Principle Power, Inc.
WindFloat Pacific Project

Final Scientific / Technical Report (DOE-F 241.3)
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Principle Power is grateful for the excellent work produced by the WindFloat Pacific project team. This work, combined with the important and irreplaceable support of the US Department of Energy's Wind and Water Power Program staff, and the US Department of Interior's Bureau of Ocean Energy Management, has helped advanced the understanding and status of the US offshore wind industry. Without this support the project would not have been possible.

Project Participants

Prime Recipient	Principle Power, Inc.
Project Partners Providing Cost Share	Houston Offshore Engineering (HOE)
	RPS Evans Hamilton
	Herrera Environmental
	Forristal Ocean Engineering
	C+C Technologies (Oceaneering)
	American Bureau of Shipping (ABS)
Working Partners and National Laboratory Participants	International Port of Coos Bay
	Siemens Wind Power
	National Renewable Energy Laboratory (NREL)
	Pacific Northwest National Laboratory (PNNL)
	Northwest National Marine Renewable Energy Center (NNMREC)

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Introduction and Executive Summary

Principle Power (PPI) is an innovative technology and services provider for the offshore deep water wind energy market. PPI's proven technology, the WindFloat - a floating wind turbine foundation – enables a change in paradigm for the industry in terms of reduced costs and risks for the installation and operations of offshore wind turbines. Principle Power sells the WindFloat as a technology solution and acts as service provider to developers, utilities and independent power producers, being present from the overall system design throughout fabrication, installation and commissioning, and providing support to customers during the operation life cycle of the platform.

Principle Power's mission is to make the WindFloat the most competitive, safe, reliable and environmentally friendly technology for deep-water offshore wind projects while enabling global offshore wind markets to reach their full potential.

Commercial advantages for floating offshore wind that are uniquely facilitated by the WindFloat solution include:

- Lower Costs and Risk in installation and operations – WindFloat allows for on-shore platform assembly, offshore turbine installation and major repairs, eliminates the need for specialized and expensive installation vessels, and has minimal environmental and ecological impact to the sea-bed;
- Location and depth constraint mitigation – WindFloat allows arrays to be optimally located in deep water with varied underwater landscapes, accessing the higher quality wind resources while eliminating negative visual impact.

PPI's WindFloat Pacific project (WFP) was an up to 30 MW floating offshore wind demonstration project proposed off the Coast of Oregon. The project was to be sited approximately 18 miles due west of Coos Bay, in over 1000 ft. of water, and is the first floating offshore wind array proposed in the United States, and the first offshore wind project of any kind proposed off the West Coast. PPI's WindFloat, a semi-submersible foundation designed for high-capacity (6MW+) offshore wind turbines, is at the heart of the proposed project, and enables access to the world class wind resource at the project site and, equally, to other deep water, high wind resource areas around the country.

The project was initiated on submission of a lease request in May 2013. PPI engaged in a lengthy process to determine the best site for the Project. Because of the WindFloat's flexibility in siting at a selected project location, consideration of local socioeconomic and environmental issues was an important part of this decision.

The Coos Bay location was selected after examination of other potential locations. Coos Bay's history as an industrial port and the fact that the Conde McCullough Memorial Bridge, which spans the bay, is east of the port's infrastructure and planned development were viewed as beneficial. These features, amongst others, distinguished Coos Bay as the preferred location for the WFP project.

PPI engaged in discussions with fishing interests and other relevant community entities, including the US Coast Guard, Oregon Fishermen's Cable Committee, Coos Bay Pilots' Association, the Port of Coos Bay, and the local chapter of the Audubon Society, among many others. While other sites near the proposed location were initially considered, most were eliminated after discussions with these stakeholders made it clear that they were subject to existing activity and important commercially to local fishing fleets.

Over the course of the project, strategies evolved to reduce its capital requirement. These included a reduction in wind turbine generators following an increase in turbine capacity. Figure 1 shows the final project site, with a proposed final configuration of three wind turbines.

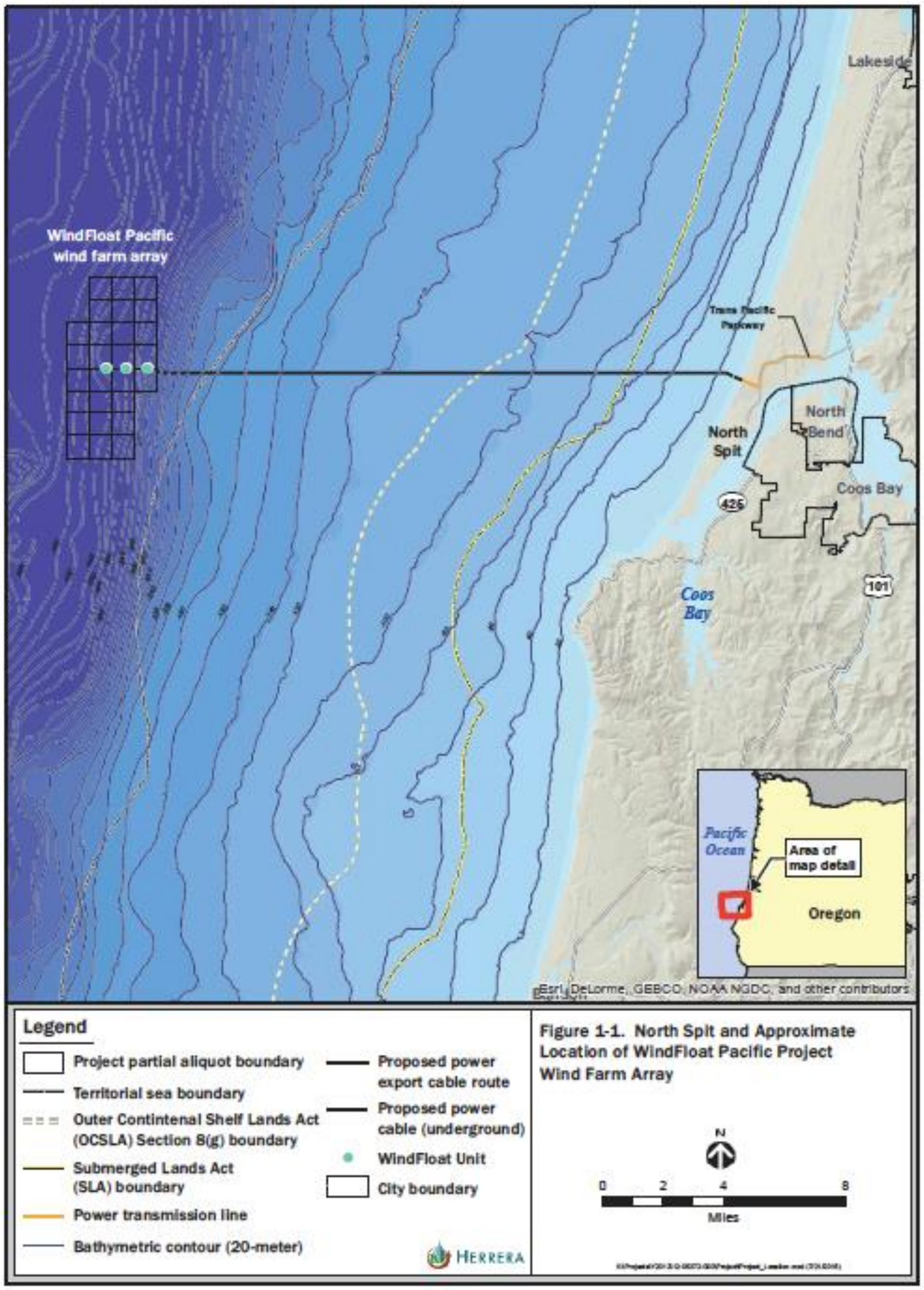

Figure 1: The final project site, with a proposed three turbine configuration.

Contributions to US Offshore Wind Development

The US Department of Energy (DOE) and US Department of Interior (DOI)'s recently released National Offshore Wind Strategy states that,

> "Cost-effective floating systems represent a significant opportunity in the United States. Fifty-eight percent (1,194 MW) of the U.S. offshore wind technical resource potential lies in waters deeper than 60 m, which is likely beyond the economic reach of current fixed-bottom offshore wind technologies. Floating

> systems could enable quayside turbine construction, commissioning, and major component maintenance and replacement, thereby eliminating specialized turbine installation vessels (TIVs) and reducing the costs of major repairs."

