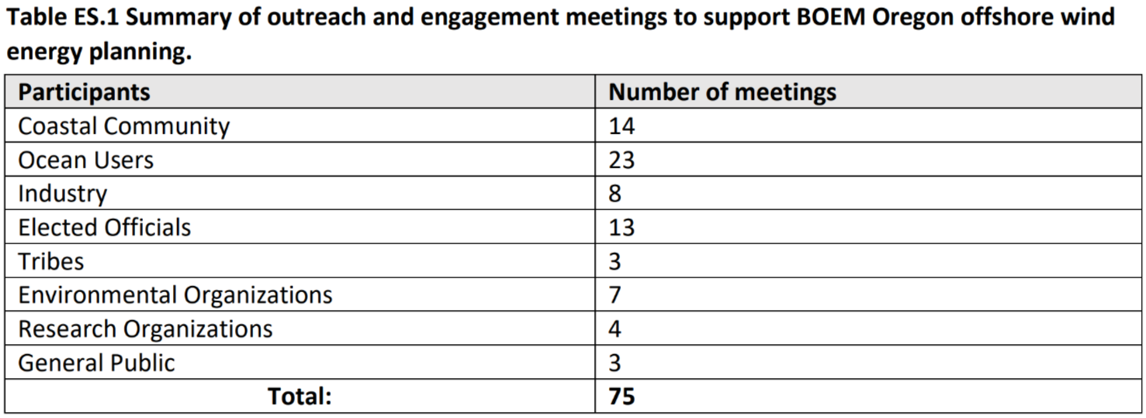


Table ES.1 Summary of outreach and engagement meetings to support BOEM Oregon offshore wind energy planning.

Participants	Number of meetings
Coastal Community	14
Ocean Users	23
Industry	8
Elected Officials	13
Tribes	3
Environmental Organizations	7
Research Organizations	4
General Public	3
Total:	**75**

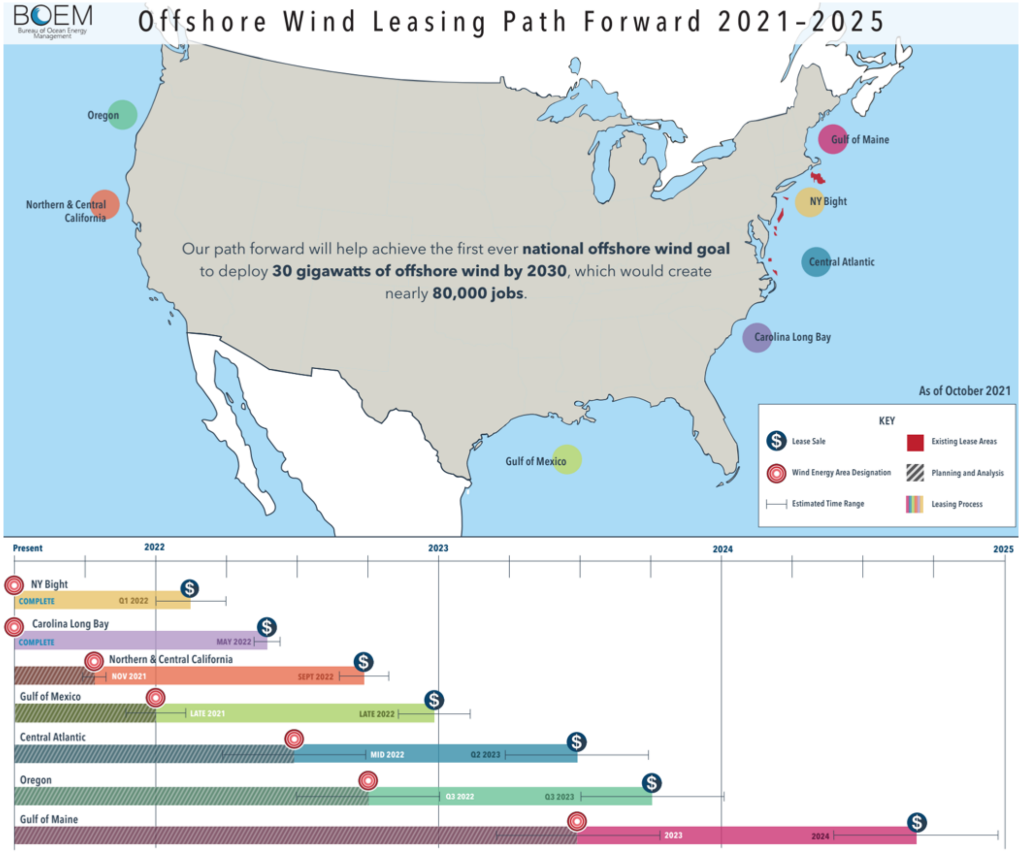
FEDERAL INTERESTS & STATE INTERESTS OUTSIDE OREGON

There is an array of recent, planned, and ongoing activities at the State and Federal level supporting the development of offshore wind.

