Northwest National Marine Renewable Energy Center Oregon State University

Feasibility Study for a Grid Connected Pacific Marine Energy Center

This report was developed by Pacific Energy Ventures, with technical support from Parametrix, on behalf of Oregon State University.

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I. Background

The Northwest National Marine Renewable Energy Center (NNMREC), one of three federally sponsored ocean energy centers, is a partnership between Oregon State University (OSU) and the University of Washington (UW). As national leaders in ocean energy research and development, NNMREC-OSU focuses on wave energy and NNMREC-UW focuses on tidal energy. The National Renewable Energy Lab (NREL) is also a key partner in the center. For the purposes of this report, references to NNMREC assume to be that of NNMREC-OSU.

Since its establishment in 2008, NNMREC has made great strides to assist and guide the development of the wave energy industry in the US through technology testing and validation, environmental study and analysis, and understanding the human dimensions of the emerging ocean energy industry. One of NNMREC's primary roles is to serve as an integrated, standardized test center for US and international wave energy developers. NNMREC is also home to world-class research facilities available to NNMREC and its partners, including the O.H. Hinsdale Wave Research Laboratory, the Wallace Energy Systems and Renewables Facility, and Hatfield Marine Science Center.

In addition to its land-based facilities, one of NNMREC's distinguishing attributes is its proximity to the ocean itself. The ocean waters just north of Newport Harbor have served as a primary testing ground for the wave energy industry in the US. In addition to testing various energy generation technologies, significant investment has been made in understanding ecosystem interactions and socioeconomic effects of this new industry. After four years of laboratory study and analysis, NNMREC will be home to the nation's first ocean test berth (non-grid connected) in 2012, capable of testing a variety of ocean energy technologies while monitoring interactions with the local ecosystem. At this Newport ocean site, NNMREC aims to have a full suite of testing capabilities to support the advancement of small-scale and full-scale devices supported by both land based and in ocean testing facilities.

While the NNMREC ocean test berth is a critical step forward, developers and policy-makers alike have determined that a full-scale, grid connected ocean test facility is needed to achieve industry commercialization and fully reap the benefits of this clean, renewable energy resource. Fulfilling this need is the primary purpose of the ***Pacific Marine Energy Center (PMEC).***

> ***PMEC Vision:*** *Leverage NNMREC expertise and industry partnerships to develop a full scale, grid-connected ocean energy demonstration center that can accommodate multiple devices of various technology types and scales.*

NNMREC has developed a four-phase approach to achieve the PMEC vision:

- <u>Phase 1:</u> Non-grid connected, ocean testing off the coast of Newport, OR for proof of concept through prototype devices (To commence in 2012).
- <u>Phase 2:</u> Grid Emulation System testing for prototype devices and system verification (Involves site selection, design and installation of subsea transmission cable and shore-based infrastructure).

- Phase 3: Grid connection of the cable to support final demonstration and testing (involves permitting for grid connect and shore-based infrastructure).
- Phase 4: Additional grid connected ocean test berths to support final demonstration and testing (Involves design and installation of a second subsea transmission cable and shore-based infrastructure).

As noted, the non-grid connected ocean test site discussed above in Phase 1 will be located just north of Newport, OR, approximately 2-3 miles offshore, and NNMREC plans to begin wave energy device testing at this location in the summer of 2012. It is possible that Phases 2-4 could be performed at the ocean test site off the coast of Newport; however, additional site characteristics will be required for the services provided in Phases 2-4. For example, to meet required water depths for some devices, the test site would need to be deeper than the current Newport site. Therefore, three other locations are being evaluated along with the Newport site as part of this feasibility study. The purpose of this study is to:

- **Identify the site characteristics required for the successful development of PMEC; and**
- **Conduct a technical evaluation of candidate sites that meet these criteria.**

II. Pacific Marine Energy Center

A grid connected ocean energy demonstration center is a critical component of advancing the marine energy industry in the US. The interest and value in this type of test center has been documented in numerous reports reflecting industry and stakeholder interests. In particular, The Ocean Renewable Energy Coalition's recently published MHK Roadmap[1] for ocean energy acknowledges that the development of a demonstration center is a necessary step in commercializing this sector. Furthermore, the report acknowledges the ***most pronounced underlying success factor for this industry is the ability to focus resources – commercial, financial, scientific and political – on deploying MHK devices and studying their interactions with the natural environment, increasing technical efficiencies and learning from direct experience.*** PMEC can meet this objective by serving as the cornerstone for the industry to not only maximize current investment, but also to direct future investment in such a way that accelerates the development of new ocean energy generating technologies.

To that end, the PMEC is designed to demonstrate the viability of marine energy off the northwest coast of the US by providing a fully functional ocean test facility for prototype and commercial scale devices (TRL 5-9). PMEC will offer up to four test berths connected to the regional grid, and will be capable of testing individual devices up to one megawatt in size. By offering numerous device testing options in conjunction with transmission and grid interconnection infrastructure, the PMEC will facilitate wave

[1] http://www.oceanrenewable.com/wp-content/uploads/2011/05/MHK-Roadmap-Final-November-2011.pdf

energy technologies' progress from early-stage ocean testing through final demonstration for commercialization use. Specifically, the PMEC will meet the following key industry development needs:

- Site for testing subscale devices with grid simulation capability;
- Ocean test berth for single device testing;
- Multiple-berth testing (e.g., small arrays of 2 to 10 devices) for commercial scale devices and prototypes; and
- Opportunity for potential expansion to commercial activity.