Accelerating the achievement of commercialized floating offshore wind technologies therefore presents tremendous opportunity to expand the nation's renewable energy portfolio and to provide environmental and economic benefits to the country. WindFloat Pacific advanced these important goals by demonstrating the viability of an offshore wind project off the West Coast of the US, where one had not been considered before.

There are three primary advantages to the WindFloat foundation: first, its static and dynamic stability provides sufficiently low pitch performance enabling use of commercial offshore wind turbines; second, its design and fabrication methodology allow for onshore assembly of the complete system including the turbine; third, its shallow draft allows for depth independent siting and wet tow (fully assembled and commissioned) to installation site.

Stability

The WindFloat is fitted with patented water entrapment (heave) plates at the base of each column. The plates "entrain" water resulting in a large added-mass component and the sharp edges of the plates increase the viscous damping due to vortex shedding. In addition, The WindFloat's patented hull-trim system (also known as active ballast) distributes water ballast between the three columns of the WindFloat to compensate for variable turbine thrust due to low frequency changes in wind velocity and direction. The system is closed-loop (no water moves in or out of the system), fail-safe, and comprises only a small fraction of the total WindFloat ballast water.

Construction and Operations

The design of the WindFloat enables the structure to be fully assembled onshore and towed to its final location. All fabrication and qualification is completed at quayside in a controlled environment; this allows for broader infrastructure availability, the greater involvement of local supply chains and increased local economic activity. Deployment cost savings are significant when compared with bottom-fixed foundations such as monopile or jacket type structures which require offshore heavy lift operations and significant vessel capabilities for installation. Most of the vessels with these qualifications that exist today are foreign flagged and therefore not Jones Act compliant. The fact that the WindFloat does not rely on offshore lifting installation processes represents a significant accelerator to US offshore wind development, in addition to reductions of risk and cost.

Mooring System

The WindFloat's conventional mooring system only includes components that are relatively inexpensive, readily available, and simple to install. The mooring configuration is similar to those on Oil and Gas platforms and permanently moored maritime structures. Drag embedment anchors permit installation in various soil conditions including mud, clay, sand and layered soils. Their installation is less weather-dependent than other alternatives, and installation does not require full geotechnical surveys of the sea bed prior to design. Further, the incremental cost increase, due to water depth, associated with a WindFloat mooring is minimal. This permits greater flexibility in site location and turbine placement to customers.

Under this project, the engineering for each of these features was advanced through work for a specific West Coast of the US application. The results of the work indicate that not only is a floating wind offshore wind project feasible at this location but, at scale, it can be an economical contributor to the region's energy mix. These favorable results extend similarly to the other coastal areas of the country, including the Northeast, Mid-Atlantic, the Great Lakes and Hawaii.

Environmental Understanding

Similarly, significant work was completed to advance the permitting process for floating offshore wind, particularly in the West Coast. Principle Power examined and identified the issues that would drive the environmental permitting process, conducted discussions with the key federal and state regulatory and resource agencies, as well as with important stakeholder groups. The highest priority environmental interactions driving baseline and post-installation monitoring were determined to be:

- Potential threats to soaring seabirds from the turbine blades;
- Potential for the physical presence of multiple wind platforms to affect the near field habitat and sediments, as well as the potential for the platforms to create a collision risk to marine mammals and interfere with whale migration;
- Potential effects of electromagnetic fields (EMF) on elasmobranchs (sharks and rays) and on sea turtles; and
- Potential effects of lighting on birds.

For each of these, study plans were developed and initiated, including in-situ avian and marine mammal surveys, EMF studies, ambient noise surveys and benthic data collection. Monitoring plans were established and mitigation opportunities discussed. Additional environmental issues that may be raised include:

- The physical presence of the device affecting the far field habitats in the region and presenting a collision risk to sea turtles, and birds;
- Potential effects of electromagnetic fields on the behavior of fish and sea turtles;
- Potential effects of boat traffic on marine mammals during installation and maintenance operations.

Collectively, these became the main areas of environmental focus as the permitting process unfolded and drove discussion with agencies and stakeholders.

In addition, the project team completed metocean, subsea and geophysical surveys – never conducted at the project location before - that contributed to the engineering design basis, mooring analysis and the requirements of the Bureau of Ocean Energy Management's (BOEM) leasing process.

Power Purchase and Economics

Finally, for any utility-scale project, securing a power purchase agreement (PPA) is a critical and necessary step to allow for the financing of construction. For WFP to secure a PPA, a strategy evolved that necessarily relied upon the passage of enabling legislation in the state of Oregon that would have allowed utilities in the region to purchase WFP's above market priced power (demonstration scale projects typically feature levelized costs of energy (LCOEs) that are above prevailing market because they do not achieve economies of scale that are so fundamental to large scale energy infrastructure).

Considerable effort was expended with in (and out of) state utilities, Oregon's Public Utility Commission, ratepayer advocates, legislators and other entities. Legislation that would have required utilities to purchase the output of WFP was drafted and submitted to the appropriate Legislative Committee (the Oregon House Committee on Energy and the Environment). But after significant debate and discussion, a reduction in project size (to 16 or 24 MW) to reduce overall capital requirement and the creation of a Governor's Advisory Committee on Offshore Wind, no legislation in the state was ultimately forthcoming, and the project did not have a solution to sell its power.

Still, while the project was ultimately unable to secure a PPA in the timeframe required by the DOE program, PPI identified ways, working with the local supply chain, to introduce economically competitive projects to the region, at commercial scale. Commercial scale projects will serve to increase resource and geographic diversity of generation, benefit the environment through the introduction of large scale emission free resources, provide rate stability to utility customers and have tremendous economic impacts to coastal communities and supply chains. Tremendous progress was made for the US offshore wind industry, through technical validation, the exercising of the permitting/leasing process and subsequent lessons learned and through early engagement with stakeholders, policy-makers, utilities and the supply chain. Without the WindFloat Pacific project, it is doubtful that US West Coast development would see the level of activity that it does today with large projects under development in California and Hawaii.

PROJECT OVERVIEW

Applicants to DOE's Offshore Wind Funding Opportunity Announcement (FOA) (DE-FOA-0000410 U.S. Offshore Wind: Advanced Technology Demonstration Projects) were invited to submit responses describing how DOE funds would lead to installation of offshore wind demonstration project(s). Usage of DOE funds could include but was not limited to:

- Demonstrating full-scale, innovative wind turbine technology that will be used in commercial offshore wind farm deployments. "Full Scale" was defined as a wind turbine or turbines and related site infrastructure, including electrical grid connection, at a commercial utility class (multi- megawatt scale);
- Improving innovative engineering and related support activities for offshore foundations, electrical systems, facility infrastructure, operation, and installation systems and methods in commercial
- Addressing specific non-technical barriers, such as environmental or socioeconomic issues or efficiency in Federal, State, or local permitting, planning and approval processes as they relate to the proposed project.
- Collecting and analyzing performance, engineering, environmental monitoring, operations, and cost data of novel technologies used as part of the deployment.

The project was separated into five separate Budget Periods (BP1 – 5). At the highest level, Budget Periods 1 and 2 related to engineering design, permitting and offtake; Budget Periods 3 - 5 were related to procurement, construction, installation and commissioning. Work conducted in BP1 was rolled up into BP2, at the completion of which WFP concluded. Specifically, expected outcomes to be achieved at the conclusion of BP2 were the following:

1. A 100% front-end engineering design (FEED) up to and including full vendor quotes from all suppliers and independent verification of all capital, O&M and regulatory costs and proposed schedule from a DOE-approved and applicant-financed third party.
2. Detailed installation methods and identification of operating and maintenance systems suited to the site.
3. Completion of Federal agency NEPA process(es), and approval of a Construction and Operations Plan (COP) or equivalent in State Waters.
4. Completion of all necessary grid interconnection requirements, as well as any needed power off- take agreements. These include any applicable FERC interconnection requirements as well as any utility specific requirements.

Progress made by the project in each of these areas is discussed in the following sections.

1. WindFloat Design (100% FEED)

Two major milestones were achieved in this category during the course of the project. Working significantly with project partner Houston Offshore Engineering (HOE), PPI advanced the WindFloat design to accommodate Pacific coast conditions and to host the world's most modern offshore wind turbines (WFP initially featured 6 MW, and ultimately 8 MW turbines).

