Final Technical Report

WAVE ENERGY PRIZE

U.S. DEPARTMENT OF ENERGY

Project Title:	Administration of the DOE Wave Energy Prize
DOE Award Number:	DE-EE0006738
Project Period:	Sep 2014 – Mar 2017
Date of Report:	March 17, 2017

Principal Investigators and Authors:

Name	Role	Company	Phone	Email
Wesley Scharmen	PI / Author	Ricardo	734-394-3943	wesley.scharmen@ricardo.com
Julie Zona	PI / Author	JZ Consulting	734-771-4306	julie.jzc@gmail.com
Christine Fuentes	Author	Polaris Strategic Communications	540-905-8448	christine.fuentes@polariscommunications.org
Alison LaBonte	Author	US DOE	202-287-1350	alison.labonte@ee.doe.gov

Recipient Organization: Ricardo, Inc. (Prime Contractor)
Van Buren Twp., MI 48111

Acknowledgment: "This report is based upon work supported by the U. S. Department of Energy under Award No. DE-EE0006738".

Disclaimer: "The information, data, or work presented herein was funded in part by an *agency* of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

Proprietary Data Notice: If there is any patentable material or protected data in the report, the recipient, consistent with the data protection provisions of the award, must mark the appropriate block in Section K of the DOE F 241.3, clearly specify it here, and identify them on appropriate pages of the report. Other than patentable material or protected data, reports must not contain any proprietary data (limited rights data), classified information, information subject to export control classification, or other information not subject to release. Protected data is specific technical data, first produced in the performance of the award, which is protected from public release for a period of time by the terms of the award agreement. Reports delivered without such notice may be deemed to have been furnished with unlimited rights, and the Government assumes no liability for the disclosure, reproduction or use of such reports.

Contents

1 List of Terms and Acronyms 5
2 Lists of Figures 7
3 List of Tables 7
4 List of Appendices 7
5 Executive Summary 8
6 Introduction 10
7 Background 10
7.1 Prize Goals and Objectives 10
7.1.1 Additional Goals and Objectives 12
7.2 Metrics 12
7.2.1 ACE 12
7.2.2 Hydrodynamic Performance Quality (HPQ) Metric 16
7.2.3 Technology Performance Level (TPL) METRIC 17
7.3 Roles /Participating Parties 19
7.3.1 U.S. Department of Energy (DOE) 19
7.3.2 Prize Administration Team (PAT) 20
7.3.3 Program Identified Partner (PIP) 21
7.3.4 Judges 21
7.3.5 Additional Supporting Entities 23
7.3.6 Teams / Participants 23
7.4 Phases/Technology Gates/Timeline Overview 24
7.4.1 Phases 24
7.4.2 Technology Gates 25
7.4.3 Timeline Overview 26
8 Results and Discussion 27
8.1 Team/Device Funneling 28
8.1.1 Official Registered Teams 28
8.1.2 Transition from Registered to Qualified Teams - TG1 28
8.1.3 Transition from Qualified Teams to Finalists and Alternates - TG2 29
8.1.4 Transition Finalists and Alternates to Testing Finalists - TG3 30
8.1.5 Ranking of the Testing Finalists - TG4 30

8.1.6 Grand Prize ($1.5M) AquaHarmonics (Portland, OR) 31
8.1.7 2nd Place ($500k) CalWave Power Technologies (Berkeley, CA) 31
8.1.8 3rd Place ($250k) Waveswing America (Sacramento, CA) 32
8.2 Prize Feedback 32
8.3 Prize ROI Evaluation 33
8.3.1 RETURNS ON THE PRIZE.. 33
8.3.2 INVESTMENT ON THE PRIZE 34
8.3.3 Comparison of the Prize and Traditional funding mechanisms........................ 35
9 Accomplishments.. 36
9.1 Technical 36
9.2 Publicity and Media 38
9.2.1 Communications and Outreach.. 38
9.2.2 Analytics 38
10 Conclusions... 39
11 References and/or Bibliography 40
12 Appendices.. 40
12.1 Appendix 1 – Wave Energy Prize Rules 41
12.2 Appendix 2 – Wave Energy Prize Terms and Conditions.................................. 100
12.3 Appendix 3 – Media Coverage of the Wave Energy Prize................................. 106
12.4 Appendix 4 – Wave Energy Prize Finalist Closeout Interview Results 122

1 List of Terms and Acronyms

Absorbed Power – The hydrokinetic to mechanical power conversion. It is product of the dynamic (forces, pressures, torques, etc.) and kinematic (velocities, flows, rotational velocities, etc.) parameters for a hydrokinetically excited device.

¢ - Cents in US currency

$ - Dollars in US currency

$M – Million Dollars in US currency

AACW - Average Annual Capture Width

ACCW – Average Climate Capture Width; measure of the effectiveness of a WEC at absorbing power from the incident wave energy field.

ACE – Average Climate Capture Width per Characteristic Capital Expenditure; primary metric for Wave Energy Prize; a benefit to cost ratio and proxy for LCOE, appropriate for comparing low TRL WEC designs comprised of ACCW/CCE.

AEP – Annual Energy Production

Capture Width – The power absorbed from the waves by the device in kW divided by the incident wave energy flux per meter crest width in kW/m.

CapEx – Capital Expenditure

CCE – Characteristic Capital Expenditure; a measure of the capital expenditure in commercial production of the load bearing device structure.

DOE – U.S. Department of Energy

Force Flow – The way forces and load penetrate the system.

FTE – Full Time Equivalent; the hours worked by one employee on a full-time basis

HPQ – Hydrodynamic Performance Quality

IP – Intellectual Property

JPD – Joint Probability Distribution

kg – kilogram

kW – kilowatt

kWh – kilowatt-hours

LCOE – Levelized Cost of Energy

LIWS – large irregular wave spectra

m – meter

MASK – Maneuvering and Seakeeping Basin, at the Naval Surface Warfare Center, Carderock, Md.

MHK – Marine and Hydrokinetic

MHKDR – Marine and Hydrokinetic Data Repository

MMC – Manufactured Material Cost

NREL – National Renewable Energy Laboratory

NSWCCD – Naval Surface Warfare Center Carderock Division

OpEx – Operational Expenditure

PAT – Prize Administration Team

PI – Principle Investigator

PIP – Program Identified Partner

Representative Power Take Off (PTO) – Primary mechanism used to control hydrodynamic power absorption and to convert the absorbed power to useful power. This may include multiple power conversion steps. In hydrodynamic model testing this system is often represented solely with respect to its influence on the primary power absorption and conversion step. Often a simple e.g. linear relationship between the dynamic and kinematic components controlling the power absorption is used.

ROI – Return On Investment

RST – Representative Structural Thickness; scalar that is used to determine the total structural mass when multiplied by the surface area of the material.

RWS – realistic wind swell spectra

SNL – Sandia National Laboratories

SSTF – Small Scale Test Facility

TG – Technology Gate

Total Surface Area – Total surface area (m^2) at full scale is identified as all structural surface area that is subject to loading and/or is inherent to the production of power. For this prize, only surface areas that define the profile of the device are considered (i.e. it is not the surface area of all components that are needed to physically construct a device, like the underlying girders and stiffeners). Included are structural surface areas below and above the water line when the system is installed with the mooring attached and in still water; Included is the station keeping mechanism; Not included are anchor lines

TPL – Technology Performance Level

TRL – Technology Readiness Level

USD – US Dollars

WEC – Wave Energy Converter

2 Lists of Figures

Figure 1: The ACE Metric 13
Figure 2: Representative Structural Thickness 15
Figure 3: Technology Gates 25
Figure 4: Phase 1 Timeline 26
Figure 5: Phase 2 Timeline 26
Figure 6: Phase 3 Timeline 27

3 List of Tables

Table 1: Finalist Ranking 9
Table 2: Technology and Performance Levels Definitions 18
Table 3: Small-Scale Test Facilities 23
Table 4: Teams, SSTF's, and Testing Dates 29
Table 5: Finalist Teams 30
Table 6: Prize Funding Distribution 34
Table 7: Overall Prize Investment, DOE and Nine Finalists 35
Table 8: Additional Prize Investment Assumptions 35
Table 9: Overall Prize Investment, DOE and All Registered Entries 35
Table 10: Prize Construct vs. Traditional Prizes and Funding 36

4 List of Appendices

Appendix 1 – Wave Energy Prize Rules........41
Appendix 2 – Wave Energy Prize Terms and Conditions........100
Appendix 3 – Media Coverage of the Wave Energy Prize........106
Appendix 4 – Wave Energy Prize Finalist Closeout Interview Results 122

5 Executive Summary

The U.S. Department of Energy's (DOE) Water Power Program is committed to developing and enabling deployment of a portfolio of innovative technologies for clean, domestic power generation from resources such as hydropower, waves, and tides. With more than 50 percent of the American population living within 50 miles of the coast, a cost-effective marine and hydrokinetic industry could provide a substantial amount of electricity for the nation. In 2014, the DOE Water Power Program received approval to utilize a prize challenge construct to aid in invigorating the deep-water wave energy conversion/generation market. Prize challenges can spur radical leaps in technology by accelerating the standard development cycle by focusing in on key areas of a problem and awarding performance in the form of a cash prize and other in-kind support. This report documents the Wave Energy Prize and its administration over the 30-month period that Ricardo executed "DE-EE0006738 - Administration of the DOE Wave Energy Prize."

The Wave Energy Prize envisioned the achievement of game-changing performance enhancements to Wave Energy Converter (WEC) devices, establishing a pathway to sweeping cost reductions at a commercial scale. The DOE defined an internal program goal that WEC devices would need to be commercially competitive by approximately 2050. This goal was reviewed by the National Labs, which calculated that a LCOE of ~6 ¢/kWh in 2050 (in 2014 USD) would be needed to achieve the timetable. Since LCOE is not practical to estimate or calculate on low Technology Readiness Level (TRL) WEC devices, the National Labs created a new metric for the Prize to use: Average Climate Capture Width per Characteristic Capital Expenditure (ACE). The National Labs calculated that a possible corresponding ACE metric value of approximately 6 m/$M would be necessary to fully achieve the DOE LCOE goal. Based on the estimated current state-of-the-art WEC devices projecting to an ACE value of 1.5 m/$M, the technical experts believed a doubling of the current device ACE from 1.5 m/$M to 3 m/$M was an aggressive but achievable target and would be a significant step change in the future market readiness of the technologies. The technical experts also believed that the remaining doubling of the ACE value to 6 m/$M could be achieved by device optimizations and economies of scale. The ACE metric is highly focused on power generation and capital cost. The National Labs created another metric for the Prize called Hydrodynamic Performance Quality (HPQ) that uses six additional factors that can be evaluated during 1/20th-scale model testing multiplied to the ACE value in order to more effectively address key aspects of the techno-economic performance. The HPQ metric encouraged teams to maintain system-level focus and engagement through the end of the competition. At the end, the device with the highest HPQ that has surpassed the ACE threshold was declared the winner of the Wave Energy Prize.

With the ACE and HPQ metrics and the Wave Energy Prize Rules approved by DOE, the Prize opened registration and began the process of teams passing through four technology gates that were progressively more intensive. The following summary explains the outcome at each gate:

- Technology Gate 1 (TG1): 66 registered teams provided a Technology Submission that explained their concept. Judges reviewed, discussed and down-selected to 20 qualified concepts to progress to TG2.
- Technology Gate 2 (TG2): 16 Qualified Teams submitted revised technical submissions, numerical modeling results, 1/50th scale models for testing and a build plan for a 1/20th scale model. The Prize tested the 1/50th scale models at one of five small scale test facilities with each team supporting their testing. At the conclusion of testing, the Prize judges reviewed all the materials/results and down-selected to nine finalists and two alternates.

- Technology Gate 3 (TG3): Teams provided documentation to verify the level of build progress and test readiness. The judges reviewed, discussed and deemed that the nine finalists had progressed sufficiently such that they were invited to progress to TG4.
- Technology Gate 4 (TG4): Teams submitted revised technical submissions and 1/20^{th-} scale models for testing. The Prize tested the 1/20th-scale models at the NSWCCD's MASK Basin. At the conclusion of testing, the Prize judges reviewed all the materials/results and defined the rankings of the eight teams shown in Table 1. One team was deemed ineligible.

Table 1: Finalist Ranking

Rank	Team	ACE	HPQ
1	AquaHarmonics (Portland, Ore.)	7.6	7.4
2	CalWave Power Technologies (Berkeley, Calif.)	5.4	6.9
3	Waveswing America (Sacramento, Calif.)	6.0	4.8
4	Oscilla Power (Seattle, Wash.)	4.4	4.3
5	RTI Wave Power (York, Maine)	1.9	-
6	Sea Potential (Bristol, R.I.)	1.7	-
7	Harvest Wave Energy (Research Triangle Park, N.C.)	1.7	-
8	M3 Wave (Salem, Ore.)	<0.1	-

From the results of the 1/20th -scale model testing at NSWCCD's MASK basin, four devices met the threshold for ACE of 3 m/$M. Of those four devices, AquaHarmonics' device achieved an ACE of 7.6 m/$M and was the only device that also exceed the National Lab calculated ACE value of 6 m/$M that correlated to a LCOE of 6 ¢/Wh in 2050 (in 2014 USD). From this, the Prize has shown that it exceeded the stated goals of the program, was able to jumpstart this market and concludes it should be possible for WEC devices to be competitive with other forms of power generation once they complete further development and optimization via more traditional advancement avenues.

In addition to the three winners, the following other program goals were all exceeded:

- **79** (goal: 5) newcomer teams registered
- **13** (goal: 10) teams from known developers registered
- **25** (goal: 7) states, plus Puerto Rico and U.S. citizens abroad all participated
- **66** (goal: 30) Technical Submissions at TG1
- **16** (goal: 10) 1/50th scale models tested at TG2
- **9** (goal: 5) 1/20th scale models tested at TG4
- **4** (goal: 1) devices exceeded ACE threshold

The Wave Energy Prize has been recognized as an example of a successful prize in the broader government community, and DOE also received two awards based upon the efforts of the Prize.

6 INTRODUCTION

With more than 50 percent of the population living within 50 miles of coastlines, there is vast potential to provide clean, renewable electricity to communities and cities across the United States by harnessing the energy from waves, tides, and ocean currents. WEC devices are designed to harness the available energy contained in waves, and turn it into usable electricity.

At the beginning of the Wave Energy Prize, current WEC concepts were not yet cost competitive with other means of generating electricity, and significant opportunities existed to reduce the associated costs so wave power could contribute to the nation's clean energy supply.

The DOE-sponsored Wave Energy Prize intended to double the state-of-the-art performance within its two years by encouraging the development of WEC devices that capture more energy from ocean waves per cost of the device, ultimately reducing the cost of wave energy, making it more competitive with traditional energy solutions.

To incentivize participation from the industry and other WEC developers, the Wave Energy Prize provided an opportunity for participants to:

- Win a substantial monetary prize.
- Receive seed funding to support the building of a 1/20th-scale model WEC device for testing.
- Participate in two rounds of valuable WEC model testing at no cost to the Finalist Teams, one of which was at the Navy's Maneuvering and Seakeeping (MASK) Basin in Carderock, MD, the nation's premier wave testing facility.
- Benefit from many opportunities for recognition so that it was worthwhile to compete, and not just for first place.
- Contribute to the development of innovative, green, alternative-energy technologies that can contribute to the nation's energy independence.

7 BACKGROUND

7.1 Prize Goals and Objectives

Through the Wave Energy Prize, the DOE was looking to identify new technologies that could achieve a step change reduction in the LCOE over current leading WEC device designs; that would ideally require no further fundamental breakthroughs or innovations to achieve commercial competitiveness post-Prize.

"**Average Climate Capture Width per Characteristic Capital Expenditure**," to be referred to as the ACE metric, was selected by the Wave Energy Prize as a reduced-content metric that is a proxy for LCOE, appropriate for comparing low-TRL WEC concepts when there is insufficient or unreliable data to enable an actual calculation of the LCOE. Cost of the device structural mass and annual energy production (AEP) are the most important LCOE drivers for WEC devices today. The Wave Energy Prize chose to identify the structural mass through total surface area and representative structural thicknesses. The two components that comprise the ACE ratio are defined as follows:

- **Average Climate Capture Width (ACCW)** = the absorbed power of the device in kW divided by the wave energy flux per meter crest width in kW/m. Thus, a device with a higher capture width is absorbing more of the available incident wave power that can be converted into usable power. Capture widths can be determined through the analysis of experimental data obtained from wave tank testing or through numerical modeling.

- **Characteristic Capital Expenditure (CCE)** = Total Surface Area (m^2) x Representative Structural Thickness (m) x Density of Material (kg/m^3) x Cost of Manufactured Material per unit Mass ($/kg). See the Metrics section of this document for more information on the calculation of CCE.

The ACCW and CCE for the $1/20^{th}$ testing was calculated values from measurements in the tank and analysis of full-scale drawings. Earlier Technology Gates also calculated ACCW from numerical modeling data. All Wave Energy Prize metrics are stated for full-scale WEC devices. All test results obtained during the Wave Energy Prize were scaled up to full scale.

The Wave Energy Prize determined that the ACE value for a group of "State of the Art" technologies at the beginning of the Prize was 1.5 m/$M (or 1.5 meters per million dollars), in typical deep water locations off the West Coast of the United States, with the numerator of the metric based on absorbed power. To achieve the goal established by the DOE and promote the necessary revolutionary advancements in WEC technologies, an ACE threshold value was established and was used to determine key decisions during the final Technology Gate of the Wave Energy Prize.

To be eligible to win a monetary prize purse, a Team's 1/20th scale WEC device had to achieve a threshold Average Climate Capture Width per Characteristic Capital Expenditure (ACE) value of 3m/$M at Technology Gate 4.

The Wave Energy Prize was designed to focus on deep-water devices. The Wave Energy Prize chose wave conditions representative of the West Coast of the continental United States (due to the large energy resource in this region), as well as Alaska and Hawaii (early market opportunity locations). Such locations have long term average annual wave energy flux per meter crest width in the range of 17-39 kW/m. Only WEC concepts that were designed for operating in these conditions were considered for entry to the Wave Energy Prize.

To achieve this technical objective with game-changing WEC device designs, the Wave Energy Prize aspired to:

- Stimulate step-change improvements in WEC technology.
- Entice both existing WEC device developers and newcomers.
- Draw competitors representing a diverse group of companies, universities and individuals from across the U.S., as well as international entities.

7.1.1 ADDITIONAL GOALS AND OBJECTIVES

In addition to the main internal goal described above, the following were additional goal/objectives of the Wave Energy Prize:

- Stimulate the development of new WEC devices for potential use in the energy industry.
- Have at least 30 competitor technologies submitted by registered teams.
- Have at least ten qualified devices for small scale testing.
- Have at least five finalist devices for MASK basin testing.
- Have at least one finalist device that meet the ACE threshold.
- Remain independent, non-partisan, and technology neutral – treating competitors with equality and fairness.
- Have the DOE receive zero justified complaints from teams regarding the lack of equality and fairness.
- Have zero qualified teams withdraw from the Prize for a stated reason of lack of equality and fairness.
- Have a set of rules that outline clear technical boundaries and establish clear and concise judging protocols for the creation of the WEC devices to ultimately facilitate the meeting or exceeding of the competition metrics.
- Entice both existing WEC device developers and newcomers.
    - Have a minimum of five of the registered teams be newcomers, as defined by the DOE list of Potential Applicants (October 23, 2014).
    - Have a minimum of ten of the registered teams be existing developers, as defined by the DOE list of Potential Applicants (October 23, 2014).
- Draw competitors representing a diverse group of businesses, universities and individuals from across the United States as well as international companies with a U.S. presence.
- Have registered teams include those from businesses, universities, and individuals from a minimum of seven different states/countries with a U.S. presence.

7.2 Metrics

The following subsections explain the two technical program metrics that were created for the Prize in greater detail than section 7.1.

7.2.1 ACE

Section 7.1 briefly discussed a new metric that was created for the Prize called ACE. ACE is a benefit to cost ratio, and is a proxy for LCOE, appropriate for comparing low TRL WEC designs.

The two components that comprise the ratio ACE are described in full in the Wave Energy Prize Rules (see Appendix 1). In summary they are:

- Average Climate Capture Width (ACCW) = a measure of the effectiveness of a WEC at absorbing power from the incident wave energy field.
- Characteristic Capital Expenditure (CCE) = a measure of the capital expenditure in commercial production of the load bearing device structure.

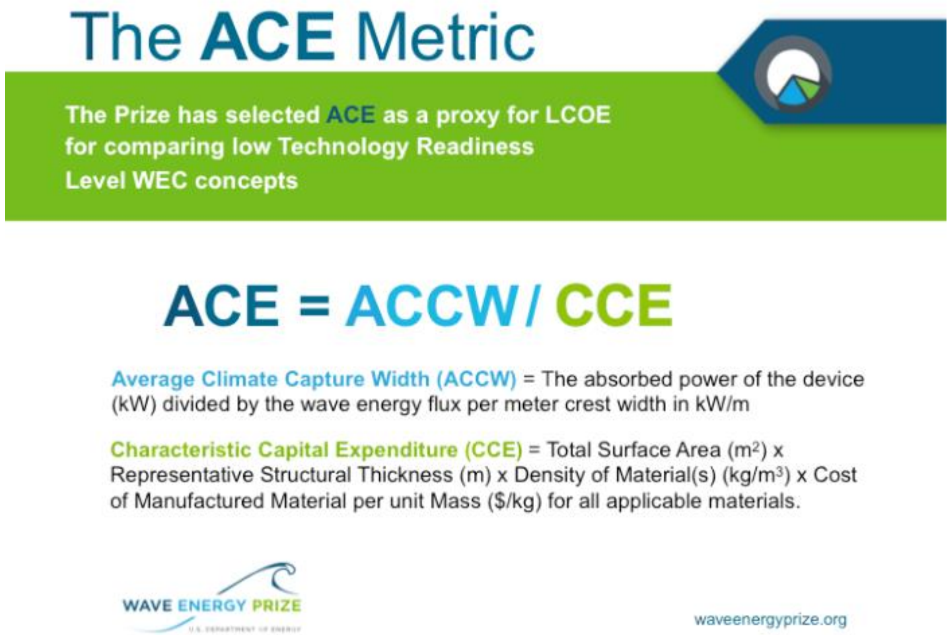


Figure 1: The ACE Metric

Analyses of the 2014 state of the art at the beginning of the Prize revealed that baseline ACE calculated from an average of three DOE WEC reference models (Neary et al. 2014, Heinrichs 2015) had an ACE value of 1.5 m/$M (meters per million dollars). For WEC technologies that emerge from the Wave Energy Prize to be on a development trajectory to become commercially competitive, our analysis showed that in the Prize, WECs had to achieve a minimum threshold value for ACE of 3 m/$M. Below is a detailed description of how to calculate ACE.

