Oregon Wave Energy Trust

"Dedicated to developing wave energy as a clean, renewable, safe and profitable natural resource."

Final Report

Close to the Customer Project

Oregon State University

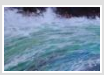
October 2009

OWET

Overview

 Research Objectives

 List of Contacts

 Methodology

 Key Findings

 What Now?

Research Objectives

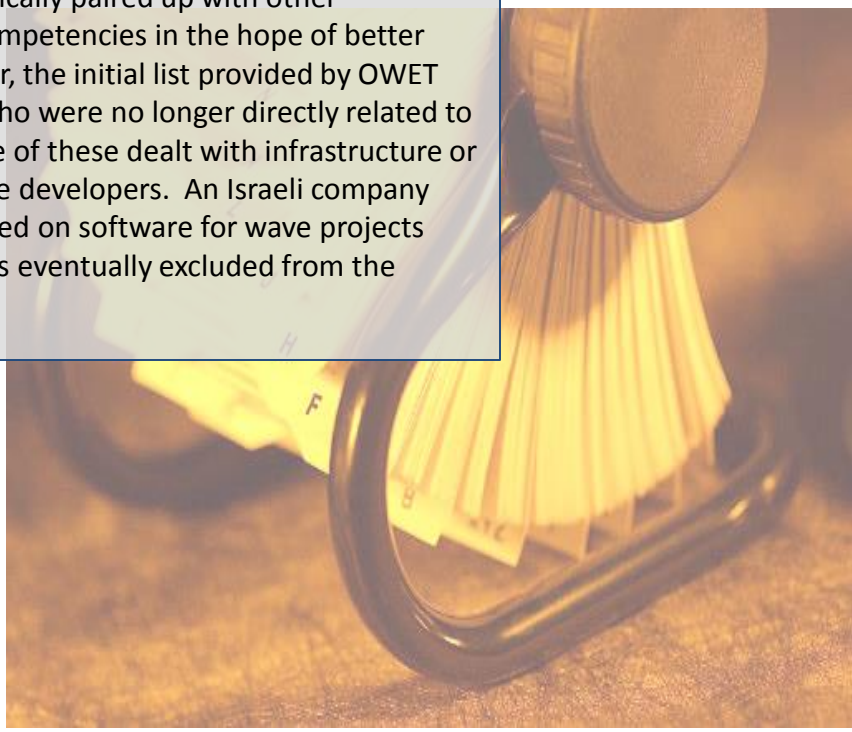
OWET seeks to uncover and anticipate the needs and interests of wave energy developers regarding the logistics and technical requirements of testing their wave energy devices on the Oregon coast. The following are among the topics of interest:

- Explore developers' general interest in testing facilities
- Explore future needs of wave energy developers
- Identify technical requirements:
  - Peak instantaneous power
  - Average power over one wave period
  - DC or AC output
  - Single phase or three phase
  - Peak voltage and Peak current
  - Grounding scheme for the device
- Explore concerns and needs regarding environmental impacts
- Mooring arrangement
- Fundamentals of deployment and removal of the device

List of Contacts

We began work with a list of relevant contacts provided by OWET. We worked to update that list in order to have the most current and correct information. To accomplish this, we did additional internet research that led to new contacts and we also asked respondents to provide additional contacts. In particular, Waveberg, a respondent company on the east coast, directed us to a list of ocean energy developers compiled by a European graduate student. These efforts expanded the number of potential contacts by nearly 40 for a total population of 101 industry representatives (e.g., developers, managers, engineers) from around the world that we invited (by telephone and/or e-mail) to participate in this survey.

This is a dynamic industry and the set of players is evolving. We found that the industry is contracting and many firms have merged with other companies. Firms have typically paired up with other organizations to combine core competencies in the hope of better meeting market needs. Moreover, the initial list provided by OWET contained a number of entities who were no longer directly related to wave energy development. Some of these dealt with infrastructure or provided support services to wave developers. An Israeli company who falsely claimed to have worked on software for wave projects was an example of a firm that was eventually excluded from the survey.



Methodology

The research began with a short list of survey topics from OWET and technical questions from OSU engineering. A brain-storming session was held that included representatives from C2C, OWET and OSU Engineering. The survey progressed through multiple iterations with comments and direction from OWET and OSU Engineering. Pre-tests were attempted with Columbia Power Technologies and Finavera Renewables.

