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Market Analysis Report

For the Pacific Marine Energy Center South Energy Test Site

Prepared by
GL Garrad Hassan
On behalf of Oregon Wave Energy Trust

December 9, 2013

Acknowledgement: This material is based upon work supported by the Department of Energy under Award Number DE-FG36-08GO18179.”

Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership funded by the Oregon Innovation Council. Its mission is to support the responsible development of wave energy in Oregon. OWET emphasizes an inclusive, collaborative model to ensure that Oregon maintains its competitive advantage and maximizes the economic development and environmental potential of this emerging industry. Our work includes stakeholder outreach and education, policy development, environmental assessment, applied research and market development.

Renewable energy consultants

GL Garrad Hassan

MARKET ANALYSIS REPORT
FOR PMEC WAVE ENERGY TEST FACILITIES

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MARKET ANALYSIS REPORT

FOR PMEC WAVE ENERGY TEST FACILITIES

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Author

J. Goldsmith, F. Jones, P. Laporte Weywada

Checked by

F. Jones, J. Goldsmith

Approved by

J. Cruz

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A	October 17, 2013	Initial issue for Client review
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EXECUTIVE SUMMARY

The Oregon Wave Energy Trust (OWET) is working with the Northwest National Marine Renewable Energy Center (NNMREC) to support their development of a full-scale, grid-connected ocean test center for wave energy converters (WECs): the South Energy Test Site (SETS) of the Pacific Marine Energy Center (PMEC) in Oregon. The primary goal of PMEC SETS is to advance understanding of the effects and capabilities of WEC devices in order to support industry to responsibly reap the benefits of this clean, renewable energy resource.

To move forward in the development of PMEC SETS, OWET commissioned Garrad Hassan America, Inc. (GL GH) to carry out a wave energy market analysis. The objective of this study is to identify potential end-users of the test center and their needs, based on current and future requirements of the wave energy industry. The findings detailed in this report will inform the infrastructure design and the services offered for PMEC SETS to be an integrated, standardized test center for wave energy developers.

GL GH approached this work in three stages.

1. Sector profile

GL GH began by analyzing the current and future prospects for wave energy. The wave energy market is dynamic, with a strong need for testing and demonstration in the next 5 to 10 years. European countries have historically been the main hubs of activity for large-scale prototype deployment, but the U.S. market is promising in terms of feasible resource, current interest and activity, and in some cases, attractive local policies. Global activity in the wave energy field over the next several years is expected to reduce costs, attract investors, and accelerate the transition from prototype testing to array planning. Growing interest from large industrial players, such as major utilities or multi-national original equipment manufacturers (OEMs), in the market could also drive a step change in the rate of deployment.

2. Stakeholder consultation

Following the “big picture” analysis of the wave energy market provided in the previous section, the stakeholder consultation drilled down to the needs of potential PMEC clients in terms of technical requirements and services offered. Drawing upon its internal database, GL GH identified 37 WEC developers who are sufficiently advanced to be potential end-users of the PMEC SETS test center considering a roughly 5-year timeframe. Nineteen of these developers completed GL GH’s online survey, and 13 follow-up interviews were conducted. GL Garrad Hassan would like to thank all developers who took the time to contribute to the stakeholder consultation.

3. Gap Analysis

Based on the results of the above two phases, GL GH conducted gap analyses that compared developers’ requirements and preferences with both site conditions at the proposed location and an initial proposed technical offering for PMEC SETS. As the general site for PMEC SETS has already been selected, there is limited scope for NNMREC to change these conditions, but it was found that the physical site conditions broadly meet the needs of developers with technologies designed for offshore applications. Should NNMREC find it advantageous, there is more scope to modify its technical offering for PMEC SETS going forward, although several of the current plans are also well matched with developer preferences.

1 INTRODUCTION

This report is issued to the Oregon Wave Energy Trust (OWET), who commissioned Garrad Hassan America, Inc. (GL GH) to carry out a wave energy market analysis to help inform the Northwest National Marine Renewable Energy Center (NNMREC)'s plan for developing a full-scale, grid-connected, open ocean test center for wave energy converters: the South Energy Test Site (SETS) at the Pacific Marine Energy Center (PMEC).

The objective of this report is to identify potential clients and their needs based on the current and future (the next 5 to 10 years) requirements of the wave energy industry.

The report is structured as follows:

- Sector profile: this section includes the analysis of the current market offering and market trends, an overview of similar facilities and the identification of potential end-users (Section 2);
- Stakeholder consultation: this section presents the results of the survey addressed to technology developers. The objective of this consultation was to define core target technical and service requirements (Section 3);
- Gap Analysis: based on the results of the previous phases, this section compares developers' requirements and preferences with both site conditions at the proposed location and an initial proposed technical offering for PMEC SETS (Section 4).

Key findings and concluding remarks are summarized in the final section of this report (Section 5). GL Garrad Hassan would like to thank all developers who took the time to contribute to the stakeholder consultation.

2 SECTOR PROFILE

In this chapter, GL GH analyzes the current and future global wave energy market by examining its likely growth, facilities, possible innovation and key players over the next 5 to 10 years. GL GH begins the chapter by considering the big picture – the global wave energy market – before drilling down to the aspects relevant to PMEC. In doing so, GL GH adopts a three-stage structure as follows:

- Summarizing global activity and dynamics in the wave energy market;
- Reviewing existing and planned wave energy testing facilities; and
- Identifying potential PMEC clients for SETS.

2.1 Market Dynamics

The wave energy market is a *global* and *dynamic* market, and it is crucial that NNMREC's development strategy for PMEC SETS is informed by worldwide trends. In this section, GL GH seeks to summarize the wave energy "big picture", considering the following points in separate subsections:

- Global activity;
- U.S. activity;
- Current technology status; and
- Areas of innovation.

2.1.1 Global Activity

Figure 2.1 provides an illustration of the geographic distribution of large-scale (100 kW+) WEC prototype deployments over the last 10 years, including the first half of 2013. As can be seen, Portugal and the United Kingdom (UK) have historically been the main hubs of activity. The Pelamis prototype became the first full-scale offshore wave energy converter to generate electricity into the UK national grid in 2004, soon followed by a 2 MW Archimedes Wave Swing (AWS) prototype later installed in Portugal during the same year. Further deployments and test campaigns have followed for a variety of concepts. A first pre-commercial array was tested in 2008 to 2009 at the same Portuguese site, again featuring Pelamis technology. The majority of additional large-scale prototype deployments have occurred at EMEC in Scotland, although there have also been others in Australia, Denmark, Italy, Spain, Brazil, China and Korea.

The United States (U.S.) is notably not included in Figure 2.1, as no large-scale WEC prototypes have yet been deployed in the country. Smaller scale (<100 kW) sea trials have occurred for a handful of developers, including one grid-connected WEC from Ocean Power Technologies deployed from 2009 to 2011 at Marine Corps Base Hawaii on the island of Oahu.

Looking to the future, there are a number of countries with promising markets for commercial marine energy deployment; Figure 2.2 summarizes these by taking into consideration feasible resource, current activity and attractive local policies. For wave energy, the countries that currently have the highest potential to see significant development in the near to medium term are the UK, the U.S., Australia, Japan and France. Although Spain and Portugal have historically had supportive policy regimes, current macroeconomic difficulties in these countries are limiting their financial capacity to support wave energy at present. Looking more long term, China and Chile show promising seeds of development.

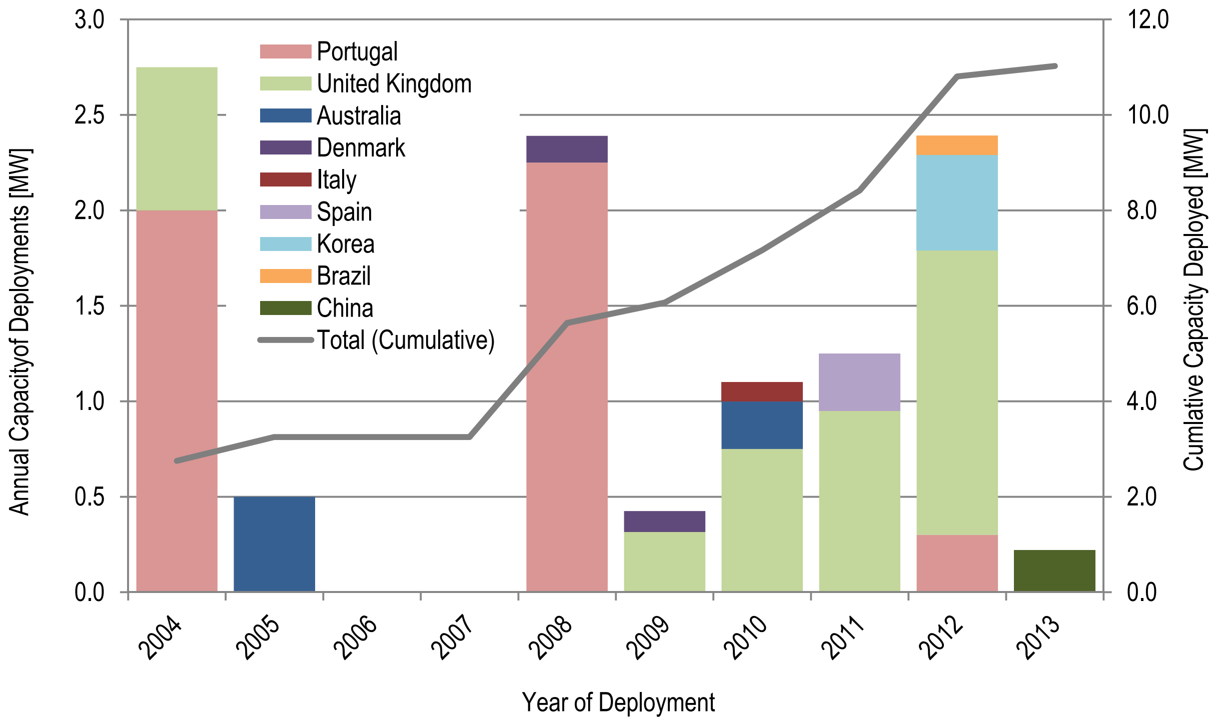

Figure 2.1. Summary of large-scale WEC prototype deployments by country over last 10 years

Notes: Includes any new, large-scale (i.e. greater than 100kW) deployment, regardless of grid-connection and time deployed (although most large-scale prototypes were grid-connected). As some units were removed after testing periods, cumulative capacity deployed does not represent total installed capacity today.

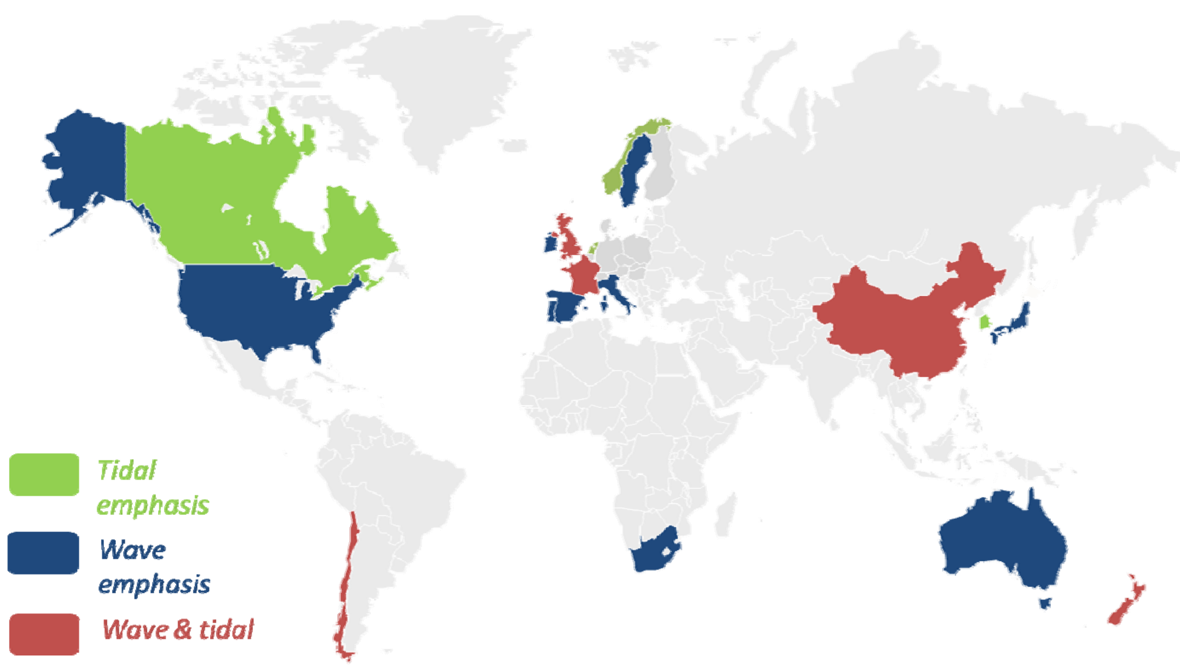

Figure 2.2. Promising markets for wave & tidal energy (based on resource, current activity and policy)

The wave energy industry is a sector under global development, and such international efforts will increase competitive pressure on U.S. businesses and on PMEC's core activities. A concerted effort will be needed to ensure that PMEC (and Oregon) can benefit from early movers that have an interest in testing prototypes at SETS. Such a coordinated effort involves other leading U.S. entities, and should aim to create unique conditions around initial facilities at SETS by:

- *Building on the U.S. Department of Energy (DOE)'s Water Power Program* to ensure that large-scale prototype (and array) deployments aimed at technology demonstration have a suitable facility at PMEC, and
- *Increasing local supply chain awareness and capabilities* by ensuring that shipyards, contractors, vessel operators and other service providers are well informed and equipped to serve this new industry.