Average Climate Capture Width

The average climate capture width (ACCW)—the numerator of ACE—represents an expected yearly average capture width for a WEC operating in typical West Coast wave climates. ACCW is calculated from a set of WEC capture widths for a select set of irregular wave conditions that are either measured in sub-scale physical model testing or calculated from numerical simulations. The full-scale capture widths are multiplied by the scaling factors of the specified test wave conditions at select locations and summed to yield the ACCW. This means that a device that performs very well in one sea state but poorly in other sea states may have a relatively low ACCW when compared with the maximum capture width. Alternatively, a device that has modest performance over a wide range of sea states and wave directions may have a higher ACCW.

Calculating ACCW

ACCW is calculated in two steps, first by calculating the average annual capture width (AACW) for each wave climate of interest through weighted absorbed power measurements in the sea states of each wave climate, and then by averaging the AACW values to give ACCW. For more details on these calculations, see Appendix I of the Wave Energy Prize Rules. Below is a description of the approach for determining which tests to perform to determine ACCW, followed by a simple illustration of calculating AACW and ACCW.

In general, to understand device performance, both tank testing and numerical simulations must cover enough sea states to represent a realistic wave climate. Simulations should be performed in enough irregular sea states that the power in every bin of the resource matrix, or joint probability distribution (JPD), at the wave climate can be approximated. For tank testing, testing at every sea state bin at the wave climate would be over burdensome, but enough sea states should be tested to represent the characteristics of that climate.

In both cases, the sea states that are tested should be weighted so that average annual power absorbed for a particular wave climate can be estimated. (This scaling is represented by the symbol '**Ξ**' in Appendix I of the Wave Energy Prize Rules.) The average power absorbed is then used to determine the average annual capture width.

For example, for a particular wave climate, if the average power absorbed by a WEC is 90 kW and the average annual wave resource is 30 kW/m, the WEC would have an *AACW* of 3 m.

$P_{\text{average absorbed}} = 90$ kW
$P_{\text{resource}} = 30$ kW/m
$AACW = (P_{\text{average absorbed (kW)}} / P_{\text{resource (kW/m)}}) = 3$ m

Per Appendix I of the Wave Energy Prize Rules, ACCW will then be determined by averaging the AACW for all wave climates of interest.

Characteristic Capital Expenditure

Prior analysis performed at NREL shows that the largest contributor to wave energy LCOE is the structural cost of a WEC, and in the Prize, the Characteristic Capital Expenditure (CCE) is used to estimate the structural cost of a device. The device structure accounts for the mass of any and all load-bearing structures that are critical to the power conversion path. This includes:

1. Any structure that interacts with the wave environment
2. Any supporting structures used to resist forces in the power conversion chain in the load path/force flow path
3. Any significant load-bearing foundation components

This implies that for a heaving buoy, for example, not only must the structure of the buoy be used to calculate CCE, but the structure of the gravity base itself must also be used. For offshore devices that require substantial structures, such as jack up barges, those structures must be included as well.

Once the structure is defined the CCE of a device is calculated using the following equation:

$$CCE\ (\$) = RST\ (m) * A_{surf}(m^2) * \rho\left({}^{kg}/_{m^3}\right) * MMC({}^{\$}/_{kg})$$

where:
RST = representative structural thickness [m]
A_{surf} = total structural surface area [m^2]
ρ = material density [kg/m^3]
MMC = manufactured material cost [\$/kg]

If more than one structural material is used in a device, the individual CCEs for each material are summed to give a total CCE. Below are details on calculating each of the variables above for a single material in a device.

Representative Structural Thickness

The representative structural thickness (RST) mentioned in the above equation is a scalar that is used to determine the total structural mass when multiplied by the surface area of the material. The RST can be visualized as a single uniform thickness obtained by "melting down" all of the structural components of a material, and then "casting" the shape of the WEC with a constant wall thickness, the RST. This means that all stiffeners and support structures are "lumped" together. A simple representation of the RST is shown below with a flat plate. The original structure includes a grid of stiffeners with a thin hull. That same quantity of material is then represented by a solid plate with the thickness given by the RST.

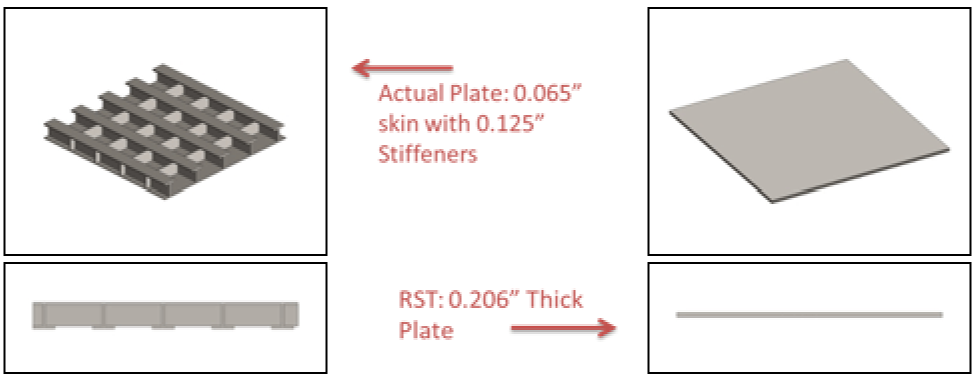


Figure 2: Representative Structural Thickness

Manufactured Material Cost

The last critical variable to calculate CCE is the manufactured material cost (MMC). This value represents the total cost to manufacture the material used in a device at full production scale. Therefore, the MMC includes the raw material cost, any fabrication, forming, and assembly.

In practice, the value of MMC will fluctuate due to material suppliers, complexity of device, number of devices, along with many other market factors. For example, the raw cost of structural steel may be approximately 1 $/kg but by the time any forming, cutting, or welding is made the MMC may be closer to 3 $/kg at full production. For a device already built, one can back out the MMC by dividing the total cost to build the device using a particular material by the mass of that material used.

Summary and Example Calculation of RST, CCE, and ACE

Once all the above variables have been defined, one can calculate the RST, CCE, and ACE values for any wave device. Below is an example calculation using cost and performance estimates from the DOE MHKDR Reference Model #5 which is made of steel and is assumed to operate offshore of Humboldt Bay, CA. The absorbed power for Reference Model #5 was simulated at each sea state using the numerical code WEC-Sim developed by the National Renewable Energy Laboratory and Sandia National Labs:

- $RST = \frac{M}{A_s * \rho} = \frac{800{,}000\ kg}{2{,}520\ m^2 * 7{,}850\ {}^{kg}/_{m^3}} = 0.04\ m$

  where
  - M = structural mass = 800,000 kg
  - A_s = total surface area = 2,520 m^2
  - ρ = density of steel = 7,850 kg/m^3
- MMC = 3,000 $/metric ton
- $CCE = M * MMC = 800{,}000\ kg * \frac{1\ metric\ ton}{1000\ kg} * \frac{\$3000}{1\ metric\ ton} = \$2.4\ million$
- $P_{average\ absorbed}$ = 131 kW
- $P_{resource}$ = 31.5 kW/m
- $ACCW = \frac{P_{average\ absorbed}}{P_{resource}} = \frac{131\ kW}{31.5\ {}^{kW}/_{m}} = 4.2\ m$
  - Note: in this case AACW is the same as ACCW because AACW is being calculated using only one ACCW)
- Thus: $ACE = \frac{AACW}{CCE} = \frac{4.2\ m}{2.4\ \$M} = 1.73\ {}^{m}/_{\$M}$

Using this method one can estimate and compare the economic viability of different devices at an early stage. However, one must be careful when employing this method for devices that have different percentage breakdowns with regards to structure, power take-off, mooring, etc. In these situations, and when comparing devices, a more reliable method would be to include all capital costs in the CCE. If all the initial capital costs were included, the CCE would increase from $2.4 million to $4.97 million, yielding an ACE of 0.84 m/$M.

7.2.2 HYDRODYNAMIC PERFORMANCE QUALITY (HPQ) METRIC

To be eligible for consideration for prize purses, a Team's results from 1/20th scale testing must first show that a WEC model exceeds a threshold value for ACE of 3 m/$M (full-scale) based on the 1/20th scale testing. Following the $1/20^{th}$ scale testing at the MASK Basin, Finalists that exceeded the ACE threshold of 3 m/$M were ranked according to the Hydrodynamic Performance Quality (HPQ) of their $1/20^{th}$-scale WEC model. This ranking was used to determine first, second, and third place winners of the Wave Energy Prize.

The Hydrodynamic Performance Quality (HPQ) metric is dependent on the overall performance of the WEC model during the final tank testing in the MASK Basin. HPQ is dependent on:

- Performance-related quantities measured during the MASK Basin test,
- Performance-related events analyzed with regard to adaptive control strategies,
- Performance-related events counted during the MASK Basin test, and
- Performance-related observations made during the MASK Basin test.

The dominant performance related quantity within the HPQ is ACE.

The two components that comprise the Average Climate Capture Width per Characteristic Capital Expenditure (ACE) metric are the most important levelized cost of energy (LCOE) drivers for WEC devices, however there are many other influential parameters. Although a scaled wave tank test cannot provide information on all influential parameters (system availability, installation, etc.), it can provide substantial useful information beyond ACE.

ACE requires knowledge of the power absorbed by the device in a West Coast deployment climate and the Characteristic Capital Expenditure needed to build the device. By requiring additional sensors to monitor other aspects of the device's performance, processing the data to obtain alternative views beyond averages, and subjecting the devices to additional wave environments, much more can be learned about a device's overall performance. In addition to monitoring averaged absorbed power, the devices were outfitted with sensors that measure mooring forces, accelerations, and the position of the device. This data was processed to reveal statistically significant peak values, ratios between peaks and means, as well as identifying events like end-stop impacts. Lastly, all the sensors and processing occurred not only for the irregular wave spectra used to establish average climate capture width (ACCW), but also for two large irregular wave spectra (LIWS) and two realistic wind swell spectra (RWS).

This additional data was processed into six performance-related quantities for each device tested in the MASK basin. These performance-related quantities were:

- Statistical peak of mooring watch circle (WC_{HPQ})
- Statistical peak of mooring forces (MF_{HPQ})
- Statistical peak-to-average ratio of absorbed power ($AP_{P2A,\ HPQ}$)
- End-stop impact events (ES_{HPQ})
- Absorbed power in realistic seas (RS_{HPQ})
- Adaptive control effort (AC_{HPQ})

These quantities relate to aspects of the techno-economic performance not addressed by ACE and allowed devices to distinguish themselves on more levels then the ACE metric alone provides.

Each of these hydrodynamic performance-related quantities were allocated to a factor (in the range of 0.94 – 1.06) and the HPQ of a device was established by multiplying the ACE metric by the factors allocated to each performance-related quantity.

$$HPQ = ACE * (MF_{HPQ} * WC_{HPQ} * AP_{P2A,HPQ} * ES_{HPQ} * RS_{HPQ} * AC_{HPQ})$$

Each of these factors may have limited beneficial, non-beneficial, or no influence on the HPQ. The allocation of the factors from the performance-related quantities was the responsibility of the judging panel.

The HPQ ensured that the winners' designs more effectively addressed key aspects of the techno-economic performance. The HPQ encouraged teams towards a systems-level engagement through the end of the competition. At the end, the device with the highest HPQ that has surpassed the ACE threshold was declared the winner of the Wave Energy Prize.

7.2.3 TECHNOLOGY PERFORMANCE LEVEL (TPL) METRIC

The Technology Performance Level (TPL) metric is a complementary assessment metric to the Technology Readiness Level (TRL) metric. The TPL metric quantifies the techno-economic performance potential of the technology under development, whereas the TRL metric expresses the commercial readiness; thus, the TPL metric is not an alternative to a TRL metric.

The Wave Energy Prize was dedicated to identifying early (TRL 1 to 3) WEC concepts that show the potential to significantly surpass the techno-economic performance of the state of the art. Given this goal it is meaningful to use the TPL metric to rank and subsequently down-select the Wave Energy Prize Registered Teams and determine the Qualified Teams.

The table below contains the TPL definitions of a WEC system:

Table 2: Technology and Performance Levels Definitions

TPL		Category Characteristic	Sub-Characteristics
9	high	Technology is economically viable and competitive as a renewable energy form.	Competitive with other energy sources without any support mechanism.
8			Competitive with other energy sources given sustainable (e.g. low feed- in tariff) support mechanism.
7			Competitive with other renewable energy sources given favorable (e.g. high feed-in tariffs) support mechanism.
6	medium	Technology features some characteristics for potential economic viability under distinctive and favorable market and operational conditions. Technological or conceptual improvements may be required.	Majority of key performance characteristics and cost drivers satisfy potential economic viability under distinctive and favorable market and operational conditions.
5			To achieve economic viability under distinctive and favorable market and operational conditions, some key technology implementation improvements are required and regarded as possible.
4			To achieve economic viability under distinctive and favorable market and operational conditions, some key technology implementation and fundamental conceptual improvements are required and regarded as possible.
3	low	Technology is not economically viable.	Minority of key performance characteristics and cost drivers do not satisfy potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.
2			Some key performance characteristics and cost drivers do not satisfy potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.
1			Majority of key performance characteristics and cost drivers do not satisfy and present a barrier to potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.

The cost and performance drivers influencing techno-economic WEC performance that are used to assess the TPL of a WEC technology concept are categorized within five criteria groups:

1. Acceptability
2. Power absorption, conversion and delivery
3. System availability
4. Capital Expenditure (CapEx)
5. Operational Expenditure (OpEx)

The five TPL criterion scores were weighted and averaged to calculate the final TPL score. This metric was used during Technology Gates 1 and 2 to assess and rank the Technical Submissions and evaluate which submissions were allowed to progress to the next stage of the Prize. Further detail into the TPL criterion and calculation methodology is available in the official Wave Energy Prize Rules (Appendix 1).

7.3 Roles /Participating Parties

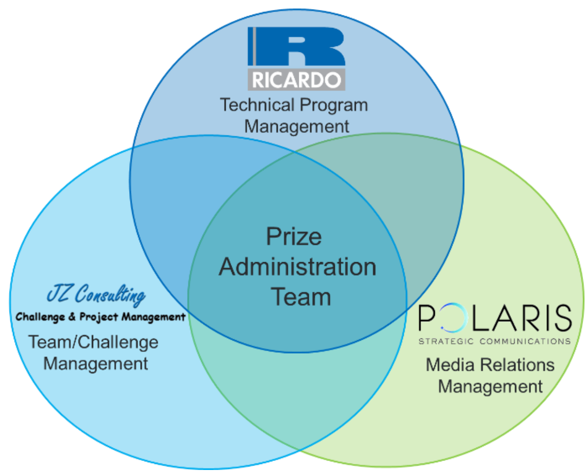
The Wave Energy Prize was a complex collaboration with the DOE, PIP, six different wave tank testing facilities, and the Prize competitors (92 registered, 66 TG1 submissions, 20 qualified, 2 alternates and 9 finalists). The following subsections provide some detail on each entity that supported the Prize.

7.3.1 U.S. DEPARTMENT OF ENERGY (DOE)

Wind and Water Power Technologies Office: The DOE Wave Energy Prize was headed out of the Water Power Technologies Office. Many different members of the DOE from this and other DOE offices interacted with the Prize, but the following DOE personnel had significant interaction with the administration of the Prize: Alison LaBonte (Marine and Hydrokinetic Technologies Program Manager and prime DOE Contact), Gary Nowakowski (Technical Project Officer Supervisor), Pamela Brodie (Contracting Officer), Stephanie Hodge (Senior Project Analyst), Adam DeDent (Legal), Darshan Karwat (DOE fellow and general support to the Prize), Annie Dallman (SNL Senior R&D Engineer on loan to the DOE and supported the Prize as general technical expert), Sara Hunt (contractor and general support to the Prize). Together this group reviewed and approved all the planning, processes, judgments and decisions needed for the Prize.

7.3.2 PRIZE ADMINISTRATION TEAM (PAT)

The DOE Water Power Program needed a Prize Administrator with expertise in prize competitions to collaborate with the DOE, Program Identified Partners (PIP) including technical experts and judges from NREL and SNL, and a wave tank testing facility at NSWCCD in developing and implementing the Wave Energy Prize. The PAT would also be responsible for all communications and interactions with the participants of the Prize along with subcontracting any other entities or services need to successfully execute the Prize. In summary, the management of the Wave Energy Prize was planned and coordinated by the PAT with Ricardo Inc. as the prime contractor. As the prime contractor, Ricardo provided both technical expertise and overall technical program management roles within the PAT and was the main conduit in interfacing with the DOE, PIP and Carderock technical teams. Ricardo was supported by two key subcontractors, JZ Consulting and Polaris Strategic Communications. JZ Consulting supported Ricardo with the team and challenge management expertise and was the main interface with the teams during the Prize. The final piece, communications management, was provided by Polaris Strategic Communications. Polaris Strategic Communications interfaced with the press and public and was the driving force behind the Wave Energy Prize website (www.waveenergyprize.org) and graphics. Together the three companies formed the PAT and successfully planned and delivered the Wave Energy Prize for the DOE. The following is a brief summary of the three companies that comprised the PAT and the key personnel that supported the Prize.



Ricardo Inc. (Ricardo): Ricardo (http://www.ricardo.com) is a global, world-class, multi-industry consultancy for engineering, technology, project innovation and strategy. With a century of delivering value, Ricardo employs over 2,100 professional engineers, consultants and staff. Our client list includes the world's major transportation OEMs, supply chain organizations, energy companies, financial institutions & governments. Our U.S. Government agency clients include DARPA, Marine Corps, Army, ARPA-E, EPA, and NHTSA. The key team members that supported this project were Wesley Scharmen (PI), Phil Michael (judge and technical expert), Dan Acker (PM and contracting), and Scott Goleniak (PM).

JZ Consulting: JZ Consulting is a woman-owned small business and is headed by Julie Zona (Challenge Administrator). Mrs. Zona brings a wealth of experience in competition management, including rule development, outreach efforts, managing teams, disputes and judging. Previously, Mrs. Zona was Director of Team Development & Challenge Operations for the XPRIZE Foundation, the largest competition facilitation foundation in the United States, with responsibility for many aspects of the Progressive Insurance Automotive X Prize. Mrs. Zona's main role on this program was as Challenge Administrator. The goal of the Challenge Administrator is to ensure a smooth, efficient and successful experience for the competitors and associated supporters.

Polaris Strategic Communications LLC. (Polaris): Polaris (http://polariscommunications.org/) is a PR and marketing firm with previous experience in public prize challenge outreach. Polaris was responsible for public outreach activities for the competition, with the objective of growing the participant community through media releases and media management, establishment of a challenge website, and social networking campaigns. The key team members that supported this project were Christine Fuentes (Communications Lead), Dino Baskovic (Digital Strategist) and Erin Nolan (Graphic Designer).

7.3.3 PROGRAM IDENTIFIED PARTNER (PIP)

The DOE defined and selected three PIPs for the Prize:

National Renewable Energy Laboratory (NREL): NREL is the United States primary laboratory for renewable energy and energy efficiency research and development. NREL was one of the two National Labs that supported the Prize. The following key people supported the Prize from NREL: Jochem Weber (technical expert for metrics and rules), Bob Thresher (judge and general wave energy technical expert), Rick Driscoll (TG1 judge, lead data analyst, and general wave energy technical expert), Scott Jenne (technical expert RST/MMC/CCE), and Lee Jay Fingersh (data analyst).

Sandia National Laboratories (SNL): SNL is operated and managed by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation. Sandia Corporation operates SNL as a contractor for the U.S. Department of Energy. For more than 60 years, Sandia has delivered essential science and technology to resolve the nation's most challenging security issues. SNL was second of the two National Labs that supported the Prize. The following key people supported the Prize from SNL: Diana Bull (technical expert for metrics and rules), Vince Neary (judge and technical expert), Budi Gunawan (technical expert and data analyst), and Kelley Ruehl (data analyst).

NSWC Carderock Division (NSWCCD): NSWCCD is the U.S. Navy's state-of-the-art research, engineering, modeling, and test center for ships and ship systems. It is the largest, most comprehensive establishment of its kind in the world, serving a dual role in support of both our U.S. naval forces and the maritime industry. NSWCCD's MASK basin was used to complete the 1/20th scale testing of the finalist's devices. The following key people supported the Prize from NSWCCD: David Newborn (judge, technical expert and MASK test lead), Miguel Quintero (technical expert and MASK test lead), and Dylan Temple (TG1 judge).

7.3.4 JUDGES

The Technical Expert Judging Panel, or Judging Panel, was responsible for evaluating compliance with the established technical requirements in the Rules governing the Wave Energy Prize. The Judging Panel was comprised of highly qualified and impartial judges. The Wave Energy Prize Judging Panel consisted of the following individuals:

Scott Beatty (All Technology Gates): Scott Beatty of Cascadia Coast Research Ltd. has over a decade of experimental and numerical marine systems research and development experience in both academia and industry, along with deep expertise in wave energy converter model testing. Beatty currently serves as a convener and subject matter expert for two International Electrotechnical Commission international project teams developing and maintaining technical specifications for wave energy converter performance assessment.

Frederick Driscoll (TG1): Rick Driscoll joined the National Renewable Energy Laboratory in March 2010 and works as a senior engineer on the Offshore Wind and Ocean Power Systems Team. Driscoll works in the areas of offshore wind and marine hydrokinetics on computer modeling, design, testing, instrumentation, and data analysis. Before joining NREL, he was an associate professor of Ocean and Mechanical Engineering at Florida Atlantic University, where he focused on ocean energy and navy projects for more than ten years.

Phil Michael (All Technology Gates): Phil Michael is Ricardo Inc.'s wave energy technical expert. While working for Ricardo-AEA in the UK, Michael was closely involved with wave power R&D since the re-opening of the UK's wave power program and its inclusion in the UK's New and Renewable Energy Program in 1999. In 2004, he developed the UK's Marine Renewables Deployment Fund (MRDF), a £50 million scheme aimed at supporting small arrays of commercial-scale wave and tidal stream devices, which he managed until its closure in 2011.

Vincent Neary (All Technology Gates): Vincent Neary is the MHK Technology Lead at Sandia National Laboratories, where he manages a diverse portfolio of marine renewable energy R&D projects. Neary's research contributions include hydrodynamic and wave modeling for tidal current, ocean current and wave resource assessments, turbulent inflow characterization to estimate power performance and dynamic loads on hydrokinetic turbines, and development of best practices for hydrokinetic energy resource assessment and environmental monitoring, amongst others.

David Newborn (All Technology Gates): David Newborn is an ocean engineer at the Naval Surface Warfare Center Carderock Division (NSWCCD), Naval Architecture and Engineering Department, Maritime Systems Hydromechanics Branch. He has served at NSWCCD for eight years, primarily in the areas of surface and underwater towed systems, unmanned systems, and marine hydrokinetic technologies. Newborn holds a Bachelor of Science degree in Ocean Engineering from Florida Atlantic University.

Dylan Temple (TG1): Dylan Temple works at NSWCCD in the Department of Naval Architecture on hydrodynamic simulation and model testing for amphibious vehicles focusing on seakeeping and maneuvering. He earned his B.E. in Naval Architecture and Marine Engineering from the State University of New York Maritime College and his Ph.D. in Naval Architecture from the University of Michigan. Temple's graduate research focused on early stage multi-disciplinary design optimization.