Federal Interests

In March 2021, the Biden Administration set a target to deploy 30 GW of offshore wind by 2030. In October 2021, the U.S. Department of Interior announced plans for BOEM to potentially create up to seven new offshore wind lease sales by 2025 in the Gulf of Maine, New York Bight, Central Atlantic, Gulf of Mexico, and off the coasts of the Carolinas, California, and Oregon. This effort builds upon a May 2021 announcement between the state of California and the U.S. Department of the Interior (via BOEM), the U.S. Department of Energy (USDOE), and the U.S. Department of Defense to develop areas off the coast of California to bring up to 4.6 GW of FOSW projects online. In addition, USDOE has been supporting the development of FOSW, including: funding for General Electric efforts toward a new 12 MW turbine specifically designed for FOSW projects;[73] funding for University of Maine efforts towards an ultra-light concrete semisubmersible platform specifically designed for a 15 MW turbine;[74] and funding for a FOSW demonstration project (New England Aqua Ventus I) off the coast of Maine that is poised to be the first full-scale FOSW project for the U.S.[75]

Figure 15: BOEM's Proposed Leasing Schedule (Oct. 2021), https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/OSW-Proposed-Leasing-Schedule.pdf



FOSW is also eligible for the Federal Production Tax Credit and Investment Tax Credit (ITC). The ITC is especially significant for offshore wind projects because they are more capital intensive and benefit from up-front tax benefits to help with the project's financial viability. There is a 30 percent ITC for any offshore wind project that begins construction by December 31, 2025.

FERC is also interested in offshore wind transmission and interconnection solutions. In March 2021, FERC issued a notice inviting public comment (AD20-18-000) on a list of questions relating to whether transmission planning and interconnection frameworks in Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) can accommodate growth in offshore wind generation in an efficient and cost-effective manner. This followed an October 2020 technical conference on the same subject.[76]

In July 2021, FERC issued an Advanced Notice of Proposed Rulemaking (RM21-17-000) more generally applicable to all regions of the country (i.e., not only RTO/ISO regions) that invited public comment on reforms to improve transmission planning and cost allocation, as well as generator interconnection processes as the nation transitions to a cleaner energy future. Regarding regional transmission planning and interconnection processes, the notice expressed specific concern about the ability of existing processes to adequately account for costs and benefits relating to the resource mix of the future, such as onshore wind and solar, as well offshore wind.[77]

State Interests Outside Oregon

California's SB 100 (2018) requires the state's retail sales of electricity to be 100 percent clean by 2045. In March 2021, the SB 100 Joint Agency Report described portfolio modeling that selected at least 10 GW of FOSW to achieve the state's 100 percent clean energy target.

California's AB 525 directs the California Energy Commission (CEC), by June 1, 2022, to evaluate the maximum feasible deployment of FOSW to achieve reliability, ratepayer, employment, and decarbonization benefits for the state, and to create 2030 and 2045 state planning goals for offshore wind deployment. The state law also requires the CEC, by June 30, 2023, to develop a strategic plan for FOSW development that:

- Identifies ocean areas suitable to accommodate the planning goals;
- Plans for improving coastal port facilities and transmission infrastructure necessary to support the planning goals;
- Develops a permitting roadmap describing the timeframes for the permitting processes necessary for implementing the planning goals; and
- Includes the potential impacts on coastal resources, fisheries, Native American and Indigenous peoples, and national defense, and strategies for addressing those potential impacts.

In addition to the activities of California, eight states on the East Coast have committed to building over 35 GW of offshore wind by 2035, and 39 GW by 2040. While offshore wind development on the East Coast currently consists of BFOSW projects, planning for FOSW is also underway – including the first U.S. FOSW project off the coast of Maine, a research project limited to 12 turbines or fewer, with turbine capacities expected to be between 10-15 MW.

SITING & PERMITTING

The scope of this study is primarily focused on the energy sector, but the Department acknowledges that there are many important resources and topics that are of interest to Tribes, communities, industries, and environmental and natural resource groups. There are other agencies with expertise and ongoing processes better suited than the Oregon Department of Energy to directly study and report on those important topics.

In relation to the energy sector, complexities in jurisdictional siting and permitting review processes relating to the evaluation of potential impacts to important resources and human activities, such as potential environmental impacts and potential impacts to ocean and land users, may lead to additional time and costs — which may make projects more challenging to develop and less attractive in energy markets compared to other energy resources. Before a FOSW project could be deployed, the potential project and location require review and approval from a broad and diverse range of local, state, tribal, and federal authorities. In addition to the FOSW project itself, other supplemental projects necessary for deploying FOSW projects, such as the development of port infrastructure and onshore transmission infrastructure, would also require review and approval from a myriad of authorities.

Siting and permitting review processes are designed to address a variety of potential effects from the construction, operation, and decommissioning of proposed projects through approaches that consider avoidance, minimization, mitigation, and monitoring of potential impacts. After reviewing existing literature, some of the key potential impacts relating to FOSW development can broadly be grouped into two categories:

1) Potential impacts to ocean and land users[viii] (e.g., interests of Tribes and coastal communities – such as cultural impacts, like Tribal first foods, visual impacts, fishing interests, shipping interests, and military interests, etc.);
2) Potential environmental impacts[ix] (e.g., disturbances to marine based fish and wildlife, effects on birds and bats, disturbance of seafloor habitat, water quality changes, etc.).

Federal Jurisdiction - Bureau of Ocean Energy Management (BOEM)

Offshore wind projects could be located in federal waters or state waters. To date, interest around Oregon from the offshore wind industry has focused on federal waters adjacent to Oregon's coast. Federal waters begin where Oregon's Territorial Sea ends (state waters end three nautical miles from the coastline) and extend out to 200 nautical miles from the coastline.[78] BOEM is responsible for the leasing of ocean areas in federal waters, and is the lead jurisdiction for permitting potential FOSW projects sited off Oregon's coast.