The PMEC is intended to be a full service test facility. Although the specific PMEC offerings are still under development, it is expected they will include, but are not limited to the following:

- Standardized testing at reduced cost;
- Standardized power analysis at accredited facility;
- Grid interconnection data from accredited facility;
    - Grid synchronization data
    - Standardized fault testing
- Power dissipation;
- Demonstration of power on the grid (e.g., technical and contractual);
- Procedures and protocols for all stages of development.

In addition, the PMEC will provide assistance through each stage of testing:

- Pre-Test Stage
    - Guidelines for Streamlined Permitting Process
    - Deployment and Testing Plans
    - Research and Monitoring Plans (including IP plans)
- Test Stage
    - Testing Protocols and Procedures
    - Device Monitoring (power and performance)
    - Environmental Monitoring
- Post-Test Stage
    - Data Analysis
    - Demobilization
    - Decommissioning

Figure 1. Ocean Power Technologies PB150 being deployed in Scotland. A similar device is planned for deployment in Oregon in 2012.

III. The Oregon Advantage

The State of Oregon and the Northwest Region of the US are uniquely positioned to lead the development of ocean energy. Oregon and the Northwest have invested more resources and expertise than any other region in the US. In addition to successful demonstration projects, Oregon will likely be home to the Nation's first commercial license for ocean generated electricity. Oregon has clearly demonstrated its ability to attract investment and develop successful projects.

In short, the Oregon advantage consists of:

- Resource Required to Test TRL 9 Utility Scale Devices (and summer climates suitable for TRL 5-7)
- Information Transferable to US West Coast Commercialization
- Oregon Wave Energy Trust and State of Oregon
- Proximity to Supply Chain
- Site Accessibility
- Comprehensive R&D Facilities
- Stakeholder Consortium

Resource Required to Test TRL 9 Utility Scale Devices (and summer climates suitable for TRL 5-7)

Oregon's wave resource is one of the best in the US, giving developers the opportunity to test a range of scaled devices, including, TRL 5-7 and most importantly TRL 9 testing capability. Although certain small scale devices may be preferable to test the only the summer months, the Oregon resource has the ability to demonstrate to utilities and other investors the commercial viability and survivability of related commercial technologies.

Information Transferable to US West Coast Commercialization

The information collected and analyzed at the PMEC in Oregon can be applied to future commercial developments along the west coast. Because the Oregon coastline is similar to the California and Washington coasts, both physically and biologically, information regarding site development, interactions with the environment, and other attributes of project development can be used to inform future ocean energy projects on the US west coast.

Oregon Wave Energy Trust and the State of Oregon

Oregon is home to the nation's only state-sponsored public/private partnership established with the sole mission to advance the wave energy industry. Since its inception in 2007, the Oregon Wave Energy Trust[2] (OWET) together with the State has invested over $10 million to advance wave energy development, funding numerous environmental, social and technical studies needed to support the industry. Furthermore, Oregon is home to multiple Technology Readiness Level (TRL) 5/6 and 7/8 and ocean energy companies, and OWET has provided direct cost match to various US Department of Energy (USDOE) sponsored programs.

Proximity to Supply Chain

Oregon is home to world class manufacturing and supporting industries for the ocean energy sector. Facilities both in Portland and along the coast are situated to construct, deploy and maintain wave energy devices and supporting services.

Site Accessibility

All potential sites are within a three hour drive of the Portland International Airport, and within 125 miles of OSU's campus in Corvallis. In addition, all sites are located within 50 nm of a deep water port that will allow for easy access to manufacturing capabilities, deployment services, and vessels.

[2] www.oregonwave.org

Comprehensive R&D Facilities

NNMREC has become a "one stop shop" for the wave industry, providing comprehensive testing facilities for all technologies from early TRL (e.g., wave tank) to advanced TRL (e.g., ocean test berth). With the ability to leverage existing world class research facilities both in Corvallis and at the Hatfield Marine Science Center in Newport, PMEC is the final component that is needed to position the US West Coast as truly competitive in the international marketplace of ocean energy industry.

Stakeholder Consortium

NNMREC is developing an consortium of stakeholders that support the vision of a grid connected test facility in Oregon. The role of this consortium is to provide technical input to both guide and contribute to the PMEC's development. The stakeholders include a variety of industry participants, including technology developers, government agencies and community leaders.

IV. Industry Benefits

A grid connected ocean test facility has been discussed and analyzed at various levels of industry and government. In addition to offering a centralized location for testing and evaluating ocean energy technologies, the PMEC will provide benefits to a variety of industry partners and stakeholders:

Technology Developers

- Provides economical means of deploying and testing prototypes in the ocean environment.
- Leverages infrastructure and experience gained through ongoing and planned investments by DOE, OWET, BOEM, and others.
- Provides performance data for third-party validation.

NNMREC

- Offers centralized location to conduct technological and environmental testing.
- Increases likelihood of significant financial support for testing activities by the public sector, given the unified industry and academic beneficiaries of the project.

State and Federal Government

- Focuses funding for infrastructure across several proposed wave energy projects to benefit the industry as a whole.
- Accelerates information gathering, technology design and testing, as well as environmental impact analysis.
- Provides standardized testing metrics for technology performance evaluation.

West Coast Region

- Limits potential conflicts among competing uses for multiple ocean energy test sites.
- Serves as a "magnet" for federal/regional/private funding for ocean energy research and development.
- Increases efficiency and effectiveness of public funding by concentrating it on one, full-service facility.
- Provides a training ground for future jobs in the ocean energy industry.