Robert Thresher (All Technology Gates): Robert Thresher, with more than 40 years of research and management experience, worked for DOE as a principal researcher to conceive and create the National Wind Technology Center, and then served as its first director. In 2008, Thresher was appointed to the position of NREL research fellow. At NREL since 1984, he serves as a strategist and spokesperson for the national research programs to develop offshore renewables, such as wind, wave, tidal, and ocean current.

7.3.5 ADDITIONAL SUPPORTING ENTITIES

Small-Scale Test Facilities (SSTF): The Prize utilized five facilities to complete the 1/50th-scale model testing which are shown below in alphabetical order along with some of the key facility information:

Table 3: Small-Scale Test Facilities

Facility	Length (m)	Width (m)	Water Depth (m)	Type of Wave Maker
Oregon State University	48.8	26.5	1.37	Piston-Type Wave Boards
Stevens Institute	98	5	2	Multi-Paddle
University of Iowa	40	20	2.97	Vertical Plunger
University of Maine	30	9	4.5	Multi-Paddle
University of Michigan	109.7	6.7	2.9	Vertically Plunging Wedge

7.3.6 TEAMS / PARTICIPANTS

The Prize had 92 teams register and meet eligibility requirements. These teams are shown below in alphabetical order:

1. 40South Energy (Palo Alto, Calif.)
2. AdapWave (Baltimore, Md.)
3. Advanced Ocean Energy @ Virginia Tech (Hampton Roads, Va.)
4. AIMMER Marine Energy (Oakland, Calif.)
5. Alternative Energy Engineering Associates (Port Orchard, Wash.)
6. Aqua-Shift (Encinitas, Calif).
7. AquaHarmonics (Oakland, Calif.)
8. ATA Engineering (San Diego, Calif.)
9. Atargis Energy Corporation (Pueblo, Colo.)
10. Atlantic Wavepower Partnership (Newport, R.I.)
11. Atlas Ocean Systems (Houston, Texas)
12. AWECS Attenuator (Glen Burnie, Md.)
13. Brimes Energy (Holbrook, N.Y.)
14. Buoyant Energy (Cambridge, Mass.)
15. Cal Poly – Protean Wave Energy, Inc. (San Luis Obispo, Calif.)
16. CalWave (Berkeley, Calif.)
17. Centipod (Santa Barbara, Calif.)
18. Crestwing (Denmark)
19. Earth By Design (Bend, Ore.)
20. eBuoy (Ayer, Mass.)
21. Energystics (Stony Brook, N.Y.)
22. Enorasy Labs (Bedford, Mass.)
23. EnSea, Inc. (San Francisco, Calif.)
24. ESI – Perpetuwave (Doral, Fla.)
25. Etymol Ocean Power (Winter Springs, Fla.)
26. Fetzer Wave (Palm Harbor, Fla.)
27. Float Inc. – BergerABAM (San Diego, Calif.)
28. GlobalOne Sciences (Dayton, Ohio)
29. Greenfield Technologies LLC (Addison, Ala.)
30. GyroGenTM (Bloomfield Hills, Mich.)
31. Healy's Wave Energy Converter (Hollis, N.H.)
32. Hui Nalu (Honolulu, Hawaii)
33. Hydrokinetic Energy Solutions (Sunnyvale, Calif.)
34. Iowec (Cambridge, Mass.)
35. James F. Marino (San Diego, Calif.)
36. Jetty Joule (Colusa, Calif.)
37. KNSwing (Denmark)
38. Kozoriz-Franklin California Maglev, Inc. (Long Beach, Calif.)
39. KymoGen (Bristol, Conn.)
40. Leviathan Energy Waves (Stony Brook, N.Y.)
41. M3 Wave (Salem, Ore.)
42. MARUTHI POWER (Cleveland, Ohio)
43. Mighty Waves Energy Team (Vienna, Va.)
44. Mocean Energy (Annapolis, Md.)
45. Neptune Wave Power, LLC (Dallas, Texas)
46. Next Gen (Sacramento, Calif.)
47. NM-AGGIE Waves (Las Cruces, N.M.)
48. Ocean Energy USA (Sacramento, Calif.)
49. Ocean Kinetics (Homer, Alaska)
50. Ocean Lab (Glendale, Calif.)
51. Ocean Motion International (Denver, Colo.)
52. Oscilla Power (Seattle, Wash.)
53. Ovsiankin Energy Group (Chicago, Ill.)
54. Poseidon's Kite (Gambrills, Md.)
55. Principle Power (Berkeley, Calif.)
56. Protean Wave Technology Inc. (San Juan, Puerto Rico)
57. ReWEB Technology (Narragansett, R.I.)
58. Rohan Patel (Bensalem, Pa.)
59. Royal Wave (Paonia, Colo.)
60. RPPC (Denver, Colo.)
61. RTI-MIT Wave Power (York, Maine)
62. Rutgers Wave Power (Piscataway, N.J.)
63. SAi Orbit Wave Power (Daphne, Ala.)
64. Sea Potential (Bristol, R.I.)
65. SeaFoil (Redwood City, Calif.)
66. SeaGreen Technologies (Annapolis, Md.)
67. SeaStar Ocean (Los Angeles, Calif.)
68. SEWEC (Redwood City, Calif).
69. Spindrift Energy (Simi Valley, Calif.)
70. Super Watt Wave Catcher Barge Team (Houston, Texas)
71. TAMU-OSSL (College Station, Texas)
72. Team FLAPPER (Research Triangle Park, N.C.)
73. Team Treadwater (Houston, Texas)
74. Thrustcycle Enterprises (Wilsonville, Ore.)
75. Undulational Harvester (Albany, Calif.)
76. Uniturbine Corporation (Lewes, Del.)
77. Vortex (Lenox, Mass.)
78. Wave Energy at Virginia Tech (Blacksburg, Va.)
79. Wave Energy Conversion Corporation of America (WECCA) (North Bethesda, Md.)
80. Wave Forest Power (Benton, Ky.)
81. Wave Water Works (Northville, Mich.)
82. Wave Wheel (Gray, Maine)
83. Waveberg Development (San Diego, Calif.)
84. WaveFlex 1 (Baltimore, Md.)
85. WaveFlex 2 (Baltimore, Md.)
86. WaveFlo (Newburyport, Mass.)
87. Waves2Energy (Union, N.J.)
88. Waveswing America (Sacramento, Calif.)
89. Wavewatts (Aliso Viejo, Calif.)
90. Wavy Turbine (La Jolla, Calif.)
91. Wizards of Energy (Dania Beach, Fla.)
92. Worldwide Windfinder (Dallas, Texas)

The down-selection of these teams to Qualified, Alternate and Finalist Teams is explained in more detail in the Results section of this document.

7.4 Phases/Technology Gates/Timeline Overview

The administration of the Prize was completed over a total of 30 months from September of 2014 to February of 2017. This duration was broken down into the five phases and four Technology Gates for the participating teams to pass through.

7.4.1 PHASES

PHASE 1: PLANNING (6 Months): This phase began with contract award to PAT after a period of negotiation. On the technical side of the Prize planning, the PAT, DOE, and PIPs all collaborated to create the Prize goals, objectives, and metrics, which all fed into the creation of the Prize Rules. On the communications side of the Prize planning, the PAT created and launched a website (www.waveenergyprize.org) and began direct outreach to known WEC developers and the public. This phase concluded with a DOE Go/No-Go program review.

PHASE 2: DESIGN (12 months): This phase began with the opening of registration and involved two Technology Gates (TG1 & TG2). Registration was open for 2.5 months and once it closed, teams submitted technical information on their devices for TG1 assessment by the judges. After the TG1 assessment, the qualified teams completed numerical modeling, built 1/50th-scale devices and submitted revised technical submissions explaining their devices. The 1/50th-scale devices were then tested at one of five small-scale test facilities to begin the TG2 period. At the end of this phase, the finalists and alternates were defined.

PHASE 3: BUILD (5 months): In this phase, the Prize provided seed funding (financial support) to the Finalists (up to $125,000) and Alternates (up to $25,000). The finalists and alternates used this funding to build 1/20th scale models and prepare for testing at the MASK basin. This phase concluded with TG3 and receipt of all 1/20th-scale model devices by Prize.

PHASE 4: TEST AND EVALUATION (3 months): This phase was focused on the 1/20th-scale model testing at the MASK basin. Each team spent two weeks onsite at the MASK basin. The first week was spent in the parking lot to get their device prepared for testing and complete spot checks of critical dimensions and sensors; the second week was spent installing the device into the MASK basin followed by commissioning and testing it. After testing, the Prize data analyst reviewed, analyzed, and submitted a results summary of the data to the judges. This phase ended with TG4 and completed judging of the finalist devices.

PHASE 5: POST-COMPETITION PUBLICITY & WRAP-UP (4 months): Phase 5 started with the Wave Energy Prize Innovation Showcase, which allowed the finalists to showcase their technologies and announced the winners. Final publicity and outreach materials were distributed. This, along with the Prize website and other media being transferred to the DOE and NREL, ended the PAT's involvement in media and outreach. The PAT involvement with the teams concluded with the transfer of technical data from testing, return of their devices, and distribution of the winning teams' monetary awards. The remaining activities for the PAT in this phase were the completion of the final report, upload of pertinent technical data, which was uploaded to the MHKDR (https://mhkdr.openei.org/) with a public release date on November 16th, 2017, and the participation in DOE's Peer Review meeting.

7.4.2 TECHNOLOGY GATES

The Wave Energy Prize has been designed with four distinct Technology Gates. The successful progression through the four Technology Gates allowed the most qualified Teams, with the highest ranking WEC designs, to be identified, tested, and placed for winning prize purses at the completion of the Prize. The Technology Gates and their purpose are identified below, while the requirements for successful progression through them are defined in the Technical Requirements (Section 6) of the Wave Energy Prize Rules:

- **Technology Gate 1 -** Technical Submission; for Determination of Qualified Teams (Prize Phase: Design)
- **Technology Gate 2 -** Small Scale (1/50th) Model Testing, Numerical Modeling for Determination of Finalists and Alternates (Prize Phase: Design)
- **Technology Gate 3 -** Verify the level of build progress and test readiness of the identified Finalists and Alternates (Prize Phase: Build)
- **Technology Gate 4 -** Testing of 1/20th-Scale Model at the MASK Basin, NSWCCD; for Determination of Prize Winners (Prize Phase: Test and Evaluation)

The following image shows some additional detail about each of the four gates:

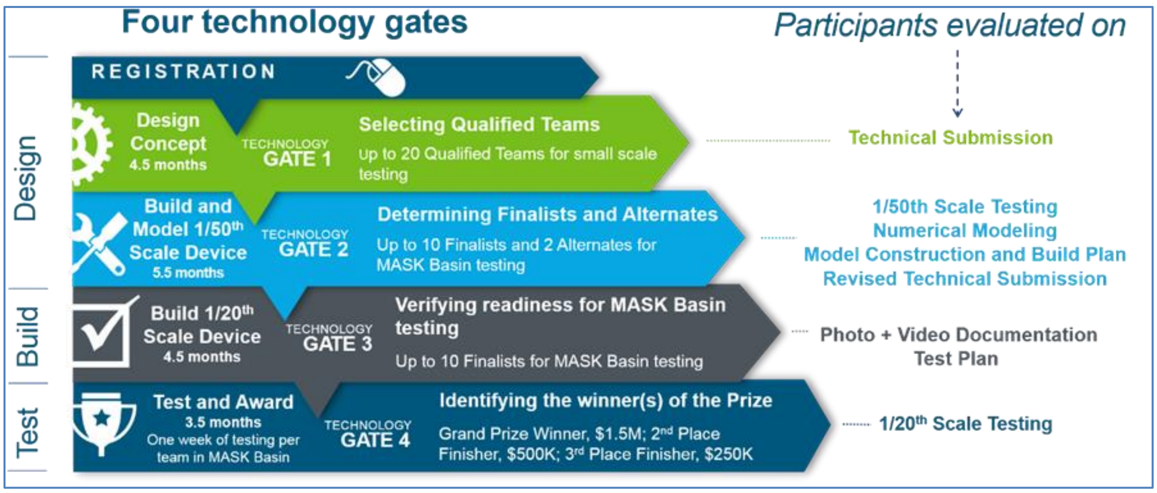


Figure 3: Technology Gates

7.4.3 TIMELINE OVERVIEW

The following images show the Prize's timelines along with some of the key dates:

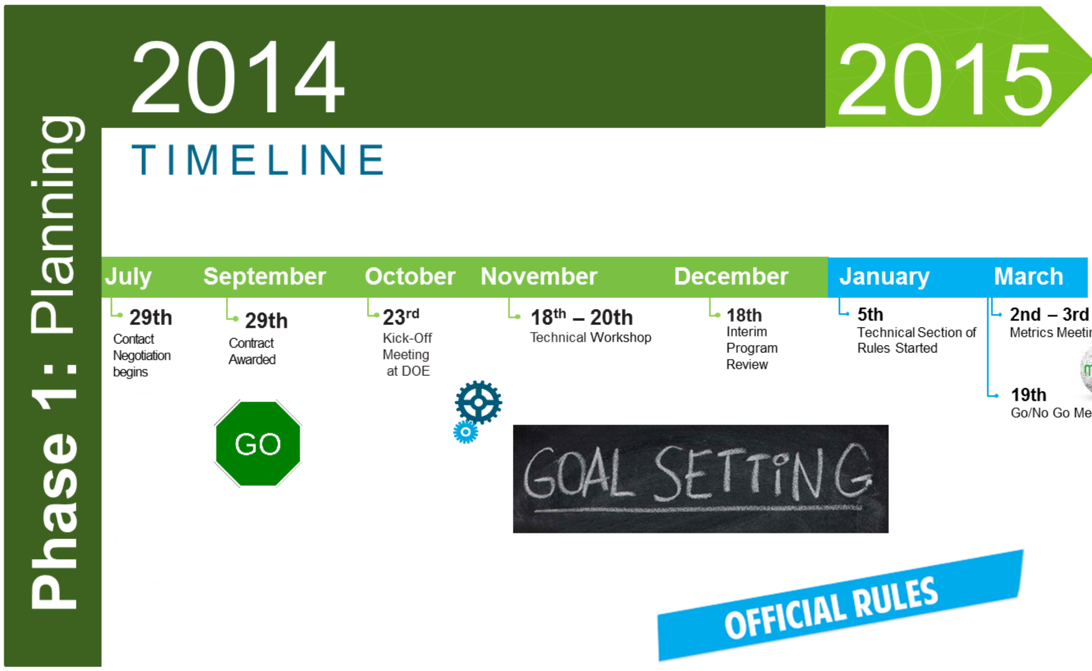


Figure 4: Phase 1 Timeline

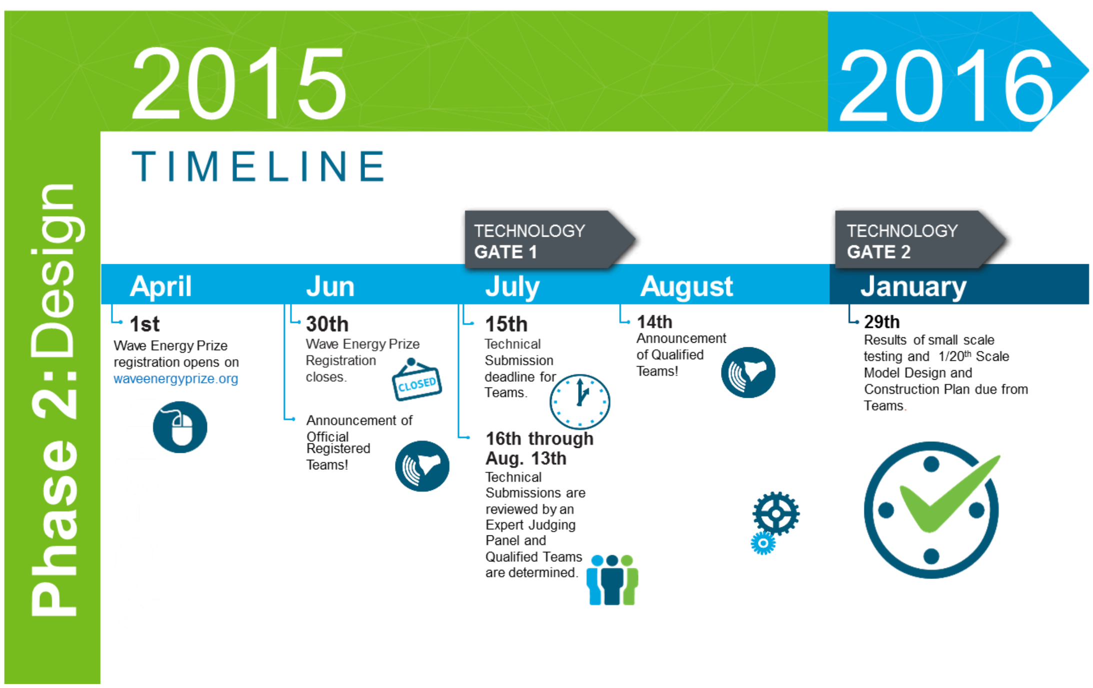


Figure 5: Phase 2 Timeline

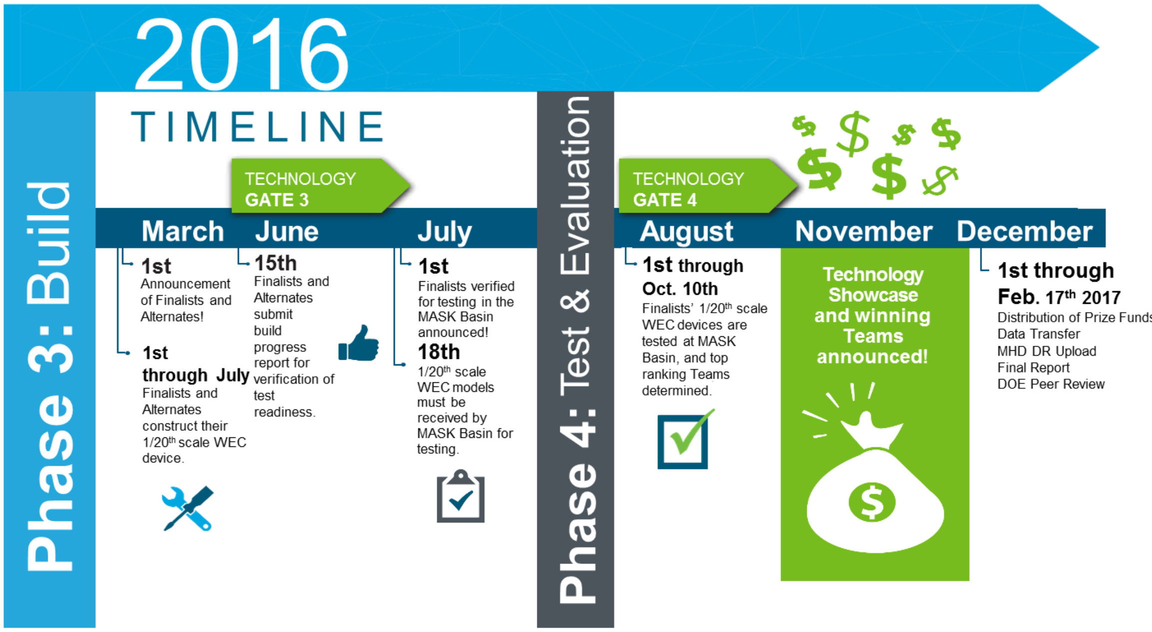


Figure 6: Phase 3 Timeline

8 Results and Discussion

The Prize was organized by the DOE to identify new technologies that could achieve a step change reduction in the LCOE over current leading WEC device designs; that would ideally require no further fundamental breakthroughs or innovations to achieve commercial competitiveness after the Prize. Therefore, the main result for the Prize was the demonstration, by multiple technologies, of a capability to achieve the step reduction and meet the DOE's long-term (2050) cost goals. The following sections focus on the funneling of teams/devices from registration to the winning teams along with their feedback on the Prize and DOE's evaluation of the Prize's ROI versus other traditional R&D funding programs.