In 2010, Governor Kulongoski requested a state-federal task force to address the use of the ocean for renewable energy development and designated Oregon's Department of Land Conservation and Development (DLCD) as the lead state agency to coordinate with BOEM.[79] Since 2010, BOEM has worked with Oregon in response to industry interest in offshore wind

---

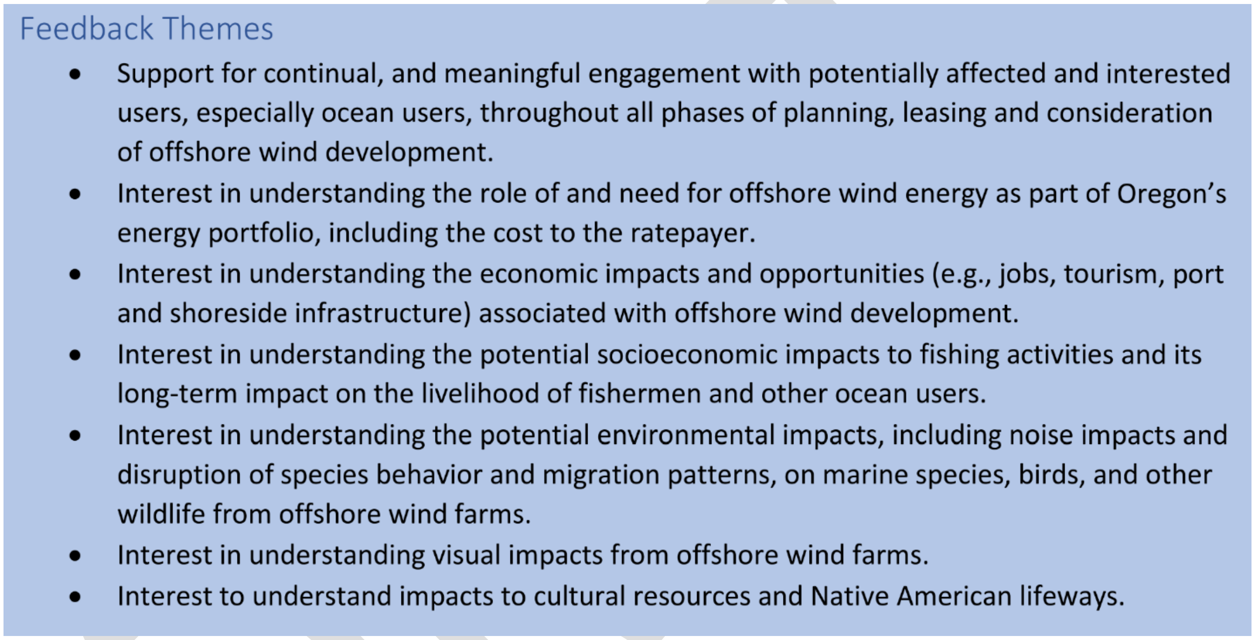
[viii] Examples are intended to be illustrative only, and are not intended to reflect any order of significance.

[ix] Examples are intended to be illustrative only, and are not intended to reflect any order of significance.

development adjacent to Oregon’s coast. After an unsuccessful leasing process was terminated in September 2018, BOEM reengaged with the Oregon Task Force in September 2019 in response to renewed industry interest.

To date, BOEM and DLCD have engaged with research organizations and potentially interested and affected parties in gathering data and information to inform offshore wind energy leasing decisions off Oregon’s shore. In January 2022, BOEM and the State issued a Data Gathering and Engagement Summary Report,[80] which identified several key themes that have emerged from the BOEM and DLCD outreach and engagement meetings.

Figure 16: Key themes of feedback gathered from BOEM and DLCD’s public engagement with Oregon stakeholders – snapshot from Data Gathering and Engagement Summary Report, Jan. 2022, pg. 3



Feedback Themes

- Support for continual, and meaningful engagement with potentially affected and interested users, especially ocean users, throughout all phases of planning, leasing and consideration of offshore wind development.
- Interest in understanding the role of and need for offshore wind energy as part of Oregon’s energy portfolio, including the cost to the ratepayer.
- Interest in understanding the economic impacts and opportunities (e.g., jobs, tourism, port and shoreside infrastructure) associated with offshore wind development.
- Interest in understanding the potential socioeconomic impacts to fishing activities and its long-term impact on the livelihood of fishermen and other ocean users.
- Interest in understanding the potential environmental impacts, including noise impacts and disruption of species behavior and migration patterns, on marine species, birds, and other wildlife from offshore wind farms.
- Interest in understanding visual impacts from offshore wind farms.
- Interest to understand impacts to cultural resources and Native American lifeways.

State Jurisdiction

Ocean planning by state agencies follow the policies and objectives of Statewide Planning Goal 19: Ocean Resources. Oregon’s Department of State Lands has primary jurisdiction for coordinating the review of ocean projects (i.e., transmission cables) that cross through state waters (within three nautical miles of shore). The cornerstone of this review is the Joint Agency Review Team. The JART is intended to serve as the vehicle to consolidate input from all key stakeholders, including: state and local government, federal agencies, Oregon’s federally recognized tribes, and other interested organizations and advisory committees.[81]

Under the federally approved Oregon Coastal Management Program (OCMP), DLCD has federal consistency authority to review federal activities that may affect coastal Oregon resources and uses. Under this authority, DLCD is the lead state agency for performing a federal consistency review of a FOSW project proposed within an area described as the Marine Renewable Energy Geographic Location Description (MRE-GLD), which covers the areas of the outer continental shelf between the western edge of the state’s territorial sea and the 500-fathom depth contour.