- 100% Front End Engineering and Design (FEED) was completed for the WindFloat Pacific Project. The design documents and plans were developed to contain sufficient details for a meaningful Request for Quotation (RFQ) for fabricators. Design reports and supporting documents were submitted to the classification society (American Bureau of Shipping, or ABS) for their review and approval. ABS provided an Approval in Principle (AIP) for this design. DOE also received these reports and had the opportunity for review and comment. In total, over the project period approximately 300 separate drawings and reports describing the WindFloat design and planning were submitted. Figures 2 and 3 are representative general arrangement drawings showing the WindFloat Pacific design.

- Quotes from vendors for fabrication and installation of the three WindFloat platforms and accompanying electrical infrastructure were obtained and analyzed to determine a base cost. The cost analysis was verified by an independent and approved third party. The 100% FEED package addressed all major design aspects of the WindFloat foundation, taking into account updates to the design basis made at the beginning of the second Budget Period. Stability, mooring and aero-hydrodynamics loading calculations were performed. Reports were submitted to the Certified Verification Agent (CVA) (America Bureau of Shipping, or ABS) covering stability, mooring, and loading, in addition to the design of the primary structure.

Over the course of the project, two key changes occurred in the design basis. PPI changed the preferred Wind Turbine Generator (WTG) from a 6MW unit to an 8 MW unit, and the number of units was decreased from five to three. These changes were implemented to increase power production per platform and reduce total capital expenditures. Specific mass (tons/MW capacity) was reduced from almost 700 tons/MW in the 2MW WindFloat 1 prototype offshore Portugal to well less than 400 tons/MW for WindFloat Pacific, thereby optimizing project economics and maximizing the likelihood of achieving a PPA and construction.

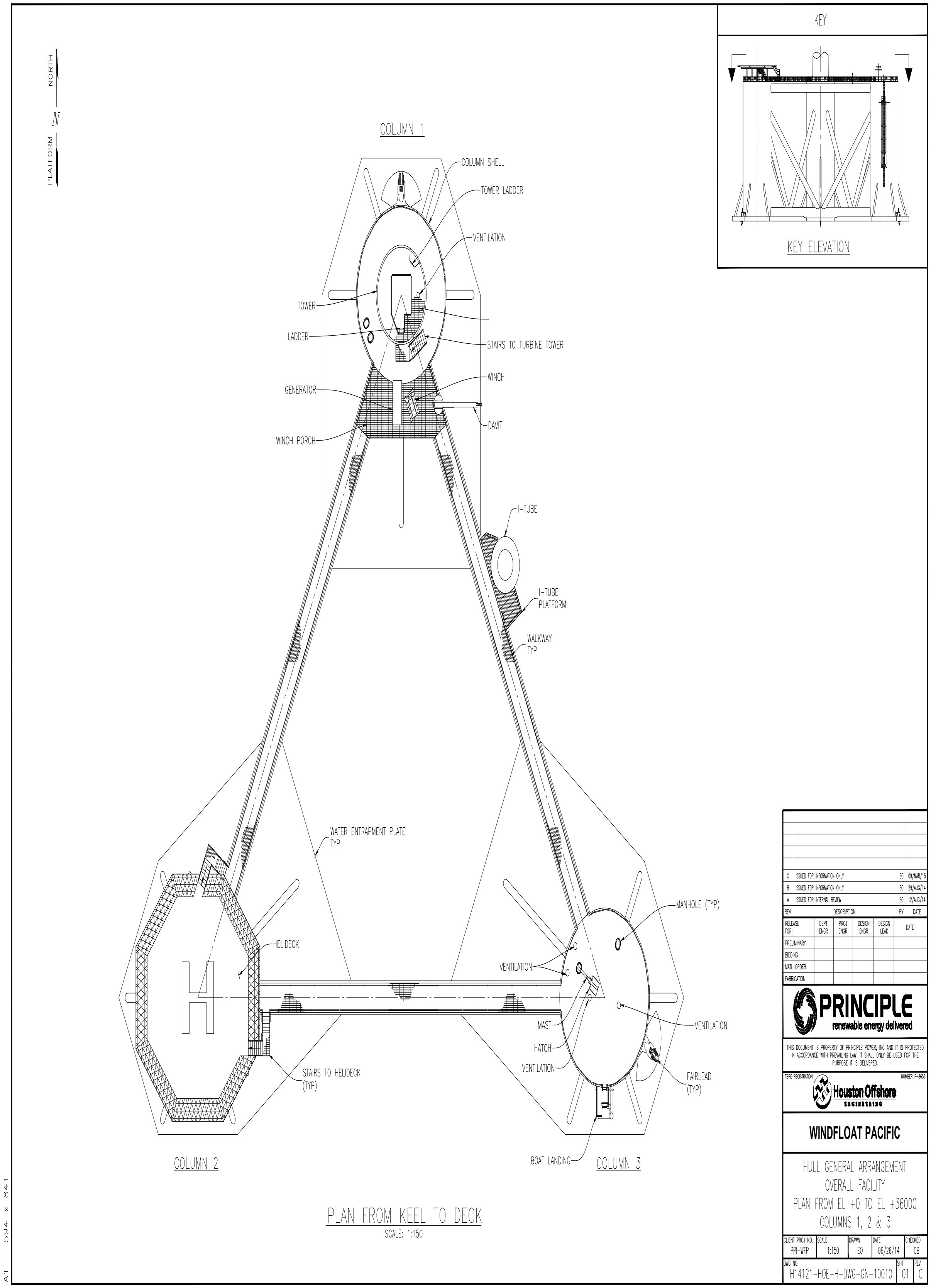

Figure 2: WindFloat Pacific hull general arrangement.

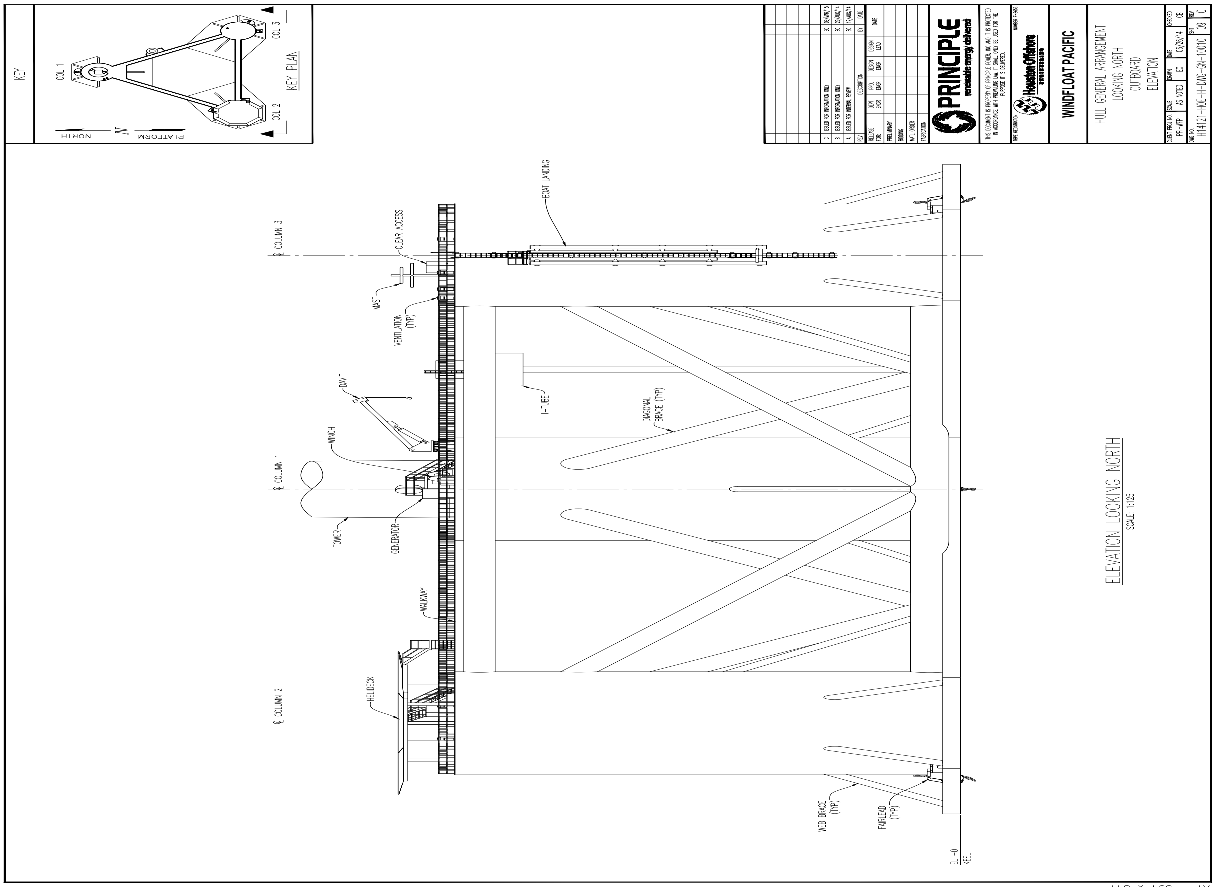

Figure 3: WindFloat Pacific hull general arrangement.