The global activities in the wave energy field also bring opportunities: higher levels of deployment help to bring costs down at a faster rate – as well as providing the *"industry buzz"* required to attract investors and, in the longer-term, project finance. A global increase in the market penetration of WEC technologies will aid the ***transition from technology/prototype testing to array (wave farm) demonstration and planning***, potentially leading to an increase in demand for PMEC facilities for the demonstration of small arrays. It is becoming apparent in Europe that larger-scale investor buy-in – and certainly commercial project financing – will not come until small arrays are tested and demonstrated in fully energetic environments. As the vast majority of all WEC developers have yet to reach the point of array testing, PMEC may be in an excellent position to facilitate such small array deployments for both U.S. and international developers. Furthermore, the marine and environmental science expertise found at Oregon State University (OSU) could potentially use array deployments at SETS to analyze array-scale effects on the environment, thus helping to reduce a key source of regulatory uncertainty in the U.S.

2.1.2 U.S. Activity

While Europe has been working to develop wave energy for well over a decade, significant U.S. interest in the sector has only really grown over the last several years. Many of the recent developments in the wave energy sector have been federally funded through the U.S. DOE. Wave energy technologies are classified within the DOE's Wind and Water Power Program as a subset of marine and hydrokinetic (MHK) energy. U.S. congressional appropriations for fiscal year 2008 allowed the DOE's Wind & Water Power Program to fund MHK research for the first time (in many years) and significant funding is now being allocated toward the development of MHK technologies. Of the DOE's allocated budget of $59 million for the Water Power Program's research and development (R&D) in fiscal year 2012, $34 million was specifically budgeted to MHK technology research, development, and demonstration. In fiscal year 2013, the specific allocation for MHK was roughly the same from the $55.6 million Water Power Program budget.

In particular, after a series of DOE-funded national resource assessments determined that the potential electric generation from waves in the U.S. is approximately 1170 TWh/yr[1], a figure significant in comparison to national electricity usage (~4000 TWh/yr) and much greater than the potential from other MHK sources, the DOE has emphasized its interest in supporting the commercialization of WEC technologies. This has been manifested in the form of recent DOE funding opportunity announcements (FOAs) for development of advanced WEC components[2], and further funding supporting the development of wave energy test facilities[3], like those of PMEC. Once the technology reaches commercial viability for the respective markets, all of the Pacific states (Washington, Oregon, California, Hawaii and Alaska) will have the wave resources to eventually support utility-scale electricity generation from WECs deployed off their coasts in offshore arrays.

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[1] http://www1.eere.energy.gov/water//marine_assessment_characterization.html
[2] http://www1.eere.energy.gov/water/financial_opps_detail.html?sol_id=599
[3] http://www1.eere.energy.gov/water/financial_opps_detail.html?sol_id=592

2.1.3 Current Technology Status

Wave energy is still at its infancy from an industrialization perspective, and as such the market is fluid and subject to considerable uncertainty in the future.

To date, the vast majority of deployments have occurred in grid-connected tests centers. For example, with the exception of the LIMPET OWEC plant (installed in 2000 and originally rated at 500 kW), all the documented deployments in the United Kingdom (~4.5MW, considering a redeployment of the first Pelamis full-scale prototype in 2007) have occurred at EMEC. This tendency partially justifies the current push for additional testing facilities in Europe (see Section 2.2).

Single machine prototype testing has been the dominant feature, with the sole exception being the 2.25 MW Pelamis P1A wave farm installed in Portugal in 2008 (currently not in operation). More recently a large number of deployments have occurred at EMEC in the Orkney Islands, UK and a first deployment of the 300 kW nearshore prototype WaveRoller occurred in Portugal, as part of the FP7 EU-funded SURGE project. The Mutriku Plant (296 kW) is the only onshore concept, and the Oyster 2 (800 kW), WaveStar (110 kW) and WaveRoller (300 kW) prototypes are the only nearshore concepts to be installed at full-scale and grid-connected post 2003.

Technology status can be summarized as follows:

- *First-Of-A-Kind (FOAK) demonstration*: technology demonstration is still necessary. In particular, demonstration of reliability remains a crucial step for most WEC technology developers.
- *1 MW class*: despite covering a wide selection of technology iterations and types, most concepts have rated capacities in the 100 kW to 1 MW range.
- *Offshore deployment*: with the exception of relatively few onshore and nearshore concepts, deeper water deployments (and facilities) are now more commonly pursued.
- *Grid-connected at full-scale*: the ability to demonstrate power generation to an electricity grid is seen as a key feature of any deployment (including those in test centers).

2.1.4 Areas of Innovation

GL GH expects that the wave energy sector will experience substantial technical and commercial innovation in the next 5 to 10 years.

The need to reduce the cost of energy for wave energy to become commercially viable will drive technical innovation. It is expected that industry-specific designs, for instance exploring alternative materials – such as fibre-reinforced plastics (FRPs) – and the deployment of bespoke wet-mate connectors will be areas of likely innovation. Furthermore, technologies that are disruptive in regard to the current major concepts may still emerge, which contributes to the considerable uncertainty that surrounds wave energy activities.

However, the main objectives of WEC and WEC farm demonstration and testing are unlikely to be affected by technology innovation, which in turn implies that *the need for grid-connected test centers in the next 5 to 10 years is decoupled from such potential innovations*. For example, any major technological leap is unlikely to modify the primary objectives for all WEC technologies in the short to medium term, which includes demonstration of reliability, survivability and performance. This priority is exemplified by the fact that EMEC is at present operating at full capacity, as well as the proliferation of planned test centers across Europe.

In terms of commercial innovation, the entry of new industrial players into the market is expected to have significant implications in terms of project development and contracting structures. In recent years, major European utilities have acquired considerable stakes in front line technologies, showing an appetite to be involved as long-term, strategic partners.[4] In addition, the entry of large Original Equipment Manufacturers (OEMs) such as Alstom and large defense contractors such as DCNS brings valuable industrialization expertise, assisting in the transition from concept to detailed design. If this trend of engagement by utilities and OEMs and other large corporations continues, it could drive a *step change in the rate of deployment.* However, this crucially depends upon momentum being maintained: it should be noted that *a lack of major progress on wave energy in the medium term is likely to divert the attention of these players into other marine renewable energy technologies* such as floating offshore wind or tidal energy.

2.2 Review of Existing / Planned Wave Energy Facilities

In this section, GL GH globally examines both operational and planned wave energy test facilities suited for full-scale technology demonstration. The purpose of this review is two-fold: to provide case studies from which NNMREC can learn, as well as to identify potential niches which PMEC might uniquely fill.

The idea of dedicated, multi-berth marine energy test sites first appeared in Europe, and the level of experience in the planning and operation found there is generally higher than in the rest of the world as a result. The main European test facilities listed below are presented in a first subsection 2.2.1. Some of these facilities are dedicated wave energy facilities; others also accommodate other marine energy technologies, such as tidal energy converters and floating offshore wind:

- The European Marine Energy Centre (EMEC) – UK;
- Wave Hub – UK;
- Atlantic Marine Energy Test Sites (AMETS) – Ireland;
- Site d'Expérimentation en Mer pour la Récupération de l'Énergie des Vagues (Wave Energy Test Site at Sea, SEM-REV) – France;
- Biscay Marine Energy Platform (BIMEP) – Spain;
- Ocean Plug – Portugal;
- Maren Test Site – Norway;
- Plataforma Oceánica de Canarias (Oceanic Platform of the Canary Islands, PLOCAN) – Spain; and
- Danish Wave Energy Center (DanWEC) – Denmark.

Technical information available in the public domain was gathered on these facilities, and when required, was verified via direct contact with the facility managing bodies. In addition to the facilities listed above, a number of test facilities for WECs, already in operation or recently announced for development outside of Europe, are briefly reviewed in Section 2.2.2. In particular, test centers in Asia and North America are addressed.

2.2.1 Existing / Planned Test Facilities in Europe

There are a number of facilities for the testing or pre-commercial demonstration of WECs. Several fully developed and long-running sites are not considered in this section when they are suitable only for smaller scale devices. For instance, the Galway Bay site in Ireland has been operational since 2006 but, due to sheltered wave conditions, it is suitable only for devices in the 1:3-1:5 scale range. Similarly, EMEC recently opened an intermediate scale test facility in Scapa Flow, to the south of Kirkwall, that provides several options for engagement with technology developers.

[4] GL GH notes that U.S. utilities operate under different models and are unlikely to acquire equity stakes in WEC technologies.

The European Marine Energy Centre (EMEC) was the first full-scale site to become operational. It was established in the Orkney Islands (Scotland) in 2003 and its wave energy test site at Billia Croo opened in 2004 when Pelamis deployed the first WEC at the site. EMEC provides a center to test both wave and tidal energy devices in two locations around Orkney. The wave energy test site contains five berths off Billia Croo, Stromness at the 50 m depth contour. This site is located to the west of the islands in the prevailing direction of swells from the Atlantic. The tidal site, located at the Fall of Warness to the west of the island of Eday, consists of eight test berths in water depths of between 25 and 50 m. The site is located in a straight between islands with tidal flows of up to 7.8 knots. Both sites are equipped with subsea power cables connected to the UK electricity grid (2.2 MW capacity per berth for the wave site; 5 MW capacity per berth for the tidal site), resource measurement equipment and a supervisory control and data acquisition (SCADA) system to monitor substation and environmental variables. The wave energy site includes two wave measurement buoys giving wave amplitude, frequency and directional information. At the tidal site the flows are measured using Acoustic Doppler Current Profilers (ADCP). Regarding the leasing costs of a wave energy test center at EMEC, the only information available in the public domain was released at the 3rd International Wave Energy Summit held in London (June 23rd-24th 2010): Richard Morris, EMEC's Business Development Manager, was queried regarding this aspect and mentioned a typical (average) cost of £220k per annum. It is understood that this indication may be subject to changes depending on the duration of lease and the berth's location. This reference value may be used when comparing the expectations regarding revenues, for scenarios involving full-scale, grid-connected wave energy converter test sites.

The Wave Hub site completed connection with the national grid in November 2010. The site is located in the South West of England, approximately 16 km off the coast of Cornwall. Surveys occurring since 2005 have resulted in average wave resource measurements of about 18 to 20 kW/m in this region. With an area of 8 km^2 and four berths, it is anticipated that it will house arrays of four different technologies with a total capacity of 16 MW. Consent is being sought to increase this capacity to 50 MW. As yet, no devices have been installed. The first technology to be deployed at the Wave Hub is likely to be the Ocean Energy Ltd (OEL) OE buoy[5]. Wave Hub expects the deployment of the 1 MW device to take place later this year (2013). OEL is currently in discussions with local supply chain companies about support with fabrication and deployment, and aims to operate from the newly refurbished North Quay in Hayle Harbor. About 40km south of Hayle, the FaB Test nursery facility in Falmouth enables wave energy device developers to test components, concepts or full-scale devices (up to three) in a moderate wave climate.

The Biscay Marine Energy Platform (BIMEP) is being developed by the Basque energy board (EVE – Ente Vasco de la Energia) in Bilbao, Spain. Some suggestions pointed out that a reduction of BIMEP's area would facilitate access to Armintza's harbor in heavy sea conditions. The initial deployment area of 8 km^2 was hence reduced to 5.3 km^2. Four berths of 5 MW capacity each are connected to the grid. Metocean conditions experienced at the site are similar to those found at Wave Hub, with an average resource estimated at 21 kW/m. The overall budget for the development of BIMEP is €15 million.

The Site d'Expérimentation en Mer pour la Récupération de l'Énergie des Vagues (SEM-REV) site off the coast of Brittany in France is similar to EMEC in terms of installed capacity and purpose: it is intended for the testing of individual units and there is currently no plan for expansion of the 8 MW installed capacity. Bathymetry and geology surveys have been conducted. The test site occupies approximately a 1 km^2 test zone area and is fully instrumented and monitored. The wave resource has been estimated at 10 to 14 kW/m. The test site comprises an 8 MW power cable connected to the national grid through an onshore substation. Facilities for monitoring and controlling the systems are currently available on the site. The test site is also suitable for testing floating offshore wind turbines. With consents approved in July 2011, the test site is considered to be "operational" although no devices have yet been deployed. The project is led by French university École Centrale de Nantes, which has a strong heritage of wave energy R&D, in particular in the development of the wave energy converter SEAREV.

[5] http://www.wavehub.co.uk/news/press-releases/marine-licence-approved-for-first-wave-hub-deployment/

The Atlantic Marine Energy Test Site (AMETS), located near Belmullet in County Mayo on the west coast of Ireland will provide grid-connected test facilities for shallow water (10-25 m, annual average wave power about 30 kW/m), intermediate (~50 m, annual average wave power about 60 kW/m) and deep water (~100 m, annual average wave power about 70-80 kW/m) WECs. Environmental scoping and cable routing surveys for the site have been completed. The site will use four 10 kV submarine cables, two from the 50 m test area and two from the 100 m test area. In April 2013, SEAI published a call for expression of interest with the aim of entering an agreement for deployment of device(s) at the 50 m and 100 m contour sites at AMETS by 2015.

The Portuguese pilot zone, Ocean Plug, is located near São Pedro de Moel, in the Marinha Grande region. It consists of a (approx.) 400 km^2 area where the water depth ranges between 30 m and 90 m. The concession contract was granted in October 2010 to ENONDAS, part of the Rede Eléctrica Nacional (REN) group (the national grid). The main site surveys were completed in 2012 and will be available publically, along with the detailed planning stage conducted in 2011. Seabed conditions are mostly sandy and port facilities are available within 30 km. Wave climate measurements carried out in 2011 completed previous wave estimates from numerical models, which indicated that the annual average wave power is between 20-30 kW/m at this location (along with more than 20 years of measurements in Figueira da Foz, a neighbor location). ENONDAS is effectively a one-stop-shop for wave energy projects at Ocean Plug, eliminating any leasing discussion with additional entities, and has a mandate to develop the offshore infrastructure to accommodate up to 80 MW of projects in a first phase. The pilot zone is estimated to be operational and ready to receive the first developers in August 2013.