V. Technical Evaluation of Candidate Sites

In order to perform a comprehensive evaluation of potential sites for the PMEC, it is important to consider the industry perspective. As such, collection of industry input was the first step in the technical site evaluation. This information was combined with regulatory needs and stakeholder interests to develop both initial screening criteria and detailed site evaluation criteria. The screening criteria were used to select four candidate sites for further evaluation. Finally, the detailed site evaluation criteria were utilized to evaluate the four candidate sites identified.

V.1 Input from Industry

Utilizing resources from NNMREC and OWET, feedback on requirements for an optimal grid connected ocean test site was gathered from industry. This industry input was used as the basis for the preliminary and detailed site evaluation criteria discussed below in Section V.3. In addition, the Cumulative Effects Tool developed by OWET was used to help guide the site evaluation process. For the purposes of this feasibility study, results of the Cumulative Effects Tool analysis are provided in spatial maps included as appendices to this report, including an industry report prepared by Parametrix. The table below summarizes input from industry, representing the most commercially advanced technologies.

Table 1: Industry Input on Site Requirements

Physical	
Min/Max/Optimal water depth for Point Absorbers	○ Single Device: 60m min., 80 - 100m opt., 150m max ○ 10 MW array: bathymetry driven and distance from shore, 100m if close enough to shore
Mooring footprint	○ Single Device: largest radius of 400m, 800m diameter ○ 10 MW array: same as single device until more information collected
Bottom Conditions	○ Preferred Types: sandy/mud bottom ○ Feasible Types: rock bottom (if use drilling to install anchors) ○ Non-feasible Types: reef
Construction	
Assembly/deployment scenarios:	○ Location for pre-commissioning tests of 4 - 8 weeks in sheltered area, min. 30-35m water depth (e.g., Swan Island near Portland or Vigor shipyard in Portland; considering dredging an area that would be deep enough) ○ Either barged to site or towed to site ○ At site, use ballasting to upright the system, then mooring, umbilical etc.
Required facilities:	Place to perform monitoring activities: Space for at least 3 engineers and their laptops, 120ft x 150ft staging area, covered work space of about 90ft x 120ft, AC power 120V, 200A; 240V, 200A; 480V, 200A, 150lbs air, potable water, waste water collection, fork lift, external lighting and shop lighting,

	500sq feet of office space, heating/AC, 120V, 50A; 240V 50A, internet and LAN access, phone lines, restrooms, etc.
Required equipment:	Power monitoring equipment, utility connection with fiber optic communication line
Mode of transport	From fabricator to assembly and deployment area: towed or barged from shipyards in Portland
Construction Window	○ Single Device: 12 months ○ 10 MW array: 6 - 8 months per device.
Interconnection/Power Sale	
Voltage – Min/Max/Optimal:	○ Developers are still investigating (11 - 40kV).
Mooring	○ Number of anchors: 1, 2, 3 or 6 ○ Cable length/type: synthetic line, 4 - 6in. diameter, likely chain, 400m. ○ Installation technique: anchor handling tug, or special purpose barge drop anchors ○ Removal technique: Same as installation. ○ Approach to providing financial surety for removal: bonding
Maximum Cable Length (Subsea/Terrestrial)	○ Single Device: 3 - 5miles subsea, to substation location ○ 10 MW array: similar to single device.
Power Conditioning – onboard or centralized	○ Single Device: Energy storage on WEC, Power Quality leveling improvement on WEC ○ 10 MW array, some energy storage and power quality may be centralized due to power smoothing of multiple device
Load Bank – for non-grid connected device	○ Capacity of load bank on board: example of 400 kW average, 2 MW peak
Operations and Maintenance	
Maximum transit distances for dockside and at-sea maintenance	○ Single Device: 1 hr transit each way (2 - 4 nm dockside, 8 - 12 nm at sea), to allow 6 hrs on site (full day) ○ Multi-Device Array (10 MW): Same as above
Required facilities and equipment: vessel requirements, and similar to above	○ Regular O&M ○ Major overhaul ○ Emergency response

V.2 Initial Site Screening

In order to conduct a detailed site evaluation, an initial set of screening criteria were used to develop a short-list of sites for consideration. In developing the screening criteria both the objectives of the PMEC and industry needs were used. PMEC is designed to test a variety of technologies in the near term (2-5 years) and to have a facility capable of testing both near shore and deep water technologies in the long term (5 - 10 years). Therefore, the near-term focus of the PMEC site will be to accommodate those technologies closest to commercialization (higher TRL levels in need of grid connection) and those currently funded by USDOE. The following screening criterion were developed based on industry needs expressed through project development and site assessment activities in Oregon over the last five years, i.e., technologies closest to commercialization.

Primary Site Requirements:

- Within 50 nautical miles of deep water port
- Within 15 nautical miles of service port
- Water Depth 60 - 100 meters
- Within 5 miles to 115kv transmission line from shore landing
- Soft Bottom
- Leverages existing industry activity

Secondary Site Requirements:

- Water Depth 15 - 40 meters

Based on these initial screening criteria, the following locations off the Oregon coast were identified as appropriate for further evaluation:

- Warrenton, OR
- Newport, OR
- Reedsport, OR
- Coos Bay, OR

Figure 2. WET-NZ device being deployed in New Zealand. A similar device is planned for deployment in Oregon in 2012.

V.3 Evaluation Criteria

To further evaluate the sites identified during the initial screening, detailed evaluation criteria were developed based on input from industry and from information gathered from site assessment and project development activities in Oregon over the last few years. For each site, information was collected and reviewed for each of the following criteria. (Table 2 on page 20 provides a summary of the information gathered for each site.)