8.1 Team/Device Funneling

8.1.1 OFFICIAL REGISTERED TEAMS

Ninety-two teams registered and met eligibility requirements for the Prize. The official registered teams are shown below in alphabetical order:

1. 40South Energy (Palo Alto, Calif.)
2. AdapWave (Baltimore, Md.)
3. Advanced Ocean Energy @ Virginia Tech (Hampton Roads, Va.)
4. AIMMER Marine Energy (Oakland, Calif.)
5. Alternative Energy Engineering Associates (Port Orchard, Wash.)
6. Aqua-Shift (Encinitas, Calif).
7. AquaHarmonics (Oakland, Calif.)
8. ATA Engineering (San Diego, Calif.)
9. Atargis Energy Corporation (Pueblo, Colo.)
10. Atlantic Wavepower Partnership (Newport, R.I.)
11. Atlas Ocean Systems (Houston, Texas)
12. AWECS Attenuator (Glen Burnie, Md.)
13. Brimes Energy (Holbrook, N.Y.)
14. Buoyant Energy (Cambridge, Mass.)
15. Cal Poly – Protean Wave Energy, Inc. (San Luis Obispo, Calif.)
16. CalWave (Berkeley, Calif.)
17. Centipod (Santa Barbara, Calif.)
18. Crestwing (Denmark)
19. Earth By Design (Bend, Ore.)
20. eBuoy (Ayer, Mass.)
21. Energystics (Stony Brook, N.Y.)
22. Enorasy Labs (Bedford, Mass.)
23. EnSea, Inc. (San Francisco, Calif.)
24. ESI – Perpetuwave (Doral, Fla.)
25. Etymol Ocean Power (Winter Springs, Fla.)
26. Fetzer Wave (Palm Harbor, Fla.)
27. Float Inc. – BergerABAM (San Diego, Calif.)
28. GlobalOne Sciences (Dayton, Ohio)
29. Greenfield Technologies LLC (Addison, Ala.)
30. GyroGenTM (Bloomfield Hills, Mich.)
31. Healy’s Wave Energy Converter (Hollis, N.H.)
32. Hui Nalu (Honolulu, Hawaii)
33. Hydrokinetic Energy Solutions (Sunnyvale, Calif.)
34. Iowec (Cambridge, Mass.)
35. James F. Marino (San Diego, Calif.)
36. Jetty Joule (Colusa, Calif.)
37. KNSwing (Denmark)
38. Kozoriz-Franklin California Maglev, Inc. (Long Beach, Calif.)
39. KymoGen (Bristol, Conn.)
40. Leviathan Energy Waves (Stony Brook, N.Y.)
41. M3 Wave (Salem, Ore.)
42. MARUTHI POWER (Cleveland, Ohio)
43. Mighty Waves Energy Team (Vienna, Va.)
44. Mocean Energy (Annapolis, Md.)
45. Neptune Wave Power, LLC (Dallas, Texas)
46. Next Gen (Sacramento, Calif.)
47. NM-AGGIE Waves (Las Cruces, N.M.)
48. Ocean Energy USA (Sacramento, Calif.)
49. Ocean Kinetics (Homer, Alaska)
50. Ocean Lab (Glendale, Calif.)
51. Ocean Motion International (Denver, Colo.)
52. Oscilla Power (Seattle, Wash.)
53. Ovsiankin Energy Group (Chicago, Ill.)
54. Poseidon’s Kite (Gambrills, Md.)
55. Principle Power (Berkeley, Calif.)
56. Protean Wave Technology Inc. (San Juan, Puerto Rico)
57. ReWEB Technology (Narragansett, R.I.)
58. Rohan Patel (Bensalem, Pa.)
59. Royal Wave (Paonia, Colo.)
60. RPPC (Denver, Colo.)
61. RTI-MIT Wave Power (York, Maine)
62. Rutgers Wave Power (Piscataway, N.J.)
63. SAi Orbit Wave Power (Daphne, Ala.)
64. Sea Potential (Bristol, R.I.)
65. SeaFoil (Redwood City, Calif.)
66. SeaGreen Technologies (Annapolis, Md.)
67. SeaStar Ocean (Los Angeles, Calif.)
68. SEWEC (Redwood City, Calif).
69. Spindrift Energy (Simi Valley, Calif.)
70. Super Watt Wave Catcher Barge Team (Houston, Texas)
71. TAMU-OSSL (College Station, Texas)
72. Team FLAPPER (Research Triangle Park, N.C.)
73. Team Treadwater (Houston, Texas)
74. Thrustcycle Enterprises (Wilsonville, Ore.)
75. Undulational Harvester (Albany, Calif.)
76. Uniturbine Corporation (Lewes, Del.)
77. Vortex (Lenox, Mass.)
78. Wave Energy at Virginia Tech (Blacksburg, Va.)
79. Wave Energy Conversion Corporation of America (WECCA) (North Bethesda, Md.)
80. Wave Forest Power (Benton, Ky.)
81. Wave Water Works (Northville, Mich.)
82. Wave Wheel (Gray, Maine)
83. Waveberg Development (San Diego, Calif.)
84. WaveFlex 1 (Baltimore, Md.)
85. WaveFlex 2 (Baltimore, Md.)
86. WaveFlo (Newburyport, Mass.)
87. Waves2Energy (Union, N.J.)
88. Waveswing America (Sacramento, Calif.)
89. Wavewatts (Aliso Viejo, Calif.)
90. Wavy Turbine (La Jolla, Calif.)
91. Wizards of Energy (Dania Beach, Fla.)
92. Worldwide Windfinder (Dallas, Texas)

8.1.2 TRANSITION FROM REGISTERED TO QUALIFIED TEAMS - TG1

Of these 92 registered teams listed above, 66 completed the Technical Submission for the judges to assess. These 66 teams are shown below in alphabetical order:

1. Advanced Ocean Energy @ Virginia Tech (Hampton Roads, Va.)
2. AIMMER Marine Energy (Oakland, Calif.)
3. Alternative Energy Engineering Associates (Port Orchard, Wash.)
4. AquaHarmonics (Oakland, Calif.)
5. Aqua-Shift (Encinitas, Calif).
6. ATA Engineering (San Diego, Calif.)
7. Atargis Energy Corporation (Pueblo, Colo.)
8. Atlantic Wavepower Partnership (Newport, R.I.)
9. Atlas Ocean Systems (Houston, Texas)
10. Brimes Energy (Holbrook, N.Y.)
11. Buoyant Energy (Cambridge, Mass.)
12. CalWave (Berkeley, Calif.)
13. Crestwing (Denmark)
14. Earth By Design (Bend, Ore.)
15. eBuoy (Ayer, Mass.)
16. Enorasy Labs (Bedford, Mass.)
17. ESI – Perpetuwave (Doral, Fla.)
18. Etymol Ocean Power (Winter Springs, Fla.)
19. Fetzer Wave (Palm Harbor, Fla.)
20. Float Inc. – BergerABAM (San Diego, Calif.)
21. GlobalOne Sciences (Dayton, Ohio)
22. Greenfield Technologies LLC (Addison, Ala.)
23. Healy’s Wave Energy Converter (Hollis, N.H.)
24. Hui Nalu (Honolulu, Hawaii)
25. Hydrokinetic Energy Solutions (Sunnyvale, Calif.)
26. Iowec (Cambridge, Mass.)
27. Jetty Joule (Colusa, Calif.)
28. KymoGen (Bristol, Conn.)
29. Leviathan Energy Waves (Stony Brook, N.Y.)
30. M3 Wave (Salem, Ore.)
31. MARUTHI POWER (Cleveland, Ohio)
32. Mocean Energy (Annapolis, Md.)
33. Next Gen (Sacramento, Calif.)
34. Ocean Energy USA (Sacramento, Calif.)
35. Ocean Motion International (Denver, Colo.)
36. Oscilla Power (Seattle, Wash.)
37. Ovsiankin Energy Group (Chicago, Ill.)
38. Poseidon’s Kite (Gambrills, Md.)
39. Principle Power (Berkeley, Calif.)
40. Rohan Patel (Bensalem, Pa.)
41. Royal Wave (Paonia, Colo.)
42. RTI-MIT Wave Power (York, Maine)
43. Rutgers Wave Power (Piscataway, N.J.)
44. SAi Orbit Wave Power (Daphne, Ala.)
45. Sea Potential (Bristol, R.I.)
46. SeaFoil (Redwood City, Calif.)
47. SeaGreen Technologies (Annapolis, Md.)
48. SEWEC (Redwood City, Calif).
49. Spindrift Energy (Simi Valley, Calif.)
50. Super Watt Wave Catcher Barge Team (Houston, Texas)
51. TAMU-OSSL (College Station, Texas)
52. Team FLAPPER (Research Triangle Park, N.C.)
53. Team Treadwater (Houston, Texas)
54. Uniturbine Corporation (Lewes, Del.)
55. Vortex (Lenox, Mass.)
56. Wave Energy at Virginia Tech (Blacksburg, Va.)
57. Wave Energy Conversion Corporation of America (WECCA) (North Bethesda, Md.)
58. Wave Water Works (Northville, Mich.)
59. Waveberg Development (San Diego, Calif.)
60. WaveFlex 1 (Baltimore, Md.)
61. WaveFlo (Newburyport, Mass.)
62. Waves2Energy (Union, N.J.)
63. Waveswing America (Sacramento, Calif.)
64. Wavewatts (Aliso Viejo, Calif.)
65. Wavy Turbine (La Jolla, Calif.)
66. Wizards of Energy (Dania Beach, Fla.)

After the judges completed their assessments at TG1, twenty teams were selected as Wave Energy Prize official qualified teams. The qualified teams are shown below in alphabetical order:

1. Advanced Ocean Energy @ Virginia Tech (Hampton Roads, Va.)
2. AquaHarmonics (Portland, Ore.)
3. Atlantic Wavepower Partnership (Newport, R.I.)
4. Atlas Ocean Systems (Houston, Texas)
5. CalWave (Berkeley, Calif.)
6. Enorasy Labs (Bedford, Mass.)
7. Float Inc. – BergerABAM (San Diego, Calif.)
8. IOwec (MIT Sea Grant College Program) (Cambridge, Mass.)
9. M3 Wave (Salem, Ore.)
10. Mocean Energy (Annapolis, Md.)
11. OceanEnergy USA (Sacramento, Calif.)
12. Oscilla Power (Seattle, Wash.)
13. Principle Power (Berkeley, Calif.)
14. RTI Wave Power (York, Maine)
15. Sea Potential (Bristol, R.I.)
16. SEWEC (Redwood City, Calif.)
17. Super Watt Wave Catcher Barge Team (Houston, Texas)
18. Team FLAPPER (Floating Lever and Piston Power ExtractoR) (Research Triangle Park, N.C.)
19. Wave Energy Conversion Corporation of America (WECCA) (North Bethesda, Md.)
20. Waveswing America (Sacramento, Calif.)

8.1.3 TRANSITION FROM QUALIFIED TEAMS TO FINALISTS AND ALTERNATES - TG2

During TG2, three teams, Atlantic Wavepower Partnership, Enorasy Labs, and Ocean Energy USA, withdrew from the competition. The remaining teams completed all necessary requirements, including numerical modeling, and building of a 1/50th-scale device. The scale models of these teams' devices were then tested at one of the five SSTFs. During the testing of its 1/50th-scale device, Float Inc. – Berger ABAM was deemed ineligible due to the fact that they brought a device with them to test, and did not ship the device by the deadline stipulated in the Wave Energy Prize Rules. The following table shows the teams, SSTFs and dates of their testing:

Table 4: Teams, SSTF's, and Testing Dates

Team	Facility	Testing Dates	
		Start	Finish
Atlas Ocean Systems	Michigan	30-Nov	4-Dec
Super Watt Wave Catcher Barge Team	Stevens Institute	30-Nov	4-Dec
Sea Potential	Iowa	7-Dec	11-Dec
SEWEC	Michigan	7-Dec	11-Dec
Team FLAPPER	Michigan	14-Dec	18-Dec
Iowec	Stevens Institute	14-Dec	18-Dec
RTI Wave Power	Maine	14-Dec	18-Dec
M3 Wave	Michigan	4-Jan	8-Jan
Mocean Energy	Stevens Institute	4-Jan	8-Jan
Oscilla Power	Maine	4-Jan	8-Jan
Principle Power	Oregon State	11-Jan	15-Jan
AquaHarmonics	Michigan	11-Jan	15-Jan
WECCA	Stevens Institute	11-Jan	15-Jan
CalWave	Iowa	11-Jan	15-Jan
Float Inc. - BergerABAM	Maine	11-Jan	15-Jan
Advanced Ocean Energy @ VT	Stevens Institute	25-Jan	29-Jan
Waveswing America	Iowa	25-Jan	29-Jan

Nine finalists and two alternates were identified from the remaining sixteen Qualified Teams. These teams were ranked by their testing results and submitted materials. Below is the ranked listing of the finalists:

1. CalWave Power Technologies (Berkeley, CA)
2. Oscilla Power (Seattle, WA)
3. Sea Potential (Bristol, RI)
4. RTI Wave Power (York, ME)
5. SEWEC (Redwood City, CA)
6. Waveswing America (Sacramento, CA)
7. Harvest Wave Energy (Team FLAPPER) (Research Triangle Park, NC)
8. AquaHarmonics (Portland, OR)
9. M3 Wave (Salem, OR)

The two Alternate Teams were:

10. Wave Energy Conversion Corporation of America (WECCA) (North Bethesda, MD)
11. McNatt Ocean Energy (Annapolis, MD)

8.1.4 TRANSITION FINALISTS AND ALTERNATES TO TESTING FINALISTS - TG3

Based on the team submissions and documented progress during TG3, the judges deemed that all the finalist teams were properly prepared for 1/20th-scale testing at the MASK basin. Thus, the nine finalist teams were approved to move forward to testing/TG4.

8.1.5 RANKING OF THE TESTING FINALISTS - TG4

During TG4, all nine teams were tested. During the TG4 judging meeting, the Wave Energy Prize judges reviewed the data collected for all the teams and determined that the data for one of the finalists, SEWEC, was inconclusive. Because of this, an ACE value could not be calculated and that device was deemed ineligible to be considered for the Wave Energy Prize. The remaining eight devices had ACE values determined. Of those eight teams, four teams exceeded the ACE threshold of 3 m/$M. These four teams had HPQ values determined by the judges; the following table shows the final rankings:

Table 5: Finalist Teams

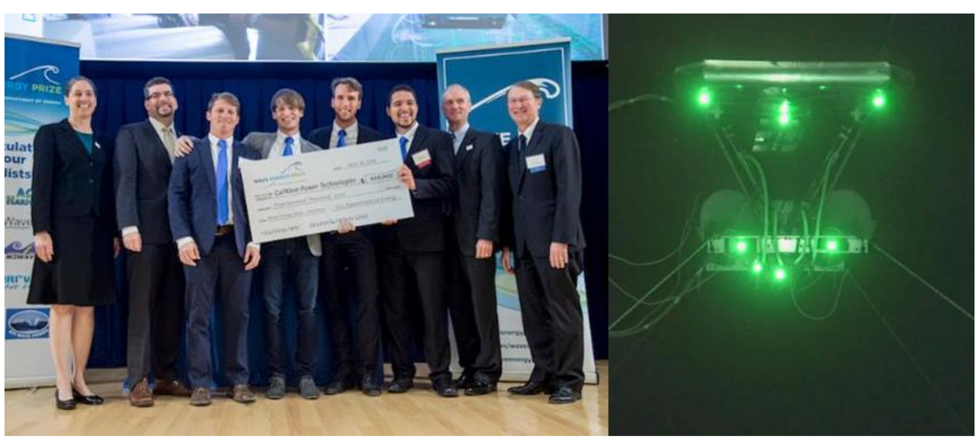
Rank	Team	ACE	HPQ
1	AquaHarmonics (Portland, OR)	7.6	7.4
2	CalWave Power Technologies (Berkeley, CA)	5.4	6.9
3	Waveswing America (Sacramento, CA)	6.0	4.8
4	Oscilla Power (Seattle, WA)	4.4	4.3
5	RTI Wave Power (York, ME)	1.9	-
6	Sea Potential (Bristol, RI)	1.7	-
7	Harvest Wave Energy (Research Triangle Park, NC)	1.7	-
8	M3 Wave (Salem, OR)	<0.1	-

8.1.6 GRAND PRIZE ($1.5M) AQUAHARMONICS (PORTLAND, OR)

The grand prize winning team, AquaHarmonics, consisted of Alex Hagmuller (lead) and Max Ginsburg, who have been friends since they met in their first year at Oregon State University. About five years ago, Alex started to build small-scale wave energy prototypes and enlisted Max to help with the design of the electrical components and software. Together they have been constructing and testing different wave energy prototypes, and the knowledge gained from each has led to many improvements and changes in the design. The AquaHarmonics WEC concept is a point absorber with latching/de-clutching control.

8.1.7 2ND PLACE ($500K) CALWAVE POWER TECHNOLOGIES (BERKELEY, CA)

The second place team, CalWave Power Technologies, was led by Marcus Lehmann. Using his extensive experience in product development and background in industry, Marcus led a diverse team of engineers, business development specialists, advisers, and industry partners around the CalWave project. CalWave's team members included Thomas Boerner, Bryan Murray, Nigel Kojimoto, Prof. Alam of the Theoretical and Applied Fluid Dynamics Laboratory at the University of California along with the Lawrence Berkeley National Laboratory, Cyclotron Road. CalWave also had advisors and collaborator support from Prof. Evan Variano of the Engineering Lab for Fluid Motion in the Environment (ELFME) and BMT Designers & Planners along with key sponsors including RobotShop (robotshop.com), ANSYS (ansys.com), and JKI (jki.net). CalWave Power Technologies' device was a submerged pressure differential device.



8.1.8 3RD PLACE ($250K) WAVESWING AMERICA (SACRAMENTO, CA)

The third place team, Waveswing America, was led by Mirko Previsic and supported by Simon Grey and Jude Monson. Their team combined entrepreneurial start-up drive with deep operational experience in the marine environment and was supported by associates with experience in wave energy. Waveswing America demonstrated a sub-sea pressure-differential point absorber wave power generator device in the Prize.

8.2 Prize Feedback

The Prize collected feedback from the finalists about their participation and the Prize in general via a closeout interview that was filled out post 1/20th-scale testing and before announcement of the winning devices. Eight of the nine finalists responded to the online questionnaire. The compiled results of this feedback can be found in the appendices of this document. The following list highlights a few of the more informative results of the team feedback.

- One of the teams began developing a WEC because of the Prize
- The compiled rankings from the eight teams on the reasons for participating in the Prize identified the opportunity to test at the MASK Basin as the top reason. The second reason was recognition/publicity for the company. Winning the cash prize was tied for third with the opportunity to build a strong technical team.
- When asked about the total number of hours the team spent on the Prize, the low (500 hours) and high (7,000 hours) showed that the amount of effort significantly differed on a team basis. One team reported their hours were 30,240, however it was believed that this value was a typo so it was excluded from the analysis. Including the other seven reported values, the average number of hours was 2,886. If the low and high were removed from the remaining seven responses, the average increases to 3,940 hours.
- Three of the teams spent more than $250k above and beyond the seed funding to design, develop, build, and test their concept over the duration of the Prize
- The amount of cash contributions teams received varied with a high of $200k to a low of none.
- Two of the teams were successful in getting investor contributions from outside their team.
- The teams were all satisfied to highly satisfied with the small-scale testing facilities.
- Seven of the teams were satisfied to highly satisfied with the MASK Basin facilities.
- Six teams believe that the data gathered during the MASK Basins testing will be highly valuable.

- Seven of the teams were satisfied to highly satisfied with the administration of the Prize with Julie Zona receiving significant praise for her interaction with them. The main rationale given for not being satisfied is a known side effect of the prize construct where participants cannot have direct contact with technical prize personnel.
- All teams were satisfied with the support they received via email, website, and phone/conference/webinars with five being highly satisfied.
- All of the teams liked the metrics with ACE receiving significant praise for accounting for both energy capture and cost.
- While all test data and results will be available on the MHKDR on Nov. 16, 2017, most of the teams also plan to be very open with the data publicly by either sharing it directly or publishing papers.
- Seven of the teams would likely participate in future DOE prizes or challenges with four teams stating that they would be very likely to do so.

8.3 Prize ROI Evaluation

As previously stated, the DOE's primary goal was to enable the development of WEC devices that will be commercially competitive by approximately 2050. The Prize was completed to be one of the first steps in achieving this long term goal so the true ROI will not be fully realized until actual WEC devices are installed at full commercial scale and proven to be competitive with other forms of power generation. However, the Prize was able to jumpstart this market and show that it should be possible for WEC devices to be competitive with other forms of power generation once they complete further development and optimization via more traditional advancement avenues based on four of the nine finalists meeting the National Lab defined ACE value goal. The remainder of this section will look at various returns that the Prize has realized, the investment put in to get the returns and how this compares to DOE's traditional funding mechanisms.

8.3.1 RETURNS ON THE PRIZE

The returns on the Prize are not easy to define as a monetary value. Instead, they are more the accomplishments of the Prize which are detailed in Section 9 of this document. A quick summary of the major returns that the Prize was able to achieve are:

- ***Define a new metric that can be used to evaluate different device types:*** The ACE and HPQ metrics were created specifically for the prize and have the ability to benefit the entire industry if adopted. These metrics, along with the TPL, can evaluate a device on a macro level as well as provide direction to a developer on a micro level of what can make their device better holistically, particularly at early TRLs.
- ***Mobilize new and existing talent:*** 79 of the 92 registered teams were new entities and had concepts that the DOE had not funded in the past. The Prize competition allowed DOE to partner with new entities outside of traditional financial assistance mechanisms and evaluate alongside other known entities on a level playing field.
- ***Reward results that are delivered on time:*** Teams were required to complete deliverables on time or they would be eliminated and only the teams that met threshold levels were awarded monetarily.
- ***Increase the visibility of wave energy:*** The public outreach and media relations associated with the Prize increased the visibility of wave energy to show it as a viable energy resource that can attract potential investors, and successfully enabled the top performers to become viable and competitive industry members.

- ***Generate data that can be used by the public to further WEC development:*** All of the 1/50th and 1/20th scale testing data will be available on the MHKDR for the industry, academia, investment and general public review and use.

8.3.2 INVESTMENT ON THE PRIZE

The total monetary investment on the Prize included direct DOE funds and Non-DOE funds. The direct DOE funds were the budgets for the Prize Administration (including funds awarded to teams), NREL, SNL and NSWCCD support. The following table shows a summary of these budgets along with some Non-DOE contributions from ONR to NSWCCD.

Table 6: Prize Funding Distribution

Entity	Budget		
	DOE	Non-DOE	TOTAL
Prize Administration	$6,728,000	$0	$6,728,000
NREL	$1,075,333	$0	$1,075,333
SNL	$1,163,975	$0	$1,163,975
NSWCCD	$1,700,000	$640,000	$2,340,000
NON-Team Totals	*$10,667,308*	*$640,000*	*$11,307,308*

Additional investment was made by the teams. This investment included labor hours, team cash investment, in-kind support, and investor contribution. The Prize gained information on the total team investment via a closeout interview that was provided to the nine Finalists. Eight of the nine teams chose to respond to the questions and their answers lacked some of the clarity necessary to get a complete summary of the total investment for each team. The Prize did still use this data by applying the following assumptions and interpretations.

- The average hourly rate for team labor is $140 per hour
- Five of the team's budget totals included their reported additional investment and in kind contributions along with their reported labor hours times the hourly rate.
- One of the other team's budget total included the additional investment, in kind, and cash contributions. Labor hours were not included as they seemed to be included in the other areas.
- Another team reported a significantly high number of labor hours (30,240) which would have equated to nine FTE over the total duration of the Prize from opening of registration to announcement of the winners. Since this did not seem reasonable, the labor hour total value was not included in this team's budget total. This would result in a conservative or lower investment total.
- The final remaining team seemed to provide some of the labor hours as budget in other areas so only half of the total reported hours were included in the total budget

These assumptions and interpretations led to the Prize to conclude that the finalist investment could range from a low of $201,000 to a high of $1,115,000. This range was expected as each team had a unique makeup and each device had its own level of maturity at the start of the Prize. A team average value of $606,880 was derived from the data and the Prize chose to use this team average value for the nine finalists when generating the overall total investment of the Prize. The following table shows the estimated total investment of the Prize by the DOE and the nine finalists.

Table 7: Overall Prize Investment, DOE and Nine Finalists

Entity	Conservative Budget (Finalist only)		
	DOE	Non-DOE	TOTAL
Non-Team Total	$10,667,308	$640,000	$11,307,308
Team Total	$0	$5,461,920	$5,461,920
Total	***$10,667,308***	***$6,101,920***	***$16,769,228***

From the total investment based on the conservative interpretation of the Finalist's responses, the Prize has concluded that the ratio of DOE funds to non-DOE funds is 64:36. The Prize believes that this is a conservative value because we did not account for any investment of the Alternate, Qualified or Registered teams, which each put in different levels of investment. With some simple assumptions listed below, it could be possible to get the ratio to 60:40 as shown below.