The Maren Test Site is situated approximately 400 m off the island of Runde (West-Norway) at 45 m water depth on gravel substratum with interspersed rock and some sand. The installation consists of an underwater switchgear and a subsea cable (2.7 km) connecting the generators to the 22 kV grid. The site has already hosted a small array of two full-scale devices (from developer Seabased AB) with a maximum capacity of 20 kW from 2009 to 2012. The five-year operational permit is valid until January 2014.

Plataforma Oceánica de Canarias (PLOCAN) is a Public Consortium ruled by the Spanish Government and the Regional Government of the Canary Islands. PLOCAN consists of marine scientific and technical infrastructure to facilitate the development of new oceanic technologies providing different services to the enterprises and researchers. Its five strategic lines are: ocean observation, underwater vehicles, marine test site for emerging oceanic technologies focused on ocean energy converters, platform of innovation and training center. The site is located on the east coast of Gran Canaria of the Canary Islands in Spain. It is located at the border of the continental platform with depths between 30-200 m in the Atlantic Ocean. This test site has been operative without grid connection since 2010. Grid connection is expected by the end 2013. PLOCAN will be built to host up to 10 MW of installed capacity. The test site avoids sensitive areas according to the terms of NATURA 2000[6] or any National and Regional Declarations. Environmental authorization, marine space occupation and grid connection/power generation procedures are currently underway.

The Danish Marine Test Site (DanWEC), established in 2009, is located in the North Sea near Hanstholm, in the northwest of Denmark. It has a fetch of about 600 km to the west, sheltered by the UK. The site is grid-connected. To date, the devices that have been tested at DanWEC are Wave Star and Dexawave. About 90 km south of Hanstholm, in the Nissum Bredning fjord, the Folkcenter Wave Test Station is a small facility in operation since November 2000. Since then, it has hosted the WaveDragon prototype from 2003 to 2005, and a 1:10 model of the WaveStar concept from 2006 to 2011.

[6] Natura 2000 is EU-wide network of nature protection areas. It is comprised of Special Areas of Conservation (SAC) and Special Protection Areas (SPAs)

2.2.2 WEC Test Site Developments Outside of Europe

Outside of Europe, a number of countries are entering the emerging marine renewable energy market, with recent announcements of test center developments across Asia, New Zealand and the United States of America (U.S.). Although there is relatively scarce information in the public domain on these test centers, such developments are indicative of momentum within the ocean energy industry. As in the previous section, sites not considered fully energetic were removed from discussion here. One such site is the University of New Hampshire in the U.S.'s Center for Ocean Renewable Energy (CORE) site, where only partial-scale WEC testing has been conducted or is planned.

In Asia, the Ocean Energy Association of Japan (OEAJ) announced in 2012 its intention to develop its first marine energy test center, the Japanese Marine Energy Centre (JMEC). An ongoing development program, sponsored by the New Energy and Industrial Technology Development Organization (NEDO), aims to bring to market both wave and tidal energy conversion technologies and create suitable protocols for the testing (and further large-scale implementation) of such technologies in Japanese waters. In March 2012, EMEC has signed a memorandum of understanding with OEAJ, arranging for EMEC to provide advice and support on the design, set up and operation of JMEC.

Also in 2012 the Republic of China announced an international collaboration agreement with EMEC to develop a marine energy test facility in Taiwan. The demonstration site for wave and tidal power in the state aims to help Taiwan meet its target for 200 MW of installed marine energy power capacity by 2025.

In New Zealand, the Aotearoa Wave and Tidal Energy Association (AWATEA) initiated the first steps toward the development of potential wave and tidal test sites. A formal business case detailing cost and funding models is to be submitted before agreement can be made with the Ministry for Economic Development for partial funding of the project. The proposal being developed aims to include the twinning of the planned New-Zealand Marine Energy Center (NZMEC) with EMEC.

More advanced steps have been taken in the U.S. In 2008, the United States Department of Energy (DOE) established three National Marine Renewable Energy Centers. These DOE-funded, university-led centers seek to facilitate the development of marine renewable energy technology via education, research, demonstration, testing, and commercial application of marine and hydrokinetic energy (MHK) technologies. By providing the necessary domestic expertise and infrastructure needed to facilitate comprehensive, standardized testing of MHK devices, and the production of environmental and performance data, their ultimate goal is to provide the necessary levels of confidence to enable the private financing of commercial generation plants. Amongst these national centers, two have an interest in WEC testing: the Northwest National Marine Renewable Energy Center (NNMREC) and the Hawaii National Marine Renewable Energy Center (HINMREC).

The Northwest National Marine Renewable Energy Center (NNMREC) is a partnership between Oregon State University and the University of Washington. The former focuses on wave energy resources and technology, whereas the latter focuses on tidal energy. In August 2012, scientists from NNMREC demonstrated a new $1.5 million mobile wave energy testing device called the Ocean Sentinel. The bright yellow buoy is based on the sturdy offshore Navy Oceanographic Meteorological Automatic Device (NOMAD) hull, and is equipped with an array of instruments to take measurements and monitor a connected WEC system. The Ocean Sentinel floats on the water's surface and was deployed (2012) at the Pacific Marine Energy Center North Energy Test Site (PMEC NETS), a 1 square-mile test site located two miles northwest of Yaquina Head off the Oregon coast, near Newport. The Ocean Sentinel is designed for testing WECs connected to it by a power and communication umbilical cable and provides power analysis, data acquisition, environmental monitoring, and an active converter interface to control power dissipation to an on-boar electrical load. In 2012, NNMREC received a new DOE award of $4 million to complete the design of a full-scale, grid-connected ocean energy test facility, the Pacific Marine Energy Center South Energy Test Site (PMEC SETS), capable of accommodating commercial scale devices. In early 2013, Newport, Oregon was selected as the home of the new PMEC SETS facilities being designed under that first installment of federal funding.

The primary objective of the Hawaii National Marine Renewable Energy Center (HINMREC) is to facilitate the development and implementation of commercial wave energy systems and to accelerate development and testing of ocean thermal energy conversion (OTEC) technologies. The Hawaii Natural Energy Institute at the University of Hawaii runs the center, which has received DOE funding to apply their capabilities and experience to the build-out of the U.S. Navy's Wave Energy Test Site (WETS). HINMREC is collaborating with the U.S. Navy to expand existing facilities to provide multiple berths for devices in the 100 to 1000 kW range. WETS, located at Marine Corps Base Hawaii in Kaneohe Bay, Oahu offers a grid-connected test berth at 30 m depth for systems classified as "point absorber" or "oscillating water column" technologies. This is the site where Ocean Power Technologies, Inc. tested one of their PowerBuoy prototypes from 2009 to 2011. The new expanded test site will allow for testing in water depths ranging from 30 m to 80 m. The vision for HINMREC involvement in this project consists of participating in activities at a fully operational WETS and continuing to provide services required to evaluate WEC designs.

2.3 Potential PMEC Client Base

Having considered the global market and existing test facilities, GL GH next focused more specifically on the identification of WEC technology developers that are most likely to seek deployment at an open ocean test facility in the next 5 to 10 years, and as such may represent NNMREC's potential client base for PMEC SETS.

GL GH developed and maintains an internal database of known wave and tidal energy developers from around the world. The database is updated regularly as new information is released in the public domain regarding the various developers and their projects. At the date of this report, the database included 172 WEC developers, of which 97 are known to be actively progressing their concepts. Of those actively engaged in development, 37 WEC technology developers were identified from 12 different countries around the world that meet a minimum threshold of assessment criteria that GL GH considers to be important in the advancement of concepts toward commercialization:

- Technology Development
  - Company History (>5 years)
  - Staff (>10 full-time)
  - Investment (>£1m)
  - Investment (>£10m)
- Technology Classification
  - Established Power Take-Off (PTO)
  - Established Deployment Strategy
  - Established Operations and Maintenance (O&M) Strategy
- Evidence of a Modeling Program
  - Numerical Modeling Program
  - Experimental Modeling Program
  - Prototype Deployed at Sea
- Full-Scale Design
  - Independent Verification Achieved
  - Full-Scale Prototype (FSP) Deployed

Using available public domain information and GL GH's informed judgment, concepts are given a point for each of the above 12 criteria that is met (0.5 points for an unconfirmed "yes"), resulting in a total score between 0-12 points. Looking at those that score more than 5/12 helps to generate a shortlist from GL GH's in-house database. As such, the shortlist generally reflects developers that are likely to have achieved higher Technology Readiness Levels (TRLs)[7], which would warrant full-scale ocean testing and/or demonstration at site such as SETS in the near term, or developers at lower TRLs that are particularly active and for which the development plan is well aligned with the PMEC timescales.

Furthermore, from GL GH's understanding of NNMREC's current plans, developers pursuing onshore WEC concepts (i.e. located on the shoreline or in shore-based coastal structures such as breakwaters, piers, etc.) were excluded from the list. Reflecting the global nature of the wave energy market, GL GH has assessed technology developers that originate in a range of countries across multiple continents. Nonetheless, given the benefits of geographical proximity, it is expected that developers based in the U.S. could be particularly interested in PMEC SETS's offering. Therefore, certain U.S. developers that are potentially in earlier stages than required are still included in the shortlist.

It is important to note that the developed list does not reflect the opinion of GL GH, OWET, or NNMREC on which concepts may ultimately prove successful at cost-effectively generating electricity from wave energy in commercial projects. Instead, the list was determined by publically available information regarding achievement of standard industry milestones along the pathway to technology readiness. The methodology helps to demonstrate what aspects of the development process each concept has undergone. It should be noted that the methodology does not fully consider individual differences between device concepts and development programs and the degree to which each criteria is met. For example, a "Prototype Deployed at Sea" could be a larger-scale (non FSP) device tested in deep ocean waters in a more extreme environment for a longer period of time, or it could mean a smaller-scale prototype deployed in more sheltered seas for a shorter period of time. In this example, there is some inherent upward bias to scoring for concepts easier to deploy or which have had shorter term and/or smaller-scale sea trials.

While it is of GL GH's opinion that generating a shortlist of WEC developers in the manner described does provide an accurate summary of WEC developers that are most likely to conduct fully energetic ocean testing in the near to medium term, it is possible that other players could advance quickly or appear on scene over the next 5 to 10 years.

[7] http://www.oregonwave.org/wp-content/uploads/OWET-Technology-Readiness-Assessment-Quick-Guide_FINAL_web.pdf

3 STAKEHOLDER CONSULTATION

Having conducted a global market analysis in Section 2, this section outlines the findings of a stakeholder consultation, which was conducted to ascertain the particular requirements of potential clients of PMEC SETS.

3.1 Approach

Selection of developers

GL GH identified 37 potential wave energy developers to be targeted in the stakeholder consultation (see Section 2.3). These were selected through consideration of both (a) technology readiness and (b) local. The majority of developers shortlisted were identified as having devices most likely to conduct a fully energetic ocean deployment within the following 5 to 10 years. Although earlier in the development process than some of the other concepts, a couple of developers were also included that were identified as having particular interest in a PMEC deployment due to their location in the U.S.

The process

Based on NNMREC's current plans for PMEC SETS and requirements as communicated by OWET[8], GL GH drafted a list of targeted questions that was reviewed and approved[9] by OWET and NNMREC. The survey was designed to capture the main requirements of the developers in a format capable of being completed in less than 20 minutes. The survey questions can be found in Section 7. Follow-up interviews were then also conducted with willing developers.

The selected developers were informed of the Stakeholder Consultation process via two sources:

- Briefing by OWET: OWET sent all developers a "warm-up email" on 8/20/2013 with an attached flyer outlining the project background and aims. The flyer is provided for reference in the Appendix.
- Direct invitation to participate by GL GH: Following OWET's initial invitation, GL GH contacted developers directly on 8/21/2013 with individualized links to the online survey. A reminder was sent to pending respondents on 8/30/2013 with a 1-week deadline for answering the survey.

The consultation process had two stages, which ran throughout late August and early September:

➢ Stage 1: Multiple choice online survey (15-20 min – 29 multiple choice questions)

- Aim: to capture technical requirements of the developer's wave devices and prioritize service requirements for the site – for aggregated quantitative analysis.
- Topics included:
    - *Timing:* target test campaign;
    - *Technology overview:* e.g. device type and maturity;
    - *Technical requirements:* e.g. depth, seabed geology, cable rating; and
    - *Potential PMEC service offerings:* ranking of relative importance.

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[8] Correspondence with Matthew Sanders (OWET), 7/10/2013, 7/11/2013, and 7/24/2013.
[9] Correspondence with Matthew Sanders (OWET), 8/5/2013, 8/14/2013, and 8/19/2013.

- Stage 2: Follow-up interviews (30-45 min)
  - Aim: to discuss qualitative requirements, and to clarify survey responses in a more flexible, semi-structured format.
  - Topics discussed included:
    - *Clarifications and elaborations to survey responses;*
    - *Requirements for other service offering*s: e.g. development, monitoring & operational support; and
    - *Other issues*: opportunity for developers to raise additional concerns/requirements.

3.2 Response

Surveys

A total of 19 completed survey responses were received developers from The U.S., Europe, Australia and Asia.

Interviews

Follow-up interviews were conducted with a total of 13 developers.

3.3 Results

In this section the survey responses and interview discussions are analyzed. Following the structure of survey and follow-up interview, this section is split into three main topics:

- Interest in PMEC;
- Technical requirements; and
- Services offered.

3.3.1 Interest in PMEC

Characterization of respondents

- LOCATION: U.S. developers demonstrated most interest: 42% of the respondents were from the US, 27% from the UK and 11% from Australia – although it is noted that developers in the contact list were also mostly coming from these three countries (27%, 19% and 14%, respectively). On the other hand, four developers from Denmark were contacted (11% of total) but none replied.