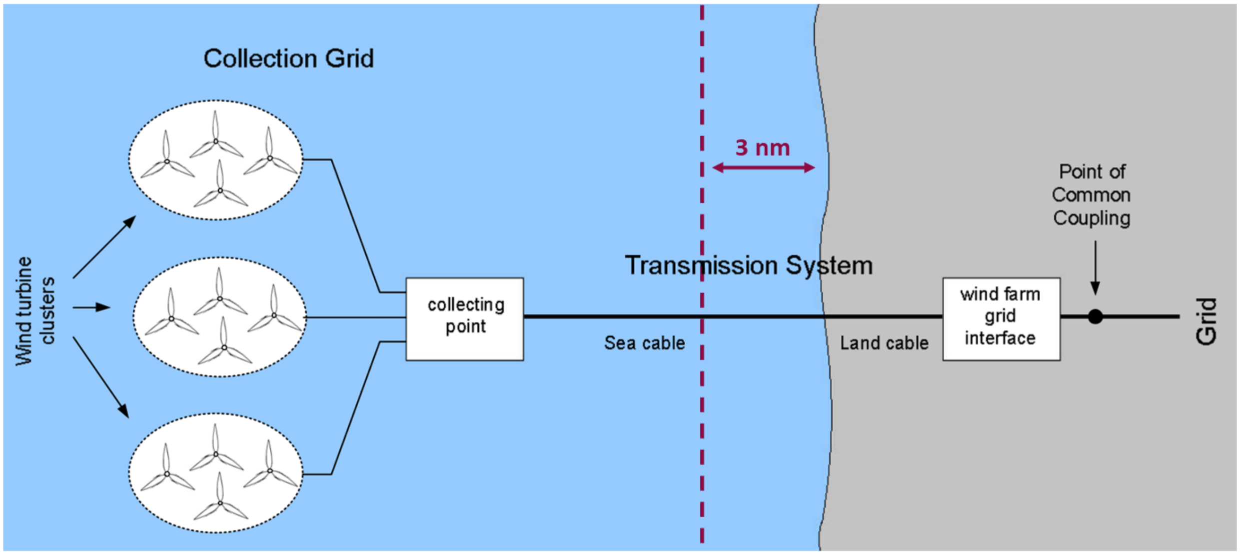
The Oregon Territorial Sea Plan (TSP) establishes the framework for state and federal agencies, as well as local governments and others, to manage ocean resources and activities through a comprehensive, coordinated, and balanced process. In addition, the state legislature created the Ocean Policy Advisory Council (OPAC), with members representing cities, counties, and ports; as well as recreation, fishing, and environmental and conservation interests. OPAC advises state agencies, the legislature, and the Governor's Office on the management of ocean resources.

Together, the OCMP, TSP, and OPAC serve as a coordinating framework for the wide range of governing authorities likely to be involved with the federal consistency review of a FOSW project located in federal waters. These reviews provide analyses of the potential adverse effects that the development of marine renewable energy projects can have on important natural and cultural resources of the state.

Figure 17: Federal, State, and Local Jurisdictional Authorities for Siting and Permitting, modified from original: https://www.researchgate.net/publication/282779426

Offshore Federal Waters
- Federal Jurisdiction—BOEM
- Consistency w/ State Territorial Sea Plan—DLCD

State Water & Onshore
- DSL & JART (Federal, State, Local)
- Other State, County, City Jurisdictions



Onshore projects relating to the development of port infrastructure and onshore transmission infrastructure necessary to deploy FOSW projects that could interconnect to Oregon’s onshore grid would also require permitting reviews from a variety of tribal, state, county, and municipal authorities; as well as the potential review from federal authorities if onshore projects are proposed in federal jurisdictions (e.g., transmission lines crossing federal forest land).

Potential Impacts to Ocean & Land Users

Any potential impacts to ocean and land users from FOSW projects could pose challenges to their deployment, including potential impacts to fisheries and military activities. Additional examples were raised in feedback from interested and potentially affected parties through local engagement efforts by BOEM and the State of Oregon. The Data Gathering and Engagement Summary Report for Oregon (Jan. 2022)[82] summarized this feedback, which included the following potential impacts to ocean and land users:[x]

1. Potential loss of commercial and recreational fishing grounds;
2. Potential impacts to fishermen's livelihoods;
3. Potential lasting impacts to the local economy;
4. Safety for fishermen and their equipment when fishing near or around floating offshore wind structures;
5. Potential conflicts with marine vessel traffic;
6. Potential impacts to taxpayers and electricity ratepayers;
7. Potential tradeoffs of increased renewable energy compared to cumulative impacts to fisheries, habitat, and ecological systems;
8. Potential impacts to wildlife important to Tribes; and
9. Potential viewshed impacts.

Potential Environmental Impacts

Any potential environmental impacts from FOSW projects could also pose challenges to their deployment. Potential environmental impacts from a West Coast FOSW study[83] include:[xi]

1. Disturbance of seafloor habitat;
2. Changes in water quality from sedimentation or contaminants;
3. Increase in ambient acoustic levels underwater;
4. Increase in the risk of vessel collisions with wildlife;
5. Wildlife disturbance from construction and operation activities;
6. Operational noise of turbines and construction and maintenance activities;
7. Seabird and bat collision with rotating turbine blades;
8. Marine mammal interactions with underwater structures;
9. Habitat changes associated with underwater structures;
10. Perching and haul-out effects;
11. Electromagnetic disturbances from inter-array cables, offshore substations, and export cables;
12. Disturbance of threatened or endangered wildlife species from the noise associated with horizontal direction drilling for transmission line improvements;
13. Removal of threatened or endangered plant species or sensitive natural communities during ground-disturbing activities;
14. Loss of wildlife habitat;
15. Hydrological interruption or the placement of fill in jurisdictional water bodies;
16. Increased risk of bird collision with transmission line improvements; and
17. The introduction and spread of terrestrial invasive plant species.