Table 8: Additional Prize Investment Assumptions

Teams	# of teams	Budget per Team	TOTAL	Notes
Registered	46	$7,700	$354,200	Assume each team spent ~55 hours completing registration, reviewing rules and filling out the Technical Submission
Qualified	9	$37,930	$341,370	Assume that each Qualified team eliminated spent a quarter of the amount of an Alternate
Alternates	2	$151,720	$303,440	Assume each Alternate spent a quarter of the amount of a Finalist
		Total	***$999,010***	

Table 9: Overall Prize Investment, DOE and All Registered Entries

Entity	Estimated Budget (All Teams)		
	DOE	Non-DOE	TOTAL
Non-Team Total	$10,667,308	$640,000	$11,307,308
Team Total	$0	$6,460,930	$6,460,930
Total	***$10,667,308***	***$7,100,930***	***$17,768,238***

8.3.3 COMPARISON OF THE PRIZE AND TRADITIONAL FUNDING MECHANISMS

DOE has not attempted to calculate ROI on past traditionally funded Water Power Programs. However, the DOE has provided the following generalities about these programs to support this ROI review:

- Traditional funding programs are:
  - often awarded to known entities in the market that understand the government funding application process and government contracting, however this is not at all a selection criterion for award;
  - able to solicit and fund solutions to a problem, but often do not evaluate solutions using a quantitative and measureable metric for all applicants and awardees, and one that is designed to be representative of overall aspects of defining what concept has the best opportunity to get to market;
  - best effort agreements that result in no cost time extensions more than half of the time to accommodate the delays encountered in research;

- often executed by awardees that attempt to deliver on their initially defined deliverables, but the awardees often learn significantly more about their device, during the performance period of the award, and therefore fall short of meeting original target metrics stated in these deliverables, and/or change their research direction from this learning;
- often not able to be shared publicly until a 5-year moratorium period expires due to IP that the contractor may have or is generating during the program;
- averaging $1,000,000 total budget with an 80:20 DOE to Non-DOE funding split.

As shown in the table below, the Prize construct has an advantage over other traditional funding on most of the criteria:

Table 10: Prize Construct vs. Traditional Prizes and Funding

Criteria	Wave Energy Prize	Traditional Prizes	Traditional Funding
Generate & evaluate new metrics & criteria	Yes	Depends	Not often
Evaluate multiple solutions consistently according to metrics	Yes	Yes	Sometimes
New entities participate	Yes	Yes	Sometimes
Known entities participate	Yes	Yes	Yes
Completed on time	Yes	Yes	Some of the time
Goals / Deliverables fully met	Yes	Yes	Roughly half of the time
Focus on solution(s) to a key problem(s)	Yes	Yes	Yes
Accounts for an overall market potential	Yes	Depends	Attempted but difficult to enforce
Engages / increases public interest	Yes	Yes	Sometimes
Data available to the public	Yes, after 1 year	Depends	Yes, after 5 years
DOE to Non-DOE fund breakdown	60:40	Depends	80:20

9 Accomplishments

The key accomplishments for the Prize have be broken down into two areas, 1) Technical and 2) Publicity and Media.

9.1 Technical

The Prize completed all phases of work and announced the three winners via a technology showcase at NSWCCD's facilities on November 16th of 2016.

From the results of the 1/20th-scale model testing at NSWCCD's MASK Basin, four devices met the threshold for ACE of 3 m/$M. Of those four devices, AquaHarmonics' device achieved an ACE of 7.6 m/$M and was the only device that also exceed the National Lab-calculated ACE value of 6 m/$M that correlated to a LCOE of 6 ¢/kWh in 2050 (in 2014 money). From this, the Prize was successful at jumpstarting this market and it should be possible for WEC devices to be competitive with other forms of power generation once they complete further development and optimization via more traditional advancement avenues.

In addition to the three winners, the Prize achieved all of the additional internal goals. It:

- stimulated the development of new WEC devices for potential use in the energy industry.
- remained independent, non-partisan, and technology neutral – treating competitors with equality and fairness.
- had no justified complaints from qualified teams regarding lack of equality and fairness or teams withdraw for this reason.
- had a set of rules that outline clear technical boundaries and establish clear and concise judging protocols for the creation of the WEC devices to ultimately facilitate the meeting or exceeding of the competition metrics.
- drew competitors representing a diverse group of businesses, universities and individuals from across the United States as well as international companies with a U.S. presence.

In addition to these met goals, the following other program goals were all exceeded:

- **79** (goal: 5) newcomer teams registered
- **13** (goal: 10) teams from known developers registered
- **25** (goal: 7) states, plus Puerto Rico and U.S. citizens abroad all participated
- **66** (goal: 30) Technical Submissions at TG1
- **16** (goal: 10) 1/50th scale models tested at TG2
- **9** (goal: 5) 1/20th scale models tested at TG4
- **4** (goal: 1) devices exceed ACE threshold

The Wave Energy Prize has become an example of prize initiatives for the broader government. The Wave Energy Prize was highlighted in the following:

- listed as one of the leading examples presented by the Government Accountability Office's 2016 report Open Innovation Practice to Engage Citizens and Effectively Implement Federal Initiatives
- selected to be a case study for the Challenges and Prizes Toolkit: https://www.challenge.gov/toolkit/case-studies/wave-energy-prize/
- mentioned in a White House blog: https://www.whitehouse.gov/blog/2017/01/09/incentive-prizes-deliver-important-results-nation-offer-more-bang-buck

The DOE also received the following awards resulting from the efforts of the Prize:

- RockStar Award (August 2015), which is an internal DOE award that was given to Alison LaBonte in honor of her efforts for getting the Prize started and successfully garnering overwhelming interest from the community (92 registered teams).
- Challenge.gov Five Years of Excellence in Federal Challenge & Prize Competition Award for Best Public Engagement Strategy (October 2015) - https://www.challenge.gov/challenge-gov-celebrates-five-years-of-open-innovation/
- Federal Laboratory Consortium for Technology Transfer Mid-Atlantic Region Interagency Partnership Award (November 2015), which recognizes agency and/or laboratory employees from at least two different agencies who have collaboratively accomplished outstanding work in transferring a technology.

9.2 Publicity and Media

9.2.1 COMMUNICATIONS AND OUTREACH

The success of the Wave Energy Prize ultimately depended upon finding the right potential participants and alerting them to the opportunity open to them. Additionally, the long-term success of the new WEC technologies developed during the prize depended upon the interest cultivated among potential investors and program partners that will extend beyond the duration of this prize.

The Prize Administration Team developed a comprehensive communications strategy to meet the following objectives:

1. Inspire innovative individuals and teams to participate in the competition.
2. Increase public awareness about MHK technologies, with a focus on wave energy.
3. Create a following for the prize and the teams.
4. Spark demand from industry leaders and interest from the financial community in the winning technologies.

The strategy identified audiences, key messages, tactics and a timeline for all outreach activities to include proactive media relations, speaking activities and other specialized communications initiatives, including the prize website and social media outreach.

9.2.2 ANALYTICS

The success of the strategy was largely demonstrated by the tracking of several key metrics, particularly those that sought to understand the reciprocal traffic between the Prize's owned channels, such as the website and social media, to gauge engagement and excitement for the Wave Energy Prize. This was accomplished through the incorporation of Google Analytics in the website and will be augmented with other measurement tools, such as HootSuite, Facebook Analytics, and other various social-media metrics tools.

Between the launch of the owned channels and the announcement of the winner(s), the Prize developed an impressive community of engaged, excited followers. A summary of Wave Energy Prize digital outreach is shown below.

OFFICIAL (PRIORITY) SOCIAL MEDIA

- Facebook: 385 Followers
- LinkedIn: 370 Followers
- Twitter: 625 Followers
- Combined Impressions: Est. ~1 million by EOY

OFFICIAL WEBSITE (WaveEnergyPrize.org traffic from 1/20/15 to 11/30/2016):

- 69,805 Visits
- 36,346 Unique Visitors
- 200,128 Total Pageviews
- 2.87 Average Pages Per Session
- 3:40 Average Session Duration

OFFICIAL BLOG (WordPress)

- 6702 Total Pageviews
- 3724 Visits
- 1.81 Average Pages Per Session
- 52 Published Blog Posts

OFFICIAL EMAIL NEWSLETTER (Campaign Monitor)

- 704 Total Subscribers
- 52.92% Average Open Rate (well above industry average)
- 24.91% Average Clickthrough Rate
- 25 Sent Campaigns

Information about general interest in MHK technologies is best gauged by analyzing media coverage. Information indicating success in reaching investors will be apparent by observing the level of interest in Prize sponsorships and commitments to support individual teams. In the 23 months between the launch of the communications strategy and the announcement of the winners, more than 170 stories appeared in the media about the Wave Energy Prize, the teams and their technologies. The coverage (see Appendix B) included broadcast and print, online and traditional publications, including coverage in tier one outlets (such as *Popular Science, National Geographic, The Weather Channel*, *Discovery Canada*, *Salon.com*), trade publications (such as *HydroWorld*, *ECO Magazine*, *Fierce Energy*, *Power Magazine*, *Tidal Energy Today*, *Engineering News Record*, *Network World*), and local press (such as *Portland Business Journal*, *WUSA-9*, *Providence Journal*, *Belfast Telegraph*). Additionally, the Prize was mentioned in blog postings by the White House Office of Science and Technology Policy as well as on the White House blog.

10 CONCLUSIONS

The Wave Energy Prize was a major success for the DOE, its participants and the public in general. DOE's goal was to attract 30 teams to register to compete in the Prize during the registration period. In the end, 92 teams registered. Of these, 20 were chosen as Qualified Teams during Technology Gate (TG1). After TG2, nine Finalists and two Alternates were selected, and all nine Finalists proceeded through TG3, with the Alternates being eliminated. The nine Finalists put forward diverse and technically innovative WEC designs, especially in the areas of geometry, materials, power conversion and controls. Some of these included:

- Sea-state-to-sea-state control
- Wave-to-wave control
- Power absorption in multiple degrees of freedom
- Optimized float shapes and dimensions for energy absorption for broad bandwidth of wave frequencies
- Survival strategies such as submerging beneath the surface for extreme storms
- Use of structures and materials that are cost-effective to manufacture
- Flexible membranes that react to the wave pressure over a broad area

While the long-term impacts of the Prize are still unfolding, the Prize successfully achieved several of its goals:

- ***Spur game-changing performance enhancements to WECs:*** Of the nine finalists, seven surpassed the state-of-of-the-art performance, and four of the seven doubled the state-of-the-art performance to become eligible to win the Prize. The winning team, AquaHarmonics, not only doubled the baseline ACE for the Prize, but more than quintupled it, and both the second place finisher, CalWave Power Technologies, and the third place finisher, Waveswing America, more than tripled it.
- ***Provide an opportunity for apples-to-apples tank testing and evaluation:*** The WECs proposed by the finalists span diverse WEC archetypes, and each of them had unique mooring configurations. The Prize team worked with each team to create individualized test plans for the teams to ensure successful testing campaigns in the MASK Basin for each team. Eight of the nine finalists successfully completed testing at Carderock, allowing the Judges of the Prize to fairly and rigorously evaluate the performance of the devices.
- ***Provide a pathway to sweeping cost reductions:*** The DOE and the public now have a robust data set of device performance for a range of device designs and configurations. The National Renewable Energy Laboratory and Sandia National Laboratories are conducting a study of the key advances made by finalists during the Prize. The study will also highlight the technical areas in which future work will be necessary to continue reducing the cost of wave energy.
- ***Mobilize new and existing talent:*** Of the nine Finalists, only two teams had received any DOE funding in the past. The Prize competition allowed DOE to partner with new entities outside of traditional financial assistance mechanisms.
- ***Increase the visibility of wave energy:*** The public outreach and media relations associated with the Prize increased the visibility of wave energy to show it as a viable energy resource that can attract potential investors and successfully enabled the top performers to become viable and competitive industry members. The Prize increased and diversified the number of players in the wave energy space. The nine finalists benefitted from strong public communications and exposure to potential investors. They also established strong partnerships with the Navy and other experts in the field.

11 References and/or Bibliography

V. Neary, M. Previsic, R. Jepsen, M. Lawson, Y. Yu, A. Copping, A. Fontaine, K. Hallett, D. Murray (2014). Methodology for Design and Economic Analysis of Marine Energy Conversion (MEC) Technologies. SAND2014-9040

Heinrichs, Todd (2015). DOE Reference Model Project. SAND 2015-3054M

12 Appendices

12.1 Appendix 1 – Wave Energy Prize Rules

WAVE ENERGY PRIZE

U.S. DEPARTMENT OF ENERGY

Wave Energy Prize Rules

4.25.16 R3

1

Wave Energy Prize Rules Revision History:

Note: All new/modified language within the Wave Energy Prize Rules is provided in blue for increased visibility within the existing text.

5/26/15 - Revisions from original (4/24/15) contained in version 5.26.15 R1:

- Section 6.2 – Addition of requirement to provide depth of Small Scale Testing Facilities for 1/50th scale model testing; added following language: Water depths in the Small Scale Test Facilities being used for the 1/50th Model Testing, if not previously provided.
- Section 7.0 – Modification to seed funding dispersement process; following language removed: Finalists and Alternates will be eligible to receive seed funding for any eligible costs incurred between the official announcement of Qualified Teams and the completion of each Team's testing at the MASK Basin.

7/8/2015 – Revisions from R1 contained in version 7.8.15 R2:

Appendix A – The methodology to evaluate the TPL level of a device/concept calculation modified in step 4 from:

4. The overall system TPL value, TPL_{System}, is determined via:

$$TPL_{System} = 0.8\,TPL_{Economic} \cdot 0.2\,TPL_{Acceptability}$$

To:

4. The overall system TPL value, TPL_{System}, is determined via:

$$TPL_{System} = 0.8\,TPL_{Economic} + 0.2\,TPL_{Acceptability}$$

4/20/16 (revisions from R2 contained in version 4.25.16 R3):

The following clarifications have been made in Appendix I –

1. Added text to page 49: Each sea state, i, for each wave climate, j, is assigned a unique scaling vector, $\Xi(i,j)$, to ensure that the sum of the omnidirectional power densities for all regions are equal to the climate's total average annual omnidirectional wave power density, $\langle C_p(j)\rangle$.
2. Changes have been made to clarify how the Average Climate Capture Width (ACCW) will be calculated, specifically to make it clear that all seven climates used in ACCW are equally weighted. The calculations have not changed, only their description and nomenclature have.
3. Changes have been made to Appendix I to clarify that HPQ is calculated using impact factors assigned by the Judges, not the values of the HPQ performance-related quantities determined from testing.

Table of Contents:

Wave Energy Prize Rules Revision History: 2

1. Wave Energy Prize Overview 5
   1.1. Why the Wave Energy Prize? 5
   1.2. Prize Goals and Objectives 5
2. Wave Energy Prize Schedule and Structure 7
3. Registration 9
4. Prize Criteria and Payment 10
5. Technical Expert Judging Panel 11
6. Wave Energy Prize Technical Requirements 12
   6.1. Technology Gate 1: Technical Submission for Determination of Qualified Teams 12
   6.2. Technology Gate 2: 1/50th Scale Model Testing, Numerical Modeling, and Assessments for Determination of Finalists and Alternates 12
      6.2.1 1/50th Scale Model Testing 14
      6.2.2 Numerical Modeling and Calculation of Characteristic Capital Expenditure 15
      6.2.3 Revised Technical Submission 16
      6.2.4 1/20th Scale Model Design and Construction Plan 16
      6.2.5 Judging Process for Determination of Finalists and Alternates 16
   6.3 Technology Gate 3: 1/20th Scale Model Verification for Determination of Finalists 17
   6.4 Technology Gate 4: 1/20th Scale Model Testing for Determination of the Prize Winner(s) 18
      6.4.1 1/20th Scale Model Testing 19
      6.4.2 Judging of 1/20th Scale WEC Devices and Determination of Prize Winner(s) 20
7. Seed Funding 20
8. Wave Energy Prize Marketing and Communication Requirements 21
   8.1. Public Relations/Media/Marketing – Cooperation and Support 21
   8.2. Required Website Updates 21
   8.3. Social Media Outreach 21
   8.4. Mandatory Events 21
   8.5. Team Uniforms 21
9. Team Sponsorship, Logos and Branding 22
   9.1. Team Sponsorship 22
   9.2. Team Name and Team Logo 22
   9.3. Prize Name and Prize Logo Use 22
10. General Terms of Participation 22
   10.1. Dispute Resolution 22

10.2. Accuracy of Information provided by Teams 22

10.3. Withdrawal 23

10.4. Disqualification 23

10.5. Cancellation or Schedule Adjustment of the Wave Energy Prize 23

10.6. Official Language and Currency 23

11. Appendices 24

Appendix A: Technology Performance Level (TPL) Assessment Methodology 24

Appendix B: 1/50th Scale Model Prototype and Data Submission Requirements 28

Appendix C: WEC Power Matrix Template (Full Scale) 31

Appendix D: Characteristic Capital Expenditure and Representative Structural Thickness 32

Appendix E: Assessment for Technology Gate 2 - Method for Determination of Finalists and Alternates 36

Appendix F: Test Plan for MASK Basin (1/20th) Physical Model Testing 38

Appendix G: MASK Basin Data Analysis 42

Appendix H: MASK Basin Requirements 44

Appendix I: Assessment for Technology Gate 4 and Method for Determination of Winner(s) 47

Appendix J: Branding and Logo Usage Guidelines 53

Appendix K: Glossary 52

1. Wave Energy Prize Overview

1.1. Why the Wave Energy Prize?

With more than 50% of the population living within 50 miles of coastlines, there is vast potential to provide clean, renewable electricity to communities and cities across the United States by harnessing the energy from waves, tides, and ocean currents. Wave Energy Conversion (WEC) devices are designed to harness the available energy contained in waves, and turn it into usable electricity.

Current WEC concepts are not yet cost competitive with other means of generating electricity, and significant opportunities exist to reduce the associated costs so wave power can contribute to the nation's clean energy supply.

The Department of Energy (DOE) sponsored Wave Energy Prize intends to double the state-of-the-art performance within two years by encouraging the development of WEC devices that capture more energy from ocean waves, ultimately reducing the cost of wave energy, making it more competitive with traditional energy solutions.

The Wave Energy Prize provides an opportunity for participants to:

- Win a substantial monetary prize.
- Receive seed funding to support the building of a 1/20th scale model WEC device for testing.
- Participate in two rounds of valuable WEC model testing at no cost to the Finalist Teams, one of which is at the Navy's Maneuvering and Seakeeping (MASK) Basin in Carderock, MD, the nation's premier wave testing facility.
- Benefit from many opportunities for recognition so that it is worthwhile to compete, and not just for first place.
- Contribute to the development of innovative, green, alternative-energy technologies that can contribute to the nation's energy independence.

1.2. Prize Goals and Objectives

Through the Wave Energy Prize, the DOE is trying to identify new technologies that can achieve a step change reduction in the Levelized Cost of Energy (LCOE) over current leading WEC device designs; that will ideally require no further fundamental breakthroughs or innovations to achieve commercial competitiveness post-Wave Energy Prize.

"Average Climate Capture Width per Characteristic Capital Expenditure," to be referred to as the ACE metric, has been selected by the Wave Energy Prize as a reduced content metric that is a proxy for LCOE, appropriate for comparing low Technology Readiness Level[1] (TRL) WEC concepts when there is insufficient data or unreliable data to enable an actual calculation of the LCOE. Device structural mass is the most important LCOE driver for

[1] https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a
http://esto.nasa.gov/files/trl_definitions.pdf

WEC devices today, along with annual energy production (AEP). The Wave Energy Prize has chosen to identify the structural mass through total surface area and representative structural thicknesses. The two components that comprise the ratio ACE are defined as follows:

- **Average Climate Capture Width (ACCW)** = the absorbed power of the device in kilowatt (kW) divided by the wave energy flux per meter crest width in kW/m. Thus, a device with a higher capture width is absorbing more of the available incident wave power that can be converted into usable power. Capture widths can be determined through the analysis of experimental data obtained from wave tank testing.

- **Characteristic Capital Expenditure (CCE)** = Total Surface Area (m^2) x Representative Structural Thickness (m) x Density of Material (kgm^{-3}) x Cost of Manufactured Material per unit Mass ($\$kg^{-1}$). See **Appendix D** for more information on the calculation of CCE.

The ACCW and CCE are calculated values from measurements in the tank and analysis of full scale drawings.

All Wave Energy Prize metrics are stated for full scale WEC devices. All test results obtained during the Wave Energy Prize will be scaled up to full scale.

The Wave Energy Prize has determined that the value **ACE for a group of today's "State of the Art" technologies is 1.5m/$M** (or 1.5 meters per million dollars), in typical deep water locations off the West Coast of the United States, with the numerator of the metric based on absorbed power.

To achieve the goal established by the DOE and promote the necessary revolutionary advancements in WEC technologies, an ACE threshold value has been established and will be used to determine key decisions during the final Technology Gate of the Wave Energy Prize.

At the final gate, Technology Gate 4, testing at 1/20th scale, WEC models must achieve a threshold of 3m/$M to be eligible to be considered for winning a monetary prize.

The Wave Energy Prize is designed to focus on deep-water devices. The Wave Energy Prize has chosen wave conditions found on the West Coast of the continental United States due to the large energy resource in this region. Such locations have long term average annual wave energy flux per meter crest width in the range of 17-39kW/m. Only WEC concepts that are designed for operating in these conditions are being considered for entry to the Wave Energy Prize.

Additionally, other types of devices may be eliminated based upon whether or not the device can be fairly and equitably scaled in comparison to other devices, and constraints of the test facility.

To achieve this technical objective with game-changing WEC device designs, the Wave Energy Prize aspires to:

- Stimulate step-change improvements in WEC technology.
- Entice both existing WEC device developers and newcomers.
- Draw competitors representing a diverse group of energy companies, universities and individuals from across the U.S., as well as international entities.

2. Wave Energy Prize Schedule and Structure

The Wave Energy Prize has been designed as a three (3) phase competition, with four (4) distinct Technology Gates.

The successful progression through the four (4) Technology Gates will allow the most qualified Teams, with the highest ranking WEC designs, to be identified, tested, and placed for winning prize purses at the completion of the Prize.