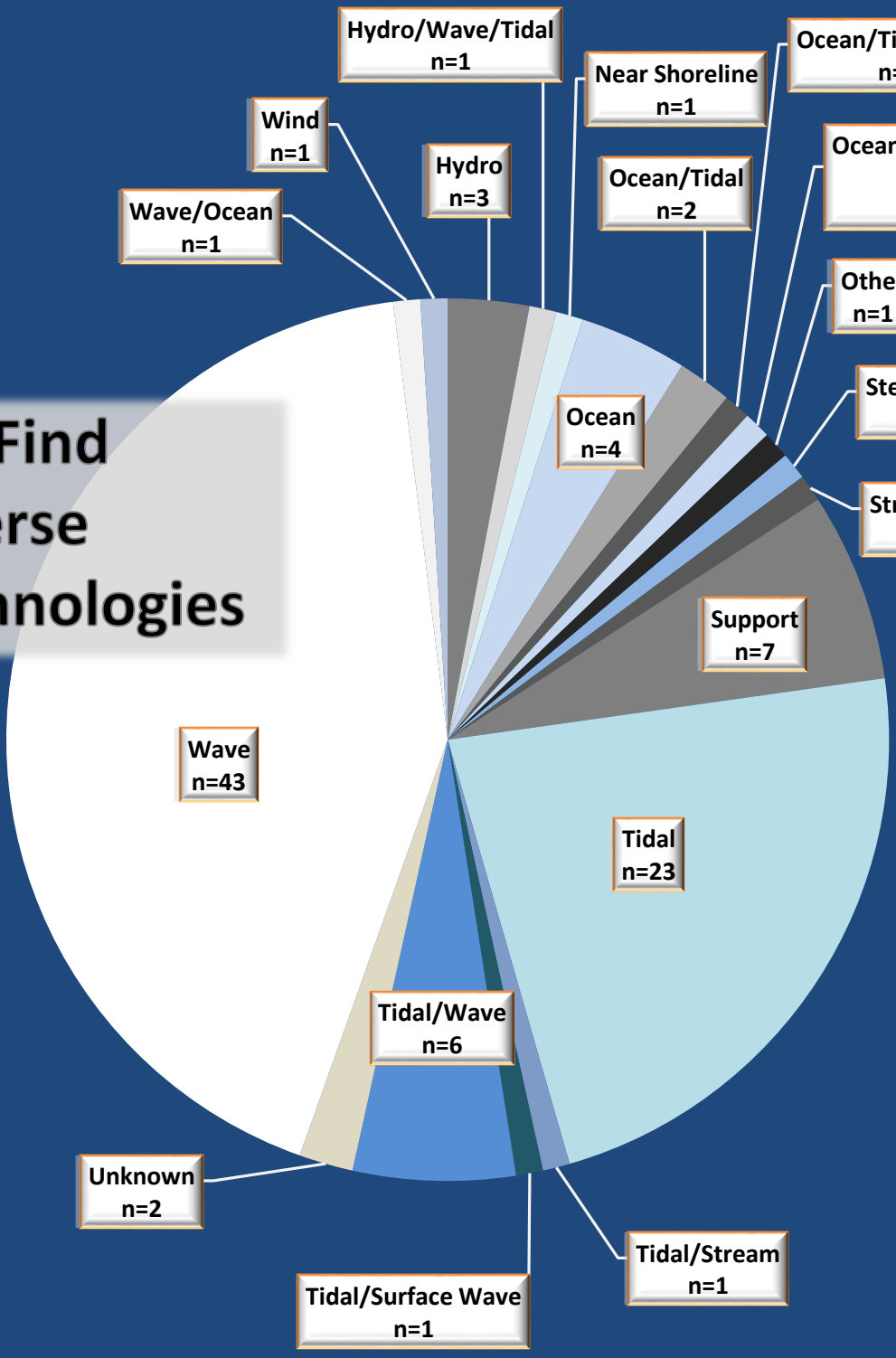
A pre-notification e-mail was sent to all participants informing them of the upcoming survey, describing Oregon's investment in wave energy, introducing them to OWET and the plan to build a test-facility on the Oregon coast. Approximately a week later, each firm received an e-mail that included the URL for the survey. Firms that did not respond to the online survey, were contacted by telephone and an attempt was made to collect the information on the phone. Data collection was completed by October 2008.

Of the 101 contacts, 51 were qualified as wave energy developers and invited to participate in the survey. Those that did not qualify were excluded because:

- They have interest in ocean current power generation, or a mix of hydro, river or stream power and have no interest in wave energy generation. This accounted for the exclusion of 10 contacts.
- Twenty-nine had an interest in tidal devices and no interest in wave development.
- There were ten infrastructure support professionals (e.g., provide testing components) and even one wind developer in the list.

Of the 51 qualified wave contacts 24 responded to the e-mail survey or participated in the phone survey. Thus, we have a response rate of 47%.

We Find Diverse Technologies



Key Findings

 Segmentation and Services

 Plans for Testing

 Opportunities and Barriers

 Educate Developers

 Competition

Segmentation and Services

We Find Diverse and Varied Needs Across Segments

Stage of Development

We segmented the respondents based on the stage of development of the firm's device. Of the twenty-two contacts that responded to this question, six are in the early development stages in which they are either in the process of **building a prototype** or in the **numerical modeling** stage. Sixteen developers have actually **built at least one prototype**. Seven of the sixteen that have a prototype indicate a need to conduct **tank tests**, one reported a need for **ocean testing**. The remaining eight contacts have completed some testing and are developing a new device.

Subcontracting During Testing: Transportation, Assembly and Divers

Of the eight participants who have t**ested a prototype and are building the next,** four are interested in help with a diverse set of services including: transportation to and from the facility, divers for deployment/removal, and assembly. Those contacts (n=5) that are currently **building initial prototypes** are not interested in any of these services. The developer with the device in the **numerical modeling** stage is interested in assistance with five of the seven services. Those who have **built a prototype and desire testing at a large scale wave tank** (n=3) are interested in more than half of the services available and the needs are varied.