Proximity to Facilities for Deployment

This criterion provides an assessment of the proximity of the project site to facilities that are suitable for final assembly and deployment of wave energy devices. For each proposed project site, the nearest port with deep water access and the required infrastructure was determined and the distance from the port to the project site was calculated using Google Earth. Note that Coos Bay has the largest industrial complex with manufacturing facilities and wharf side assembly areas that are suitable. Astoria and Yaquina Bay have less infrastructure, but are likely suitable for demonstration programs in single device deployments. Commercial deployments from these ports, however, would require new investments in infrastructure. As such, it is important to evaluate transit distances to facilities that currently have the required infrastructure. Accordingly, distances to Vigor Marine (Portland), American Bridge (Reedsport), and Saus Brothers (Coos Bay) were determined.

Note that Ocean Power Technologies plans to deploy its first wave energy device from Vigor Marine in Portland. However, its moorings are being fabricated by American Bridge in Reedsport. Vigor is approximately 287 miles from the Reedsport project site, while American Bridge is about 16 miles. This illustrates that for demonstration programs, the capabilities of the manufacturer are likely more important than the transportation distance. This is likely to change as deployments get larger and companies seek to minimize transportation costs.

Proximity to Port for Service Vessels Capable of Conducting Onboard Maintenance

This criterion provides an assessment of the proximity of the project site to facilities that are suitable for ongoing operations and maintenance that will be performed at the project site. It is assumed that these operations will be conducted by vessels approximately 40 feet in length. As such, ports with less infrastructure are suitable for this purpose. Interviews with wave technology developers have indicated that a minimum transit time from port to project site is essential. A general rule of thumb is that the transit distance should be less than two hours. The four candidate sites that have been selected generally meet these criteria. The Newport site is the closest (8 miles) and the Coos Bay site is the longest (14 miles). The Coos Bay case assumes that the operations base is located at the Saus Brothers facility, which is approximately 10 miles upriver from the jetties; however, distance to the Coos Bay site could be significantly shorter if the operations base was located closer to the jetties.

Another important factor in proximity to port is the site's susceptibility to closures due to treacherous conditions at the harbor entrance during bad weather. While recent, detailed data from the US Coast Guard are not presently available, Coos Bay and Newport are generally considered to be the best all weather ports. Access to Astoria and Winchester Bay can be significantly more difficult in the winter months because of severe weather. This is an important consideration, as early-stage projects will likely require frequent trips for maintenance, inspection, and repairs.

Proximity to Facilities for Dockside Repair

Unlike operation and maintenance, this criterion assumes that the ocean energy device must be returned to a port with infrastructure suitable for the intended repair. Failure analysis will likely indicate that devices will need dockside repair and/or maintenance approximately once per five years. This analysis assumes that it is financially infeasible to tow devices back to Portland for service. As such, ports with moderate levels of infrastructure are considered. Disconnecting and towing an ocean energy device will likely only be attempted during periods of calm weather, so port accessibility is a somewhat lesser criterion than dockside repair during severe weather.

Logistical Convenience for Staff, Developers, Researchers

This criterion attempts to provide an assessment of the convenience of the site for staff, researchers, and developers. Recognizing that the selected site will be visited frequently, it is important to consider flying and driving times. Driving distances were calculated using Google maps and flying times were calculated based on direct or one-stop flights. As expected, the Warrenton and Newport sites are the most convenient to the Portland International Airport.

Energy Resources

The Oregon coast has been studied and identified as having some of the best ocean energy resources in the lower US. The energy resource is assumed to be relatively equivalent for all sites analyzed in this study. Below is an excerpt from the work conducted by Pukha Lenee-Bluhm, Robert Paasch, and H. Tuba Ozkan-Haller on Oregon's wave energy resource (included as Appendix 1 to this report):

> *The wave energy resource has been assessed and characterized at ten locations in the US Pacific Northwest using archived spectral records from wave measurement buoys. Seasonal bias due to the distribution of missing records was compensated for by weighting the existing records such that the appropriate number of hours for each month was considered. The wave energy resource at each location was characterized using six quantities derived from each hourly spectrum: omnidirectional wave power, significant wave height, energy period, spectral width, direction of maximum directionally resolved wave power and directionality coefficient.*
>
> *. . . Strong seasonal trends were observed with greater wave power, significant wave height, energy period and directionality coefficient, and narrower spectral width, when comparing winter months to summer months. The mean wave power during the winter months was found to be up to 7 times that of the summer mean. The direction of maximum directionally resolved wave power tends to head more towards the south in the summer months, with a typically 10° - 20° less in the summer than in the winter. The sea states observed at stations closer to shore (depth <50 m) exhibited much greater directional uniformity, with a larger directionality coefficient and the direction of maximum directionally resolved wave power occurring within a smaller range.*
>
> *The wave resource was presented in detail for two representative locations, with mean water depths of 135 and 40 m. Monthly means and statistical ranges were presented for the six characteristic quantities, showing the broad range of sea states that should be anticipated at any time of the year. In addition to knowing how the characteristics of the wave resource are distributed over time, it is critical to consider distributions over energy. Empirical cumulative distributions were presented, in terms of both occurrence and contribution to total energy, for six quantities characterizing the resource.* ***While a mean annual wave power of 31 kW/m was observed at the shallower location, mean hourly wave power varied over a vast range. Wave power of 10 kW/m or less occurs 40% of the time, contributing only 8% of the expected annual energy while wave power of 200 kW/m or more occurs 1% of the time and accounts for 10% of the annual energy.***

Proximity to Interconnection

Cable length is perhaps the single largest cost factor in the development of a wave energy demonstration center. This criterion evaluates both the subsea and terrestrial distances from the proposed project sites to electrical substations (69 kV, 115 kV, 230 kV). Subsea cable lengths were calculated using the bathymetry shown in the NOAA map for each site (in Appendix 20 and assumes a perpendicular route to the beach. The terrestrial routes are based on existing rights-of-way between the beach and the substation, and the distances were determined using Google Earth. Additionally, this criterion presents the seafloor conditions for the cable route and a littoral geology, both of which could have significant influences on installation costs and permitting. Information for subsea bottom conditions was obtained from Oregon Marine map, and Google Earth was used to estimate the littoral geology (defined as the type of soil conditions at the interface between ocean and land).