The Technology Gates and their purpose are identified below, while the requirements for successful progression through them are defined in the Technical Requirements (Section 6):

- Technology Gate 1 - Technical Submission; for Determination of Qualified Teams (Prize Phase 1: Design)
- Technology Gate 2 - Small Scale (1/50th) Model Testing, Numerical Modeling for Determination of Finalists and Alternates (Prize Phase 1: Design)
- Technology Gate 3 - Verify the level of build progress and test readiness of the identified Finalists and Alternates (Prize Phase 2: Build)
- Technology Gate 4 - Testing of 1/20th Scale Model at the MASK Basin, Carderock; for Determination of Prize Winners (Prize Phase 3: Test and Evaluation)

The following table provides the timing and key dates associated with the Wave Energy Prize:

Prize Phase 1: Design (April 1, 2015 - February 29, 2016)	
April 1, 2015	Registration for the Wave Energy Prize opens on-line, with access to the Wave Energy Prize Rules and Terms and Conditions. Upon registration acceptance, teams will receive access to the Technical Submission package and the participant only website.
June 15, 2015	Wave Energy Prize Registration closes at 5:00 PM ET; Announcement of official Registered Teams will follow.
July 15, 2015	Technical Submission deadline by 5:00 PM ET; must include electronic agreement to the Terms and Conditions.
July 16 – August 13, 2015	Technical submissions are reviewed by the Judging Panel and qualifying designs are promoted through Technology Gate 1 to the next level of the Design Phase, the 1/50th scale model testing.
August 14, 2015	Announcement of up to 20 Qualified Teams; Qualified Teams are provided: • Judges assessment of Froude scaling applicability for each Team's WEC device (See Section 6.0) • Template for the 1/20th Scale Model Design and Construction Plan • Contracted testing facility locations and the identification of the Small Scale Test Facility that each Qualified Team must use

7

	• The testing schedule for each Team's specific small scale (1/50th) model, including shipping details and requirements
August 15 – January 29, 2016	Qualified Teams develop a small scale (1/50th) model, demonstrating proof-of-concept via small scale prototype testing, numerical simulations, and a 1/20th scale Model Design and Construction Plan.
August 24, 2015	Qualified Teams confirm their device scales with Froude scaling laws or provide documentation on how their device scales for the Judging Panel to review.
September 7, 2015	The Prize informs the Qualified Teams of the final scaling methodology for their device.
September 15, 2015	The Prize informs the Qualified Teams of the Representative Structural Thickness (RST) table of materials outlining load and the $/kg assumptions.
September 25, 2015	Qualified Teams accept or challenge the RST Table via an email to the Prize Administrator, providing the necessary data to support the challenge. (See Section 6.2.2)
September 30, 2015	The Prize provides the Qualified Teams: • Final RST table • Numerical modeling and Power Take-Off (PTO) unit requirements template
November 23, 2015	Qualified Teams 1/50th scale WEC devices must be received by the designated testing facility.
November 30, 2015	The Prize provides the Qualified Teams the test area for the 1/20th scale WEC device testing facility.
November 30, 2015	Qualified Teams must submit their numerical modeling results and simulations, revised Technical Submission and Characteristics of the PTO unit utilized in the 1/50th scale WEC model to the Wave Energy Prize Administrators by 5:00 PM ET.
December 1, 2015 – January 29, 2016	Testing of the 1/50th scale WEC devices will occur at designated facilities December 1, 2015 through January 29, 2016.
January 29, 2016	Qualified Teams must submit 1/20th Scale Model Design and Construction Plan to the Wave Energy Prize Administrators by 5:00 PM ET.
February 1 – February 29, 2016	Submissions are reviewed by the Judging Panel and succeeding designs are promoted through Technology Gate 2 to the 1/20th scale model Build Phase.
Prize Phase 2: Build (March 1 – July 29, 2016) **The Finalists and Alternates enter this phase and are responsible for the procurement**	

8

and construction of a 1/20th scale prototype WEC device for tank testing.	
March 1, 2016	Up to 10 Finalists and 2 Alternates announced; seed funding distribution begins to Finalists and Alternates.
June 15, 2016	Finalists and Alternates submit build progress and test readiness report to the Judging Panel for review by 5:00 PM ET.
June 16 – June 30, 2016	Submissions are reviewed by the Judging Panel and successful Finalist Teams are promoted through **Technology Gate 3** to the Test and Evaluation Phase.
July 1, 2016	Announcement of Finalists to have 1/20th scale WEC devices tested at MASK Basin.
July 18, 2016	1/20th scale WEC devices of Finalists to be tested must be received by the Carderock MASK Basin.
Prize Phase 3: Test and Evaluation (August 1 – October 31, 2016)	
August 1 – October 10, 2016	Testing of Finalist Teams' fabricated 1/20th scale devices at Carderock MASK Basin facility.
October 11 – October 31, 2016	Assessment by Judging Panel of Finalist's test results from the Carderock MASK Basin, and identification of the top scoring concepts that successfully completed **Technology Gate 4**.
Post-Competition Publicity	
Mid November, 2016	Announcement of Teams to be awarded a prize (if a winner is determined based on scores and thresholds associated with 1/20th scale WEC device testing at the MASK Basin); Awards ceremony with announcement of winning Team(s), if a winner is determined.

Table 1 – Wave Energy Prize Schedule

Specific dates for announcements, testing, and other noted items will be confirmed and provided to the competing Teams closer to the designated event. The Wave Energy Prize Administrators reserve the right to modify the timing associated with the Prize, and will provide proper notification to participants should a timing change occur.

3. Registration

The Wave Energy Prize registration application is found on the Prize website, at www.waveenergyprize.org

The purpose of the registration process is to collect and review the Team specific information necessary to accept applicants as official "Registered Teams" of the Wave Energy Prize.

All Teams desiring to compete in the Wave Energy Prize are required to complete and submit the registration application. The Wave Energy Prize Administrators will use the information provided in the application to determine if each applicant will be accepted as an official "Registered Team" and allowed to continue in the Wave Energy Prize.

Completed registration applications must be submitted by 5:00 PM (ET) on June 15, 2015 via the Wave Energy Prize website.

All information must be typed into the appropriate form field, and all provided fields completed. Handwritten applications will not be accepted. All applications must be completed in English.

The Wave Energy Prize Administrators will use best efforts to notify the Teams of acceptance or rejection within seven (7) business days of receipt of the registration application. A registration application containing a single WEC concept may only be submitted once per Team. Teams that have more than one WEC concept they wish to enter into the Wave Energy Prize may submit an application for each individual WEC concept.

The DOE and Wave Energy Prize Administrators reserve the right to deny an application for any reason, including, but not limited to insufficient information and lack of eligibility. See Terms and Conditions for details regarding eligibility.

Upon the acceptance or rejection of a Team's registration application, the Team will receive email notification regarding their status. Teams receiving an acceptance notice, and named an official "Registered Team," will also receive information regarding the login and password generation procedures for the Team-only protected website, which will be used as the center for communication and documentation repository.

4. Prize Criteria and Payment

To be eligible to win a monetary prize purse, a Team's 1/20th scale WEC device must achieve a threshold Average Climate Capture Width per Characteristic Capital Expenditure (ACE) value of 3m/$M. The Judging Panel will rank all Teams whose devices achieve the threshold and assess their overall performance using the Hydrodynamic Performance Quality, outlined in Section 6 of this document. Prize purses available to the winner(s) of the Wave Energy Prize are distributed as follows:

- Grand Prize Winner: Team ranked the highest after testing of the 1/20th scale WEC device at the Carderock MASK Basin - $1,500,000
- 2nd Place Finisher: Team ranked second after testing of the 1/20th scale WEC device at the Carderock MASK Basin - $500,000
- 3rd Place Finisher: Team ranked third after testing of the 1/20th scale WEC device at the Carderock MASK Basin - $250,000

The Wave Energy Prize Administrators will issue prize payments no later than sixty (60) days after the announcements of the winner(s) of the Wave Energy Prize. Checks will be paid by electronic funds transfer to the Team Leader. The Team acknowledges that the Prize Administrators shall only be obligated to make purse payments to the Team Leader. Teams acknowledge that any failure of the Team Leader to make payments of any kind to team members is the responsibility of the Team Leader, and not the responsibility of the Department of Energy or the Prize Administrators.

The prize purse will be subject to U.S. Federal income taxes per the Internal Revenue Service withholding and reporting requirements, where applicable.

If it is determined by the Judging Panel that none of the Finalist Teams are able to achieve the stated threshold ACE value of 3m/$M with their 1/20th scale WEC device after the Test and Evaluation Phase at the MASK Basin, a prize will not be awarded.

5. Technical Expert Judging Panel

The Technical Expert Judging Panel, or Judging Panel, will be responsible for evaluating compliance with the established technical requirements in the Rules governing the Wave Energy Prize.

The Judging Panel will be comprised of highly qualified and impartial judges. The Wave Energy Prize Judging Panel currently consists of representatives from the following organizations:

- Sandia National Laboratories, Albuquerque, NM
- National Renewable Energy Laboratory, Boulder, CO
- Naval Surface Warfare Center, Carderock Division, West Bethesda, MD
- Ricardo, Inc., Van Buren, MI

Additional highly qualified members may be added to the Judging Panel throughout the Wave Energy Prize to appropriately support the review processes during each Technology Gate, as outlined in Section 2. Teams will be notified if and when new members are added to the Judging Panel. All members of the Judging Panel will sign conflict of interest statements (COIs) and non-disclosure agreements (NDAs), as well as statements acknowledging that they make no claim to the intellectual property developed by Teams.

Current members of the Judging Panel for the Wave Energy Prize have signed COIs and NDAs with the Prize Administrators to govern their handling of data provided and generated by participants in the Prize. Per the terms of the NDAs, the Judges may not share or reveal any confidential or proprietary information they receive in order to perform their duties for this Prize.

The Prize cannot be contested; all decisions and opinions made by the Judging Panel per the technical requirements outlined in Section 6 will be rendered by a majority of the members and are binding and not subject to review or contest. The Judging Panel, in conjunction with the Wave Energy Prize Administrators, retains sole and absolute discretion to declare Registered Teams, Qualified Teams, Finalist Teams (and Alternates) and ultimately the Winner(s) of the Wave Energy Prize. The final decisions of the Judging Panel are binding and may not be challenged by the participating Teams. (See Section 6.2.2 “Challenge to RST” and Section 10.1 “Dispute Resolution”)

6. Wave Energy Prize Technical Requirements

The following sections define the requirements and judging processes for each Technology Gate within the Wave Energy Prize.

6.1. Technology Gate 1: Technical Submission for Determination of Qualified Teams

The Technical Submission consists of a series of questions designed to assess the potential of a Team's WEC concept. Teams are required to provide responses via both written descriptions and drawings. Official Registered Teams will receive a template via the Team-only secured website upon the Prize Administrator's acceptance of their registration application.

The Prize Administrators will conduct a webinar, tentatively scheduled for the week of **June 15, 2015**, to provide an overview of the Technical Assessment and an explanation of the Judging Panel's review process.

Each Registered Team must complete and electronically submit the Technical Submission and supporting documentation to the Prize Administrators via the Team-secured website by 5:00 PM ET on July 15, 2015.

Using the Technology Performance Level (TPL) assessment methodology described in **Appendix A**, the Judging Panel will assess the Technical Submissions, rank them, and determine which Teams will be allowed to progress to the next stage of the Wave Energy Prize. The Judging Panel will select up to twenty (20) Qualified Teams to be allowed to progress in the Wave Energy Prize.

Feedback will be provided to submitting Teams following the Judging Panel's assessment of their Technical Submission; Teams will be notified regarding their status in the Prize no later than **August 14, 2015**. The Judging Panel's decisions are final; neither the Prize Administrators nor the Judging Panel will enter into a dialogue with participating Teams about this feedback.

Results and rankings will be announced and posted on the public Wave Energy Prize website, as specified in the Wave Energy Prize Terms and Conditions.

Qualified Teams will proceed through Technology Gate 1, and begin working to meet the requirements defined for Technology Gate 2.

6.2. Technology Gate 2: 1/50th Scale Model Testing, Numerical Modeling, and Assessments for Determination of Finalists and Alternates

Up to twenty (20) Qualified Teams will proceed to Technology Gate 2, which is designed to identify up to ten (10) Finalist Teams, and two (2) Alternate Teams, eligible to proceed to Technology Gate 3 of the Wave Energy Prize.

Upon notification of the results of Technology Gate 1, Qualified Teams will receive the following information:

- Judges assessment of Froude scaling applicability for each Team's WEC device (see note below in bold).
- Template for the 1/20th Scale Model Design and Construction Plan.
- Contracted testing facility locations and the identification of the Small Scale Test Facility that each

Qualified Team must use.

- Water depths in the Small Scale Test Facilities being used for the 1/50th Model Testing, if not previously provided.
- Testing schedule for each Qualified Team's specific 1/50th scale model, including shipping details and requirements.

In addition to the testing of a 1/50th scale model (section 6.2.1,) Teams will be required to submit the following information to support the assessment at Technology Gate 2:

Deliverable:	Section Described:	Due Date:
Characteristics of the Power Take Off unit utilized in the 1/50th WEC model	Appendix B	November 30, 2015; by 5:00 PM ET
Numerical modeling results for full scale concepts	Section 6.2.2	November 30, 2015; by 5:00 PM ET
Revised Technical Submission	Section 6.2.3	November 30, 2015; by 5:00 PM ET
1/20th scale model Design and Construction Plan	Section 6.2.4	January 29, 2016; by 5:00 PM ET

Table 2 – Technology Gate 2 Deliverables

Note: The standard methodology for scaling the WEC devices participating in the Wave Energy Prize is the Froude methodology (Section 2.1 in following paper describes Froude scaling: http://www.supergen-marine.org.uk/drupal/files/reports/WEC_tank_testing.pdf). Judges will review all WEC designs and determine if the Froude methodology is appropriate for each device. Should the Judges determine for a specific WEC device that the Froude methodology is not viable or has specific test set-up requirements, the affected Team will be notified at the time of the announcement of the Qualified Teams. These Teams will be required to provide documentation to illustrate and substantiate their scaling method and/or describe the test set-up that ensures applicability of Froude scaling to the Judges by August 24, 2015. The Judging Panel will review the information and provide direction by September 7, 2015. If it is determined that the results from the tank testing cannot be fairly scaled, the device will be eliminated from the Prize.

WEC devices that are determined by the Judging Panel to not meet the required 1/20th and 1/50th scale (+/- 5%) of the Team's full scale design (i.e. the scale models supplied are not truly to scale) when the physical models are reviewed at the testing facilities will be eliminated from the Wave Energy Prize.

Teams will, during this phase, begin to discuss mooring strategies and the Data Acquisition System (DAQ) for their 1/20th scale WEC device with MASK Basin personnel in preparation for testing during Prize Phase 3: Test and Evaluation. These discussions and associated actions must be completed with the MASK Basin personnel by the time the 1/20th scale devices are delivered to the MASK Basin on **July 18, 2016.**

Teams will be allowed limited control of the representative Power Take-Off (PTO) during 1/50th scale model testing. No limits on control will be enforced in the 1/20th model testing. Numerical modeling results for the full scale WEC concept should reflect both the limited control as implemented in the 1/50th scale WEC model and the unlimited control implemented in the 1/20th scale WEC model testing. Details are specified in **Appendix B**.

13

6.2.1 1/50th Scale Model Testing

All 1/50th scale model testing, data analysis and reporting will be performed by small scale test facilities selected by the Wave Energy Prize Administrators; the small scale facilities costs will be met directly by the Wave Energy Prize and at no cost to Qualified Teams.

Testing, data analysis, and reporting for all WEC devices submitted by the Qualified Teams for 1/50th scale testing will occur during the period of December 1, 2015 through January 29, 2016. All Qualified Teams are required to ship their 1/50th scale model to be received at the designated testing facility on or before November 23, 2015.

Qualified Teams will—at their own cost—design and build a 1/50th scale physical model of their WEC concept; instrument their 1/50th scale model; deliver numerical modeling results at full scale simulating the 1/50th scale test conditions and typical West Coast conditions; ship the 1/50th scale model to a testing facility designated by the Prize Administrators; support the onsite testing with the appropriate Qualified Team members; and after testing, ship their 1/50th scale model device back to the Team's facility or location.

PTO unit specifications, as well as testing requirements, instrumentation requirements, analysis and reporting specifications are outlined in **Appendix B**.

Qualified Teams will be invited to participate in a webinar, tentatively scheduled for the week of **August 17, 2015**, designed to share good practices on scale model design and construction following the official announcement. The contracted wave tank facilities will participate in this webinar to ensure that roles, responsibilities, and interfaces are clear for all parties, especially in relation to mooring configurations and sensors to be provided and located by the Qualified Teams on their 1/50th scale model.

The testing facilities will provide additional support to the Qualified Teams to ensure a successful testing program, but they will not help Qualified Teams improve the design of their WEC device. Qualified Teams are encouraged to contact the small scale testing facilities early in the design of the 1/50th scale model to ensure the correct implementation of sensors and moorings.

The Wave Energy Prize will pay for the testing of a single design of a 1/50th scale WEC model at the designated small scale facility for the purpose of obtaining test results specifically outlined for judging the device for the Prize. Qualified Teams, at their own expense, may choose to have identical duplicate devices available for testing if the initial device is damaged. Teams may wish to commission further testing at the designated testing facilities, and may do so at their own expense and through independent negotiation with the facility. Any additional work commissioned directly by Qualified Teams must not interfere with the work contracted by the Prize Administrators. The results of any additional testing will not be included in reports that are provided to the Prize Administrators.

Qualified Team members will be permitted to attend the testing, to observe and support the test program. The number of Team members able to attend the testing will be determined by the small scale test facility.

Members of the Judging Panel, DOE and Prize Administrators may be present during the tests to observe the activities at the testing facilities. All tests will be video recorded.

Should it prove impossible to complete the testing due to physical damage to the WEC model caused by the testing, the Judging Panel will use best efforts to work with the tests that were successfully performed to complete the judging of the 1/50th scale model. But, if the Judging Panel is unable to do this in a manner it considers having satisfactory credibility, or fairness to other competitors, the WEC concept will no longer be considered as a candidate for the Wave Energy Prize, and the Team will be eliminated.

All reports and video recordings from 1/50th scale testing will be provided directly to the Prize Administrators, and will be shared with the Judging Panel and DOE. Teams will receive a copy of the data and the report describing the performed tests, results and analyses, as well as the video recording.

Please note: In the construction of the 1/50th scale model, Prize Administrators will accept minor changes to the WEC concept described in the Technical Submission, but the device must still be fundamentally the same WEC concept. For example, Teams cannot jump from a point absorber to a terminator, or modify their concept's working principles. Small changes to geometries and dimensions are acceptable. If in doubt about any proposed detailed changes, please consult the Prize Administrators before implementing them in model design and construction.

6.2.2 Numerical Modeling and Calculation of Characteristic Capital Expenditure

On **November 30, 2015, by 5:00 PM ET**, each Qualified Team must submit the results of numerical modeling analyses of their full scale WEC concept.

The full scale simulation results must be submitted to the Prize Administrators in a template to be provided to the Qualified Teams on **September 30, 2015**. The modeling will be based on a series of regular and irregular waves. Example types of waves can be found in **Appendices B and C**; exact waves will be provided with the template. All numerical modeling, for both waves at 1/50th and 1/20th scales, must be completed utilizing the same equations of motion, software, and code, except for the specifics of the PTO control.

A brief description of the numerical model and the physical model must be supplied when submitting the simulation results. The numerical model description must describe the origin of the physics of the wave-structure interaction (potential flow, non-linear potential flow, RANS, etc.) as well as a description of the control strategy implemented. If a control strategy utilizes wave prediction, a limitation on the amount of foreknowledge will be imposed based on realistically achievable values given the MASK Basin setup. These limitations will be communicated to the Teams by **October 31, 2015**. Any approximations and assumptions that are made should be explained and justified. The template to be provided on **September 30, 2015** will provide the exact requirements.

During this phase, independent structural engineers from the National Laboratories will establish the required Representative Structural Thickness (RST) and associated loading conditions, as well as the Characteristic Capital Expenditure (CCE) for each WEC device. Qualified Teams will receive initial information regarding RST and associated loading conditions for review and comment by **September 15, 2015**. Teams have until **September 25, 2015** to accept or challenge the RST assumptions via email and provide evidence to the Prize Administrators to support the challenge. Teams will be supplied the refined RST table on **September 30, 2015**. **Appendix D** outlines the methodology that will be used to calculate RST and CCE.

6.2.3 Revised Technical Submission

Qualified Teams must provide an updated Technical Submission from Technology Gate 1 to reflect the learning and any limited resultant changes in the WEC design that have been gained from the competition to this point and re-submit it for assessment. Please note, the Judging Panel will not accept radical and significant changes to the revised Technical Submission; it will accept minor changes to the WEC concept described in the original Technical Submission, but the device must still be fundamentally the same WEC concept. For example, Teams cannot jump from a point absorber to a terminator, or modify their concept's working principles; small changes to geometries and dimensions are acceptable. If in doubt about any proposed detailed changes, please consult the Prize Administrators before implementing the changes. Teams will be eliminated from the Prize if the Judging Panel determines it is not the same WEC concept.

To assist the Judging Panel, changes (deletions, modifications, additions) made to the Technical Submission at this point must be clearly visible, with all changes highlighted in the document and noted in a cover sheet. **The revised Technical Submission must be submitted to Prize Administrators by November 30, 2015 by 5:00 PM ET.**

6.2.4 1/20th Scale Model Design and Construction Plan

Qualified Teams are required to submit a plan for design and construction of a 1/20th scale model that will be tested at the MASK Basin if determined to be a Finalist. The 1/20th Scale Model Design and Construction Plan must include:

- A short narrative of less than one thousand words that outlines the phases, tasks, and/or steps that the Team plans to complete to successfully design and construct a 1/20th scale model in the allotted timeframe.
- A detailed timing plan that shows the phases and tasks that the Team plans to complete.
- A Bill of Materials (BoM) that includes description of the major subsystems, assemblies and components, and sensors that will be required for the final test and evaluation phase as specified in **Appendix G**, along with as much known data (quantity, mass, cost, supplier, etc.). A BoM template will be provided to the Qualified Teams post announcement of the Qualified Teams.

The 1/20th Scale Model Design and Construction Plan must be submitted by January 29, 2016, by 5:00 PM ET.

6.2.5 Judging Process for Determination of Finalists and Alternates

Appendix E describes the process to be used by the Judging Panel in determining the Finalists and Alternates. Finalists will include the up to ten (10) Teams receiving the highest scores following the Technology Gate 2 assessment. Two (2) Alternates, determined by the next highest scores, will also be named. If a Finalist is eliminated or withdraws from the Wave Energy Prize, the Alternate receiving the highest score following the Technology Gate 2 assessment will be offered the opportunity to become a Finalist. If the first Alternate declines, the second Alternate will be offered the opportunity to become a Finalist. Seed funding distribution and amounts are outlined in Section 7.

Alternates understand that up to ten (10) 1/20th scale model WEC devices will be tested at the MASK Basin, and acknowledge the risk associated with building a 1/20th scale WEC device that may, ultimately, not be provided an opportunity for testing or consideration for the Prize purse.

All Qualified Teams will be provided feedback following the Judging Panel's assessment of small scale testing results, modeling simulation results, 1/20th Scale Model Design and Construction Plan, and the revised Technical Submission by **March 1, 2016.** At that time, Qualified Teams will be notified regarding their status in the Prize. Neither the Prize Administrators, nor the Judging Panel will enter into a dialogue with the participants about the feedback; the Judging Panel's decisions are final.

Test results and rankings will be announced and posted on the public Wave Energy Prize website as specified in the Wave Energy Prize Terms and Conditions.

Finalist and Alternate Teams determined by Technology Gate 2 will, with seed funding (levels of funding outlined in Section 7) provided by the Department of Energy, proceed into Prize Phase 2 – Build, and commence building a 1/20th scale physical model of their WEC concept.

6.3 Technology Gate 3: 1/20th Scale Model Verification for Determination of Finalists

The purpose of Technology Gate 3 is to verify the level of build progress and test readiness of the identified Finalists and Alternates, and determine the up to ten (10) Finalist Teams that will participate in the 1/20th scale testing at the MASK Basin.

The required submission from each Team consists of:

- Video and photo documentation showing build progress of the device.
- Video and photo documentation showing the critical dimensions for the device.
- Plan showing status of Team within their build process along with the tasks remaining before build complete / ship to the MASK Basin, including any updates to the Model Design and Construction Plan submitted on **January 29, 2016.**

All requested materials are due to the Prize Administrators by 5:00 PM ET on June 15, 2016.