Additionally, a review of the engineering performance of the WindFloat, based on BP1 results, led to modifications of the design, most notably in the configuration of the water entrapment plates. The new design placed more surface area closer to the inside of the platform, reducing the overall footprint of the WindFloats, simplifying fabrication and transportation. Using the new and optimized configuration, all other engineering processes were examined and modified as needed.

Stability

Stability calculations for the intact and damaged structure were updated to account for the change in configuration, including turbine payload, as compared to BP1. The accuracy of the design details to predict the mass properties of the platform, including the center of gravity, were sufficient to submit the stability report to ABS for approval during BP2. The intact stability calculations were verified according to the philosophy agreed upon in BP1; these requirements are standard and similar across all classification companies. Calculations for damaged structure stability are less uniformly accepted; the current WFP design is consistent with ABS current damage stability requirements. In light of the differences among accepted standards, the PPI team applied a risk analysis that highlighted a slightly different philosophy than that of the current ABS FOWTI guidelines. This new philosophy could result in further steel optimization. The modified philosophy was submitted to ABS for review; the PPI team and ABS will discuss the change before the documents are finalized.

Wind Turbine

PPI acknowledges that the turbine selected to complete FEED was made in the context of uncertainty on several aspects of the project (namely PPA capacity and conditions), so the project team weighed facts and circumstances and believed selecting an 8MW turbine (the Vestas V-164) was the most reasonable approach for the following reasons: (i) The first motivation for this decision was to improve the economics of the project by maximizing the turbine rated power on each substructure; (ii) A second motivation was the relationship and deeper knowledge that PPI has developed with the turbine supplier through collaboration on PPI's seminal prototype project, and; (iii) The choice of a design basis using a larger turbine allows larger flexibility in the future by designing for the most conservative case. All in all, the project team perceived this turbine to provide the lowest risk to the project.

PPI used prior experience working with the turbine supplier and modeling turbines and turbine controllers to advance the FEED work with limited involvement from the turbine manufacturer. An 8MW turbine was the largest turbine being considered for the WFP project, with the largest loads. The WindFloat hull was designed to meet these loads, which would simplify adjustments should there be a need to change the turbines as a result of the commercial outcomes of the project during Detailed Design, requiring little rework other than adjustments of the interface between the tower and foundation. This approach would minimize the cost of any possible re-engineering. In a harsh ocean environment, such as the Pacific Ocean off Oregon, wave conditions are a major driver in the platform size. The platform size needed to survive these conditions does not scale linearly with turbine size; the optimized platform for a 6MW platform is not necessarily much smaller than that for an 8MW, as can be seen from the sizing differences presented in BP1 and in BP2. The differences and similarities between selected turbines are highlighted in Table 1.

Description	30 MW WindFloat Pacific Budget Period 1	24 MW WindFloat Pacific Budget Period 2
Wind Plant Rating, MW	30	24
Number of Turbines	5	3
Turbine Spacing, km	1,540	1,617
System Design Life, years	25	25
Turbine Rating, kW	6,000	8,000
Rotor Diameter, m	154	164
Hub Height, m	97	105
Gearbox Type	Direct Drive	Medium Speed
Generator	Permanent Magnet	Permanent Magnet
Foundation Type	WindFloat	WindFloat
Distance to Cable Landfall, km	30	30
Distance to Construction Port	43	370
Distance to O&M Port	43	43
Water Depth, m	435	435
Wind Speed @ Hub Height, m/s	8.83	8.91
Weibull K Factor	1.87	1.87
Base Wind Shear	0.104	0.104
Air Density, kg/m^3	1.225	1.225
Max Rotor C_p	0.45	0.45
Tip Speed Ratio at Max C_p	10.80	10.80
V_{cut-in}, m/s	3.00	3.00
$V_{cut-out}$, m/s	25.00	25.00
Energy Losses	5.4%	4.5%
Availability	94.0%	94.0%
Effective Tax Rate	40.0%	40.0%

Table 1: Comparison between assumed size and performance of 6 and 8 MW turbines examined for WindFloat Pacific.

The PPI engineering team did not have access to the Vestas controller, instead used a turbine model with similar motion performance, in cooperation with NREL. This work allowed FEED to proceed, with a reliable turbine response in numerical simulations, featuring realistic and appropriate levels for fatigue analysis.

Structural Design

During BP2, the structural analysis of the primary structure was updated and the design optimized, based on BP1 results. The final structural weight was calculated to have increased only modestly (less than 3%) despite the larger turbine size and including more structural details like brackets and insert plates on critical locations such as the water entrapment plate, and the bottom and upper flats.

Additional structural analysis and design included the following:

- Strength analysis - Extreme load cases were processed to extract snapshots of extreme structural loads. Plates and shells were checked for strength and buckling. Where stress concentrations were identified, the area was detailed with brackets or an insert plate to avoid increasing the scantlings of the entire piece.

- Fatigue analysis – Efforts were concentrated at the top of the turbine-bearing column, where there were significant uncertainties in steel weight estimates. Several configurations were considered for the connections, and a significant optimization effort was carried out to identify the fatigue-prone areas and reduce stress concentrations through geometric optimization and local stiffening. The fatigue in other locations will be considered in detailed design but is expected to less significant than that at the top of the turbine-bearing column. Similar stiffening methods may be used in these other locations.
- Secondary Structure Design - Definition of the appurtenances was carried out during BP2, to obtain reliable quotes for fabrication. In particular, the helideck was designed to overcome weight uncertainties; detailed drawings are provided as part of the BP2 deliverables. A Material Take-Off (MTO or Bill of materials) was generated for the secondary structure at the end of BP2. Mooring and cable design The mooring was optimized during BP2 to simplify and reduce the cost of at-sea operations on mooring and electrical cable configurations. This activity is a key driver of the overall project economics.

It is not possible to perform large corrective operations offshore for a floating wind farm in the Pacific Ocean. Therefore, simplifying the procedures for disconnecting and reconnecting of the WindFloat units from mooring and electrical cable has significant advantages. The mooring will be comprised of three lines (instead of the four proposed during BP1), passes all ABS safety factors, and exhibits very low pre-tension. These attributes allow the reconnection of the mooring line from the platform itself without the use of a very large vessel. All operations can be done with the use of local tugs, broadly available on the west coast of the US, with the exception of the mooring pre-lay which requires a pull test and a larger vessel (likely sourced from the Gulf of Mexico).

Certified Verification Agent (CVA) Review

The American Bureau of Shipping (ABS) was nominated as the CVA for the COP. ABS will class the WindFloat for the WFP Project as a Floating Offshore Wind Turbine. As part of the classification process, ABS reviews all design documentation, starting with design documents submitted during BP2, as listed in Table 2.

Reports Submitted to ABS	**Date Submitted**
Global Frame Analysis Report	6/29/2015
Global Strength Analysis Report	6/29/2015
Fatigue Analysis Report	6/29/2015

Local Structural Design Report - Water Entrapment Plates	6/29/2015
Mooring Analysis	7/1/2015
In-Service Intact and Damage Stability Report	7/2/2015
In-Service Stability Philosophy	7/6/2015
Structural Drawings	7/7/2015
Hull Design Basis	7/14/2015
Hull Structural Philosophy	7/14/2015
Aerodynamic and Hydrodynamic Modeling Report	7/23/2015
Global Performance Report	7/23/2015
WFP Metocean Design Basis	7/23/2015

Table 2: Reports and dates they were submitted to ABS for review and approval.

Vendor Quotes

With the completion of all structural calculations and FEED, a new set of drawings was created to solicit fabrication costs from vendors, using an RFQ. The 8MW design required that the WindFloats be slightly larger than the 6 MW design that had been established from BP1. The RFQ package was submitted to five fabricators, including vendors from the US Gulf of Mexico, California, Oregon and Korea. All but one of the estimates were reduced from BP1.