- TECHNOLOGY: Respondents are developing a diverse range of technologies – but point absorbers are most common: The largest proportion of respondents (42%) is developing a point-absorber technology, as seen in Figure 3.1. Although one of the respondents classified their technology under "other" since it shares certain characteristics of both point absorber and attenuator technologies, GL GH notes that its sizing and layout could enable it to be considered as a point absorber, which would further increase that percentage. None of the respondents were pursuing an overtopping technology and only one respondent had no active technology development project.

- STATUS: Respondents' devices are generally between lab tests and prototype demonstration: 32% of the technologies believe they will have reached a technology readiness level[10] (TRL) of 7 (system prototype demonstration in an operational environment) by the end of 2013, and all of the respondents expect a TRL superior to 4 (component and/or partial system validation in laboratory environment) at that horizon. The latter result was expected, due to the created shortlist (Section 2) that determined which developers were contacted for the survey. It is noted that a level of 9 on the TRL scale would represent commercial readiness and systems proven through successful operation as arrays in the appropriate operational environment, and as such, there would limited value in a system deployment at a testing/demonstration site (unless the main scope of the test site changes and it can be developed into a commercial site).

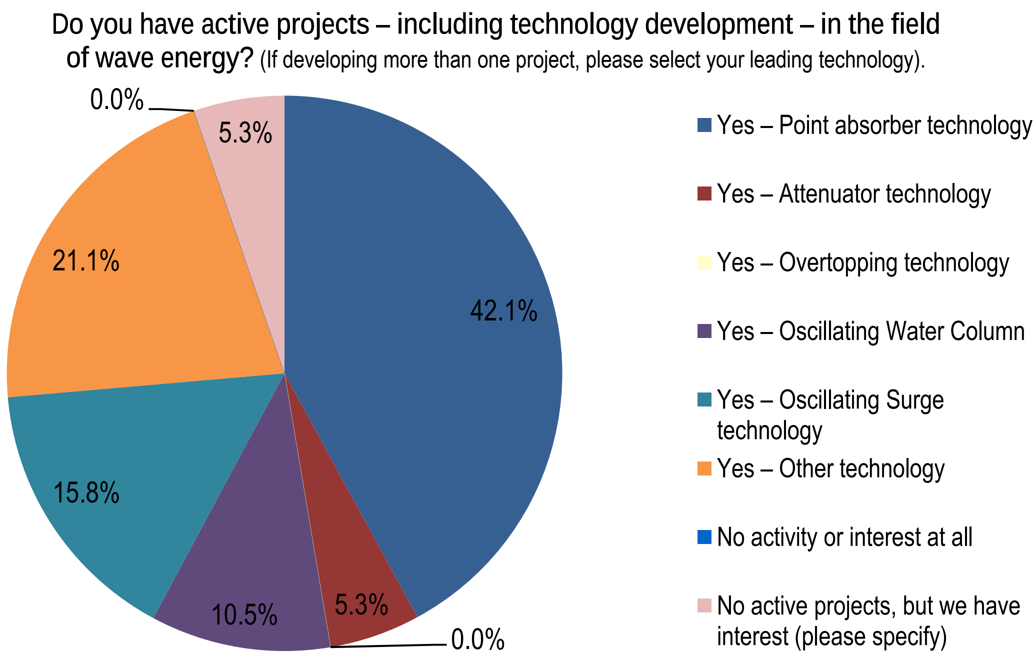

Figure 3.1. Developers' activity in the field of wave energy by type of leading technology.

Respondents' interest in PMEC SETS

- All respondents expressed a degree of interest in deploying in Oregon: This may partly be explained by the self-selecting nature of the participants, since those lacking interest in Oregon had no clear incentive to complete the survey. Just under half of those invited to respond (49%) did not, and a good proportion of them may not have done so due to a lack of interest in Oregon deployments at this time. Of those who did respond, 63% caveated their interest in Oregon by ticking the box which stated that this was contingent upon the right "conditions/local support."

- Interest from U.S. developers is particularly strong: Three U.S. developers listed Oregon as a planned deployment site, while four developers said they had completed some initial studies of Oregon as a potential site. Amongst these four developers, three were U.S.-based.

[10] http://www.oregonwave.org/wp-content/uploads/OWET-Technology-Readiness-Assessment-Quick-Guide_FINAL_web.pdf

- Respondents cited the following areas as factors which might prevent deployment:
  - Insufficient financial support: The majority of respondents expressed concerns that financial support mechanisms might be insufficient for deployment: developers perceive a general lack of incentives in the U.S. Some respondents expressed this view very strongly.
  - Onerous consenting requirements: Some respondents expressed a concern that consenting procedures and timescales may be unclear and / or onerous in the U.S. During interviews, most respondents expressed the need for a reasonable consenting timescale for them to consider going to SETS.
  - Uncertain market conditions: Some respondents perceive the market conditions in Oregon and/or the U.S. as uncertain, particularly given the "bumpy" history of support for onshore wind in the past. It was also noted that the market price of electricity is also relatively low in Oregon due to a high proportion of electricity in the region being generated from cheap conventional hydro.
  - Insufficient infrastructure: A few respondents expressed concerns about insufficient infrastructures or partnerships, although this was a smaller concern than the previous three issues in this list.
  - Note that no respondent had concerns about the resource being insufficient, and none said that they had not previously explored Oregon as a potential market.

Planned deployment

Assuming a perfect scenario, and that the site suited their technology (e.g., for nearshore technology developers), the respondents who are interested in PMEC SETS stated that they would intend to deploy at SETS according to the timeframes indicated in Table 3-1 below.

<table>
<tr><th rowspan="2">Respondent</th><th colspan="2">2016</th><th colspan="2">2017</th><th colspan="2">2018</th><th colspan="2">2019</th><th colspan="2">2020+</th></tr>
<tr><th>S1</th><th>S2</th><th>S1</th><th>S2</th><th>S1</th><th>S2</th><th>S1</th><th>S2</th><th>S1</th><th>S2</th></tr>
<tr><td>1</td><td colspan="2">1</td><td></td><td></td><td colspan="6">10</td></tr>
<tr><td>2</td><td colspan="2">1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td colspan="2">1</td><td colspan="2">1</td><td></td><td></td><td colspan="2">5</td><td colspan="2">Commercial Array</td></tr>
<tr><td>4</td><td colspan="2">3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td colspan="10">15</td></tr>
<tr><td>6</td><td colspan="10">Commercial Array (for 25 years)</td></tr>
<tr><td>7</td><td colspan="2">1</td><td colspan="8">10 for 10+ years</td></tr>
<tr><td>8</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="6">12</td></tr>
<tr><td>9</td><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10</td><td></td><td colspan="2">1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>11</td><td></td><td colspan="3">1</td><td colspan="6">3</td></tr>
<tr><td>12</td><td></td><td colspan="6">1</td><td colspan="3">10</td></tr>
<tr><td>13</td><td></td><td colspan="2">1-2</td><td colspan="2">7-9</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>14</td><td></td><td></td><td colspan="2">1</td><td colspan="2"></td><td colspan="4">2+</td></tr>
<tr><td>15</td><td></td><td></td><td colspan="2">1</td><td></td><td></td><td colspan="2">10</td><td></td><td></td></tr>
<tr><td>16</td><td></td><td></td><td colspan="8">3-5 or 5-10 for 15+ years</td></tr>
<tr><td>17</td><td></td><td></td><td></td><td colspan="3">3</td><td colspan="2">6</td><td colspan="2">15</td></tr>
<tr><td>18</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Commercial Array (for 20 years)</td></tr>
<tr><td>19</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">5 for 20years</td></tr>
</table>

Table 3-1. Testing/demonstration project plans for respondents, from 2016 to 2020 onwards, by semester (S1, S2). The values in the blue cells indicate the number of devices in the deployment.

- There is a strong appetite to begin deployment as soon as the test center is live, in 2016: Thirteen of the respondents (68%) wish to use SETS from 2016 onwards, and most of those for single device deployment in that first year.

- Most developers plan to test for longer than one year: The majority of the respondents (68%) also demonstrated a clear appetite to deploy at SETS for an extended period of time – spanning several years.

- 95% of the respondents would like to expand their demonstration deployment into a commercial project: For 10 of the respondents (over half), the option was considered as essential. Such developers would require PMEC to enable long-term deployments of ~20-25 years. Eight others stated that it was not expected, but would be desirable. Only one respondent stated that a deployment at just a test site that provides added services and/or enables easier access would be sufficient for their development plans. It should be noted, however, that this developer is not developing a stand-alone WEC, but rather one that needs to be coupled with an existing offshore structure, such as a wind turbine.

3.3.2 Technical Requirements

Physical conditions:

- WATER DEPTH: Most respondents target water depths of 50 to 100 m: As detailed in Section 2.3, developers pursuing onshore WEC concepts were not contacted. This is reflected in the water depth requirement, with 84% of the respondents opting for depths between 50 and 100 m. A number of developers selected more than one category, indicating a degree of flexibility in water depth for their systems. Figure 3.2 below summarizes the results:

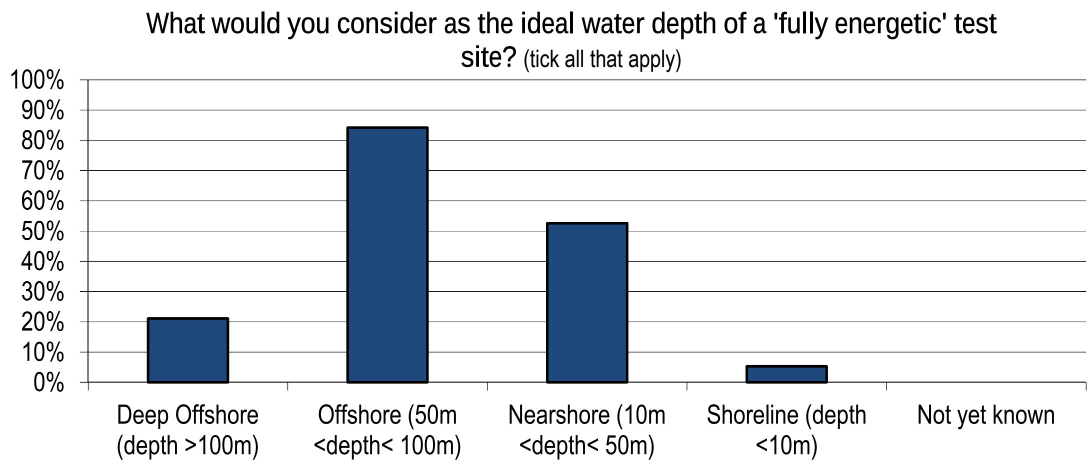

Figure 3.2. Water depth targeted by developers.

- MEAN ANNUAL WAVE ENERGY RESOURCE: Respondents mostly prefer a mean annual wave energy resource between 20 kW/m and 40 kW/m: Figure 3.3 shows that 79% of the respondents indicated a preference for sites with a wave resource between 20 and 40 kW/m. Only one respondent favored a resource below 10 kW/m and one favored a resource larger than 60 kW/m. Note that the latter selected a range of annual resource between 10 to greater than 60 kW/m, thus including the 20 to 40 kW/m resource band in their selection.

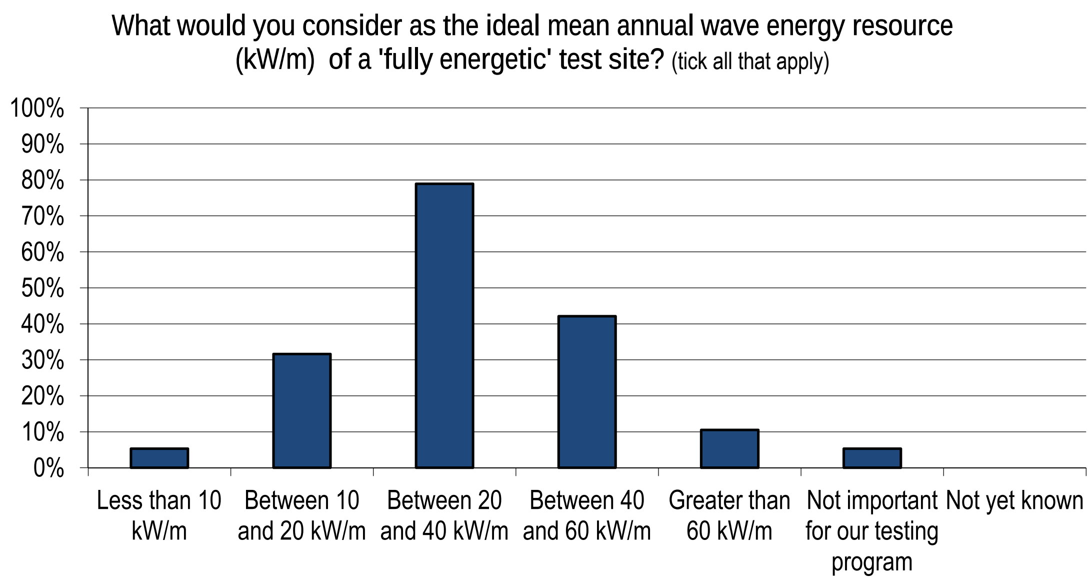

Figure 3.3. Mean annual wave energy resource (kW/m) at site.

- PREFERRED 1-YEAR SIGNIFICANT WAVE HEIGHT: For most respondents the 1-year return value of significant wave height ideally could be between 6 and 8 m at a PMEC deployment: 21% have not done design studies to determine the preferred 1-year extreme wave event for a deployment location, while 11 respondents (58%) would ideally want a testing/demonstration site with a 1-year return value of significant wave height between 6 and 8 m. A large proportion (42%) also selected the 8-10 m range, with others selecting even higher values. Only three developers selected less than 6 m as an ideal value. These results along with interview responses imply that the majority of developers would seek to fully expose their systems in a PMEC deployment.

- SEASONAL VARIATION: Respondents in general did not express strong views on seasonal variation, though they tended to include the range between 4 and 5.5 as a preferred ratio: seasonal variation was defined in the survey as the ratio between maximum and minimum monthly mean power flux. 32% stated that it was not an important variable for their testing program, and another 21% did not know their requirements. Six of the 9 remaining respondents included the range 4 to 5.5 as a preferred ratio.