Segmentation and Services (continued)

Still Finding Diverse and Varied Needs Across Segments

Assistance with Energy Generation, Control and Monitoring and Power Transmission Sub-Systems

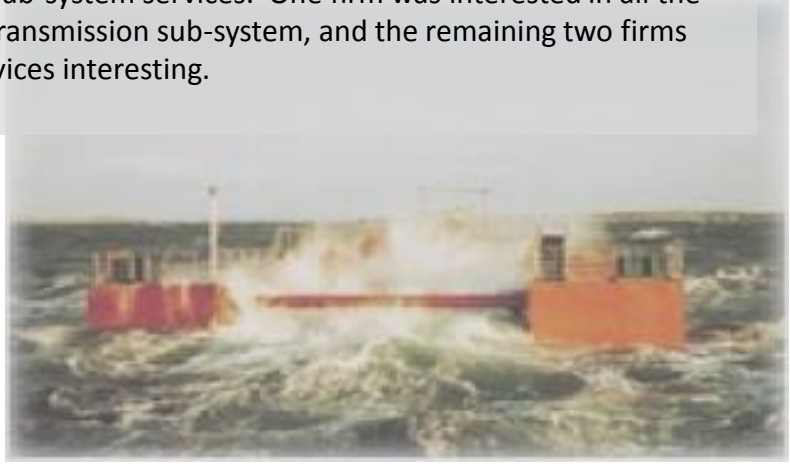
Of the four developers who had a **prototype and needed large-scale wave tank** or **ocean testing**, one desired sub-system services (Energy Generation, Control/Monitoring, and Power Transmission). For this developer, the Control and Monitoring sub-system services were of interest.

The developer in the **numerical modeling phase** is interested in all sub-system services .

Those **building prototypes** have mixed thoughts on whether they need services or not. One developer in this stage did not request any of the services, the others have interest in a variety of services.

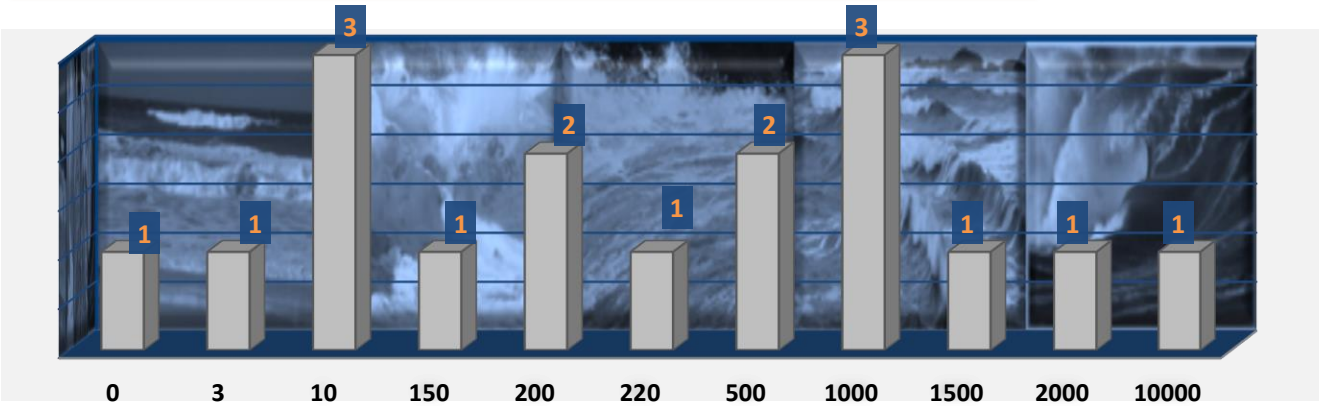
Of the four developers in the **'built a prototype and need small scale wave tank testing'** stage we find similarly diverse needs. One developer asked for help in a broad mix of seven different services, one did not request any assistance, and two developers requested one Energy Generation sub-system service.

Five of the eight developers with a device in the **'testing one prototype and building the next'** stage desired none of the sub-system services. One firm was interested in all the services provided in the Power Transmission sub-system, and the remaining two firms found a mix of seven to nine services interesting.



Segmentation and Capacity

What peak instantaneous power in kW would a testing facility need for your device?



- As indicated by seventeen respondents, the mean peak instantaneous power a testing facility would need to accommodate is 1,077kW and ranged from zero to 10,000kW.
- As indicated by thirteen respondents, the mean average power per wave period is 207kW with a range of zero to 700kW.
- As indicated by fifteen respondents, the mean peak voltage is 5,967 volts with a range of 6 to 33,000 volts.
- As indicated by nine respondents, the mean peak current is 187 amps and ranged from 0.5 to 800 amps.
- In general, those developers that have built one prototype and are building a second, are reporting that they will require higher capacities from the test berth.