---

[x] This list is not intended to represent all potential impacts to ocean and land users from a proposed FOSW project.

[xi] This list is not intended to represent all potential environmental impacts from a proposed FOSW project.

SUMMARY OF THE PRIMARY BENEFITS AND CHALLENGES WITH FOSW

The primary benefits of FOSW relate to its potential to add large amounts of clean and renewable energy that also add resource diversity to the power grid, and the economic development that would likely accompany such large-scale infrastructure projects. However, the challenges for developing large FOSW and related transmission projects, as well as the planning, siting, and permitting complexities, for these projects are significant.

Primary Benefits

- **Help Meet Clean Energy and GHG Emission Reduction Goals**. Significant amounts of FOSW electricity would help Oregon and other western states achieve clean energy and GHG emission reduction goals.
- **Potentially Large Size**. FOSW turbine size can scale very large in the open ocean. Research indicates the wind industry is developing larger turbines and indicates 15 MW-sized turbines could be commercially available by 2032. While large turbines have higher capital costs, larger turbines lead to lower cost of electricity over the life of the project (i.e., a lower LCOE). If potential environmental or natural resource effects of projects can be avoided and mitigated, the open ocean allows the cumulative capacity of FOSW projects to be significant. With studies indicating a technical potential of 60 GW for FOSW projects adjacent to Oregon's coast, deployment of 10, 20, or more than 30 GWs could eventually be possible.
- **Diversity of Supply**. FOSW adds diversity to the power grid due to its unique, relatively consistent, and complementary generation profile, and its coastal location on the western edge of the grid. FOSW can provide output when onshore renewables such as solar, onshore wind, and hydro are unavailable across diurnal and seasonal timeframes.
- **Added Transmission Reliability and Coastal Resilience**. Due to its coastal location, FOSW also has the potential to bolster reliability and resilience for coastal customers by providing an alternative source of energy to coastal power systems, such as those serving lower income and tribal communities that currently rely on inland power supplied via transmission lines coming over the Coast Range, as well as those at risk of disruption due to storms, wildfires, and earthquakes. Also, because its output would be positioned on the western edge of the grid, FOSW adds locational diversity that can help re-balance onshore transmission flows and help optimize the onshore transmission system, which could help mitigate transmission constraints in Oregon and potentially the larger region. This can enhance reliability of the broader state-wide and regional grid, and make transmission capacity available in other areas of the grid that can help add new onshore renewables to support clean energy and GHG emission reduction goals.
- **New Renewables Option in the Toolbox**. Considering the tremendous scale of new clean resources necessary to meet the clean energy goals of Oregon and other western states by 2050, FOSW offers another large-scale renewable energy deployment option.

This could be thought of as adding another tool to the toolbox, and having another option to contribute to an "all of the above"/diversifying deployment strategy to help mitigate the risks and constraints that are challenging the pace and scale of renewable and transmission development on land.

- **Jobs and Economic Development**. FOSW has the potential for direct, indirect, and induced economic development for coastal Oregon, other areas of the state, and neighboring West Coast states.[84] [85] [86] In Oregon, this economic development would likely scale up in proportion to the scale of FOSW deployment over the near and long-term.[87] Direct economic impacts could accrue to coastal communities through initial construction and assembly jobs, followed by permanent jobs to support continued operations and maintenance.[88] Indirect economic impacts resulting from supply chains that support FOSW projects could also accrue more broadly across Oregon.[89] Induced economic impacts to sectors such as housing, hospitality, and others, could also accrue to Oregon.[90]

Primary Challenges

- **High Project Costs**. The costs for FOSW (2022 LCOE estimates ranging from $74/MWh to $107/MWh) currently put it at a competitive disadvantage with less expensive clean resources, such as existing hydro and new solar and onshore wind projects. FOSW projects are currently nearly double the costs of BFOSW, primarily due to the more complicated and costly anchoring systems of FOSW projects that rely on floating platform designs that are still evolving, differ in design based on different site characteristics, and aren't currently mass produced.
- **High Transmission and Interconnection Costs**. Transmission infrastructure necessary to interconnect to the grid and transfer power to load is another component that adds significant costs to the installation of FOSW projects. FOSW projects require subsea transmission lines and ocean-based substations that are complicated and costly to install. In addition to the offshore transmission infrastructure, upgrades to existing onshore substations would be required to interconnect FOSW into the onshore grid. Studies examining four-to-five coastal substations from Astoria to Coos Bay indicate Oregon's existing coastal transmission infrastructure does not have sufficient capacity to accommodate more than 2 GW of FOSW, with none of the substations individually capable of accommodating more than 1 GW.
- **Siting and Permitting**. On par with costs, complexities relating to siting and permitting add significant potential challenges for FOSW project development. Potential effects to ocean users and the environment could limit the cumulative capacity of FOSW deployment. Because economies of scale achieved with large cumulative deployments of FOSW capacity are so critical to decreasing the LCOE for FOSW projects, this could be a critical constraint to the economic viability of FOSW adjacent to Oregon's coast.

Ultimately, future development of FOSW will depend on its benefits outweighing its challenges, and whether the overall value of FOSW — including its LCOE, its ability to provide output when other renewable resources are unavailable, and its related transmission projects — can compete with other clean generation and transmission resources.