- SEABED: Developers indicated flexibility on seabed conditions: 32% of respondents listed sand or clay as a preferred bottom type (see Figure 3.4). Another 38% did not have a strong preference, although bedrock and cobble seabeds were generally not selected as preferred geology.

- OTHER: Developers often did not yet know detailed technical requirements: For questions on power conditioning, significant wave height and seasonal variation, around a third of developers ticked the box “not yet known.”

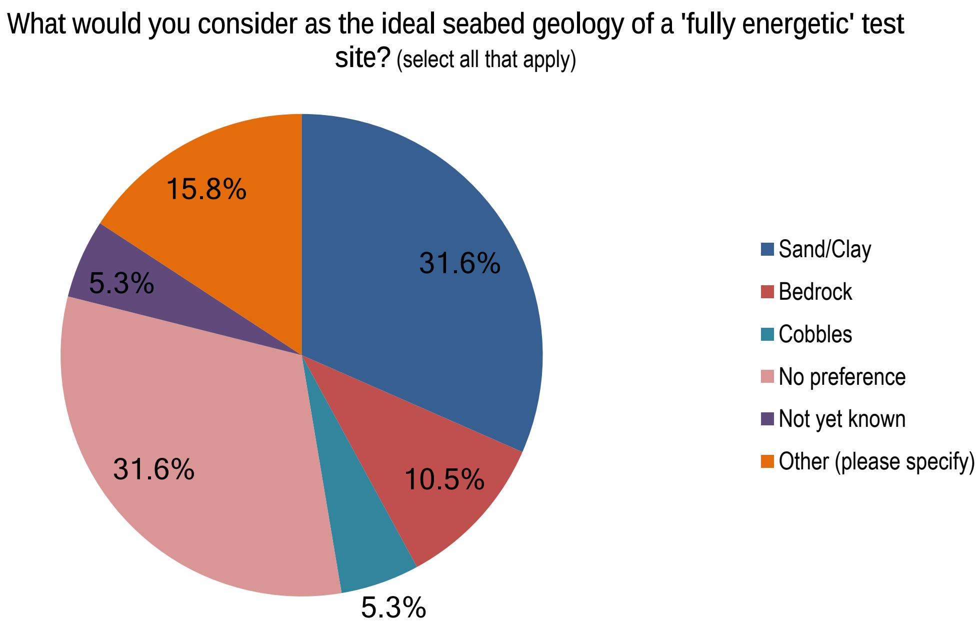

Figure 3.4. Preferred seabed conditions.

Electrical requirements:

- GRID: Grid connection is typically viewed as “a necessity”: 84% of the respondents saw grid-connection as a necessity. Only three developers said grid connection was not a necessity, and 1 of these 3 developers is developing a system that aims to feed offshore wind turbines.

- VOLTAGE: Developers are mostly flexible on voltage requirements: most respondents stated that they could accommodate a range of output voltage, with many stating values between 5 kV and 20 kV at the umbilical cable. It is noted that this range of voltage requirements corresponds to the common subsea connectors. A number of developers also stated that they would expect output from an array deployment to be up in the 33 kV range, a voltage common for offshore transmission cables.

- POWER CONDITIONING: When known, power conditioning is typically within the device: 32% of the respondents do not know yet if the power will be conditioned within or outside their device. Of those who have already decided, 53% have opted for power conditioning within the device.

- BERTHING REQUIREMENTS: Required rated capacity and number of connection points will increase more than fivefold from 2016 to 2025: average figures per berth for horizons 2016, 2020 and 2025 are summarized below:

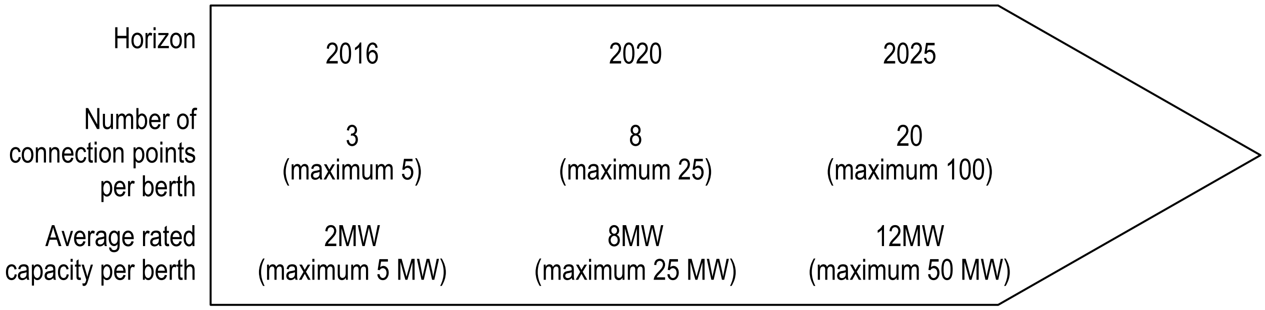

Figure 3.5. Berthing requirements for horizons 2016, 2020 and 2025: number of connection points and average rated capacity per berth.

3.3.3 Services Offered

Deployment, Retrieval and Operations & Maintenance (O&M):

- INSTALLATION METHOD: Most of the respondents plan to deploy by towing their device, typically using a tug. Figure 3.6 shows that 94% would tow the device to the site for installation. 83% would require a tug for deployment, retrieval and/or maintenance. For some developers these plans are not clear yet and, thus, neither are their requirements.

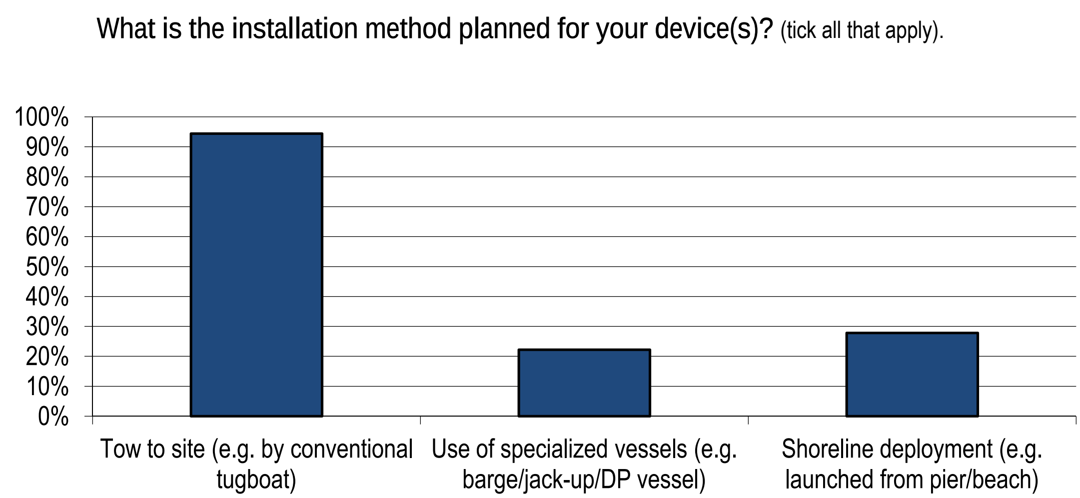

Figure 3.6. Installation method planned by developers.

- ITEMS TO BE TESTED DURING DEPLOYMENT: Respondents' plans for testing are wide-ranging: All of the items suggested in Figure 3.7 are considered part of the test plan by more than 40% of respondents. The most common items targeted for testing/demonstration during a PMEC SETS deployment were remote operation (74% of respondents), environmental effects of the device (74%) and mooring configurations (63%). Additional items were mentioned during interviews such as anchor types, control systems, and installation and O&M strategies/procedures.

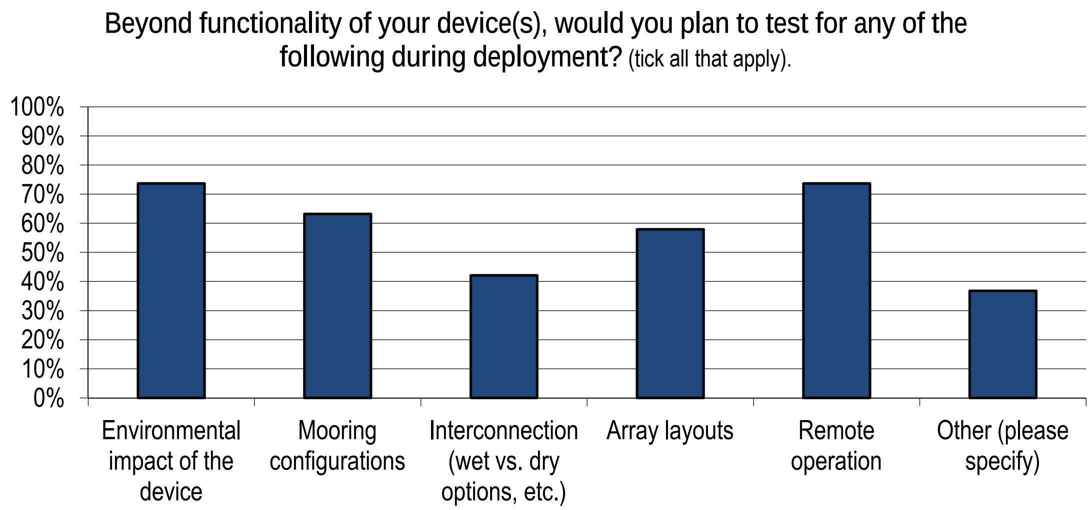

Figure 3.7. Items to be tested during deployment.

- MOORING SYSTEMS: Respondents mostly want to use their own anchor/mooring arrangement: When asked about their expectations for existing mooring systems at SETS, 58% of respondents prefer to use their own proprietary anchor/mooring systems rather than having them installed at the site, while relatively few indicated a preference for existing moorings arrangements to be pre-installed at the site. Figure 3.8 summarizes the results.

  It is interesting to note that among the developers who expressed interest in testing mooring configurations, half of them would agree to mooring systems pre-installed at the site. During the interviews, one of the developers explained that although they are currently using a three-point system they would like to test a single point system for comparison; ideally both would exist at SETS for them to try, or else they would prefer to have their own moorings.

  Another developer also underlined the important costs associated with installing moorings. Having them pre-installed would then bring a significant financial advantage.

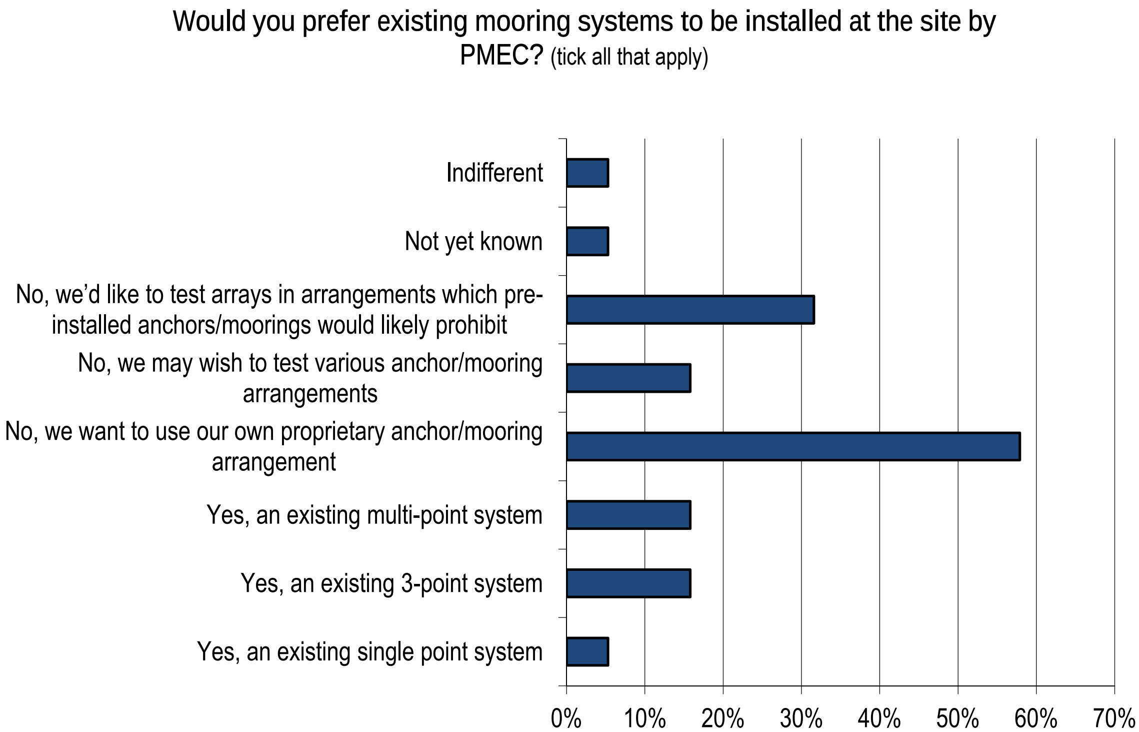

Figure 3.8. Mooring system requirements.

Wider service offering:

- SITE INFORMATION PROVIDED: Most respondents stressed that NNMREC should focus on providing technology-neutral information such as metocean data requirements and metocean hindcasts: As demonstrated in Figure 3.9 below, respondents value services that are applicable to a range of end-users, thus avoiding the need for developers to duplicate studies. Additional or complementary items were also specified through the "*Other*" box:
    - o <u>Environmental monitoring:</u> baseline data such as marine mammals, navigational assessments; and
    - o <u>Resource monitoring:</u> tidal measurements, real time water surface level, standard wave conditions.