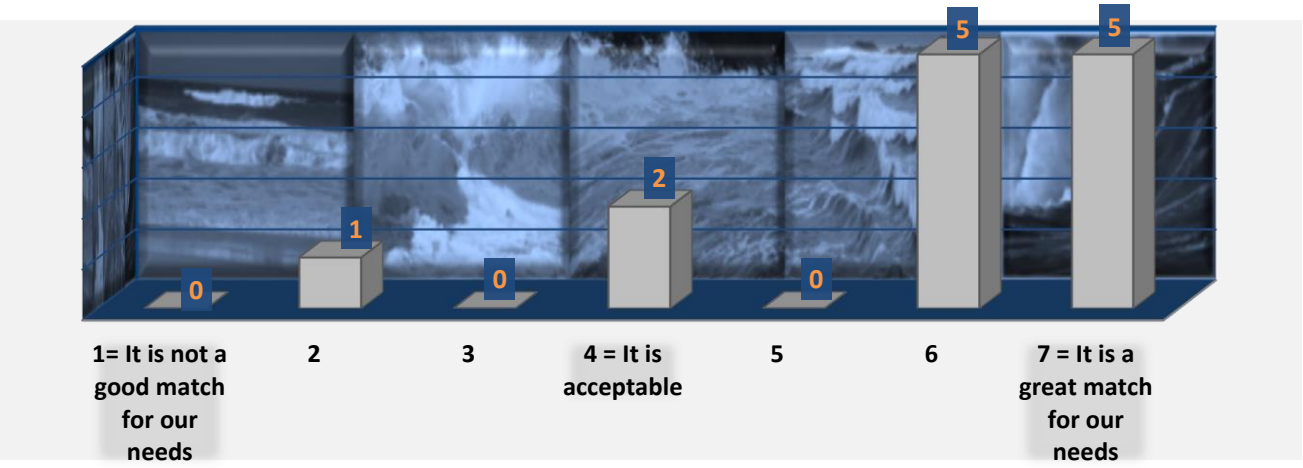
Plans For Testing

All respondents indicated they were planning to test their devices at some point. In terms of anticipating timing of testing, responses varied widely. **For those developers that plan to ocean test their device** (n = 23), eight said they would be testing within six months, thirteen anticipate ocean testing their device in a year to twenty-three months. There was one developer that did not plan to ocean test their current device in the near future because they were in the second round of large tank test. This developer did anticipate ocean testing within two to three years, when a new prototype was completed.

When asked if they are developing other or larger prototypes that will need to be ocean tested, eleven of the thirteen firms responded "Yes." Of these eleven companies, two anticipate being ready for ocean testing within six months, four anticipate being ready in a year to twenty-three months, four within two years to thirty-five months, and one in three years or more.

Plans for Testing (continued)...

To what degree does the facility you plan to use suit your needs?



Eighteen of twenty-four developers have a "test facility in mind" for doing their ocean testing. Of these eighteen, thirteen will do their own testing and only five will hire a firm. Of the six that indicated they will do their own testing, five do not anticipate ever needing another firm to do their testing.

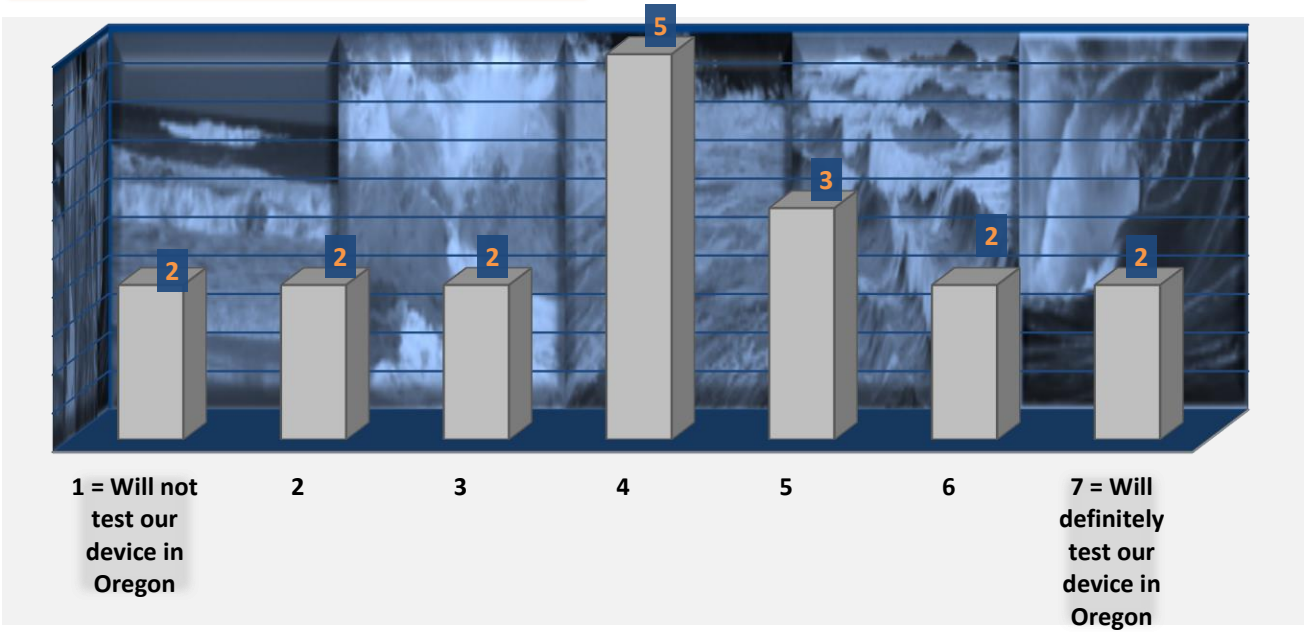
The thirteen respondents that have a test facility in mind were asked, "To what degree do you believe that the test facility you plan to use is suitable for your needs?" Respondents were asked to select a response from one to seven, where one was "It is not a good match for our needs" and seven was "It is a great match for our needs." All but one responded that the facility would be acceptable or a good match to their needs.

Opportunities

When asked how likely they would be to use a testing facility in Oregon, the respondents can be placed into one of three groups. Six of eighteen respondents indicated that it would be unlikely they would test a device off the Oregon coast (response of 1, 2 or 3). Five respondents were indifferent (response of 4), while seven answered they were at least somewhat inclined to the concept of testing a device in Oregon. Of these seven, only two selected the "top box" that was labeled, "Will definitely test our device in Oregon."

How likely are you to test in Oregon?