It is assumed that each site would require directional drilling as the cable crosses the beach. Soil conditions are unknown for each site as detailed cable routing has not yet been established. However, it is assumed that conditions are similar at each site and that the cable crossing could be made in areas of sand and low lying land in order to minimize cost. Therefore, the primary cost differential of the transmission infrastructure is distance, with the subsea distance being the dominating factor. The general bathymetry of the Oregon coast is characterized by shallower water along the North Coast and deeper water along the South Coast. As such, the Warrenton and Newport sites have the longest subsea transit distances of 8.9 nm and 7.8 nm, respectively, to 75-meter water depth. Reedsport and Coos Bay have much shorter subsea transmission distances – 2.9 nm and 2.0 nm respectively, to 75-meters. Terrestrial distances are minimal for all four sites, with Newport being the shortest (0.8 nm) and Reedsport being the longest (3.4 nm). In summary, Warrenton will likely have the highest transmission cost, with Newport, Reedsport, and Coos Bay having similar total costs of interconnection.

Figure 3. Northwest power grid.

Potential Environmental Effects

As the environmental resources are homogenous in sandy bottom regions of the Oregon coast, no particular site is likely to have a relative benefit over another. However, the four candidate project sites are be evaluated with the goal of minimizing potential environmental effects. Based on the environmental analyses conducted by Ocean Power Technologies for their Reedsport OPT Wave Park and the West Coast Wave Energy Framework conducted by Pacific Energy Ventures, there is a strong understanding of potential stressors and receptors. Detail analyses of a selected site for a given technology type (e.g., point absorber) will be required, however, to further determine the suitability.

Potential Effects to Human Uses

This criterion evaluates each of the proposed sites based on potential for conflicts with human uses. Impacts to commercial fishing vary with the depth of the project site: shallower sites typically have more impact on the Dungeness crab fishery while sites with depths exceeding 60 m generally have little to no impact to this fishery. This assumption will be validated with the maps for each site provided by Parametrix (see Appendix 2). Aesthetics are also an important factor in site selection; devices located closer to shore (e.g., Oyster) would likely have higher potential for aesthetic effect. Similarly, sites near headlands may experience more view shed effects.

Access to Utilities for Energy Off-Take

This criterion presents some basic information on utilities that are likely to purchase power from the grid connected demonstration project. The value for this power may be a function of utilities' demand for renewable energy or mandate to buy renewable power. Interconnecting to a utility that has neither a government mandate nor self-imposed requirement (e.g., Central Lincoln Public Utility District) may require that the power be wheeled to a customer that does. This criterion is especially important as projects transition from single device testing to small array demonstration.

In addition to the above criteria discussed, site selection will be subject to other considerations such as:

- Economic Development
- Marine Traffic
- Marine Debris
- Salvage plans
- Permits/Authorizations (e.g., Oregon Territorial Sea vs. OCS)
- Baseline studies
- Long-term environmental monitoring
- Adaptive Management Plans

V.4 Candidate Site Options

Based on the initial screening criteria discussed in Section V.2, the following locations off the coast of Oregon were identified as appropriate for continued evaluation:

- Warrenton, OR
- Newport, OR
- Reedsport, OR
- Coos Bay, OR

The following section offers a detailed technical description of each of the above site location options and a summary of distinguishing features. Further detailed analysis of each site as well as stakeholder outreach will be required to determine the final, optimal location for PMEC.

Site Option 1: Warrenton, Oregon

LOCATION

This site is located on the northern coast of Oregon, west of the Camp Rilea Military base, approximately 10 miles south of the Port of Astoria.

Deployment Port:	Astoria, 10 NM
Maintenance Port:	Astoria, 10 NM
Dist. to Portland via Barge:	114 NM
Dist. to Coos Bay via Barge:	179 NM
Driving Dist. from Corvallis:	172 mi.
Driving Dist. from PDX:	97 mi.

INTERCONNECTION

Subsea Transmission Dist.:	2.7 NM to 25 m depth
	5.6 NM to 50 m depth
	8.9 NM to 75 m depth
Substrate for Cable Run:	Sand/Mud
Onshore Dist.	1.0 mi. to 115 kV
to Substation:	7.8 mi. to 230 kV
Geology at Cable Crossing:	Sand
Interconnection Utility:	PacifiCorp

POTENTIAL IMPACT ON EXISTING USES

Commercial Fishing:	Mod at 25 m depth
	High at 50 m depth
	High at 75 m depth
Aesthetics from Land:	High at 25 m depth
	Low at 50 m depth
	Low at 75 m depth
Surfing:	Low