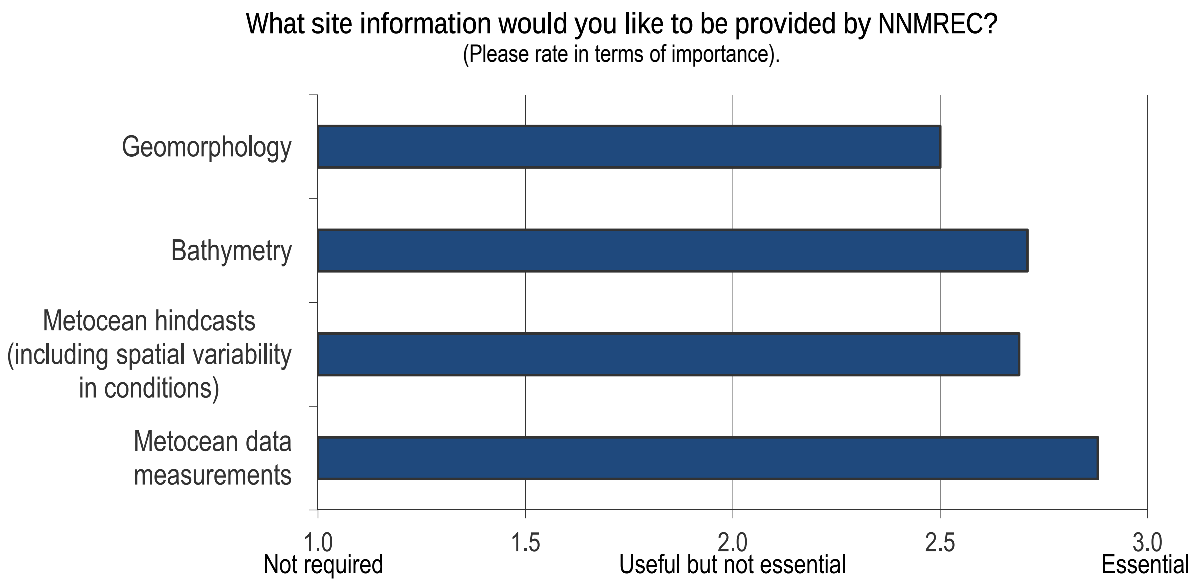

Figure 3.9. Rating average for the site information provided by NNMREC: a rate of 1 means that the service is "Not required", 2 is "Useful but not essential", 3 is "Essential".

- LIST OF SERVICES: Most respondents stressed the need for flexibility in service provision: Interview discussions revealed respondents' views that flexibility is required in two key respects:
  - Services – "Pick and mix" approach to services available: Flexibility in the service offering is required to reflect the different requirements of different developers. A "one size fits all" approach to services – and associated requirements – is not deemed appropriate, and indeed was highlighted as a flaw of some existing test centers.
  - Rules and regulations – need to be open to changing over time: Flexibility in PMEC rules is required to respond to technology developments and avoid stifling innovation. One respondent highlighted that the industry is still relatively immature and, as a result, it can be difficult for developers to foresee future changes. It was suggested that PMEC SETS should be set up in such a way as to dynamically respond to these changes, rather than imposing the same rules over time.

Table 3-2 summarizes the results with the average rate given by the developers for each item listed (a rate of 1 means that the service is "Not required", 2 is "Useful but not essential", 3 is "Essential").

Services offered by NNMREC		Rating Average
Development support	Independent performance verification	2.32
	Support to certification	1.89
	Resident engineering team and/or generic R&D support	1.42
Monitoring support	Resource monitoring and support	2.68
	Environmental impact monitoring and support	2.42
	Technology monitoring and support	2.11
Operational support	Marine works & operations planning and supervision	2.37
	Deployment and maintenance barges	2.42
	Professional diving and specially trained maritime work teams	2.22
	Workshop, shipyards facilities and storage of large items	2.47
	Office, team accommodation and storage room for minor items	2.32
	Community liaison and logistical support (e.g. transport, partner search)	2.26
Policy/ contractual/ legal support	Power purchase agreement	2.47
	Support understanding/navigating state policy (e.g. securing state incentives, the state regulatory process)	2.58
	Support understanding/navigating national policy (e.g. securing federal incentives, the federal regulatory process)	2.63
	Site pre-permitted for your type of device (avoidance of regulatory process)	2.84
Outreach support	Local public outreach (e.g. informational plaques, community newsletters etc.)	2.37
	Finding housing, office space, relocation assistance	1.84

Table 3-2. Rating average for the services offered by NNMREC: a rate of 1 means that the service is not required, 2 is useful but not essential, 3 is essential.

Each of the above areas is discussed further below.

- POLICY, CONTRACTUAL & LEGAL SUPPORT: Streamlined permitting processes are critical – and support in navigating national/state policy is also welcomed. As indicated in Figure 3.10, respondents were very keen to avoid long-winded permitting processes. In addition, two respondents highlighted that policy/regulation varies substantially by country and state; it was suggested that NNMREC could add value through helping developers understand local policy conditions, especially for companies that are not U.S.-based.

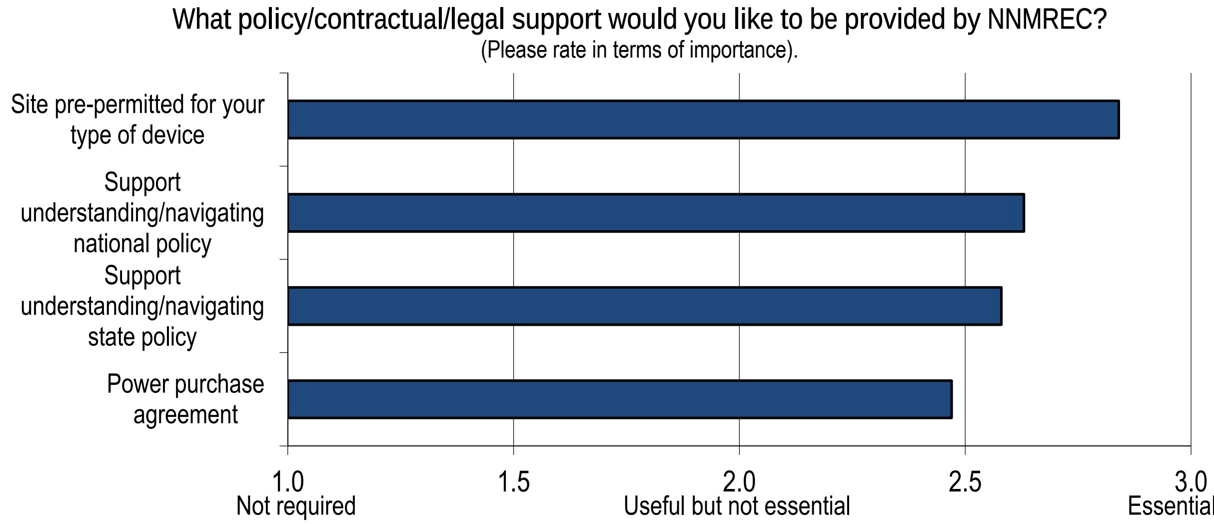

Figure 3.10. Policy/contractual/legal support requirements.

- MONITORING SUPPORT: Resource monitoring support is considered more important than technology monitoring support: As indicated in Figure 3.11 below, respondents were most interested in NNMREC support for resource and environment monitoring, with generation monitoring also stated as a high priority for independent monitoring (see "independent performance verification" below). Some developers indicated that they would use the data produced by NNMREC to validate their own data to bring evidence of reliability.

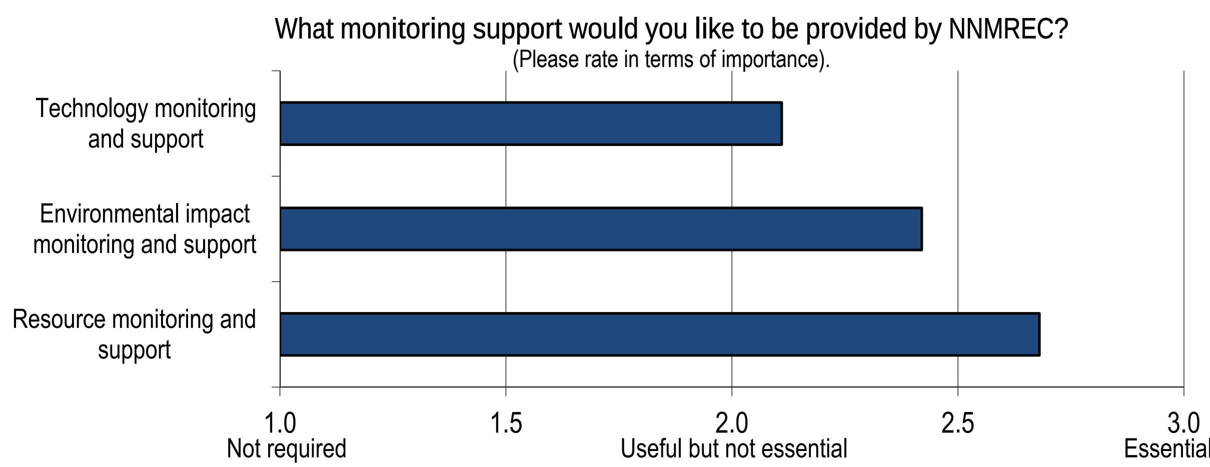

Figure 3.11. Monitoring support requirements.

- DEVELOPMENT, OPERATIONAL & OUTREACH SUPPORT: Operational support is the most important of these three areas – but can take many forms. This is demonstrated in Figure 3.12 to Figure 3.14.
  - Operational support is key: One respondent explained that although developers can bring their general skills and expertise to Oregon, some elements of the work are inherently local – such as facilities, vessels and operations. These elements of work are also often high-risk – for instance, some respondents highlighted the risks in the installation process, in terms of budget and timescale. It is in these local, high-risk areas where NNMREC support would be particularly valued.
  - Development support is less critical: Development support is very specific to each technology (e.g. device engineering), and so, in general, it is not viewed as a required service by respondents. A number of developers strongly felt that PMEC should not have a resident engineering team or get involved in R&D support. Independent performance verification, however, was felt to be an important service.
  - Outreach support is a prerequisite for establishing SETS: For most respondents, the outreach requirements fall under the responsibility of NNMREC; as a pre-permitted site, this support should not be essential as an ongoing service to developers, but rather should be a prerequisite for PMEC SETS to be established.
  - NNMREC can add value through connecting developers to the local network: NNMREC's potential role at PMEC SETS was mostly seen as a connector between local supply chain/communities, etc. and developers. This would accelerate the otherwise long process of relationship-building. However, it should also be noted that some developers said they considered it to be a core competency of a developer to establish necessary local relationships, and so NNMREC's role should only be to loosely facilitate this effort (e.g. providing contact information, etc.).
  - NNMREC should focus on core equipment: A number of developers said that PMEC should have at least some basic equipment available for common operations (e.g. a versatile medium-size vessel). This measure was viewed to as useful to mitigate the risk of delays with marine contractors.
  - NNMREC could facilitate a collaboration platform for developers: One developer argued that such a platform would encourage developers to work on common requirements for vessels, and would potentially reduce the mobilization and pre-mobilization costs, which can account for up to 50% of the total vessel costs.

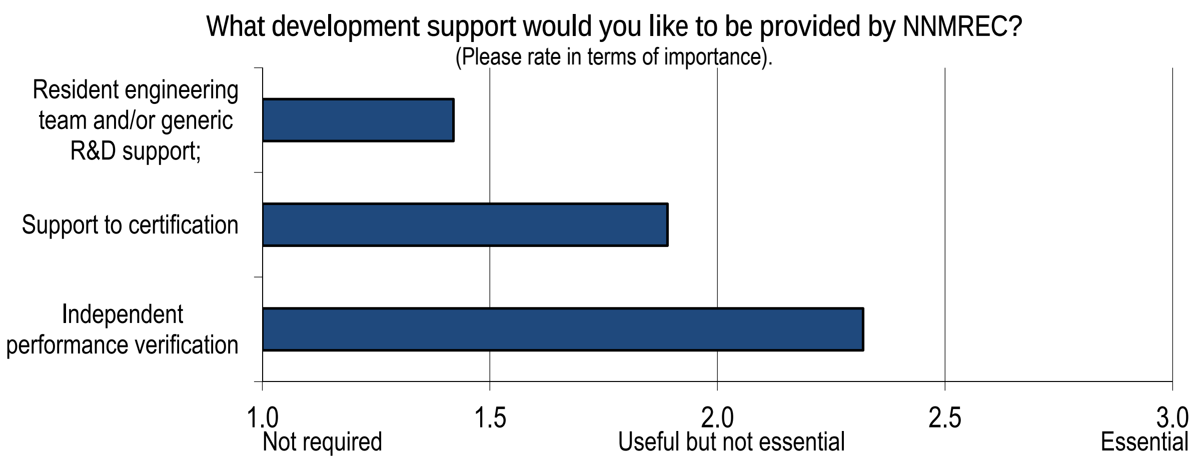

Figure 3.12. Development support requirements.