Mean: 4.056



Opportunities

Educating Developers

Participants were asked to rate the importance of information about environmental issues such as the acoustic profile of the device, impact on fishing habitat, mammal migration, sediment transport and EMF generation. The highest means were for fishing habitat impact and mammal migration impact with means of 5.18 and 4.94 on the seven point scale, and the remaining questions had means between 3 and 4 on the same scale.

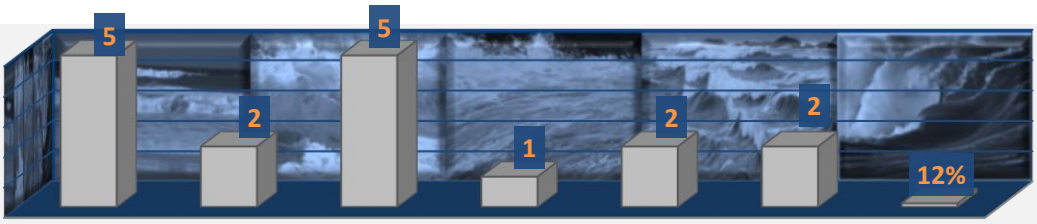
It would seem that the developers are not considered the issues that coastal communities may raise about having wave energy devices deployed off their coastline. Such issues may be beyond their current planning/development horizon which presents an educational opportunity for this test facility.

For these developers, the most important issue was survivability which had the highest mean response with 6.5 on a seven point scale.

Survivability

1 = Not important at all | 2 | 3 | 4 | 5 | 6 | 7 = Extremely Important

Sediment Transport



1 = Not important at all | 2 | 3 | 4 | 5 | 6 | 7 = Extremely Important

Barriers

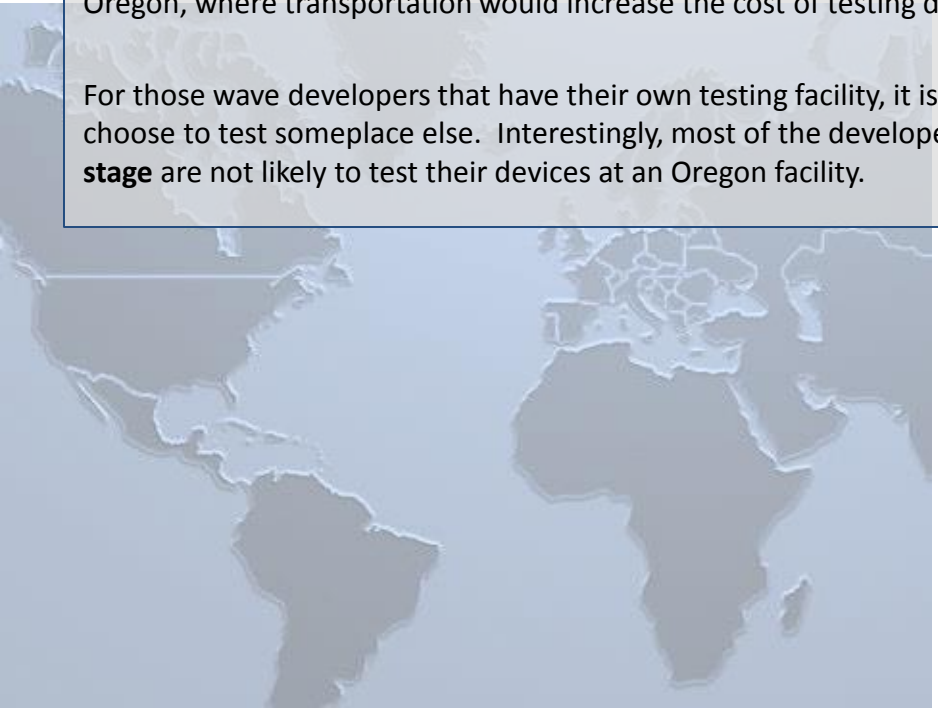
Must Be Overcome

There are three main reasons why wave developers would not test in Oregon. First, is the lack of capital; as one wave developer said, “we don’t get paid for testing.” Most also indicated that if testing was subsidized or they could obtain sufficient funding, bringing their device to Oregon for testing would be more likely.

The second barrier is geography; they are not near Oregon. A final barrier to an Oregon testing facility is that a number of wave energy developers already have adequate access to a testing facility.

Aside from the lack of funding, the physical location of many wave developers poses an obvious obstacle for OWET. The participants that we contacted for this survey were spread throughout the world, with the majority in Europe. If testing facilities are readily available in the vicinity of the wave developers, many felt that it would be difficult to use a testing facility as far away as Oregon, where transportation would increase the cost of testing dramatically.

For those wave developers that have their own testing facility, it is highly unlikely that they will choose to test someplace else. Interestingly, most of the developers in the **building prototype stage** are not likely to test their devices at an Oregon facility.