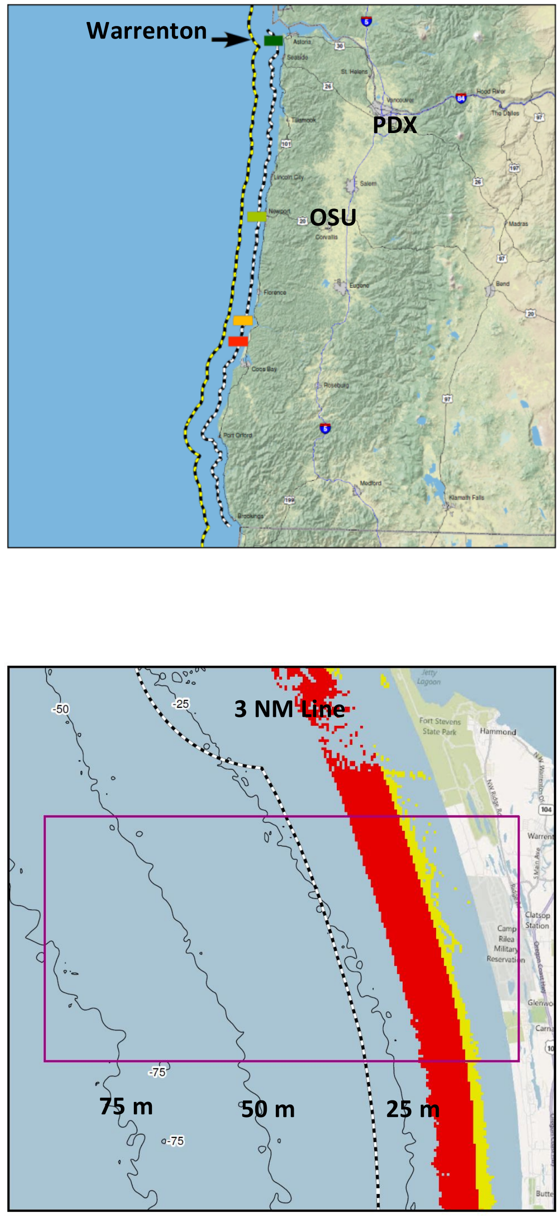


Figure 4. Warrenton Site Location Map. The lower map illustrates "locations suitable for ***coastal devices"***. More detailed analysis can be found in Appendix 2.

SUMMARY OF DISTINGUISHING FEATURES

- Close proximity to the Port of Astoria, but weather windows may be limited for port access.
- Shortest driving distance to PDX and longest driving distance from Corvallis.
- Potential to partner with OR Military Department and leverage Department of Defense infrastructure investment.
- Potentially less impact on commercial fishing pending a higher resolution analysis.
- Longest transmission distance will increase infrastructure costs.
- Gradually increasing water depth provides large potential for future commercial expansion.

Site Option 2: Newport, Oregon

LOCATION

This site is located off the central coast of Oregon to the southwest of the Newport test berth. It is southwest of Yaquina Head and approximately 8 miles north of the Port of Newport.

Deployment Port:	Newport, 8 NM
Maintenance Port:	Newport, 8 NM
Dist. to Portland via Barge:	221 NM
Dist. to Coos Bay via Barge:	94 NM
Driving Dist. from Corvallis:	52 mi.
Driving Dist. from PDX:	144 mi.

INTERCONNECTION

Subsea Transmission Dist.:	1.3 NM to 25 m depth
	2.8 NM to 50 m depth
	7.8 NM to 75 m depth
Substrate for Cable Run:	Sand/Mud
Onshore Dist.	0.8 mi. to 115 kV
to Substation:	10.1 mi. to 230 kV
Geology at Cable Crossing:	Sand/Mud
Interconnection Utility:	Central Lincoln PUD

POTENTIAL IMPACT ON EXISTING USES

Commercial Fishing:	Mod at 25 m depth
	High at 50 m depth
	High at 75 m depth
Aesthetics from Land:	High at 25 m depth
	Mod at 50 m depth
	Low at 75 m depth
Surfing:	Low

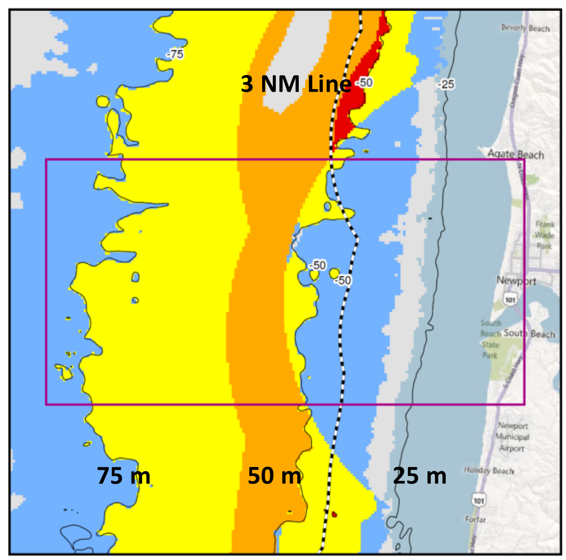


Figure 5. Newport Site Location Map. The lower map illustrates "locations suitable for ***off-shore devices***". More detailed analysis can be found in Appendix 2.

SUMMARY OF DISTINGUISHING FEATURES

- Close proximity to the Port of Newport.
- Only interconnection is with Central Lincoln PUD, a public utility with no RPS requirement.
- Very close to OSU facilities, including Hatfield Marine Science Center and Oregon Sea Grant.
- Closest site to OSU campus in Corvallis.
- Strong existing relationship with Fishermen Involved in Natural Energy (FINE).
- Gradually increasing water depth provides large potential for future commercial expansion.