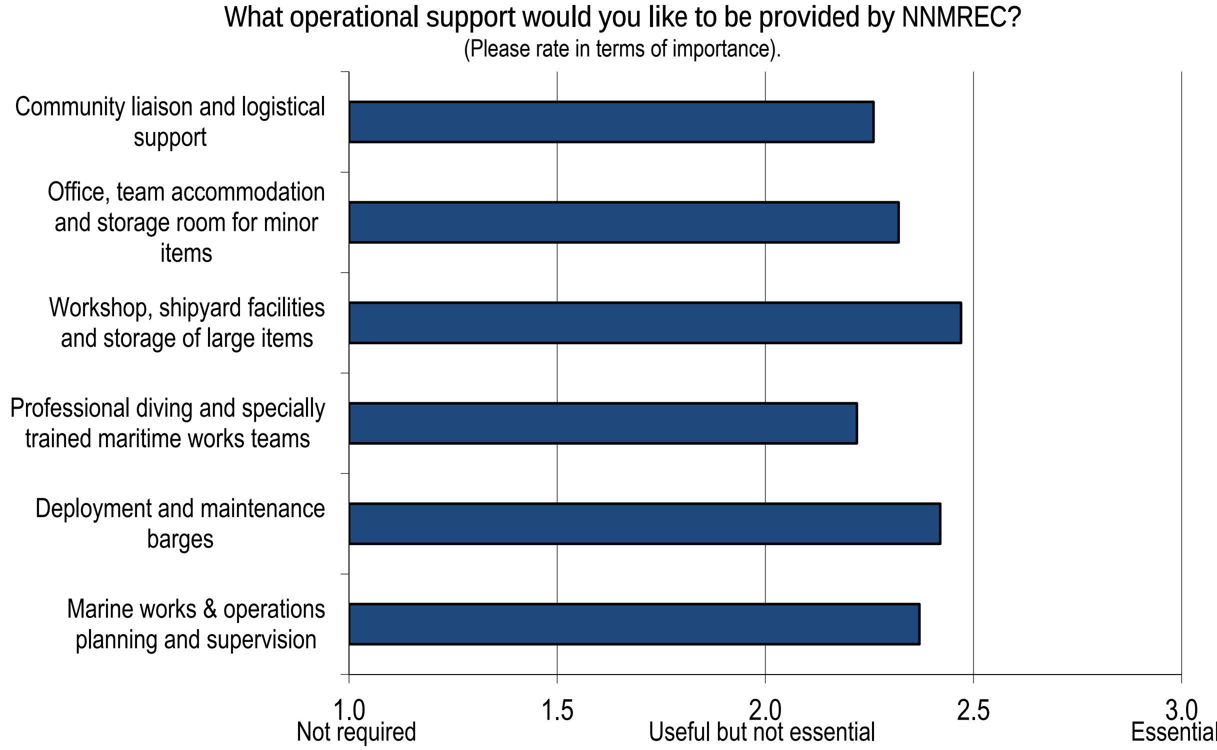

Figure 3.13. Operational support requirements.

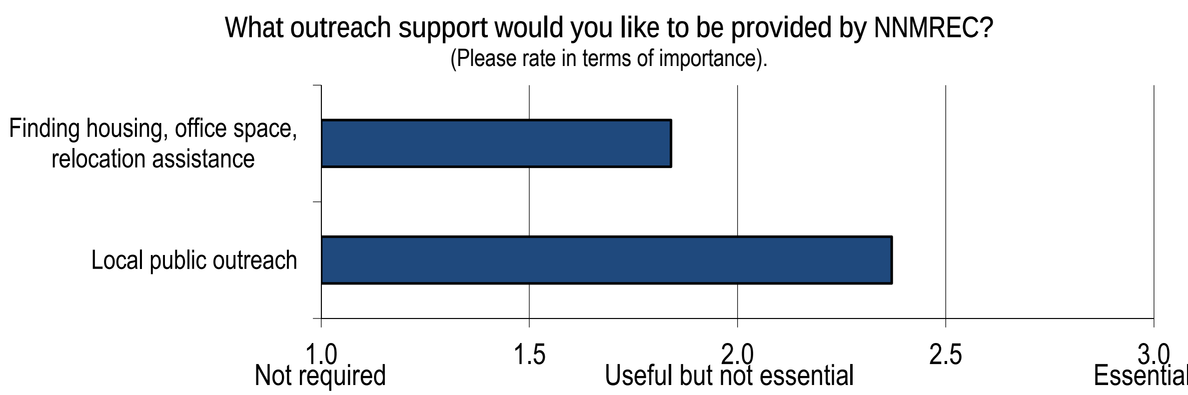

Figure 3.14. Outreach support requirements.

- MONTHLY FEE: Respondents mostly dodged the question of leasing fee expectations: Few respondents quoted a specific price, although most of them suggested that they would expect the fee to be comparable to fees at other existing test facilities. The following points were made:
  - <u>Fees should depend upon the services offered and used:</u> Most respondents insisted that the leasing fee should depend on the service package offered at PMEC SETS. Some went on suggest a “pick and mix” approach to services, whereby developers choose which services they would use and pay for.

- SETS could arguably be provided "for free": If the test site is not grid-connected or if it is just a permitted site that DOE funding has paid for, a developer suggested that it should arguably be free to developers. One other developer pointed out that facilities in Norway's test center were provided free of charge.
- Monthly fees should reflect period of deployment: One respondent, targeting a long term array deployment, argued for a cheaper monthly or yearly leasing fee compared to other pre-permitted short term test sites, perhaps coupled with a base berth fee, to account for the longer deployment period with high utilization.
- The leasing fee design could be linked to developer revenues: One developer suggested that the leasing fee should be tied back to expected revenues, e.g. reflecting 5% of gross sales of electricity.
- Consider insurance requirements: One respondent highlighted the importance of the insurance requirements/costs associated with the leasing fee: very strict insurance requirements can make the project costs too onerous.
- Quotes: Between free (as in some European university operated, non-grid-connected test centers) and at the cost of grid-connected test sites in the UK.

Summary of Consultation Findings

Respondents' interest in PMEC SETS

- Interest: All respondents expressed a degree of interest in deploying in Oregon
- Key concerns which might prevent deployment are as follows:
    - Onerous consenting requirements
    - Insufficient financial support
    - Uncertain market conditions
    - Insufficient infrastructure
- Planned deployment
    - There is a strong appetite to begin deployment as soon as the test center is live, in 2016
    - Most developers plan to test over periods >1 year
    - 95% of the respondents would like to expand from demonstration to commercial deployment

Technical requirements

- Physical conditions
    - Most respondents target water depths of 50-100m
    - Respondents mostly prefer a mean annual wave energy resource between 20 and 40kW/m
    - For most respondents the maximum significant wave height should be between 6 and 8m
    - Developers indicate flexibility on seabed conditions
- Electrical requirements
    - Grid connection is typically viewed as "a necessity"
    - Developers are mostly flexible on voltage requirements
    - Capacity and connection points requirements will increase more than fivefold from 2016 to 2025

Services offered

- Deployment, Retrieval and Operations & Maintenance (O&M)
    - Most of the respondents plan to deploy by towing their device, typically using a tug
    - Developers, by significant majority, want to use their own anchor/mooring arrangement
- Service requirements
    - Most respondents stressed that NNMREC should focus on providing technology-neutral information
    - Most respondents underlined the need for flexibility in the services offered and site requirements
    - Key concerns in the services provided to developers are:
        - Policy/contractual/legal support is mostly required to enable site to be pre-permitted for their devices, or to at least make the permitting process as swift as possible
        - Development, operational and outreach support: NNMREC is mostly seen as a connector between local supply chain/communities etc. and developers
- Leasing fee: The monthly fee depends highly on the level of services provided and developers were typically reluctant to state their expectations.

4 GAP ANALYSIS

This section presents gap analyses for PMEC SETS, derived from the findings of the previous two sections. Where appropriate, GL GH has critically assessed the practicability of developer responses from Section 3.

This section is structured as follows:

1. Gap analysis – fixed site conditions: The fixed physical site conditions of the proposed SETS location are compared with developer needs.
2. Gap analysis – technical offering: A proposed technical offering for SETS is compared with development preferences – to assess whether there are any gaps to address.

4.1 Gap Analysis – Fixed Site Conditions

Table 4-1 below compares the PMEC SETS site conditions at the proposed location with developer requirements, in order to assess the overall degree of "fit" with what developers are seeking. GL GH notes that since the site has already been selected, there is very limited scope for NNMREC to change these conditions.

Technical area	Proposed SETS site conditions	Development requirements	PMEC fit with developer requirements
Water depth	58-75 m	Respondents to the consultation generally target water depths of 50 to 100 m. (Note, however, that at least one nearshore developer did not complete the survey as they knew the water depth at the proposed SETS location does not meet their requirements). PMEC's conditions exclude testing by the subset of developers whose technologies require nearshore deployment (10 to 15 m in the latter case). Three nearshore developers responded to the remainder of the survey, as if a site like PMEC SETS were established at a suitable location.	●
Distance to shore	5-6 nautical miles	Only a couple developers expressed concerns in regard to the distance to shore. Pressurized water technologies have a transmission limit of about 3 miles to beach crossing, and, more generally, long cables increase the overall costs for all WEC systems.	●
Wave resource	10-200 kW/m (mean: 31kW/m)	Most consultation respondents are targeting sites with a wave resource between 20 and 40 kW/m.	●
Seabed conditions	Sandy bottom	All but 2 respondents had no strong preference on seabed conditions or favored a sand seabed. A sandy seabed is typically better suited for simpler anchoring solutions such as drag embedment anchors; in contrast, a rocky seabed typically requires more complex (and expensive) equipment.	●
1-year return significant wave height	6-8 m extreme wave	Many respondents had not yet conducted design studies detailed enough to have a clear view on ideal one-year extreme wave values. For those who had a preference, the characteristics of SETS tended to match their expectations (6-8 m extreme wave).	●
Seasonal variation	Ratio of seasonal variation in incident wave power around 5	Many respondents had not yet conducted design studies detailed enough to have a clear idea about seasonal variation in incident wave power. For 63% of the developers, their preference (ratios of about 4 to 5.5 between the maximum and minimum monthly mean power flux) roughly matches the seasonal variations observed at SETS or is not important for their testing program. The seasonal variation does not match for only one developer.	●
Tidal conditions	Unknown	Some technology developers wish to avoid areas with high tidal currents.	Unknown

Table 4-1. Gap analysis – physical conditions of SETS site.

Key: ● = Good match; ● = Partial match/more consideration recommended; ● = Poor match.

Overall, the physical site conditions at the proposed PMEC SETS location broadly meet the needs of developers – there is an overwhelming "green light" here. The only (minor) uncertainty is related to the tidal conditions: it is currently unknown whether SETS will meet the developers' needs in this area.

4.2 Gap Analysis – Technical Offering

Item	PMEC plans	Developer requirements	PMEC fit with developer requirements
TRL of target projects and length of deployments	Deployments of prototypes and small arrays – Length of deployment not yet defined	45% of the developers surveyed state that their technologies will have reached at least the seventh level of technology readiness (system prototype demonstration in an operational environment) by the end of 2013, and all of the respondents expect a TRL superior to 4 (component and/or partial system validation in laboratory environment) at that horizon. Based on GL GH experience, this assessment is optimistic; most of the technologies are more likely to be at TRL 5 by the end of 2013. Nonetheless, focusing SETS on short term deployments (<2 years) for single prototypes and/or small arrays may be misaligned with market needs: most of the developers plan to deploy for an extended period of times (spanning several years), and all but one developer would like to expand their demonstration deployment into a commercial project. This may be especially true given the timeframe required to develop SETS, which itself would only be operating by 2016 under an optimistic timeline. It is also expected that lower TRL technologies developed abroad that may require initial one-off testing (i.e. first prototype sea trials) are less likely to go to PMEC if they have closer, suitable alternatives.	
Site capacity	Total capacity of 10MW	For 2016-2017, the most realistic developer requests are for a rated capacity of 2-3 MW per "berth" consisting of 2-3 connection points for each. By 2020, a number of developers plan to deploy relatively large arrays that would require a rated capacity per berth of up to 50+ MW, which would not be suitable for SETS. GL GH notes that some of the developers' plans appear very ambitious. On the other hand, the least advanced technologies would require only about 5 connection points and up to 10 MW rated capacity. In the early years, the planned 10 MW (4 berths of 2.5 MW each) export capacity for SETS may be sufficient. However, even adjusting for developer optimism, the berthing capacity of SETS appears to be too low from around 2020 onwards. GL GH recommends permits and plans that would enable an expansion to allow developers to conduct longer-term deployments of small arrays be considered at this early stage.	
Grid connection	Grid-connected	Most developers consider grid connection a necessity for their testing program. Only four developers (out of 19) said they do not consider grid connection as a necessity for their testing program, and of these: • One has a device that feeds the energy produced into the offshore wind turbine it is attached to, and is not dependent on a grid connection; • Another did feel they would benefit from a grid connection to analyze the signal or the interaction with the grid, however; and, • A third would only require a grid connection if granted a long-term deployment. However, as they would mostly aim for a long-term deployment at SETS, it is unlikely they would seek a berth if such a deployment could not be granted.	

Power conditioning	Not yet defined	Most developers (53%) have the power conditioned within the device. Only 3 developers require an external unit. For the rest, no design studies have been made on the subject.	-
Electrical output voltage (kV)	Not yet defined	Developers are mostly flexible on voltage requirements. Their preference tends to be for 11 kV and 33 kV, a range of voltage that corresponds to the common subsea connectors.	-
Type of technology tested	Target wave energy technologies only	One developer would only consider testing if they can partner with an offshore wind technology (floating or bottom mounted). GL GH notes that this developer's technology design is relatively niche within the wave industry. Only WEC developers were contacted in this study, and as such the relative interest from floating offshore wind developers was not assessed. GL GH does note that a number of other European test facilities have opened up their berths to floating offshore wind in an effort to increase the current demand for their facilities.	●

Table 4-2. Gap analysis: non-fixed technical offering at SETS.

Key: ● = Good match; ● = Partial match/more consideration recommended; ● = Poor match.

The table above indicates two significant potential gaps:

- SETS targets prototypes and small arrays, and NNMREC has yet to determine length of deployments, whereas developers want to demonstrate long-term pre-commercial and commercial arrays.
- SETS planned to have 10MW capacity only, whereas developers plan larger projects by the late 2010s.

Even factoring in likely developer over-optimism, there is a potential mismatch that requires further investigation by NNMREC. In addition, it is noted that PMEC SETS's current exclusion of floating wind will prevent deployment by 1 developer contacted in the consultation.

5 CONCLUSION

The wave energy market is a global, dynamic market, with a strong need for testing and demonstration in the next 5 to 10 years. European countries have historically been the main hubs of activity for large-scale prototype deployment, but the U.S. market is promising in terms of feasible resource, current interest and activity, and in some cases, attractive local policies. Global activity in the wave energy field in the coming years is expected to reduce costs, attract investors and accelerate the transition from prototype testing to array planning. Growing interest from large industrial players, such as major utilities or multi-national OEMs, in the market could also drive a step change in the rate of deployment.