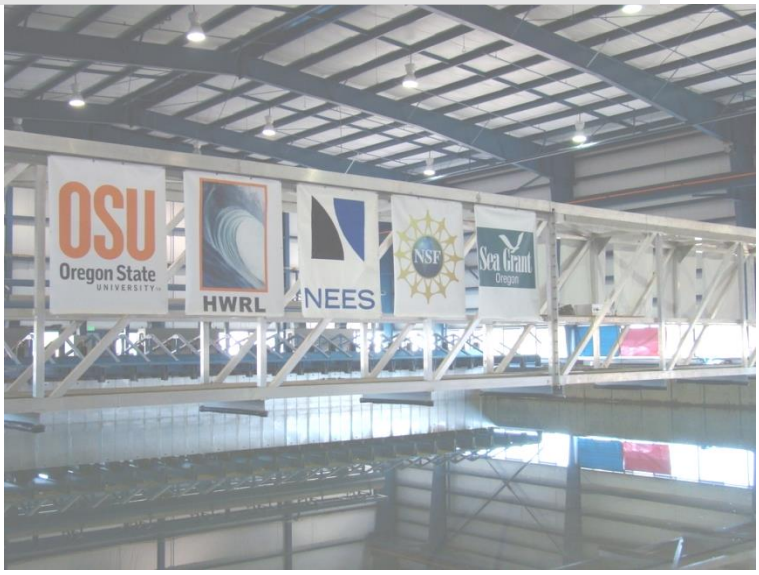


Competition

The European Marine Energy Center (EMEC), located in Orkney, Scotland, is a testing facility that includes four test berths that are capable of both wave and tidal testing. The facility is relatively close to wave developers in Europe making it the obvious testing facility for European developers.

The existence of this particular testing facility is the biggest impediment to bringing European wave developers to Oregon. As mentioned in the earlier sections, funding is a major concern for wave developers and the extra cost for transportation is a luxury that few can afford.

Of the four test berths available at EMEC, at present, only one of the berths is being used for testing. Perhaps this is due to the lack of capital for wave developers. The Oregon facility should be expected to face similar challenges as well.



Interpretation/Future Research…

There are some important issues that emerge from our research that merit attention. According to feedback from a developer, 70-80 percent of the current development is focused on hydraulic energy devices. While we cannot verify or refute this claim, it should be considered in the design of the test facility. To this end, some company representatives we spoke to said they had difficulties answering questions on the survey. These companies were developing hydraulic devices, but their device was different from Finavera Renewables' AquaBuoy* as it did not incorporate an onboard generator. As the device was not a "wave-to-wire" solution some of the technical questions did not apply to their device. For example, this developer when asked about peak instantaneous power in kW would be likely to answer "zero."

Similarly, developers had devices at various stages of development. A number of developers provided their best estimates given the knowledge they had at the time from small scale devices to answer the technical questions regarding peak voltage, instantaneous power, and average wave period. These issues bear upon the application of the quantitative results to the design of the testing/monitoring aspects of the facility.

In addition, developers outside of Oregon appear to have good knowledge of the planned facility. One developer who had done extensive testing on their device was aware of OWET and was curious why this survey was their first contact from OWET. **People in the alternative energy business are interested and want to be kept up to date** with the latest advances and news whether or not they are interested in testing their device at this time.

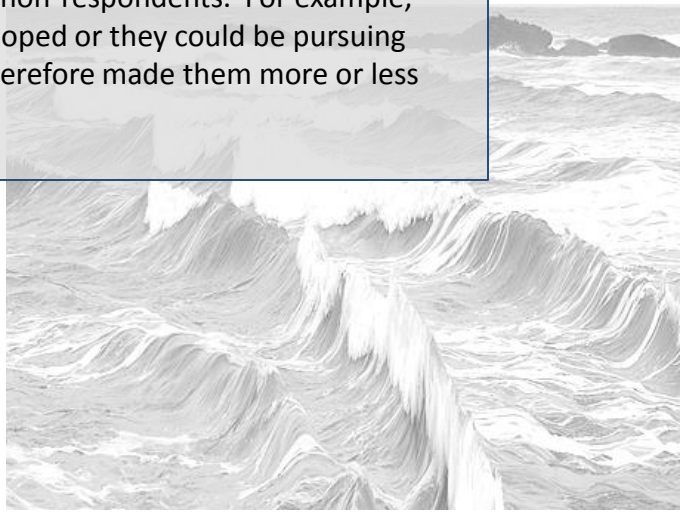
Certain wave developers expressed their desire to have more contact and input from OWET in the developer community. In addition, our findings indicate that to be a successful competitor in the realm of testing facilities, OWET needs to stay in touch with key wave developers around the world and carefully assess the needs for testing so that its facility will be a **suitable match for the variety of devices** being developed.