Finalist Teams and Alternates will be invited to participate in a webinar tentatively scheduled for the week of **March 7, 2016**, to share good practices on scale model design and construction. A MASK Basin representative will also participate in this webinar to ensure roles, responsibilities, and interfaces are clear between all parties. Additionally, the Prize Administrators will facilitate direct discussions between each Finalist and Alternate Team and the MASK Basin representatives to discuss specific requirements associated with each Team's design, especially in relation to mooring designs and mooring loads anticipated as well as the instrumentation provided by the Teams.

Identified Finalists making it through Technology Gate 3 will be announced and posted on the public Wave Energy Prize website, as specified in the Wave Energy Prize Terms and Conditions, **no later than July 1, 2016**. These identified Finalists will proceed to Prize Phase 3 – Test and Evaluation, 1/20th scale wave tank testing at the MASK Basin in Carderock, MD.

6.4 Technology Gate 4: 1/20th Scale Model Testing for Determination of the Prize Winner(s)

Upon verification and announcement of the Finalist Teams proceeding to the MASK Basin, the Finalists will receive the following information:

- 1/20th scale WEC device shipping details to MASK Basin in Carderock, MD.
- Specifications for and facilitation of conversations regarding moorings.
- Any additional information from **Appendix E** regarding specific tests that will be performed at the MASK Basin.

Testing will occur at the MASK Basin **August 1, 2016 through October 10, 2016**. Teams will be provided specific dates during which their 1/20th scale WEC model will be assembled and tested. It is required that Team representatives be at the MASK Basin facility for the assembling and testing of their device. Details are provided in **Appendix H**.

All 1/20th scale WEC devices must be shipped and received at the MASK Basin on or before **July 18, 2016**.

The required sensors to be located on the WEC device are outlined in **Appendix F**. Support and guidance will be provided by the National Laboratories and/or MASK Basin personnel to ensure appropriate sensor selection and location. However, it is the Teams' responsibility to physically mount the sensors appropriately. An *in situ* calibration check will be conducted at the MASK Basin.

Teams are permitted to submit an amended calculation of the total surface area of their WEC concept at 1/20th scale to the Prize Administrators on or before the **July 18, 2016** 1/20th scale WEC device receiving deadline at the MASK Basin.

Software control of the 1/20th scale WEC device is permissible during testing in the MASK Basin. During the testing, Finalists can only make modifications to previously defined variables within the controls code that has been disclosed prior to shipping their device for testing. If a Finalist device uses any software-based controls that will be accessed live or may be modified during the final testing, the Finalist must:

- Provide a copy of the complete controls code to the Prize Administrators at the time of shipping their device to Carderock.
- Provide a document explaining the control variables for which control values may be modified during testing.
- Provide a copy of the complete controls code to the Prize Administrators prior to the start of their models' testing at Carderock.
- Be able to provide a copy of the complete controls code being used live during the test if requested by the Prize Administrators.
- Provide a copy of the complete controls code to the Prize Administrators at the conclusion of the testing at Carderock.

If evidence is found showing that the Finalists has modified areas of the code outside the previous disclosed variables, that Finalist will be disqualified.

All controls code submitted to the Prize Administrators will be considered each individual Finalist Team's intellectual property, and will therefore be treated as confidential material that will not be shared with other Finalists or the general public.

Additional refinement of the DAQ at the MASK Basin, if required to accommodate the specific WEC designs being tested by the Finalists, will be communicated to the Teams as soon as possible after the identification of the Finalist Teams.

Please note: In the construction of the 1/20th scale model, Prize Administrators will accept minor changes to the WEC concept described in the Technical Submission, but the device must still be fundamentally the same WEC concept, as described earlier. For example, Finalist Teams cannot jump from a point absorber to a terminator, or modify their concepts' working principles. Small changes to geometries and dimensions are acceptable. Finalist Teams must update all drawings and information in the Technical Submission to reflect the changes, and re-submit the Technical Submission **on or before August 1, 2016.** Teams will be disqualified if the Judging Panel determines it is not the same WEC concept. If in doubt about any proposed detailed changes, please consult the Prize Administrators before implementing them in model construction.

6.4.1 1/20th Scale Model Testing

All 1/20th scale model testing at the MASK Basin will be provided by the Wave Energy Prize at no cost to Finalist Teams.

Information regarding the specific tests to be performed at the MASK Basin is provided in **Appendix F**, with the data analysis described in **Appendix G. Appendix H** describes high level logistics requirements at the MASK Basin.

Up to five (5) members of each Finalist Team can use seed funding for domestic travel and associated expenses to attend the testing, to observe and support the test program. U.S. General Services Administration rules for appropriate travel costs and expenditures apply. MASK Basin representatives will provide support to ensure a successful testing program, but they are not permitted to help improve the design or performance of a WEC concept.

Members of the Judging Panel, DOE, Prize Administrators and other VIPs (including, but not limited to, members of the press) may be present during the tests to observe the activities at the testing facility. All tests will be video recorded.

Should it prove impossible to complete the testing due to physical damage to a WEC model, the Judging Panel will use best efforts to work with the tests that were successfully performed to complete the judging of the 1/20th scale model. But, if the Judging Panel is unable to do this in a manner it considers having satisfactory credibility, or fairness to other competitors, the test program will be ended and the WEC concept will no longer be considered as a candidate for the Wave Energy Prize.

Data and reports from the 1/20th scale model testing will be provided directly to the Prize Administrators, and will be shared with the Judging Panel and DOE. Teams will receive a copy of the data and any reports describing the performed tests, results, and analyses. Test results, and resultant rankings, will be posted on the public Wave Energy Prize website, as specified in the Wave Energy Prize Terms and Conditions.

6.4.2 Judging of 1/20th Scale WEC Devices and Determination of Prize Winner(s)

To be eligible for consideration for prize purses, the MASK Basin test results must show that a WEC device exceeds a threshold value of **ACE of 3m/$M (full-scale) based on the 1/20th scale testing.** This represents a 100% increase, or doubling, in this metric above the current "state of the art" in representative sea states and deep water.

Following the 1/20th scale testing at the MASK Basin, Finalists will be ranked based on a quantity referred to as the **Hydrodynamic Performance Quality (HPQ),** described in detail in **Appendix I**. This ranking will be used to determine the Grand Prize Winner, 2nd Place Finisher, and 3rd Place Finisher of the Wave Energy Prize. The HPQ is solely dependent on the overall performance of the WEC model during the tank testing in the MASK Basin.

Appendix I describes how both the ACE and additional information captured during the 1/20th scale testing will be used to determine the value of the HPQ, the ranking of the Finalist Teams, and identify the overall Prize Winners, if any. For example, in the case that a Team is ranked in the top three according to the HPQ, yet has not exceeded the ACE threshold value, the Team will not be awarded a monetary prize.

The Judging Panel's assessment of HPQ will be provided to the Teams, along with their position in the overall ranking. Results and rankings will be announced and posted on the public Wave Energy Prize website, as specified in the Wave Energy Prize Terms and Conditions.

7. Seed Funding

The Wave Energy Prize will provide seed funding (financial support) to the Finalists (up to $125,000) and Alternates (up to $25,000) determined at the end of Technology Gate 2. This seed funding will be provided to the Finalists and Alternates for costs associated with the building of the 1/20th scale model to be tested at the MASK Basin, as well as costs associated with the shipment of the 1/20th scale model and participation in the testing process.

All seed funding support will be terminated upon the withdrawal or elimination of a Finalist or Alternate Team. Eligible costs incurred up to that date will still qualify for seed funding.

Should an Alternate be named as a Finalist as the result of a Finalist withdrawing from the Prize or being eliminated, the Alternate will be provided up to an additional $100,000 with the initial $25,000, totaling the full seed funding amount of $125,000.

Following the announcement of Finalist and Alternates in March 2016, the Prize Administrators will provide Finalists and Alternates information regarding eligible and ineligible costs, as well as the process for seeking seed funding.

8. Wave Energy Prize Marketing and Communication Requirements

8.1. Public Relations/Media/Marketing – Cooperation and Support

It is in the best interest of the Teams to participate and cooperate fully with the DOE and Wave Energy Prize Administrators in all public relations, advertising, marketing and content distribution efforts related to the Wave Energy Prize. The DOE and Wave Energy Prize Administrators will provide continuous information to the public regarding the Wave Energy Prize, Team stories, and Team progress. The DOE may seek to create a long-term public educational legacy from the Wave Energy Prize, and as such may continue public relations efforts upon conclusion of the Prize to keep its goals and objectives in the public eye.

8.2. Required Website Updates

The Wave Energy Prize has a public facing informational website that is intended to educate the public and serve as the source for regular updates regarding the Wave Energy Prize. Each Team will have a page featuring the Team and dedicated to its efforts. The active (defined as Teams officially participating in the Wave Energy Prize at any given phase) Teams are required to provide a minimum of one update to the website per month throughout the duration of the Wave Energy Prize, beginning the month their registration application is accepted.

The update may be a video, photo, or written update on the progress of the Team or related topic. Updates will be provided to the Wave Energy Prize Administrators to upload to the website.

8.3. Social Media Outreach

The Wave Energy Prize Administrators will use social media to promote the Prize and the Teams. It is suggested that, at a minimum, each Team create and manage a Team specific Facebook page and Twitter feed. The Prize Administrators will host a webinar, tentatively scheduled for the week of **November 14, 2015**, to provide guidance to Teams regarding the creation of a Facebook page and Twitter feed.

8.4. Mandatory Events

The following events require mandatory participation if Teams wish to remain eligible to be awarded the prize purse(s) or any other funding associated with the Wave Energy Prize:

Qualified Teams – testing of small-scale WEC devices is mandatory for the determination of Finalists, and thus requires mandatory participation.

Finalist Teams – testing of the WEC devices, as outlined in the Wave Energy Prize Rules, at the Carderock facility is required to ultimately be named a winner in the Wave Energy Prize; Winners are required to participate in an awards ceremony to be held following the testing period, in Washington, D.C., should a Winner(s) of the Wave Energy Prize be determined.

8.5. Team Uniforms

It is not required that Teams produce uniforms for the Wave Energy Prize, but should Teams choose to do so (at their own expense), they must follow the provided Branding and Logo Usage Guidelines found in **Appendix J**.

9. Team Sponsorship, Logos and Branding

9.1. Team Sponsorship

Teams are encouraged to seek sponsors to assist in their participation in the Wave Energy Prize. Sponsors will not be limited by the DOE and Wave Energy Prize Administrators.

9.2. Team Name and Team Logo

Teams are required to develop a "Team Name" and logo for use throughout the Wave Energy Prize. The DOE and Wave Energy Prize Administrators reserve the right to reject chosen team names and / or logos if deemed inappropriate or were previously approved for use by another Team.

9.3. Prize Name and Prize Logo Use

Teams are granted permission to use the Wave Energy Prize name and logo on their informational materials, including website. The use of the Prize name and logo are outlined in the Branding and Logo Usage Guidelines in **Appendix J**.

Teams are urged to use the Wave Energy Prize logo on their WEC devices to be tested during the Wave Energy Prize to help promote the Prize and the Team's involvement.

Teams are permitted to make items such as hats, shirts, mugs, and other appropriate items, with the Wave Energy Prize name and logo, for limited and targeted use.

The DOE and Wave Energy Prize Administrators reserve the right to review any Team usage of the Prize name and / or logo and reject specific applications. Should a Team utilize the Prize name and /or logo in an unacceptable manner, the Team will be required to remove the name/logo immediately. Lack of compliance may result in the disqualification of the Team.

10. General Terms of Participation

10.1. Dispute Resolution

All disputes, disagreements, and appeals will be handled by the Wave Energy Prize Administrators at their full and sole discretion, and their decisions are binding and final.

Any issues or concerns, including appeals, requiring the ruling or decision of the Wave Energy Prize Administrators must be submitted to the Administrators via email within twenty-four (24) hours of the perceived infraction. The Wave Energy Prize Administrators will review the email and provide final resolution within three (3) business days.

10.2. Accuracy of Information provided by Teams

The Teams and all Team Members will provide accurate and truthful information and data in all submissions required by the Wave Energy Prize, including, but not limited to, the registration application, Technical Submission, numerical modeling simulations, and 1/20th Scale Model Design and Construction Plan. Teams that provide false or deliberately misleading information will be disqualified.

10.3. Withdrawal

Teams may withdraw from the Wave Energy Prize at any time. In order to withdraw, Teams must notify the Wave Energy Prize Administrators of their intention to withdraw from the Prize, and the Wave Energy Prize Administrators will acknowledge the withdrawal. The Team's withdrawal will be effective the date the Wave Energy Prize Administrators notify the Team that the withdrawal has been received.

10.4. Disqualification

The Wave Energy Prize Administrators reserve the right to disqualify any Team whose actions are deemed to violate the spirit of the competition for any reason, including, but not limited to, violation of the Wave Energy Prize Terms and Conditions, lack of adherence to the rules and requirements outlined in the Wave Energy Prize Rules, and any gaming of the rules and requirements outlined in the Wave Energy Prize Rules. The Wave Energy Prize Administrators will notify the disqualified Team via email, and provide an explanation for disqualification. Disqualification is not subject to appeal.

10.5. Cancellation or Schedule Adjustment of the Wave Energy Prize

The DOE and Wave Energy Prize Administrators may, (a) cancel the Wave Energy Prize at any time without cause, and/or (b) adjust the Wave Energy Prize schedule as necessary. Teams will be notified immediately regarding any changes to the status or schedule of the Wave Energy Prize. Reasons for cancellation could include, but are not limited to, an insufficient number of participating teams and facility breakdowns. If the Prize is cancelled, the DOE and Wave Energy Prize Administrators are not liable for any costs borne by Teams not reimbursed to that point.

10.6. Official Language and Currency

English is the official language of the Wave Energy Prize. All communication and submissions must be supplied in English.

All references to currency contained within this document, and all Wave Energy Prize documentation will be references to United States Dollars.

11. Appendices

Appendix A: Technology Performance Level (TPL) Assessment Methodology

The Technology Performance Level (TPL) metric[2] is a complementary assessment metric to the Technology Readiness Level (TRL) metric[3]. The TPL metric quantifies the techno-economic performance potential of the technology under development, whereas the TRL metric expresses the commercial readiness; thus, the TPL metric is not an alternative to a TRL metric.

The Wave Energy Prize is dedicated to identifying early (TRL 1 to 3) WEC concepts that show the potential to significantly surpass the techno-economic performance of the state of the art. Given this goal it is meaningful to use the TPL metric to rank and subsequently down-select the Wave Energy Prize Registered Teams and determine the Qualified Teams.

The table below contains the TPL definitions of a WEC system:

TPL		Category Characteristic	Sub-Characteristics
9	high	Technology is economically viable and competitive as a renewable energy form.	Competitive with other energy sources without any support mechanism.
8			Competitive with other energy sources given sustainable (e.g. low feed- in tariff) support mechanism.
7			Competitive with other renewable energy sources given favorable (e.g. high feed-in tariffs) support mechanism.
6	medium	Technology features some characteristics for potential economic viability under distinctive and favorable market and operational conditions. Technological or conceptual improvements may be required.	Majority of key performance characteristics and cost drivers satisfy potential economic viability under distinctive and favorable market and operational conditions.
5			To achieve economic viability under distinctive and favorable market and operational conditions, some key technology implementation improvements are required and regarded as possible.
4			To achieve economic viability under distinctive and favorable market and operational conditions, some key technology implementation and fundamental conceptual improvements are required and regarded as possible.

---

[2] J. Weber; *WEC Technology Readiness and Performance Matrix – finding the best research technology development trajectory*, 4th International Conference on Ocean Energy, 17th October 2012, Dublin.

[3] https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a

3	low	Technology is not economically viable.	Minority of key performance characteristics and cost drivers do not satisfy potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.
2			Some key performance characteristics and cost drivers do not satisfy potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.
1			Majority of key performance characteristics and cost drivers do not satisfy and present a barrier to potential economic viability and critical improvements are not regarded as possible within conceptual fundamental.

Table A1 - Technology Performance Levels Definitions

The cost and performance drivers influencing techno-economic WEC performance that are used to assess the TPL of a WEC technology concept are categorized within five (5) criteria groups:

1. Acceptability
2. Power absorption, conversion and delivery
3. System availability
4. Capital Expenditure (CapEx)
5. Operational Expenditure (OpEx)

Within each of the five (5) criteria groups, a number of applicable cost and performance drivers, or sub-criterion, are assessed to determine the techno-economic performance potential for each group. These include:

1. Acceptability:
   - Lifecycle environmental acceptability
   - Social acceptability and socio-economic impact and/or benefit
   - Legal, regulatory, and certification acceptability
   - Safety
   - Risk Mitigation
   - Insurability
   - Market acceptability by investor, financier, operator, utility
2. Power absorption, conversion, and delivery:
   - Hydrodynamic wave power absorption
   - Internal power conversion
   - Power output and delivery
   - Controllability with fast, wave by wave control
   - Controllability & adaptability with slow, sea state by sea state control
   - Short term energy storage capability
3. System availability:
   - Survivability
   - Reliability

25

- Durability
- Redundancy
- Force, power & information flow
- System adaptability supporting availability
- Forced shutdown

4. Capital Expenditure (CapEx):
- Supply chain
- Material types
- Mass and required material quantity
- Manufacturability
- Transportability
- Wave farm infrastructure (non-WEC device)
- Device deployment, installation and commissioning
- Maintainability CapEx requirements
- Modularity CapEx requirements
- Redundancy CapEx requirements
- Loading and load bearing CapEx requirements
- Acceptability CapEx requirements

5. Lifecycle Operational Expenditure (OpEx):
- Monitorability, ease of monitoring
- Accessibility
- Maintainability
- Modularity and ease of subsystem and component exchange
- Ease of partial operation and graceful degradation
- Insurability cost
- Planned maintenance effort
- Unplanned maintenance effort
- Acceptability OpEx requirements

The methodology to evaluate the TPL level of a device/concept is as follows:

1. The proposed system is evaluated against each of the sub-criterion and a TPL score is allocated for each sub-criterion
2. The sub-criteria scores of each of the five (5) criteria groups are weighted averaged to determine and the five (5) group TPL scores. These groups are named
   a. TPL_{Power}
   b. $TPL_{Availability}$
   c. TPL_{CapEx}
   d. TPL_{OpEx}
   e. $TPL_{Acceptability}$.
3. The combined economic TPL value $TPL_{Economic}$ is determined via:

26

$$TPL_{Economic} = \left(TPL_{Power} \cdot TPL_{Availability} \cdot \left(0.7\, TPL_{CapEx} + 0.3\ TPL_{OpEx}\right) - 1\right) \frac{9-1}{9^3-1} + 1$$

This equation reflects the multiplicative nature of power, availability, and cost effectiveness in the techno-economic performance. Subsequently the product is linearly scaled back to the TPL scale ranging from 1 to 9.

4. The overall system TPL value, TPL_{System}, is determined via:

$$TPL_{System} = 0.8\, TPL_{Economic} + 0.2\, TPL_{Acceptability}$$

Appendix B: 1/50th Scale Model Prototype and Data Submission Requirements

The Prize Administrators will provide Qualified Teams with a template for submitting the following information and data on **September 30, 2015.**

Qualified Teams must provide the following before 1/50th scale testing:

- Qualified Teams must test the Power Take-Off (PTO) to be used in their 1/50th scale model to illustrate that they have a well characterized physical PTO system on the model. These tests should be for a variety of dynamic and kinematics conditions—the results of these tests should show predominantly linear characteristics between dynamic and kinematic parameters. The range of linear coefficients (i.e. damping values) that can be obtained with this representative PTO should be reported.

  Fundamentally, the numerical model must be able to represent the physics of this characterized PTO system. In cases where the Teams need to deviate from the above they may seek guidance from the Judging Panel. If the Judging Panel is unable to provide guidance in a fair manner, the Team will be eliminated from the Prize.

- Modeling simulation data predicting the device performance at full scale for the specific waves in the 1/50th scale tests in the small scale testing facility, given a linear resistive damping control strategy over the below stated range of tests. The modeling simulation data will include: absorbed power, power producing kinematics and dynamics, e.g. motions and forces of moving solid body/bodies in power absorbing degree of freedom and other relevant system dynamics, body motion in six (6) degrees of freedom. The damping value used in each numerical simulation needs to be stated. The damping values for experimental tests must match those numerically simulated. See specifications on control for 1/50th scale tests below.

- Modeling simulation data predicting the relevant system dynamics, kinematics and the WEC device's root mean square (RMS) absorbed power at full scale using expected control strategies (with limited wave prediction) for waves representative of the West Coast in the 1/20th scale tests in the MASK Basin over the range of sea states required in the WEC Power Matrix Template (**Appendix C**). See specification on control for 1/20th scale tests in **Appendix F**.

- A physical 1/50th scale model of the WEC device. This must include all sensors/instrumentation needed, as described below.

Specifications of Control of Power Absorption:

Control affecting the representative PTO in the 1/50th scale testing is limited in the following ways:

1) the control variable (i.e. PTO force) is limited to being linearly proportional to the kinematics of the power absorption (i.e. velocity);
2) the constant of proportionality must not change during each test, but it may be altered between tests for each wave condition); and
3) the device cannot be motored (i.e. power cannot be supplied to the representative PTO).

28

Qualified Teams can change the control variable through a mechanical change between wave conditions, or through an electronic/software update. However, once each test begins the Qualified Team may not alter the software control of the representative PTO.

Adaptive control (see **Appendix K**), such as configuration/structural changes (i.e. actively changing ballast, actively changing shape or orientation, etc.), are not allowed for the 1/50th scale test.

Range of Tests:

The following groups of waves (defined using full scale parameter values) represent the potential testing scope for 1/50th scale testing. The exact waves and the number of waves tested may change.

Three types of tests will be completed at the 1/50th scale.

1. Sixteen (16) monochromatic waves at a head direction, with steepness varying between 1:100 and 1:40.
2. Sixteen (16) monochromatic waves at off-head directions (20 degrees and 60 degrees), with steepness of 1:100.
   a. These off-head directions may be achieved in two manners: physical rotation of the WEC scale model, or directional waves. The facility capabilities will dictate this.
3. Five (5) irregular Bretschneider waves at a head direction.

Wave Range:

1. Between 4-15 seconds full scale T or Tp.
2. Between 0.1-5 m Full scale Amplitude or Significant Amplitude.

Sensors/Instrumentation:

Sensor types and locations are dependent upon the design of each WEC device.

Each Qualified Team will be responsible for instrumenting their 1/50th scale model WEC device with all appropriate instrumentation.

- Instrumentation is required to determine absorbed power at each body. This will be through appropriate combination of measurements:
    - Dynamic side of absorbed power: "Load measurement" (force, torque, pressure, etc.)
    - Kinematic side of absorbed power: "Velocity measurement" (velocity, angular velocity, flow, etc.)
- Instrumentation is required to determine motion in all degrees of freedom for each body.
    - Orientation of each body, using on board sensors: string pots (measure relative displacement), gyroscope (measure rotation), or other instrumentation capable of accurately tracking relative body motions.