Site Option 3: Reedsport, Oregon

LOCATION

This site is located on the southern coast of Oregon, due west of the Ocean Power Technologies (OPT) Reedsport Project site and approximately 40 miles north of Coos Bay.

Deployment Port:	Coos Bay, 39 NM
Maintenance Port:	Winchester Bay, 11NM
Dist. to Portland via Barge:	287 NM
Dist. to Coos Bay via Barge:	39 NM
Driving Dist. from Corvallis:	114 mi.
Driving Dist. from PDX:	211 mi.

INTERCONNECTION

Subsea Transmission Dist.:	1.0 NM to 25 m depth
	2.0 NM to 50 m depth
	2.9 NM to 75 m depth
Substrate for Cable Run:	Sand
Onshore Dist.	3.4 mi. to 115 kV
to Substation:	4.9 mi. to 230 kV
Geology at Cable Crossing:	Sand
Interconnection Utility:	CLPUD, PNGC, BPA

POTENTIAL IMPACT ON EXISTING USES

Commercial Fishing:	Mod at 25 m depth
	High at 50 m depth
	High at 75 m depth
Aesthetics from Land:	High at 25 m depth
	Mod at 50 m depth
	Low at 75 m depth
Surfing:	Low

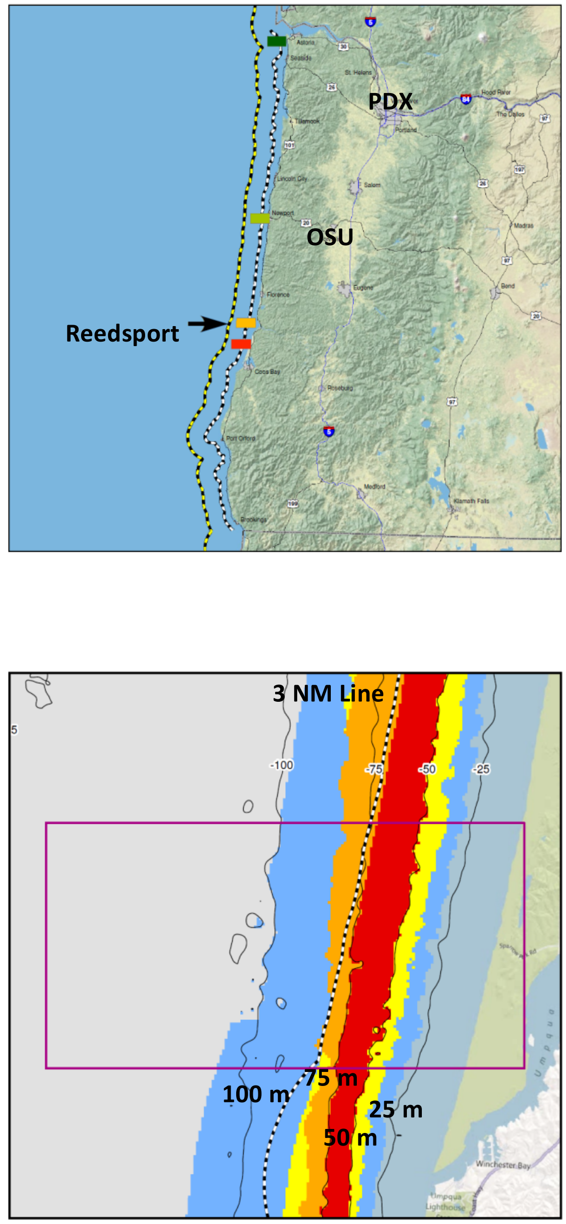


Figure 6. Reedsport Site Location Map. The lower map illustrates "locations suitable for ***off-shore devices***". More detailed analysis can be found in Appendix 2.

SUMMARY OF DISTINGUISHING FEATURES

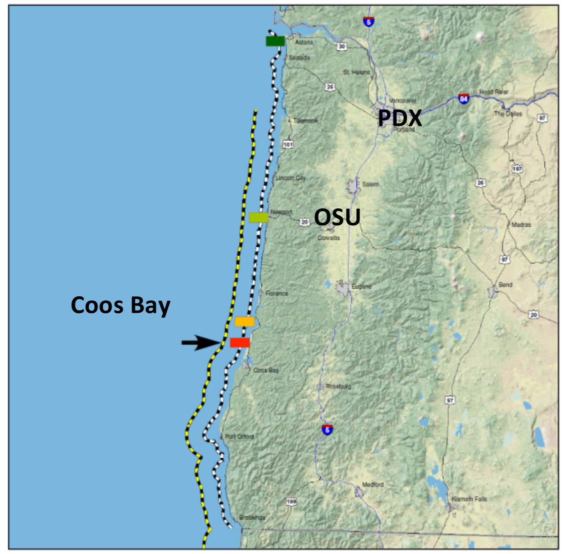
- Moderate proximity to the Port of Coos Bay, a very good all weather port.
- Very close to Winchester Bay, suitable for ship based maintenance.
- Good access to transmission and potential load base.
- Potential to partner with OPT and leverage extensive environmental analyses and studies.
- Deep water depths near shore minimize cost of infrastructure.
- Rapidly increasing water depth may limit ability to expand site for commercial development.

Site Option 4: Coos Bay, Oregon

LOCATION

This site is located off of the southern coast of Oregon, west of the town of Lakeside and approximately 14 miles north of Coos Bay

Deployment Port:	Coos Bay, 14 NM
Maintenance Port:	Coos Bay, 14 NM
Dist. to Portland via Barge:	303 NM
Dist. to Coos Bay via Barge:	14 NM
Driving Dist. from Corvallis:	136 mi.
Driving Dist. from PDX:	234 mi.