* - http://www.youtube.com/watch?v=r89xQxZsaN8

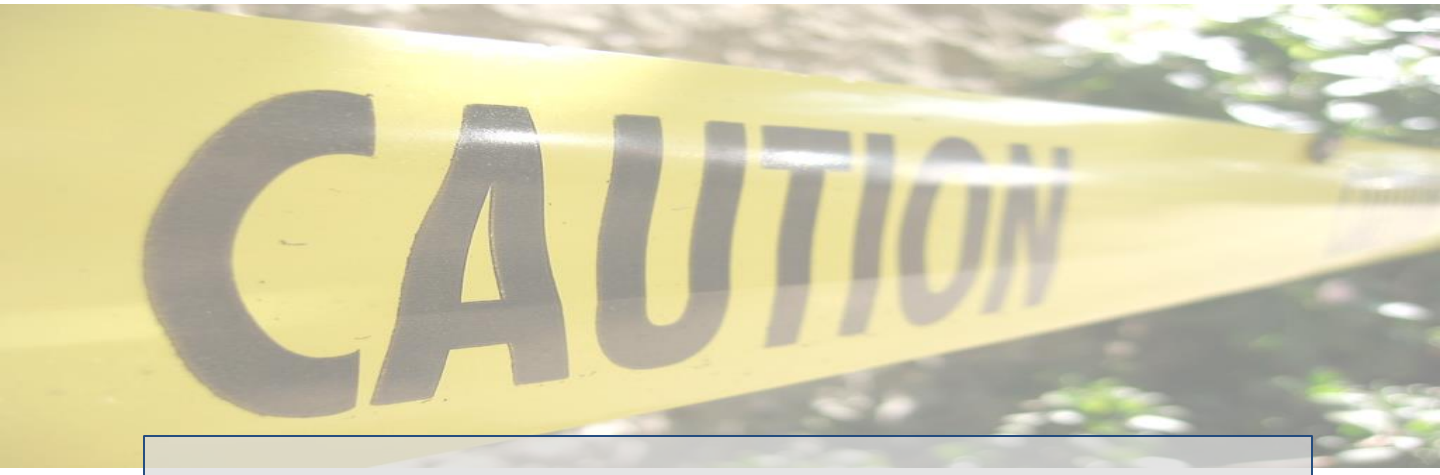
Limitation

It is important to note that the list was intended to be a **census** of wave energy developers. Most surveys use the results from a small random sample to **generalize** to the larger population (e.g., the political polls reporting voter preferences for state and federal candidates). For this study, we **attempted a census** of all qualified wave energy developers, rather than **a randomly generated sample** from the list. Therefore, it would be **very risky to generalize these results** to the group of developers that did not respond to our survey requests.

These results only apply to those surveyed as we do not know if there are differences between the respondents and non-respondents. For example, one group's devices could be further developed or they could be pursuing solutions that are not wave-to-wire and therefore made them more or less likely to respond.



Caution is Key



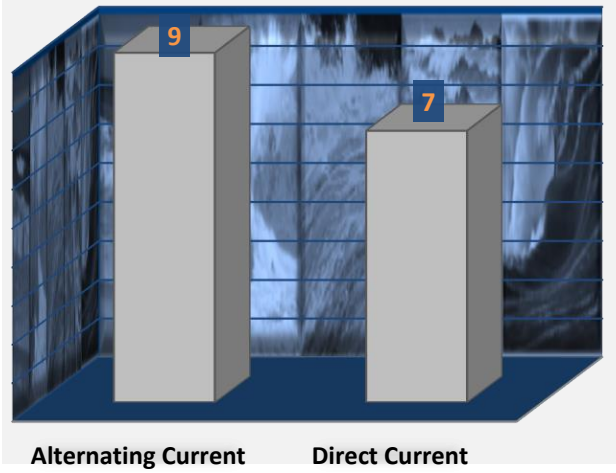
With the firm's finances playing a key role in the decision to test at an Oregon facility, we suggest to slowly build the capacity of the facility according to market dynamics. Some developers were very interested in the OWET facility, but will not be ready to test for two to four years. Focusing efforts on educating developers regarding the importance of assessing environmental impacts could be beneficial and valuable. With the dramatic slow down in the global economy, the demand for energy is lower than it has been and prices of fossil fuels have dropped. Investors are having a difficult time finding reasons to invest money in alternative energy efforts at this time.

Another point of caution comes from the diverse technologies that are under development. It might be risky to plan for a singular approach to the development of wave energy and the testing of devices. A **comprehensive test berth** would be one that can test alternative technologies and approaches. This can help attract more firms – this will be important as there were only two respondents that replied they would "definitely" test their device in Oregon.

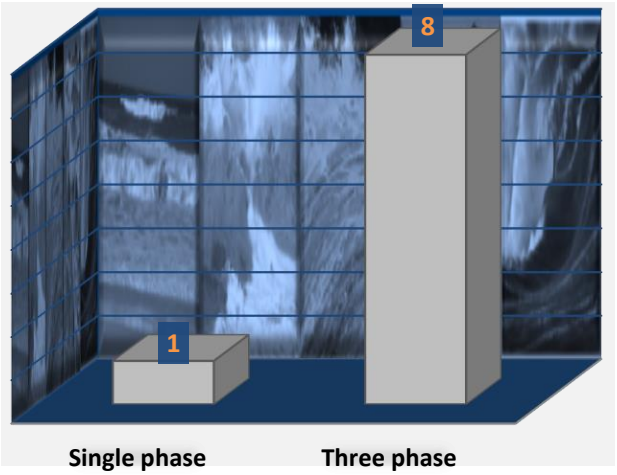
It is important to be proactive, listen and talk with customers and find what additional needs this undecided and growing alternative energy market needs and positioning your product around those needs. Most of these developers are interested in what OWET is doing and want to be kept up-to-date on the latest OWET news.

Technical Findings

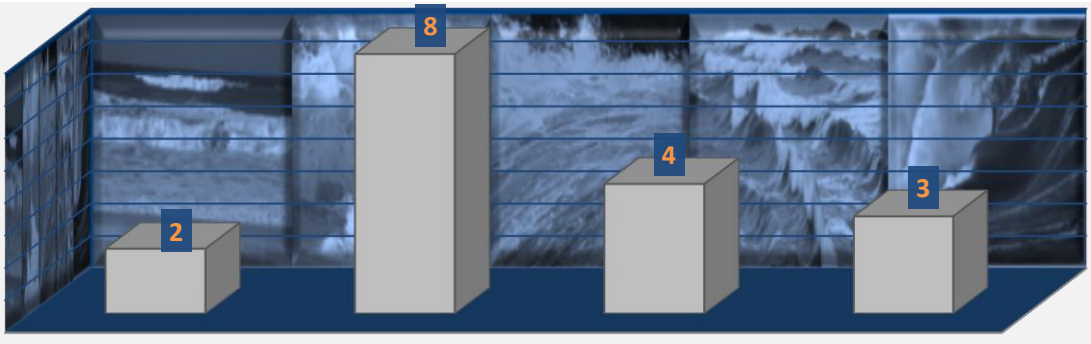
Will your device generate alternating current or direct current?