The scale of the opportunity is clear. The question for NNMREC is: what is the unique role for PMEC SETS in this global market? GL GH contacted WEC developers directly to find out. Drawing upon its internal database, GL GH identified 37 WEC developers who are sufficiently advanced to be potential end-users of the PMEC SETS test center considering a roughly 5-year timeframe. Nineteen of these developers completed GL GH's online survey, and 13 follow-up interviews were conducted. GL Garrad Hassan would like to thank all of the developers who took the time to contribute to the stakeholder consultation.

This process of stakeholder consultation indicated that the physical site conditions at PMEC SETS broadly meet the needs of interested developers. However, the consultation findings also revealed a number of items that warrant more consideration from NNMREC. These items were identified in gap analysis comparing developer needs with current plans for PMEC SETS.

6 APPENDIX 1 - FLYER

NNMREC
Oregon State University
University of Washington

OregonWaveEnergy TRUST

GL Garrad Hassan

Stakeholder Consultation for Pacific Marine Energy Center

Identifying wave energy developer requirements for a test site in Oregon, USA

The Oregon Wave Energy Trust (OWET) invites you to participate in a stakeholder consultation conducted by GL Garrad Hassan. The aim is to identify the needs of potential end-users of a Pacific Marine Energy Center (PMEC) wave energy testing facility in Oregon, USA, being developed by the Northwest National Renewable Energy Center (NNMREC). PMEC is planning to develop a fully energetic grid-connected site, the South Energy Test Site (SETS), located on the Pacific coastline ~10km offshore of Newport, Oregon.

The consultation

The consultation process has two stages, which will run throughout August:

- Stage 1: Multiple choice online survey (15 min – 28 multiple choice questions)
  - Aim: to capture technical requirements of your wave device – for aggregated quantitative analysis.
  - Topics covered include:
    - *Timing:* target test campaign
    - *Technology overview:* e.g. device type and maturity
    - *Technical requirements:* e.g. depth, seabed geology, cable rating
- Stage 2: Follow-on interviews (30-45 min)
  - Aim: to discuss qualitative requirements, and to clarify survey responses in a more flexible format
  - Topics discussed:
    - *Requirements for other service offering*s: e.g. development, monitoring & operational support
    - *Other issues*: opportunity for developers to raise additional concerns/requirements

Benefits of Participation

- Avoid a drawn-out regulatory process – feeding information about your device into NNMREC's planning at this early stage, as they conduct permitting for SETS, is expected to save significant permitting costs and reduce regulatory barriers for those seeking to deploy at the test site in the future.
- Ensure that your technology can be accommodated – understanding of your technical needs will inform test site development, helping to ensure that your technology can be accommodated.

Publication and confidentiality

Both GL Garrad Hassan and OWET treat confidentiality concerns seriously: *requests to anonymize information will be fully respected*.

The findings will be made publically available via:

- A public domain report, available on OWET's website – presenting aggregated data only, not individual company responses.
- A presentation at the 8th Annual Ocean Renewable Energy Conference hosted by OWET in Astoria, Oregon on September 25-26, 2013.

For questions

- GL Garrad Hassan – Jarett Goldsmith: jarett.goldsmith@gl-garradhassan.com
- Oregon Wave Energy Trust – Matt Sanders: msanders@oregonwave.org

August 2013

7 APPENDIX 2 – SURVEY QUESTIONS

11-page survey attached.

Wave Energy Market Analysis

INTRODUCTION

The Oregon Wave Energy Trust (OWET) invites you to participate in a stakeholder consultation being conducted by GL Garrad Hassan. The aim is to identify the needs of potential end-users of wave energy testing facilities, specifically the fully-energetic, grid-connected South Energy Test Site (SETS), at the Pacific Marine Energy Center (PMEC). PMEC is being developed by the Northwest National Marine Renewable Energy Center (NNMREC) and PMEC-SETS will be located approximately 10 kilometers offshore near Newport, Oregon, USA.

Confidentiality is fully respected: although aggregated analysis will be released into the public domain, individual responses will not be published.

The questionnaire consists of 29 questions and has been designed to be completed in less than 15 minutes.

If you incur any difficulties, please email: jarett.goldsmith@gl-garradhassan.com

Thank you very much for contributing your informed responses to this study. Your input is greatly valued and can help shape the development of a successful open ocean test site in Oregon - one that most effectively facilitates growth of the wave energy industry in the USA.

INTEREST IN PMEC

1. Do you have active projects – including technology development – in the field of wave energy? (If developing more than one project, please select your leading technology).

- ◯ Yes – Point absorber technology
- ◯ Yes – Attenuator technology
- ◯ Yes – Overtopping technology
- ◯ Yes – Oscillating Water Column
- ◯ Yes – Oscillating Surge ('Flapper') technology
- ◯ Yes – Other technology
- ◯ No activity or interest at all
- ◯ No active projects, but we have interest (please specify)

2. Please indicate the development stage that you consider your leading wave energy technology will have achieved by the end of 2013:

- ◯ TRL 1 – Basic principles observed and reported
- ◯ TRL 2 – Technology concept and/or application formulated
- ◯ TRL 3 – Analytical and experimental critical function and/or proof of concept
- ◯ TRL 4 – Component and/or partial system validation in laboratory environment
- ◯ TRL 5 – Component and/or partial system validation in relevant environment
- ◯ TRL 6 – System/subsystem model validation in relevant environment (i.e. beyond small-scale laboratory tests)
- ◯ TRL 7 – System prototype demonstration in an operational environment
- ◯ TRL 8 – Actual system completed and service qualified through test/demonstration in operational environment
- ◯ TRL 9 – Actual system proven through successful operation (e.g. array demonstration in operational environment)

3. Is Oregon, United States of America, a region where you would consider testing and/or installing your technology or developing your project?

- ◯ Yes, it is a planned deployment site
- ◯ Yes, we have made initial studies
- ◯ We might consider depending on conditions/local support
- ◯ No, it is not a target market

4. If Oregon (USA) is not a target market for your technology, why not? Please tick all that apply:

☐ Resource is insufficient

☐ Market conditions in the state/country are uncertain

☐ Consenting procedures and timescales are unclear/onerous

☐ State/national financial support mechanisms are insufficient

☐ Infrastructure/partnerships are insufficient (logistical and/or operational support; offshore experience, suitable shipyards, O&M support)

☐ Have not previously explored it as a potential option

☐ Other (please specify)

5. In a perfect scenario, if you were to test in Oregon at the PMEC South Energy Test Site, how many months would you like a testing/demonstration project to last for, and with how many devices?
(For each, please write: # months; number of devices in array).

In 2016:

In 2017:

In 2018:

In 2019:

In 2020 and after:

6. After testing/demonstrating your device(s), would you expect to later build out to a commercial project at the same site?

○ No, deployment at just a test site which provides added services and/or enables easier access for testing/demonstration is sufficient

○ Not expected, but would be desirable

○ Yes, it is essential that a fully-energetic test/demonstration deployment can be expanded into a commercial project at the same location

TECHNICAL REQUIREMENTS (part 1/2)

What would you consider as the ideal high-level technical characteristics of a 'fully energetic' test site? (In the case of equal preference for more than one option, please select all that apply).

7. Water depth:

- ☐ Deep Offshore (depth >100m)
- ☐ Offshore (50m <depth< 100m)
- ☐ Nearshore (10m <depth< 50m)
- ☐ Shoreline (depth <10m)
- ☐ Not yet known

If Offshore is not selected, can your device be adapted for this range? (Yes/No)

8. Mean annual wave energy resource (kW/m) at site:

- ☐ Less than 10 kW/m
- ☐ Between 10 and 20 kW/m
- ☐ Between 20 and 40 kW/m
- ☐ Between 40 and 60 kW/m
- ☐ Greater than 60 kW/m
- ☐ Not important for our testing program
- ☐ Not yet known

9. 1-year return value of significant wave height (m) experienced at site (1-year extreme wave event):

- ☐ Hs(1-yr) less than 6m
- ☐ Hs(1-yr) between 6 and 8m
- ☐ Hs(1-yr) between 8 and 10m
- ☐ Hs(1-yr) between 10 and 12m
- ☐ Hs(1-yr) between 12 and 14m
- ☐ Not yet known

10. Seasonal variation as a ratio between max and min monthly mean power flux at site (climatic monthly average):

- ☐ Max/Min < 2.5
- ☐ Max/Min between 2.5 and 4
- ☐ Max/Min between 4 and 5.5
- ☐ Max/Min between 4.5 and 6
- ☐ Max/Min between 6 and 7.5
- ☐ Max/Min greater than 7.5
- ☐ Not important for our testing program
- ☐ Not yet known

11. Seabed geology:

- ○ Sand/Clay
- ○ Bedrock
- ○ Cobbles
- ○ No preference
- ○ Not yet known
- ○ Other (please specify)

12. Other comments (please specify):

TECHNICAL REQUIREMENTS (part 2/2)

What are your anticipated technical requirements for electrical connection?

13. Do you consider grid connection a necessity for your fully-energetic testing program?

- ◯ Yes
- ◯ No

14. Is the power conditioned within your device or does it require an additional unit for conditioning?

- ◯ Contained within device
- ◯ External unit required
- ◯ Not yet known

15. What is the expected voltage of electrical output from your device, i.e. at the umbilical? (please enter a number in kV).

[ ]

16. In accordance with your development plan, if you were to lease a berth at a fully-energetic test site such as SETS, what would you consider to be the most appropriate rated capacity per berth, and the number of connection points per berth? (Please input a number for each: capacity (MW); number of connection points).

2016 horizon: Capacity per berth [MW] and Number of connection points [ ]

2020 horizon: Capacity per berth [MW] and Number of connection points [ ]

2025 horizon: Capacity per berth [MW] and Number of connection points [ ]

SERVICES OFFERED (part 1/2)

17. What site information would you like to be provided by NNMREC? (Please rate in terms of importance).

	Not-required	Useful, but not essential	Essential
Metocean data measurements	◯	◯	◯
Metocean hindcasts (including spatial variability in conditions)	◯	◯	◯
Bathymetry	◯	◯	◯
Geomorphology	◯	◯	◯

Other (please specify)

18. Beyond functionality of your device(s), would you plan to test for any of the following during deployment? (tick all that apply).

- ☐ Environmental impact of the device
- ☐ Mooring configurations
- ☐ Interconnection (wet vs. dry options, etc.)
- ☐ Array layouts
- ☐ Remote operation
- ☐ Other (please specify)

19. What is the installation method planned for your device(s)? (tick all that apply).

- ☐ Tow to site (e.g. by conventional tugboat)
- ☐ Use of specialized vessels (e.g. barge/jack-up/DP vessel)
- ☐ Shoreline deployment (e.g. launched from pier/beach)

Other (please specify)

20. If deployment, retrieval, and/or maintenance vessels are needed, please specify the type (tick all that apply):

- [ ] Jack-up vessel
- [ ] Crane vessel
- [ ] Tug
- [ ] Multi-Cat or other generic workboat
- [ ] Lightweight rigid or semi-rigid hulled inflatable
- [ ] DP Vessel
- [ ] ROV and support vessel
- [ ] Divers and support vessel
- [ ] Other (please specify)

Please specify (if known) the size, and capacity of vessel/crane required for operation

21. Would you prefer existing mooring systems to be installed at the site by PMEC (tick all that apply)?

- [ ] Yes, an existing single point system
- [ ] Yes, an existing 3-point system
- [ ] Yes, an existing multi-point system
- [ ] No, we want to use our own proprietary anchor/mooring arrangement
- [ ] No, we may wish to test various anchor/mooring arrangements
- [ ] No, we'd like to test arrays in arrangements which pre-installed anchors/moorings would likely prohibit
- [ ] Not yet known
- [ ] Indifferent

SERVICES OFFERED (part 2/2)

What additional services would you like to be available at PMEC?

22. Please rank in terms of importance (most=1 to least=6):

- [ ] Development support
- [ ] Monitoring support
- [ ] Operational support
- [ ] Policy/contractual/legal support
- [ ] Outreach support
- [ ] Other incentives/services

Within each category please rate in terms of importance:

23. Development support:

	Not-required	Useful, but not essential	Essential
Independent performance verification	○	○	○
Support to certification	○	○	○
Resident engineering team and/or generic R&D support;	○	○	○

24. Monitoring support:

	Not-required	Useful, but not essential	Essential
Resource monitoring and support	○	○	○
Environmental impact monitoring and support	○	○	○
Technology monitoring and support	○	○	○

25. Operational support:

	Not-required	Useful, but not essential	Essential
Marine works & operations planning and supervision	○	○	○
Deployment and maintenance barges	○	○	○
Professional diving and specially trained maritime works teams	○	○	○
Workshop, shipyard facilities and storage of large items	○	○	○
Office, team accommodation and storage room for minor items	○	○	○
Community liaison and logistical support (e.g. transport, partner search)	○	○	○

26. Policy/contractual/legal support:

	Not-required	Useful, but not essential	Essential
Power purchase agreement	○	○	○
Support understanding/navigating state policy (e.g. securing state incentives, the state regulatory process)	○	○	○
Support understanding/navigating national policy (e.g. securing federal incentives, the federal regulatory process)	○	○	○
Site pre-permitted for your type of device (avoidance of regulatory process)	○	○	○

27. Outreach support:

	Not-required	Useful, but not essential	Essential
Local public outreach (e.g. informational plaques, community newsletters, etc.)	○	○	○
Finding housing, office space, relocation assistance	○	○	○

28. Other incentives/services (please specify):

FOLLOW-UP INTERVIEW (to be held August 2013)

29. Are you open to discuss this further in a 30-45 min interview over the phone? (Information can also be provided at that time about a potential face-to-face meeting in Oregon).

- ◯ Yes
- ◯ No

If yes, please indicate (a) contact person, (b) e-mail address and (c) phone number