After securing a PPA, PPI's plan was to request updated bids from the fabricators. Fabrication in the US, preferably on the west coast, remained the preferred scenario, especially given economic development and political sensitivities associated with legislation in support of a PPA. PPI worked closely with the local fabricators to ready them for the project, to optimize the local economic impact of the project, to develop supply chain and installation capabilities locally, and to minimize the LCOE.

Ultimately, the final plan for fabrication resulted as a balance between an acceptable PPA price and an active collaboration with the local fabricator, seeking ways to reduce local fabrication costs. PPI had planned to work under the auspices of the Governor's Advisory Committee to implement an approach that minimized impact to ratepayers while maximizing economic benefit to the region. Figure 4 shows facilities at Vigor Shipyards in Portland, OR, part of the local supply chain that would have contributed to the construction of the project.

Figure 4: Vigor Shipyard in Portland, OR.

Detailed Design

With the completion of FEED at the end of BP2, all future design adjustments were intended to be local, with no major configuration changes and design variations anticipated in subsequent budget periods. Detailed design was intended to proceed during BP3, upon securing a PPA and turbines supply agreement, as follows:

- Review design loads with the turbine manufacturers, to satisfy the CVA;
- Complete local structural design for strength, including the fairlead connection, and for fatigue, including the water entrapment plate details;
- Complete all details in the secondary structure;
- Initiate procurement of electrical equipment and marine systems; and
- Complete detailed design of piping, electrical and instrumentation systems.

2. Installation and Operations & Maintenance:

A key element of the project was to establish a load out and installation plan for the WindFloats. As no offshore wind projects have been commissioned on the West Coast, this type of operation had never been conducted. WindFloat Pacific's Identification of appropriate facilities and build out of operations and maintenance plans illustrate progress made towards the establishment of a viable floating offshore wind industry in the West, and elsewhere in the country.

Installation

PPI completed a Construction Cost Analysis report that highlighted updates in installation methodologies and corresponding quotes from various vendors, with the greatest change being the location of turbine installation. Over the course of the project, PPI determined that facilities in Coos Bay were less capable of supporting the turbine installation sequence than others in the region. In their place, PPI determined that the turbines would be installed in the Port of Astoria, at the mouth of the Columbia River. While some upgrades would be required, in particular to load bearing capacity, the Port of Astoria has the space for laydown of turbine assemblage and the infrastructure is sufficient to accommodate the land shore turbine crane needed to perform the heavy lifts and ballasting operations. (Though a full analysis was not completed, PPI estimated the costs for required upgrades to be approximately $5 million.) After turbine installation, the WindFloats, with the turbines mounted, would be towed from Astoria directly to the offshore lease site. PPI intended to use the Port of Coos Bay as the shore-based headquarters for O&M and procurement activities, such as receiving mooring and electrical cable components. Figure 5 shows the locations where these major operations would occur.

Figure 5: Locations where operations would occur: 1) construction; 2) turbine assembly; 3) project site and O&M hub.

PPI also modified the installation operations to install all the WindFloats in one season, rather than two, as overwintering an installation vessel would create a financial burden to the project. With the project reduced to fewer platforms with larger turbines, the single season installation is possible. Following pre-lay of the mooring lines early in the season, one WindFloat can be installed every 6-8 weeks. This timeframe is inclusive of the full process, from load-out from the fabrication facilities, to turbine assembly, to towing and connections at the Project site. PPI determined that the risk of meeting this schedule is very low, based on Monte Carlo simulations performed for the purpose.

Operations and Maintenance

The PPI engineering team benefited from the valuable experience of O&M for WF1 in Portugal, which has similar metocean conditions as the WFP project site. The lessons learned fed into project plans, detailed design, and other project documents. Operations and Maintenance (O&M) activities are split in the following two categories:

- Large corrective maintenance are interventions that require towing a WindFloat platform back to a protected area or a port for replacement of a large component. This can include replacement of blades, the nacelle or tower sections. These operations are essentially described in the installation plan.
- Recurrent O&M involves activities that can be performed in-situ (i.e. at the platform offshore location), which include inspections, preventive maintenance or repairs. Recurrent O&M is the main focus of the present report. The following areas are discussed in this plan: facilities, vessels, equipment, people, methodologies and Health, Safety and Environment (HS&E)

In addition, during BP2, PPI carried out a feasibility study for helicopter access and the use of the helideck for WFP. This preliminary study showed that the helideck would allow access to the platform 70% of the time, which is significantly higher than PPI WF1 platform, which is outfitted with a boat landing only.

These reports describe an O&M strategy that takes advantage of the WindFloat's unique capacity to be towed to shore for large correctives, and combines planned maintenance with non-productive down times (i.e. no wind events, when no generation is occurring). Together, they represent a strategy that is efficient, and obviates any need for heavy-lift vessels and the subsequent issues associated with Jones Act compliance. These are features unique to semi-submersible floating wind foundations like the WindFloat and are key elements to the reduction of required new infrastructure that can support the rapid development of the industry.

3. NEPA and Permitting

Over the course of the project, significant progress was made towards securing all necessary permissions to develop the WindFloat Pacific project 18 miles offshore of the Oregon coast. Working closely with project partners PNNL and Herrera Environmental, Principle Power engaged with agencies (state and federal) and stakeholders regarding the development of the WFP project near Coos Bay. Because the WFP project was primarily located in federal waters, Principle Power focused initial outreach efforts on federal agencies (U.S. Fish and Wildlife, NOAA Fisheries, U.S. Coast Guard, U.S. Army Corp of Engineers) through in- person meetings and phone calls to discuss the overall intentions of the WFP project and to receive feedback on potential permitting issues that may arise. Discussions focused around the issues anticipated to be of concern, prior to formal federal and Oregon State permitting activities, including compliance with the National Environmental Policy Act (NEPA).

The project team also contacted Oregon State agencies such as Oregon Department of Land Conservation and Development regarding the WFP project's cable routing plans and consistency and compliance with the Coastal Zone Management Act and the Oregon Territorial Sea Plan. Meetings with ODFW and the Oregon Cable Commission were conducted. In addition, stakeholder meetings and phone calls were held with environmental groups, local Coos Bay economic and development groups, and fishing organizations. These engagements primarily focused on informing stakeholder groups of the WFP project including the proposed project area, answering project-specific questions, and seeking input on areas or issues that may be of concern. Research results and the outcome of discussions with regulatory agencies, as well as important stakeholder groups, were documented for the NEPA process.

BP1 work on NEPA and permitting set the stage for all activity conducted in BP2, with the submittal and acceptance of the offshore lease application, and determination of no competitive interest (DNCI) that provided site control for Principle Power. Surveys and interactions with the regulatory and resource agencies during BP1 also set in motion many of the processes completed and continued in BP2.

Key developments during BP2 include:

- Geophysical and archeological surveys
- Environmental report
- Biological Assessment
- Construction and Operations Plan (COP)
- Meetings with stakeholders and tribes
- Discussions with regulatory and resource agencies
- Monitoring plans for pre- and post-installation

Progress in these areas is highlighted in greater detail in the sections below.

Geophysical and Archeological Surveys

Geophysical and archaeological surveys are needed to support the COP, to determine the structural stability of the area into which the WindFloat units and export power cable will be installed, and to ensure that cultural and archaeological resources will not be threatened by installation or operation of the project. The underwater survey firm C&C Technologies (now

Oceaneering International) was contracted to provide geophysical surveys of the offshore lease site and the cable route using side scan sonar and sub bottom profilers; in addition, C&C used a magnetometer to survey for marine archeological and cultural resources along the cable route to a depth of 120 m. The marine surveys were initiated in October 2014, immediately following execution of the BP2 award contract, but were called off due to inclement weather in November 2014. Both the geophysical and archeological surveys were successfully completed during July 2015 [13]. Land-based archaeological and cultural investigations were carried out by Historical Research Associates, specialists in historical and archaeological research, at the cable landing site and along the proposed power transmission line route during July 2015 [14]. Data and findings from the marine and terrestrial surveys were used in preparing the COP, and to advance compliance with NEPA, Section 106 of the National Historic Preservation Act (NHPA) and other state and local regulatory requirements.

Environmental Report

An environmental report was developed by the WFP project team to serve as input to BOEM's Environmental Assessment (EA); the EA will act as the NEPA decision document for the offshore wind development. The 500+ page report was developed to mirror the structure and content of an EA, and included: an extensive project description from fabrication to installation and operation of the WindFloat Pacific project; an assessment of the key regulatory drivers and requirements under NEPA as they apply to the project; a description of the existing conditions for the potentially affected environmental and socio-economic resources; an assessment of the potential impacts and proposed mitigation for the project on those resources; and a description of interactions with key stakeholders and engagement with the public. A preliminary draft of the report was submitted to BOEM in February 2015, with the final draft submitted in July 2015.