END NOTES

---

[1] Global Wind Energy Council, "Global Wind Report 2021," https://gwec.net/wp-content/uploads/2021/03/GWEC-Global-Wind-Report-2021.pdf

[2] W. Musial, "Updated Oregon Floating Offshore Wind Cost Modeling," NREL, Sept. 2021, p. 28 https://www.nrel.gov/docs/fy22osti/80908.pdf

[3] Lazard, "Lazard's Levelized Cost of Energy Analysis—Version 13.0," 2021, https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf

[4] U.S. DOE, "Offshore Wind Market Report: 2021 Edition," https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf

[5] Global Wind Energy Council, "Global Wind Report 2021," https://gwec.net/wp-content/uploads/2021/03/GWEC-Global-Wind-Report-2021.pdf

[6] W. Musial, "Cost Modeling Update to Oregon FOSW LCOE Heat Maps," NREL, 2021, https://www.nrel.gov/docs/fy22osti/80908.pdf

[7] W. Musial, "2019 Offshore Wind Technology Data Update," NREL, Oct. 2000, https://www.nrel.gov/docs/fy21osti/77411.pdf

[8] W. Musial, "Oregon Offshore Wind Site Feasibility and Cost Study," NREL, 2019, https://www.nrel.gov/docs/fy20osti/74597.pdf

[9] T. Stehly, et. al., "2019 Cost of Wind Energy Review," NREL, Dec. 2020, p. 25, https://www.nrel.gov/docs/fy21osti/78471.pdf

[10] W. Musial, "Cost Modeling Update to Oregon FOSW LCOE Heat Maps," 2021, https://www.nrel.gov/docs/fy22osti/80908.pdf

[11] Berkeley Lab, "Wind Power Technology Trends," 2021, https://emp.lbl.gov/wind-power-technology-trends

[12] T. Stehly, et. al., "2019 Cost of Wind Energy Review," NREL, Dec. 2020, p. 25, https://www.nrel.gov/docs/fy21osti/78471.pdf

[13] W. Musial, "Cost Modeling Update to Oregon FOSW LCOE Heat Maps," NREL, 2021, pp. 28 & 30. https://www.nrel.gov/docs/fy22osti/80908.pdf

[14] W. Musial, et. al., "2016 Offshore Wind Energy Resource Assessment for the U.S.," NREL, Sept. 2016, p. v, https://www.nrel.gov/docs/fy16osti/66599.pdf

[15] BOEM, "Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii," 2016, pg. 6, https://espis.boem.gov/final%20reports/5503.pdf

[16] W. Musial, et. al., "Coast of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology," NREL, p. 1, https://www.nrel.gov/docs/fy20osti/75618.pdf

[17] USDOE, "National Offshore Wind Strategy," Sept. 2016, pg. 28 https://www.energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategy-report-09082016.pdf

[18] Schatz Energy Research Center, "Port Infrastructure Assessment Report," Dec. 2020, p. 24 http://schatzcenter.org/pubs/2020-OSW-R19.pdf

[19] BOEM, "Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii," 2016 https://espis.boem.gov/final%20reports/5503.pdf

[20] W. Musial, "Cost Modeling Update to Oregon FOSW LCOE Heat Maps," NREL, 2021, pg. 17 https://www.nrel.gov/docs/fy22osti/80908.pdf

---

[21] BOEM/BSEE, “Potential Earthquake, Landslide, Tsunami and Geo-Hazards for the U.S. Offshore Pacific Wind Farms,” May 2020, p. 47, https://www.rpsgroup.com/media/5565/potential-earthquake-landslide-tsunami-and-geohazards-for-the-us-offshore-pacific-wind-farms.pdf

[22] BOEM, “Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii,” 2016, https://espis.boem.gov/final%20reports/5503.pdf

[23] BOEM, “Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii,” 2016, p. 87 https://espis.boem.gov/final%20reports/5503.pdf

[24] BOEM, “Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii,” 2016, p. 87 https://espis.boem.gov/final%20reports/5503.pdf

[25] BOEM, “Determining Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West Coast and Hawaii,” 2016, p. 97 https://espis.boem.gov/final%20reports/5503.pdf

[26] American Clean Power, “Offshore Wind and Commercial Fishing, Co-existence FAQs,” 2021, p. 6, https://cleanpower.org/wp-content/uploads/2021/02/FAQ_OffshoreWind_ACP.pdf

[27] U.S. GAO, “Offshore Wind Industry – Planned Projects May Lead to Construction of New Vessels in the U.S., but Industry Has Made Few Decisions amid Uncertainties,” Dec. 2020, https://cleanpower.org/wp-content/uploads/2021/02/FAQ_OffshoreWind_ACP.pdf

[28] W. Musial, et. al., “Oregon Offshore Wind Site Feasibility and Cost Study,” NREL, Oct. 2019, p. 5, https://www.nrel.gov/docs/fy20osti/74597.pdf

[29] Northwest Power and Conservation Council, “Draft 2021 Northwest Power Plan,” Sept. 2021, p. 6-51, https://www.nwcouncil.org/sites/default/files/2021powerplan_2021-5.pdf

[30] Jorgenson, Jennie, et.al., “A systematic evaluation of wind’s capacity credit in the Western United States,” Wind Energy, 2021, https://doi.org/10.1002/we.2620

[31] Novacheck and Schwarz, “Evaluating the Grid Impact of Oregon Offshore Wind,” NREL, Oct. 2021, p. 19, https://www.nrel.gov/docs/fy22osti/81244.pdf

[32] Oregon HB 2021 (2021), https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/HB2021; California SB 100 (2018), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100 ; Washington SB 5116 (2019), https://lawfilesext.leg.wa.gov/biennium/2019-20/Pdf/Bills/Session%20Laws/Senate/5116-S2.SL.pdf?q=20220107122111