Is the alternating current single phase or three phase?

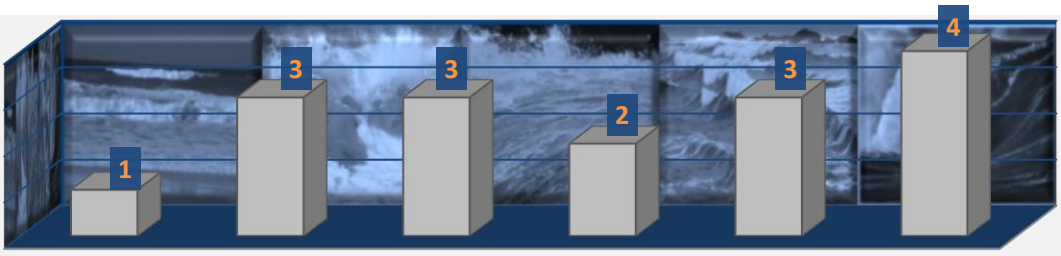


What method will be used for grounding your wave energy device?



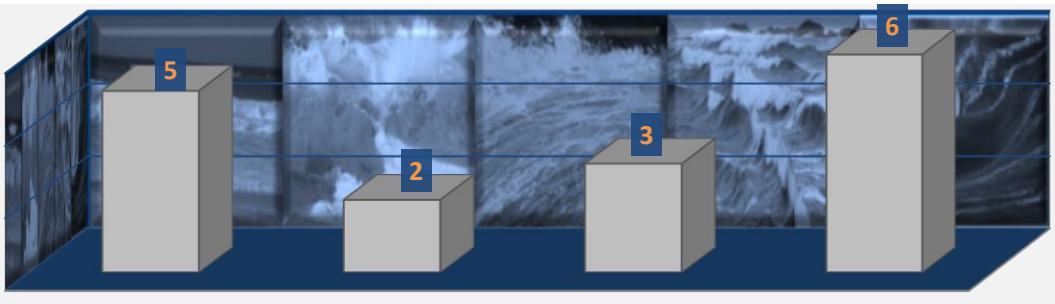
Technical Findings

What is the size of the "watch circle" needed for mooring your device?



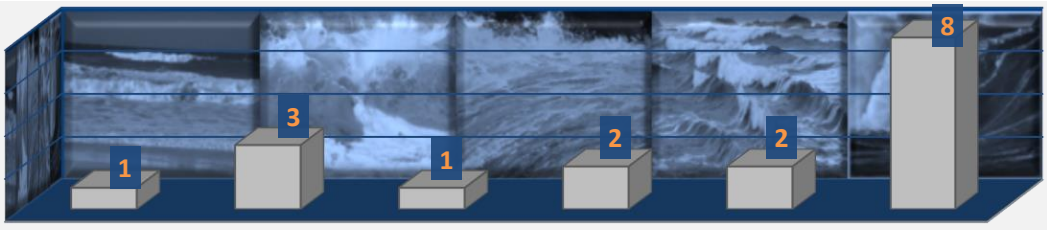
0-25 meters | 25-50 meters | 51-150 meters | 151-250 meters | Over 250 meters | Don't know

What method of mooring will be necessary to secure your device?



Catenary | Taut | Semi-taut | Other

What sampling rates meet your needs?

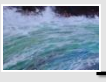


Less than or equal to 1.0 milliseconds | 101 milliseconds to 1.0 second | 1.1 to 10 milliseconds | 11 to 100 milliseconds | 1.1 second or more | Don't know

Appendix: TBD

 How did we qualify developers?

 Text Responses

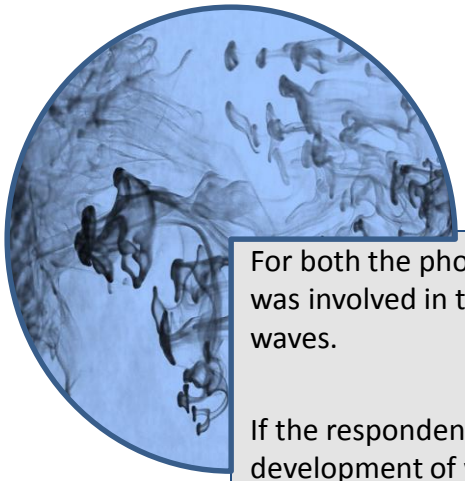
 Contact Information

 Frequency Tables

 Cross-tabulations

 Means of Technical Questions

How did we qualify developers?



For both the phone and e-mail surveys the first question asked if the respondent was involved in the development of devices that generate power from ocean waves.

If the respondents of the phone survey indicated that they were involved in the development of wave energy devices they would then be asked, “Which of three types of development they were involved in that captured or developed power from the movement of water?” These three categories are:

- Wave
- Tidal current
- Ocean current

If the respondent indicated that they were involved in the development of wave they were then asked a series of questions regarding their work on these devices. If the respondents chose tidal current or ocean current the survey was terminated.

A similar set of questions was used in the e-mail survey, except developers were not asked to specify if they were developing devices to harness tidal or ocean current energy.