Biological Assessment

A biological assessment was developed by the WFP project team to serve as input to BOEM's document for use in informal consultations with NOAA and USFWS in compliance with Section 7 of the Endangered Species Act (ESA). The document contains a description of the existing conditions for the potentially affected biological resources; an assessment of the potential impacts and proposed mitigation for the project on those resources; and a description of the likelihood and degree of potential effects. A draft of the report was submitted to BOEM in July 2015.

Construction and Operations Plan (COP)

The COP acts as BOEM's decision document for determining issuance of the seabed lease, which then triggers most other permitting and leasing activities at the federal, state and local level. The WFP team prepared the COP to the specifications of BOEM's guidance, and submitted the plan to BOEM in July 2015. The COP included a departure request from the requirement for submission of geotechnical survey results to be submitted with the COP under §585.626(a)(4), a brief background and description of the project; nomination of the Certified Verification Agent (CVA); a summary of site investigations to date; the detailed construction and operations plans; a conceptual level decommissioning plan; a summary of the environmental affects and mitigation (from the environmental report); the regulatory framework against which the WFP development will be measured; and financial assurance details of the project. In addition, the COP includes numerous appendices, most of which are included in the July 2015 submittal. It is a document that contained more than 1,300 pages. Certain appendices were planned to be added later, including the Final Design Report, the Fabrication and Installation Report, and other backup documents. Geotechnical surveys were planned to be conducted once a PPA had been secured, due to the large investment they require.

Meetings with Stakeholders and Tribes

The WFP project team met with key stakeholder groups, particularly the fishing community in southern Oregon, on potential conflicts and synergies between the industry and the WFP project; and with representatives of the major Tribal groups in the area on potential issues of salmon survival around the WindFloats, interactions with tribal cultural resources, and areas in which the Tribes might have some involvement in the WFP project. Table 3 is a representative example of entities with whom the project team met.

Discussions with Resource and Regulatory Agencies

During the process of developing the environmental report and COP, numerous meetings were held with BOEM to determine requirements, clarify guidance, and discuss key issues to determine the level of significance of potential environmental and socio-economic effects of the WFP project. Meetings were also held with the US Fish and Wildlife Service and with NOAA to determine the levels of potential effect that should be considered for wildlife and habitats under the Endangered Species Act, the Marine Mammal Protection Act, and the Migratory Bird Treaty Act, as well as to discuss monitoring plans for key marine and avian species [18]. The WFP team also met with the Oregon Department of Fish and Wildlife on wildlife and habitat issues in state waters (mainly for the export power cable installation and landfall); with Oregon State Lands on state leasing requirements for the power cable route and Coastal Zone Management Consistency; with the US Army Corps of Engineers on Clean Water Act and Rivers and Harbors Act requirements and consistency; with the US Coast Guard on navigation safety risks; and with Coos County and the Bureau of Land Management on the installation of the landfall transition of the power export cable, the power conversion station, and the power transmission line. Table 3 is a representative example of entities with whom the project team met.

In addition, PPI held a workshop in Alexandria, VA, that included the US Coast Guard (USCG), BOEM, the Bureau of Safety and Environmental Enforcement (BSEE) and ABS, along with project partners PNNL, Herrera and representatives from the DOE. The purpose was to clarify the federal requirements and jurisdictions that would apply to floating offshore wind projects in the early stages of the development. In particular, questions of jurisdiction and applicable standards had arisen, especially regarding safety and onboard systems. The outcomes of the workshop were published and disseminated through the Offshore Technology Conference in Houston (May 2016).

Sector	Organization	Focus
Fishing	Southern Oregon Ocean Resource Coalition (SOORC)	• Project location and impacts on fishing industry
	Fishermen Involved in Natural Energy (FINE)	
	Mid-water trawler fisherman	
	Oregon Fishermen's Cable Committee	
	Bandon Trawlers' Association	
	Oregon Dungeness Crab Commission	
Environmental Organizations	Our Ocean	• Potential environmental effects • Potential disruption of existing human uses • Proposed cable route and installation process
	Audubon Society of Portland/Oregon South Coast Audubon Society	
	National Resources Defense Council	
	Oceana	
	Coos Bay WaterKeepers	
Clean Energy Organizations	Renewable Northwest Project	• Project information and status briefings
	Climate Solutions	
	Northwest Environmental Business Council (NEBC)	
	Oregon Wave Energy Trust (OWET)	
	American Council on Renewable Energy (ACORE)	
	American Wind Energy Association (AWEA)	
	California Wind Energy Association (CalWEA)	
	Clean Energy BC	
Economic Development and Labor Organizations	Coos County Commission	• Project information and status briefings • Potential for job creation and manifestation of Port "vision"
	South Coast Development Council	
	Coos Bay Chamber of Commerce	
	Oregon International Port of Coos Bay Commission	
Elected Officials	US Senators Wyden and Merkley (OR); Murray and Cantwell (WA); Feinstein (CA); Schatz and Hirono (HI)	• Project information and status briefings
	US Representatives DeFazio, Schrader, Bonamici, Blumenauer (OR)	

Sector	Organization	Focus
	Governor Kitzhaber (OR); Governor Brown (OR) Governor Inslee (WA)	
	Oregon State Legislature Representatives	
	Oregon State Legislature Senators	
	Coos Bay Mayor Shoji	
	Coos County Commissioners	
Federal Agencies	Bureau of Ocean Energy Management (BOEM)	• WindFloat Pacific leasing and siting process • Permitting process
	NOAA Fisheries	• Potential environmental effects • Potential destruction of modifications to sensitive benthic habitats
	US Fish and Wildlife Service (USFWS)	• Potential environmental effects
	US Coast Guard (USCG)	• WindFloat Pacific siting and installation process • Potential hazard to vessel traffic
	Federal Aviation Authority (FAA)	• Potential hazard to air traffic
	US Department of Defense	• Potential hazard to military and naval activities
	US Army Corps of Engineers (USACE)	• Water quality permits • Cable installation and construction activities
State Agencies	Oregon Department of Land Conservation and Development (DLCD)	• Cable installation and construction activities
	Oregon Department of State Lands (ODSL)	• Cable installation and construction activities
	Oregon Parks and Recreation Department (OPRD)	• Cable installation and landfall activities
	Oregon Department of Fish and Wildlife (ODFW)	• Potential environmental effects • Potential destruction or modifications to sensitive benthic habitats • Cable installation and construction activities
	Oregon Department of Environmental Quality (ODEQ)	• Cable installation and construction activities
	Oregon State Historic Preservation Office (SHPO)	• Potential location of archaeological sites
	Oregon Governor's Office	• Potential environmental effects • Cable installation and construction

Sector	Organization	Focus
		activities
Tribes	Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians (CTCLUSI)	• Proposed cable route and installation process • Viewshed of WindFloat Pacific project • Offshore and onshore archaeological/cultural investigations
	The Confederated Tribes of the Grande Ronde	• Potential environmental effects • Offshore and onshore archaeological/cultural investigations
	Coquille Tribe	• Potential environmental effects • Offshore and onshore archaeological/cultural investigations

Table 3: Representative list of stakeholder meetings conducted for the project.

Monitoring Plans for Pre- and Post-installation

Draft plans were developed for pre- and post-installation monitoring around the WindFloat units for marine mammals and sea turtles, and for seabirds and bats. These plans were developed in discussion with NOAA, USFWS, and BOEM to begin planning data collection efforts that will: provide insight into interactions of biota with the WindFloat Pacific array; inform future offshore wind installations on the continental shelf; address needs of the various regulatory frameworks under which the agencies operate; and to set in motion the framework for developing an adaptive management plan for the project.

A number of permitting items remained to be completed before the WindFloat Pacific project was ready to advance to the fabrication and deployment phase. These activities and approvals were expected to take place over subsequent budget periods, and include:

- Completion of the BOEM NEPA process
- Geotechnical Surveys, which will be initiated following the securing of an appropriate power offtake agreement
- Informal consultations with NMFS and USFWS for compliance with ESA, Magnuson Stevens, MBTA, and MMPA
- State and local permit processes associated with export cable beach crossing and seafloor installation, power conversion station construction, and transmission line installation; OCS air regulations; Coastal Zone Management Consistency; and water quality protections.