[33] Northwest Power and Conservation Council, “Draft 2021 Northwest Power Plan,” Sept. 2021, p. 6-54 https://www.nwcouncil.org/sites/default/files/2021powerplan_2021-5.pdf

[34] Evolved Energy Research, “Northwest Deep Decarbonization,” May 2019, p. 73, https://github.com/cleanenergytransition/mtc-report-EER-technical-report/raw/gh-pages/EER_Northwest_Deep_Decarbonization_Pathways_Study_Final_May_2019.pdf?raw=true

[35] Evolved Energy Research, “Oregon Clean Energy Pathways,” June 2021, p. 39, https://www.cleanenergytransition.org/files/oregon-clean-energy-pathways-analysis-final-report-2021-06-15

[36] T. Douville, et. al., “Exploring the Grid Value Potential of Offshore Wind Energy in Oregon,” PNNL, May 2020, pg. ii, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[37] Levitan & Associates, “Offshore Wind Transmission Study Comparison and Options,” Dec. 2020, p. 1, https://www.nj.gov/bpu/pdf/publicnotice/Transmission%20Study%20Report%2029Dec2020%202nd%20FINAL.pdf

---

[38] Schatz Energy Research Center, Subsea Transmission Cable Conceptual Assessment, Sept. 2020, p. 1, http://schatzcenter.org/pubs/2020-OSW-R5.pdf

[39] Levitan & Associates, "Offshore Wind Transmission Study Comparison and Options," Dec. 2020, p. 3, https://www.nj.gov/bpu/pdf/publicnotice/Transmission%20Study%20Report%2029Dec2020%202nd%20FINAL.pdf

[40] Schatz Energy Research Center, Subsea Transmission Cable Conceptual Assessment, Sept. 2020, pg. 4, http://schatzcenter.org/pubs/2020-OSW-R5.pdf

[41] Levitan & Associates, "Offshore Wind Transmission Study Comparison and Options," Dec. 2020, pp. 7-8,https://www.nj.gov/bpu/pdf/publicnotice/Transmission%20Study%20Report%2029Dec2020%202nd%20FINAL.pdf

[42] Levitan & Associates, "Offshore Wind Transmission Study Comparison and Options," Dec. 2020, App. 1 pp. 91-94, https://www.nj.gov/bpu/pdf/publicnotice/Transmission%20Study%20Report%2029Dec2020%202nd%20FINAL.pdf

[43] Schatz Energy Research Center, Subsea Transmission Cable Conceptual Assessment, Sept. 2020, pg. 11, http://schatzcenter.org/pubs/2020-OSW-R5.pdf

[44] Schatz Energy Research Center, Subsea Transmission Cable Conceptual Assessment, Sept. 2020, pg. 11-12, http://schatzcenter.org/pubs/2020-OSW-R5.pdf

[45] Schatz Energy Research Center, Subsea Transmission Cable Conceptual Assessment, Sept. 2020, pg. 18, http://schatzcenter.org/pubs/2020-OSW-R5.pdf

[46] Idaho Power, Transmission Projects Update, May 2021, pg. 5 https://docs.idahopower.com/pdfs/AboutUs/PlanningForFuture/irp/2021/IRPAC_TransmissionUpdate_May2021.pdf

[47] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[48] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[49] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[50] Novacheck and Schwarz, "Evaluating the Grid Impact of Oregon Offshore Wind," NREL, Oct. 2021, p. 19, https://www.nrel.gov/docs/fy22osti/81244.pdf

[51] Oregon Department of Energy, "2020 Biennial Energy Report," Nov. 2020, p. 8, https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Energy-101.pdf#page=5

[52] NorthernGrid, "Regional Transmission Plan for the 2020-21 NortherGrid Planning Cycle," Dec. 2021, p. 5, https://www.northerngrid.net/private-media/documents/2020-2021_Regional_Transmission_Plan.pdf

[53] NorthernGrid, "Regional Transmission Plan for the 2020-21 NortherGrid Planning Cycle," Dec. 2021, p. 6, https://www.northerngrid.net/private-media/documents/2020-2021_Regional_Transmission_Plan.pdf

[54] NorthernGrid, "Regional Transmission Plan for the 2020-21 NortherGrid Planning Cycle," Dec. 2021, p. 6, https://www.northerngrid.net/private-media/documents/2020-2021_Regional_Transmission_Plan.pdf

[55] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, p. 36, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[56] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, p. 36, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[57] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, p. 37, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

---

[58] Novacheck and Schwarz, "Evaluating the Grid Impact of Oregon Offshore Wind," NREL, Oct. 2021, p. 47, https://www.nrel.gov/docs/fy22osti/81244.pdf

[59] Novacheck and Schwarz, "Evaluating the Grid Impact of Oregon Offshore Wind," NREL, Oct. 2021, p. 47, https://www.nrel.gov/docs/fy22osti/81244.pdf

[60] T. Douville, et. al., "Exploring the Grid Value Potential of Offshore Wind Energy in Oregon," PNNL, May 2020, p. 42, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29935.pdf

[61] Portland General Electric, "2019 Integrated Resource Plan," Jul. 2019, https://downloads.ctfassets.net/416ywc1laqmd/6KTPcOKFlLvXpf18xKNseh/271b9b966c913703a5126b2e7bbbc37a/2019-Integrated-Resource-Plan.pdf