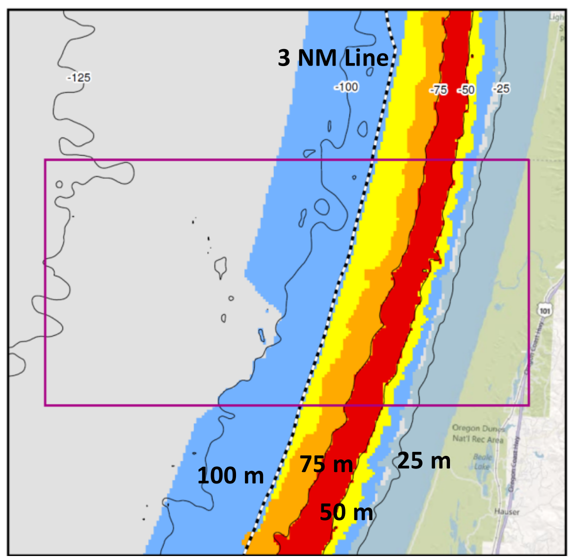


Figure 7. Coos Bay Site Location Map. The lower map illustrates "locations suitable for ***off-shore devices***". More detailed analysis can be found in Appendix 2.

INTERCONNECTION

Subsea Transmission Dist.:	0.9 NM to 25 m depth
	1.4 NM to 50 m depth
	2.0 NM to 75 m depth
Substrate for Cable Run:	Sand
Onshore Dist.	2.0 mi. to 115 kV
to Substation:	12.0 mi. to 230 kV
Geology at Cable Crossing:	Sand
Interconnection Utility:	CLPUD, PacifiCorp, BPA

POTENTIAL IMPACT ON EXISTING USES

Commercial Fishing:	Mod at 25 m depth
	High at 50 m depth
	High at 75 m depth
Aesthetics from Land:	High at 25 m depth
	Mod at 50 m depth
	Low at 75 m depth
Surfing:	Low 7

SUMMARY OF DISTINGUISHING FEATURES

- Very close proximity to the Port of Coos Bay, a very good all weather port.
- Best site for deployment and maintenance.
- Very good access to transmission and potential load base, including investor owned utilities with RPS requirements.
- Longest driving distance from PDX.
- Shortest transmission route will minimize cost of infrastructure.
- Rapidly increasing water depth may limit ability to expand site for commercial development.

Table 2: Site Evaluation Summary Table

Evaluation Criteria	Candidate Site Location			
	Warrenton	Newport	Reedsport	Coos Bay
Proximity to Deployment Facilities	10 miles	8 miles	39 miles*	14 miles
Distance to Port for Vessel Based Maintenance	10 miles	8 miles	11 miles	14 miles
Proximity to Port for Dock Repair	10 miles	8 miles	39 miles*	14 miles
Convenience to Staff, Developers and Researchers	Good	Best	Good	Good
Wave Resource	Excellent	Excellent	Excellent	Excellent
Subsea Transmission Distance	5.6 miles to 50 m*	2.8 miles To 50m	2.0 miles To 50m	1.4 miles To 50m
Potential Environmental Effects	Known Manageable	Known Manageable	Known Manageable	Known Manageable
Potential Effects to Existing Users	Low	Low to Moderate	Dungeness Fishery*	Dungeness Fishery*
Access to Utilities for Energy Take-Off	PacifiCorp	CLPUD	CLPUD PNGC BPA	BPA PacifiCorp CLPUD

* Denotes attribute that may not meet the criteria discussed in Section V. Further investigation is required to assess accurate site characteristics.

VI. Cost Drivers and Estimates

NNMREC has estimated the cost of developing the PMEC to be approximately $25 million. This estimate is based on outreach with industry representatives and international marine energy centers similar in size and scope. At this cost, it is anticipated the PMEC could accommodate up to four full scale ocean energy devices at a time. A more detailed analysis of the total costs of the PMEC is underway, in conjunction with a robust fundraising strategy.

Although a more detailed cost proposal is still under development, NNMREC has determined that the majority of the cost drivers for this project include:

- Sea Based Infrastructure (e.g., subsea cables, power pod, etc.)
- Land Based Infrastructure (e.g., interconnection, load bank, shore based facilities, etc.)
- Operations and Maintenance
- Testing and Commissioning

Based on current analysis, it has been determined that the subsea cable lengths will the primary cost differential between the sites, whereas the other cost drivers should remain relatively constant.

NNMREC anticipates a combination of private and public funds to fully develop PMEC, and has a proven track record in developing industry partnerships. These leveraged funds will come from a variety of sources, but likely to include the following:

- State of Oregon
- Federal Agencies
- Private Foundations
- Industry Associations
- Developers/Utilities

VII. Conclusion and Next Steps

Based on the detailed site analysis outlined in this report, all four locations meet the technical feasibility requirements for a grid connected test facility. However, there are other factors to consider before a final site selection is made. NNMREC will pursue the following actions over the next few months to determine which site would best support the grid-connected elements of PMEC.

- *Cost Evaluation*: NNMREC will pursue detailed cost estimates and evaluate how each site may increase or decrease the cost of deployment and operation.
- *Leveraging Value*: NNMREC will evaluate each site in how best they leverage existing and future activities and investments.
- *Stakeholder Input*: NNMREC will take the analysis to local stakeholders and other interested parties to gather additional input prior to moving forward on one or more PMEC site options.

Results from this information gathering will inform the final site-selection decision, with an anticipated completion date of early 2012.