4. Grid Interconnection and Power Purchase:

Generally, in order for energy projects to move to financing, they need to have stable, creditworthy sources of revenue in the form of a long-term Power Purchase Agreement, or other similar arrangement, with one or more utilities, or other comparable off-takers. Combined with Interconnection Agreements, this is generally the primary point of interaction between a project and a utility or utilities. Interconnection agreements are key because they establish the contractual relationship that facilitates the delivery of energy generated by the project into the electrical grid. Both of these were key elements of WFP project planning.

Interconnection

Utilities owning transmission in the area include the Bonneville Power Administration (BPA), Central Lincoln People's Utility District (Central Lincoln), and PacifiCorp. BPA provides transmission service but does not serve retail load. Central Lincoln serves customers along the coast from Depoe Bay to just north of Coos Bay. PacifiCorp owns substations that are most proximate to the project site and it is to these that the project will interconnect.

Analysis identified several possible interconnection points within the nearby PacifiCorp service territory. Discussions with the utility narrowed the preferred option to the South Dunes/Jordan Point substation, which is connected to the PacifiCorp grid by a 115kV line. There is also adequate existing capacity to incorporate up to 30 MW of additional capacity on the line. The exact nature of the potential upgrade would be covered under the PacifiCorp's System Impact and Facilities studies, which was planned to be conducted during subsequent Budget Periods. These potential expenditures were included in future budget analysis. Figure 6 shows substations in the area planned for beach crossing and interconnection.

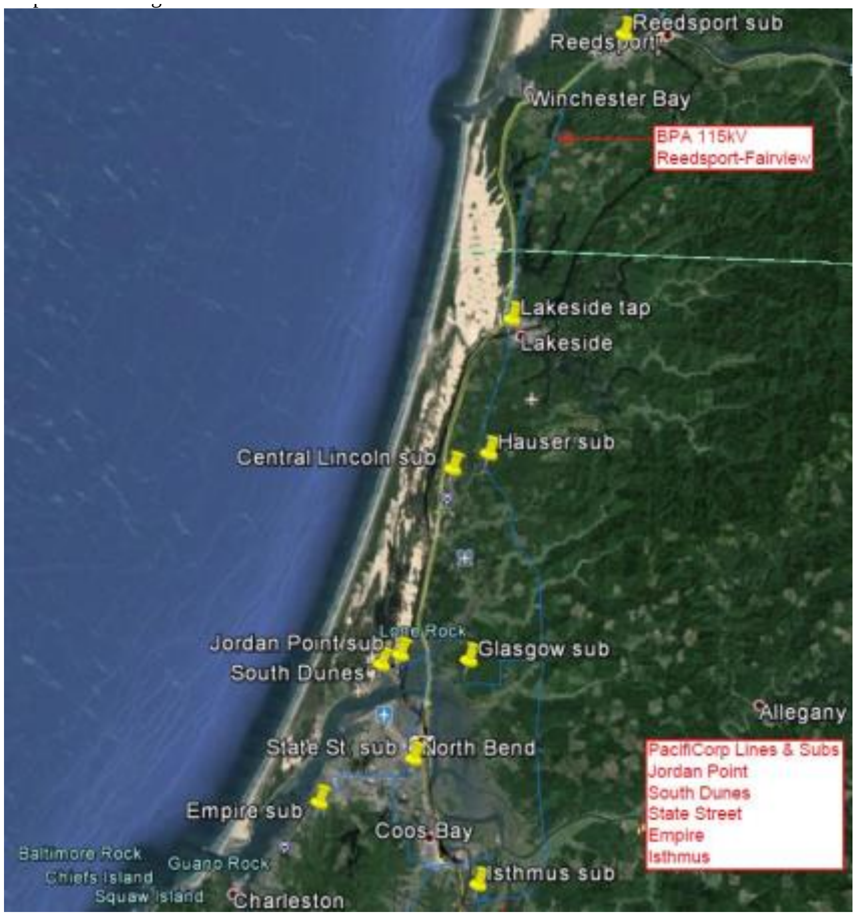

Figure 6: Location of available substations onshore the project area.

A scope was prepared with a qualified contractor to initiate the formal Large Generator Interconnection Application process with PacifiCorp. This is a standard process with established timeframes. Had the project been able to secure a PPA, required interconnection agreements would have been in place in time to allow a 2018 deployment.

Offtake Agreements and Legislative Approach

For any utility-scale power project, securing a power purchase agreement (PPA) is a critical and challenging factor. Certainty on PPA terms is critical to (i) provide visibility on profitability and economics, (ii) attract financing of equity and debt, and (iii) be able to advance to large expenditures and investments. This is particularly true at the demonstration scale, in which needed prices are almost inevitably higher than the prevailing market, because demonstration projects do not typically benefit from the economies of scale that reduce cost on a per/kWh basis.

Upon the announcement of the WFP Award, PPI began working with the Oregon Governor's office, the local legislative community (OR House and Senate), the Oregon Public Utility Commission and other local leaders to develop a strategy to secure a PPA for the project. Initial concepts included the potential for the Jordan Cove Energy Project (JCE), an LNG export facility under development in Coos Bay, to purchase a portion of the project's generation. Ultimately it was determined that a plan to pass state legislation that would enable or require Oregon utilities to enter offtake agreement(s) with the project presented the greatest likelihood for success.

But the challenges for securing a PPA were magnified when the sitting Oregon governor John Kitzhaber resigned in February 2015, amidst allegations of abuse of power. He was a popular and established advocate for renewable energy and the project team's strategy partially depended on his team's championship of WindFloat Pacific.

With the appointment of a new governor in Oregon, Kate Brown, PPI and project partner Deepwater Wind (with whom PPI held a co-development agreement) spent considerable energy and time working to structure appropriate legislative concepts. Many of these concepts were modeled after the successful legislation in Rhode Island that enabled development of the US' first offshore wind farm, Deepwater Wind's Block Island Wind Farm. After consultation with utilities, legislators and regulators, a legislative concept was finalized and adopted by a member of Oregon's House of Representatives (Rep. Caddy Mckeown (D) Coos Bay), and drafted by the state's Legislative Counsel. This bill required in-state utilities to purchase the output of WindFloat Pacific, while including rate-impact protections for the utilities' customers. This approach was required because of the presence of existing, exceptionally low cost resources like hydropower, and a regulatory environment that, in essence, does not allow for new or above market-rate power to be purchased by utilities. After debate, discussion and hearings, PPI's legislation was pulled once it became clear it would not pass in the 2015 session.

The project team's final approach was based on the formation of a Governor's Advisory Committee, which was formed under the authority of Oregon's new governor Kate Brown. This Committee convened over the summer and fall of 2015 with the intention to create recommendations for new legislation to be considered in the 'short' 2016 session, which ran from February to March 2016.

In parallel with the work of the Advisory Committee, PPI re-engaged with Oregon's utilities and the Public Utility Commission to begin negotiating possible PPA terms and conditions with the goal of maximizing consensus by the time new legislation was proposed. These meetings were comprehensive and examined all options open to the state's utilities. Significant effort was made to reduce costs to ratepayers; several levels of analysis were conducted to explain different scenarios, including: expanding the power purchase obligation to the broadest possible pool of buyers (including the Investor Owned Utilities (IOUs), Consumer Owned Utilities (COUs) and the full Bonneville Power Administration (BPA) service territory) and modifying the project size to minimize CapEx.

Table 4 shows the results of some of the analysis conducted for WFP. It becomes clear that smaller projects (in this case, 16 MW versus 24 MW) have lower CapEX requirements but, given the large fixed costs associated with an offshore wind farm (i.e. cable procurement and installation, vessel mobilization, facility leasing, etc.), have higher per/kWh prices.

	Units	**24 MW Project (3 Turbines)**	**16 MW Project (2 Turbines)**
CAPEX Net of DOE Grant	2015$	210 to 250 MM	150 to 180 MM
Annual OPEX	2015$	5 to 6 MM	4 to 5 MM
Average Annual Generation	MWh	91,560	61,040
Full Load Hours	MWh/MW	3,815	3,815
Capacity Factor	%	43%	43%
First Year PPA Price (2.5% escalator)*	2015$/MWh	240 to 260	255 to 275

*PPA prices estimated using the NREL System Advisor Model (https://sam.nrel.gov/)

Table 4: WFP cost analysis, including CapEx and first year PPA price proposed.