[62] PacifiCorp, "2021 Integrated Resource Plan – Vol. 1," Sept. 2021, p. 193, https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2021-irp/Volume%20I%20-%209.15.2021%20Final.pdf

[63] Oregon Public Utility Comm'n, "Summary Document of Implementation Plan for HB 2021 Clean Energy Standard," Oct. 2021, p. 2, https://www.oregon.gov/puc/Documents/HB2021-Summary.pdf

[64] Northwest Power and Conservation Council, "Draft 2021 Northwest Power Plan," Sept. 2021, p. 6-48, https://www.nwcouncil.org/sites/default/files/2021powerplan_2021-5.pdf

[65] W. Musial, "Cost Modeling Update to Oregon FOSW LCOE Heat Maps," NREL, 2021, p. 28 https://www.nrel.gov/docs/fy22osti/80908.pdf

[66] California Public Utilities Comm'n, "2019-20 IRP: Propose Reference System Plan," Nov. 2019, pp. 102-104, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2019-2020-irp-events-and-materials/2019-irp-proposed-reference-system-plan_20191106.pdf

[67] California Public Utilities Comm'n, "Fact Sheet: Decision on 2019-20 Electric Resource Portfolios to Inform Integrated Resource Plans and Transmission Planning," April 2020, https://www.cpuc.ca.gov/-/media/cpuc-website/files/legacyfiles/i/6442464699-irp-2019-rsp-fact-sheet-v3.pdf

[68] California Public Utilities Comm'n, "Descriptions of the Proposed Portfolios for the 2021-2022 Transmission Planning Process," pg. 9, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M348/K821/348821204.PDF

[69] California Public Utilities Comm'n, "Modeling Assumptions for the 2021-2022 Transmission Planning Process," pg. 56, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M359/K000/359000745.PDF

[70] 2021 California Law, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB525

[71] Clean Energy States Alliance, "Offshore Wind to Green Hydrogen – Insights from Europe," Oct. 2021, https://www.cesa.org/wp-content/uploads/Offshore-Wind-to-Green-Hydrogen-Insights-from-Europe.pdf

[72] Bureau of Ocean Energy Mgmt. & State of Oregon, "Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning," Jan. 2022, pg. 2, https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022

[73] U.S. Department of Energy ARPA-E, "Control Co-design and Co-optimization of a Lightweight 12 MW Wind Turbine on an Actuate Tension Leg Platform," Aug. 2019, https://arpa-e.energy.gov/technologies/projects/control-co-design-and-co-optimization-lightweight-12-mw-wind-turbine-actuated

[74] U.S. Department of Energy ARPA-E, "NASA Floater: 15 MW Ultra-light Concrete Hull with Sea-water Ballast Tuned Dampers," Aug. 2019, https://arpa-e.energy.gov/technologies/projects/nasa-floater-15-mw-ultra-light-concrete-hull-sea-water-ballast-tuned-mass

[75] Aqua Ventus I information found at https://maineaquaventus.com/index.php/the-project/

[76] Federal Energy Regulatory Comm'n, "Technical Conference regarding Offshore Wind Integration in RTOs/ISOs and Related Links," https://www.ferc.gov/news-events/events/technical-conference-regarding-offshore-wind-integration-rtosisos-10272020

---

[77] Federal Energy Regulatory Comm'n, "Advance Notice of Proposed Rulemaking, Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection," July 15, 2021, https://www.ferc.gov/media/e-1-rm21-17-000

[78] Bureau of Ocean Energy Mgmt. & State of Oregon, "Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning," Jan. 2022, p. 5, https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022

[79] Bureau of Ocean Energy Mgmt. & State of Oregon, "Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning," Jan. 2022, p. 4, https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022

[80] Bureau of Ocean Energy Mgmt. & State of Oregon, "Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning," Jan. 2022, https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022

[81] Oregon Secretary of State, "Rules Governing The Placement of Ocean Energy Conversion Devices On, In, or Over State-Owned Land Within the Territorial Sea," OAR 141-140-0020 (12), https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=238755

[82] Bureau of Ocean Energy Mgmt. & State of Oregon, "Data Gathering and Engagement Summary Report, Oregon Offshore Wind Energy Planning," Jan. 2022, pp. 26, 27, 30, https://www.boem.gov/OR-OSW-Data-Engagement-Summary-Report-2022

[83] Schatz Energy Research Center, "Existing Conditions and Potential Environmental Effects," Sept. 2020, pp. iii-iv, http://schatzcenter.org/pubs/2020-OSW-R13.pdf

[84] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios," NREL, May 2016, https://www.nrel.gov/docs/fy16osti/65432.pdf

[85] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts in Oregon Coastal Counties from Two Future Scenarios," NREL, Jul. 2016, https://www.nrel.gov/docs/fy16osti/65432.pdf

[86] A. Rose, et. al., "California's Offshore Wind Electricity Opportunity," University of Southern California Schwarzenegger Institute for State and Global Policy, Aug. 2021, http://schwarzeneggerinstitute.com/images/files/OSW_Report.pdf

[87] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios," NREL, May 2016, p. vi, https://www.nrel.gov/docs/fy16osti/65432.pdf

[88] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios," NREL, May 2016, p. 6, https://www.nrel.gov/docs/fy16osti/65432.pdf

[89] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios," NREL, May 2016, p. 6, https://www.nrel.gov/docs/fy16osti/65432.pdf

[90] T. Jimenez, et. al., "Floating Offshore Wind in Oregon: Potential for Jobs and Economic Impacts from Two Future Scenarios," NREL, May 2016, p. 6, https://www.nrel.gov/docs/fy16osti/65432.pdf