Table 5 shows the difference in marginal cost to average Oregon ratepayers' bills under three scenarios: 1) in which only the state's IOUs were required to purchase WFP's output; 2) In which all of the state's utilities (IOUs and COUs) purchased the output, and; 3) in which all of the state's utilities and BPA's full service territory purchased the output. While in each case the average monthly power bill is similar, spreading the offtake obligation to a broader pool of buyers presents a clear reduction in impact to individual ratepayers.

Offtake Scenario	**Average Monthly Residential Bill**	**Impact on Average Monthly Residential Bill***	
		24 MW Project	**16 MW Project**
1) IOUs Only	$99.70	$0.45 (0.5%)	$0.32 (0.3%)
2) IOUs and All COUs	$97.64	$0.33 (0.3%)	$0.24 (0.2%)
3) IOUs and BPA (BPA 50% offtake)	$98.85	$0.14 (0.1%)	$0.10 (0.1%)

*Impact calculated with WFP Rate Impact model; assumes average of PPA price range shown in table above

Table 5: Ratepayer impacts estimated at different project sizes and assuming different purchase pools.

The achieved power purchase price proposals were in line with other demonstration-scale offshore wind projects using established technologies, in the US and elsewhere. At the same time, costs could have been reduced further had PPI simply chosen the most economic options available for fabrication and delivery of the WindFloat units. While attractive from an economic standpoint, this was not a politically viable option given demand for local economic development opportunity.

While the Governor's Advisory Committee recognized its interest in offshore wind generally and the economic potential of the WindFloat more specifically, energy costs associated with the demonstration scale project were too high relative to the mature energy (conventional and renewable) resources available in the market. As a result, the Advisory Committee could not agree to recommend a legislative approach sufficient to enable the construction of the project, and it was ultimately discontinued.

CONCLUSION

PPI's WindFloat Pacific Project was the first floating offshore wind array proposed anywhere in the United States and the first of any kind proposed for the west coast of the US. As such, it was a ground-breaking project that established the technical viability of a floating offshore wind industry along the Pacific Coast and other coastal markets in the US (including the Northeast, Mid-Atlantic, the Great Lakes and Hawaii). The work of the project team also significantly advanced industry's understanding of the permitting/leasing process, and in turn, the regulatory bodies' understanding of floating offshore wind issues and potential. Together, these lessons represent tremendous advancement along the lines of the nation's offshore wind strategy.

Additionally, while the project was ultimately unable to secure a PPA in the timeframe required by the DOE program, PPI identified ways, working with the local supply chain, to introduce economically competitive projects at commercial scale.

WindFloat Pacific was an essential step on the WindFloat technology commercialization pathway. This pathway began with proof-of-concept deployment and validation of the 2 MW WindFloat Prototype in Portugal (2011), extended through technology-scaling and refinement during the WindFloat Pacific project and, according to NREL analysis, achieves cost competitiveness with conventional fixed-bottom offshore wind technology at commercial scale (in this analysis, 500 MW) in about 2020. Figure 7 shows this WindFloat commercialization and LCOE reduction pathway; it also shows the DOE Baseline LCOE (intended as a price target, along with the local hurdle rate) as a reference point.

Commercial scale projects will serve to increase resource and geographic diversity of generation, benefit the environment through the introduction of large scale emission free resources, provide rate stability to utility customers and have tremendous economic impacts to coastal communities and supply chains.

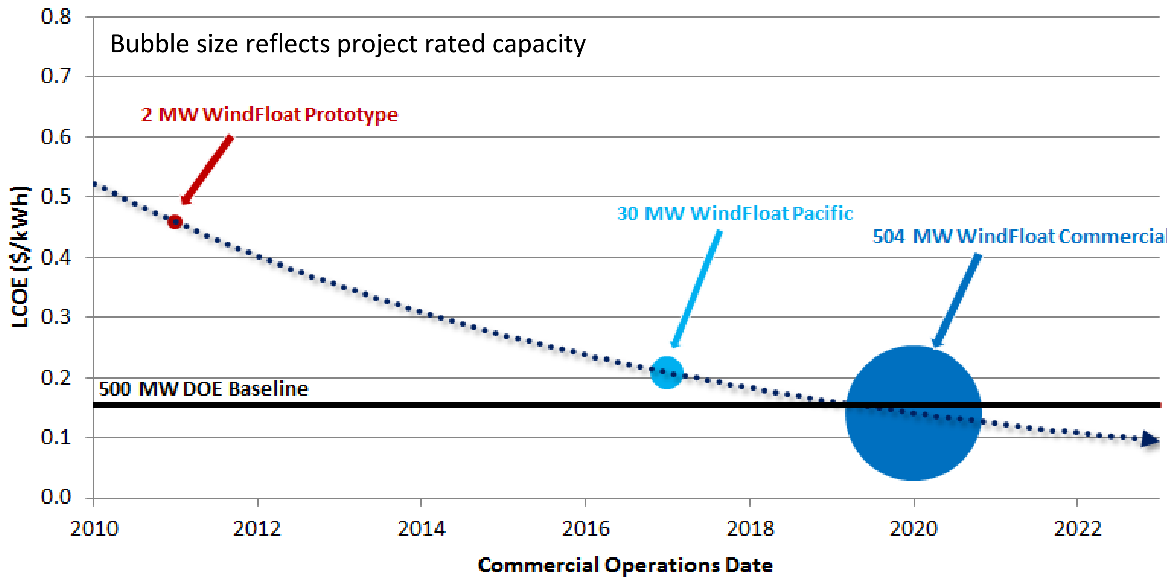

Figure 7: The WindFloat's path to commercial costs associated with project size.

Figure 7 shows significant cost reduction potential between the three WindFloat scenarios. These are associated with wind turbine generator scaling, technology improvement, and project size. There is, however, significant potential for further LCOE improvement beyond this near-term WindFloat commercialization pathway. The main drivers of long-term cost reduction are expected to include:

- Larger, more reliable offshore wind turbines to increase energy capture, reduce BOS requirements (e.g., fewer substructures, less cable), and increase reliability
- Further WindFloat technology refinements to reduce specific mass (kg/kW) and simplify fabrication
- Improved electric infrastructure solutions for floating offshore wind projects,
- Industrialization of domestic infrastructure including ports and manufacturing facilities.
- Increased competition within key markets (e.g., turbines, subsea cables, substructures) to drive down prices.

These factors are expected to lead to eventual parity with other low carbon sources of generation available in coastal regions. The prospective cost reduction opportunities beyond 2020 suggest that the WindFloat is a durable technology solution with high long-term potential for growth in US and global offshore wind markets.

The US Department of Energy (DOE) and US Department of Interior (DOI)'s recently released National Offshore Wind Strategy states that the nearly 60% of the nation's offshore wind resource can be found in waters deeper than 60m, "which is likely beyond the economic reach of current fixed-bottom offshore wind technologies". The strategy document goes on to say,

> "The advantages of floating technology include the possible reduction of site conflicts, access to higher winds in waters farther offshore, and a larger resource base. Floating technology also offers the potential for reduced marine operations during construction and installation, and in O&M. Floating technologies could allow for final turbine assembly, commissioning, and major maintenance in port at quayside, in a wide range of weather conditions and using generally available equipment. Quayside assembly and maintenance could present significant cost savings and risk reduction compared to the current practice of utilizing specialized infrastructure to conduct major construction activities offshore, particularly as developers begin to look at more challenging sites in deeper water and more extreme metocean conditions."

Floating offshore wind has evolved tremendously since DOE first issued the offshore wind demonstration program FOA in 2012. The successes of the WindFloat Pacific project suggest that the National Offshore Wind Strategy's assessment around the expected potential for floating offshore wind are not just on track but, in many ways, now demonstrated.

Now the US market, while still facing some challenges, seems to be coming into focus. At the time of writing, legislation has passed in Massachusetts that requires 1600MW of energy from offshore wind, and experienced and well-capitalized international developers are aggressively investigating and entering the market. Proposed projects off of California and Hawaii are introducing plans for GWs of energy from offshore wind to new jurisdictions. By addressing risk and cost, reducing environmental impacts, increasing siting flexibility and stakeholder acceptance and requiring less new infrastructure than conventional bottom-fixed offshore wind projects, the WindFloat addresses market barriers that are specific to the US, and can help the US leapfrog European and Asian development. Support to PPI from the USDOE's offshore wind demonstration program played a significant role in these advancements and for that PPI is extraordinarily grateful.