The instrumentation plan must be discussed with the small scale testing facility. Advance information regarding required sensors may be requested of the Qualified Teams by the Prize Administrators by **October 31, 2015.**

Optical tracking systems may be available at small scale facilities. The facilities will measure the wave environment and will also provide mooring load cells. Video recording will also be available from the small scale facility.

Any Qualified Team provided instrumentation will be subject to verification checks at the small scale facility.

Appendix C: WEC Power Matrix Template (Full Scale)

Significant Wave Height, Hs [m]	Peak Period, Tp [sec]													
	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
0.500														
1.000														
1.500														
2.000														
2.500														
3.000														
3.500														
4.000														
4.500														
5.000														
5.500														
6.000														
6.500														
7.000														
7.500														
8.000														
8.500														
9.000														
	3.4	4.3	5.1	6.0	6.9	7.7	8.6	9.4	10.3	11.1	12.0	12.9	13.7	14.6
	Energy Period, Te [sec] $2\pi(m_{-1}/m_0)$													

The above matrix should be populated with the root mean square (RMS) power expected for each bin. The black-shaded bins do not have to be run as these represent breaking waves. The Prize Administrators will provide Qualified Teams with the time series of incident wave height for each bin, along with the numerical modeling template, on **September 30, 2015**. The time series will only propagate in one direction and will be created from a standard Bretschneider spectrum (i.e. a two parameter PM).

These numerical modeling results presented in the power matrix will, along with information specified in Table 2 (Technology Gate 2 Deliverables), be used in the determination of Finalists, and should be representative of the expected full scale performance of the 1/20th scale WEC performance in the MASK Basin. The expected control strategy (with limited wave prediction, if applicable) for the 1/20th scale model to be used for testing in the MASK Basin should be implemented in these simulations. The numerical model should represent the full dimensionality and degrees of freedom as experienced during operation at sea.

The number of waves requiring simulation may be decreased from what is shown above.

Appendix D: Characteristic Capital Expenditure and Representative Structural Thickness

Evaluating diverse and novel WEC devices at very low TRLs is very challenging because at low TRLs there is very little or no reliable information available on the likely future levelized costs and performances of competing WEC devices. The Wave Energy Prize is designed such that as Teams proceed through each Technology Gate, the quality and quantity of information available on a WEC device's techno-economic performance increases.

For the final Technology Gate of the Wave Energy Prize, ***Average Climate Capture Width per Characteristic Capital Expenditure,*** or ACE, has been selected by the Wave Energy Prize as a reduced content metric that is a simplifying and content reducing proxy for LCOE. It is appropriate for comparing low TRL WEC concepts when there is insufficient data or unreliable data to enable an actual calculation of the LCOE.

As a ***benefit-to-effort*** metric, ACE has been developed by the National Laboratories from existing metrics used by the wave energy research community[4] that are themselves attempts to be fundamental measures of the effectiveness of a WEC concept, i.e. to be a proxy for LCOE.

The numerator of ACE (i.e. the benefit) is the Average Climate Capture Width. Capture Width is a well-established concept in wave energy research and the Average Climate Capture Width is described in detail in **Appendix I.**

The denominator of ACE (i.e. the effort) is Characteristic Capital Expenditure, which is a new metric developed by the National Laboratories being used for the first time in the Wave Energy Prize. This uses a calculated measure of the structural load bearing mass of a device, and adjusts for the material types selected for the design as well as their cost/unit mass in volume production, as a proxy for capital expenditure.

Previous work[5] has indicated that the structural load bearing mass is the greatest Capital Expenditure (CapEx) driver, and that CapEx is the greatest part of overall cost (on a levelized basis). CapEx is determined by the design choices of the proposed WEC device, with the structural expenditure playing a dominant role. However, since existing metrics to evaluate WEC devices are derived from a body of research and knowledge based on the current state of the art, which are predominantly rigid bodies systems manufactured out of steel, they do not cater for novel materials and non-rigid bodies. ACE is thus designed to allow for benefit-to-effort evaluation of novel devices, like collapsible structures made out of materials other than steel, or perhaps concepts manufactured out of concrete or composite materials, each with differing structural, loading type and material cost.

Characteristic Capital Expenditure will be *calculated* by the Judging Panel using input (see parameters below) from independent structural engineers and the National Laboratories. It is a calculation of the CapEx of the load

---

[4] "Numerical benchmarking study of a selection of wave energy converters." Babarit et al. Elsevier Renewable Energy 41 (2012).

[5] Neary, V.S., Previsic, M., Jepsen, R.A., Lawson, M., Yu, Y., Copping, A.E., Fontaine, A.A., Hallett, K.C., and Murray, D.K., 2014, "Methodology for design and economic analysis of Marine Energy Conversion (MEC) technologies," SAND-2014-9040, March 2014; http://energy.sandia.gov/rmp

bearing structural mass of the WEC device design, the loads it encounters, the material types selected for the design, the material amount, and their cost/unit mass in volume production.

To quantify the Characteristic Capital Expenditure quantities for the following parameters are used:

- Total Surface Area (TSA) of the load bearing structure of the WEC device at full scale verified by the dimensions obtained from the 1/20th scale model. TSA reflects a simple profile of the device and not the surface area of a detailed device design (e.g. does not including surface area of supporting girders, stiffeners, etc.).
- Total displaced mass of the WEC device at full scale and determined by the measured ballasted weight of the 1/20th scale model.
- Representative structural thickness (RST) of the WEC device at full scale determined by full scale design requirements including material type *and* loading.
    - RST = Thickness that will identify the structural volume of a structural material type when multiplied with the related TSA. RST is not the actual physical thickness of a structure; instead, it is the thickness that when multiplied with the TSA of the WEC device represents the total volume of the structural material that is used to build the manufactured structural design of the WEC system, i.e. the structural material volume. Multiplication of this volume with the structural material density will give the total structural mass. RST serves as a scalar factor between the structural surface area and the volume of this structural material. It is a thickness that accounts for all of the structural elements (e.g. girders, stiffeners, etc.) in a generalized/averaged manner.
    - RST is also a function of the loading conditions the TSA will experience; different WEC devices and different parts of the TSA can be exposed to different loads. Thus, the independent structural engineers and the National Laboratories will consider approximate anticipated loading cases. This classification, influenced by the WEC design and flow conditions, will consist of a finite and small number of distinctly different load cases e.g. possibly just three (3) categories: i.e. "low", "medium", "high". Examples for classifications are given in Table D1 below, but the final finite number of distinct load cases will be determined after review of the Qualified Teams' WEC designs:

Load Case Type	Low	Medium	High
Possible Distinct Load Case	Pure tension (no shear or bending loads) in highly flexible elastic material	Shear and bending loads on the walls of an OWC where interior and exterior hydrostatic pressure gradient is in balance	Shear and bending loads on the walls of an closed structure where exterior hydrostatic pressure difference has to be balanced by structure

Table D1 - Load Case Types and Classifications

33

- Consideration of the structural load bearing materials and the generic load cases will allow the independent structural engineers and the National Laboratories to determine the RSTs to be used in the Wave Energy Prize. The values to be used in the Wave Energy Prize, which are independent of the WEC device, will be provided to the Teams that proceed through Technology Gate 1 by **September 15, 2015** for comment. Comment could lead to the amendment of these values, if technologically justified and supported by appropriate technical information or analysis.

Material	Load Case Low	Load Case Medium	Load Case High
Steel	Thickness 1	Thickness 2	Thickness 3
Etc.	Etc.	Etc.	Etc.

Table D2 - Material Types and RST

- Density of material choice(s) of the WEC device at full scale.
- Material type(s) in the TSA are to be specified as a percentage of TSA.
- In cases where multiple material types are used in the TSA, the total representative structural mass will be determined by the sum of the individual surface areas of each material.
- Masses for small portions of materials that form part of the TSA (e.g. nuts and bolts) will not be separately accounted. Only materials that are essential elements of the Load Bearing Mass will have a RST assigned for the fraction of TSA they represent. In other words, for material types that are a small proportion of the TSA and that are not essential elements of the load bearing mass, their mass will be allocated to one of the other material types in the load bearing mass.
- Cost of manufactured material per kilogram based on a 100 unit farm size at the rollout of commercial production and operation.

$$Characteristic\ Capital\ Expenditure\ [\$] = Total\ Surface\ Area\ [m^2] \cdot Representative\ Structureal\ Thickness\ [m] \cdot material\ density\ \left[\frac{kg}{m^3}\right] \cdot cost\ of\ material\ [\frac{\$}{kg}]$$

- For all Qualified Teams, an assessment of the RST and the required information for the determination of the effort part of the fundamental performance metric will be conducted. This assessment will be done after the completion of the 1/50th scale tank testing, and will allocate portions of the TSA to thicknesses, based on the observed hydrodynamic behavior and performance in the 1/50th scale testing (yielding observations of loads experienced by portions of the WEC device TSA), and the selection of the appropriate load case. This assessment will utilize design information contained in the revised Technical Submission provided by Qualified Teams on **November 30, 2015.**
- For all Finalists, a revised assessment of the RST and the required information for the determination of the effort part of the fundamental performance metric will be conducted. This assessment will be done after the completion of the 1/20th scale tank testing in the MASK Basin and will allocate portions of the TSA to thicknesses, based on the observed performance in the MASK Basin; the evidence observed regarding loads experienced by portions of the WEC device TSA; and the selection of appropriate load case, which is the only planned adjustment of the effort related part of

ACE after the MASK Basin tank test campaign is completed. This assessment will utilize design information contained in the revised Technical Submission provided by Finalists entering Technology Gate 4.

- The reasoning for allowing adjustment of the effort part of ACE to be adjusted as the Teams proceed through the Prize's Technology Gates is to allow for changes to small details of the WEC device design as a result of the learning experience during the Prize, and to allow for all information from tank testing to influence the selection of load cases for each portion of the TSA.

Teams must abide by this independent assessment of the RST and cost of manufactured material per ton and accept that National Laboratories will be fair and impartial in making this assessment. Teams also must accept that this assessment is made when information on designs and loads is sparse at low TRLs, especially for very novel concepts.

Appendix E: Assessment for Technology Gate 2 - Method for Determination of Finalists and Alternates

The Judging Panel, using criteria listed in Table E1 below, will first assess readiness for 1/20th scale testing via the evaluation of the Team's submitted Model Design and Construction Plan for the 1/20th scale model for testing at the MASK Basin and determine if the Team has provided a plan that exhibits a reasonable understanding of the effort, tasks, timeline and materials that will be needed to design and build a 1/20th scale model.

Criterion	Narrative Document	Timing Plan	Bill of Materials
To score a "Pass" Assessment	The document illustrates a concise and thought out plan describing how the Team will successfully design and construct a 1/20th scale model in the allotted timeframe	A detailed Gantt chart or similar timeline graphic shows the tasks that the Team plans to complete in the allotted timeframe	The provided BoM template document is filled out with a logical breakdown of systems, subsystems, assemblies, and components along with actual or predicated quantity, mass, cost, supplier data for each item
To score a "Fail" Assessment	No document provided or a document that shows a significant lack of understanding of the phases, tasks, and/or steps needed to design and build a scale model	No document provided or the provided document shows a significant lack of understanding the tasks and timeline needed to complete the build of a scale model.	No document provided, document provided is not in the approved template form or the provided document shows a significant lack of understanding the materials to build and test a scale model

Table E1 – Model Design and Construction Plan Assessment

If the plan is assessed by the Judging Panel to not be credible, and the Team is deemed to have a low prospect for successfully designing and constructing a 1/20th scale model in time for testing at the MASK Basin, the Team will not be granted seed funding and will be eliminated from the Wave Energy Prize.

If the Judging Panel determines that a Team's plan is credible, it will then proceed to use the following information to evaluate the likelihood of the proposed WEC technology concept satisfying the required threshold value for ACE during the 1/20th scale testing:

- The Capture Width of the physical 1/50th scale model from the 1/50th testing scaled up to full scale.
- Numerical modeling results of the 1/50th scale wave environment (at full scale) and the determination by the Judging Panel of how well the numerical model predictions correlate with scaled up experimental measurements including absorbed power, motions, and forces.
- Revised Technical Submission and its re-evaluation using the TPL.
- Predictions of ACE (in m/$M) that can be expected in the MASK Basin testing, as determined by the Judges with support of the National Laboratories.

As defined in Table E2 below, the Judging Panel will:

36

- Score each of the above four (4) criteria on a scale of 1-9.
- Calculate the overall combined score via weighted averaging of the four (4) above criteria scores.
- Provide a ranked list of WEC technology concepts sorted from highest overall combined score down.

Criterion	Capture Width of the Physical 1/50th Scale Model from 1/50th Scale Testing, Scaled up to Full Scale	Correlation of Numerical Modeling Results to 1/50th Scale Waves	Re-Evaluation of Technical Submission using TPL	Predictions of ACE Expected in MASK Basin
Value range	1 to 9 grouped in low, medium, high	1 to 9 grouped in low, medium, high	1 to 9 grouped in low, medium, high	1 to 9 grouped in low, medium, high
Weighting for combined score	15%	25%	30%	30%

Table E2 - Technology Gate 2 Criteria

If it is determined that the Judges and/or small scale facilities are unable to test, measure and analyze the 1/50th scale WEC device in order to adequately determine absorbed power, the device will be eliminated from the Wave Energy Prize.

Appendix F: Test Plan for MASK Basin (1/20th) Physical Model Testing

Finalist Teams must provide the following before 1/20th scale testing:

- A physical 1/20th scale model of the WEC device; this must include all sensors/instrumentation needed, as described below.
- Refined and updated Technical Submission.
- Power Take-Off (PTO) calibration for the 1/20th scale model to demonstrate that Teams have a well characterized physical PTO system on the model. These tests should be for a variety of dynamic and kinematics conditions.

Scale: The MASK Basin testing will use 1/20th scale deep water waves suitable for 1/20th scale deep water physical models.

Specifications on control of physical 1/20th scale model:

Control affecting the representative PTO in the 1/20th scale testing is fundamentally different from the 1/50th scale test with considerably fewer limitations. Changes to the control variable (e.g. PTO force) may occur through a mechanical change between wave conditions, or this may occur through an electronic/software implemented change during testing. At the 1/20th scale:

1) the controlled variable(s) is not limited to being proportional to the kinematics of the power absorption—it may take on any form;
2) the **parameters** associated with controlled variable(s) may be updated **instantaneously and continuously** within a single wave condition (i.e. within a test); furthermore the controlled variable(s) does not have to be updated continuously (i.e. switching strategies are allowed); and
3) the device can be motored (i.e. power can be supplied to the representative PTO).

In summary, few limitations are placed on the control strategies affecting the representative PTO at 1/20th scale except that once the wave condition are established and the test begins the Team may not alter the software control of the representative PTO; the software control may only respond to the programmed architecture and instrumentation on-board, wave gauges, and/or optical tracking instrumentation provided by the Wave Energy Prize.

The exact time series of the incoming waves will not be provided to the Teams in advance of the 1/20th scale test. All spectral properties for each of the ten (10) identified waves will be provided on **March 1, 2016**.

Furthermore, real-time instantaneous wave measurements from upstream sensors will be made available to the Finalists during each thirty (30) minute test. Specifications on the location of the wave sensors, type of wave sensors, accuracy of wave sensors, and their data collection rate will be provided on **March 1, 2016**.

Adaptive control (see **Appendix K**), such as configuration/structural changes, are permitted in the 1/20th scale tests. The practical implementation of adaptive control options must clearly reflect feasible and controllable changes of the full-scale system during remote operation in the open ocean and cannot be associated to fundamental changes requiring an operator or external vessel to touch the device.

If there is a configuration change(s) that is required **during operation of the fully developed system, as described in the Technical Submission,** then two options are available:

1) the adaptive control can be implemented any time during a wave condition through some on-board automated mechanism. The energy efforts for such on board adaptive control actuation will be measured (e.g. electric power) and will be considered in the calculation of the HPQ,
2) the adaptive control may occur between wave conditions by physically interacting with the device model and will be considered in the calculation of the HPQ.

For instance, if a WEC device actively changes its ballast during operation, changes may occur either during the wave testing or it may occur between the wave conditions.

All types of control strategies, their implementation method, and their expected control variables must be documented in advance to the Prize Administrators. Only documented methods will be allowed within the 1/20th test.

Wave Types and Wave Range:

- IWS: Six (6) Bretschneider irregular waves (likely with distinct directions but no spreading).
- LIWS: Two (2) large irregular waves (likely with spreading). These two waves will have high steepness (above 50). They will either be Bretschneider or JONSWAP directionally spread waves.
- RWS: Two (2) realistic wind-swell waves with 6-parameter spectrum (see Ochi[6] or Dean and Dalrymple[7] for further details).
- Full-scale peak period (Tp) between 6-17 seconds.
- Full-scale significant wave height between 2-9 m.

Definition of the specific waves will be provided on **March 1, 2016**, upon notification of the status of Finalists and Alternates.

Only the six (6) Bretschneider irregular waves from the above list will be used to determine ACE.

All the waves from the above list will provide data, observations and counted events that contribute to the Hydrodynamic Performance Quality described in **Appendix G**.

Duration of test period for each wave:

The test period will be thirty (30) minutes.

- The first ten (10) minutes of the test period can be used by the Team for control learning and to allow for any directional aligning of mooring systems (if appropriate).
- Only the last twenty (20) minutes of the test period will be used for data analysis.

---

[6] M. K. Ochi, *Ocean Waves: The Stochastic Approach*, vol. 6. Cambridge University Press, 1998.
[7] Water Wave Mechanics for Engineers and Scientists, R. G. Dean and R. A. Dalrymple, Englewood Cliffs: Prentice-Hall, Inc., ISBN 0-13-946038-1, 1984. Reprinted Singapore: World Scientific Publishing Co., ISBN 981-02-0420-5, 1991.

There will be at most twenty (20) minutes for basin-calm down between each test period.

The ten (10) tests listed above are required for judging. They will take one (1) day to complete. There will likely be two (2) days available for testing (depending upon each Team's installation plans), potentially allowing for repeat tests if necessary as well as changing of control settings between tests.

If repeat tests of the same wave are completed, the test producing the highest average absorbed power will be included in the final calculations used for judging.

Measurements in the MASK Basin:

The test area is approximately 250ft (77m) long, 75ft (23m) wide, 12ft (4m) tall and 20ft (6m) deep. The height value is a maximum height off of the free surface, and is governed by the optical tracking sample volume and clearance below the bridge in the MASK Basin. The final test area that will be used will be determined by the WEC device designs submitted by the Qualified Teams. Teams will be notified of this final test area by **November 30, 2015**.

The wave environment over the test area will be calibrated before testing begins on **August 1, 2016**.

In situ determination of the wave environment during each test period test will also occur, using a combination of sonic and resistive wave probes.

An optical motion tracking system will be used to determine the six degree of freedom motions of at least one body of the device using retro-reflective markers, a series of cameras, and real-time software to establish a sample volume within the larger test area. (Note: The optical motion tracking system could potentially capture more than one body, but must capture at least one body at all times. The motions of the bodies outside of the optical tracking sample volume must be measured by the Team with onboard sensors.)

Figure F1 illustrates the maximum representative test area (in orange) and notional optical tracking area (in green). The device motions must stay within the representative test area while one body must stay within the representative optical tracking area. The determination of the exact extent of these areas will be done to maximize the number of potential Teams who can compete.

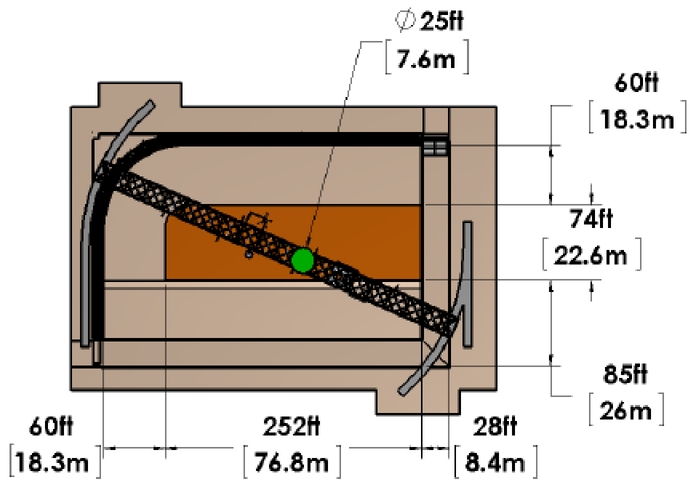


Figure F1 – Representative Test Area

Force measurement at each mooring connection point will be measured. Load cells will be provided by the MASK Basin facility. A list of available load cells can be circulated to Teams.

Team Instrumentation:

Each Team will be responsible for instrumenting their WEC device with all appropriate instrumentation required to determine absorbed power. The required instrumentation is WEC specific.

- Instrumentation is required to determine Absorbed Power at each body. This will be through appropriate combination of measurements:
    - Dynamic side of absorbed power: "Load measurement" (force, torque, pressure, etc.)
    - Kinematic side of absorbed power: "Velocity measurement" (velocity, angular velocity, flow, etc.)
- Instrumentation is required to determine degrees of freedom motion per body that is not tracked with an optical motion tracking system:
    - Orientation of each body, using on board sensors: string pots (measure relative displacement), gyroscope (measure rotation), or other instrumentation capable of accurately tracking relative body motions.
- Instrumentation to determine impact events.
    - An approved high-g three-axis accelerometer on each body.

Any Team-provided instrumentation will be subject to verification checks at the MASK Basin.

The Wave Energy Prize will provide equipment for photo and video documentation throughout the MASK Basin testing.

41

Appendix G: MASK Basin Data Analysis

Total surface area is determined for the 1/20th scale model at the MASK Basin through an understanding of the geometry and dimensions measured at the MASK Basin. This measurement informs the calculation of the Characteristic Capital Expenditure portion of ACE.

To determine the Average Climate Capture Width portion of ACE in the MASK Basin requires the determination of the incident wave energy density during testing at the MASK Basin and the corresponding absorbed power by the model WEC device. These values are then related to sea states typical of the West Coast using weightings determined via extensive analysis of long term average data from wave buoys at deep water sites of relevance.

Incident Wave Energy Density:

The test area within the MASK Basin (to be finalized when the geometries of the model WEC devices to be tested at the MASK Basin are known, as stated in **Appendix F**) will be calibrated to ensure the programmed waves are being delivered by the wave maker.

These calibrated waves will be used to determine the incident wave energy density in the testing area of the MASK Basin. Individual spectral shapes will be used to assess the power density using standard equations (see Ochi[8] or Dean and Dalrymple[9] for example).

During testing, a smaller subset of wave elevation sensors will be deployed in the MASK Basin. These sensors will be used to confirm that the tested wave matches the calibrated wave. Additionally, data from these sensors can be made available in real-time to the Team for WEC model control purposes, if required. The exact location of all sensors will be communicated within one month after the announcement of the Finalists.

Absorbed Power:

Instantaneous absorbed power is determined using the appropriate calculation, some representative examples are:

- Power = Force x Velocity
- Power = Pressure x Volume Flow Rate
- Power = Torque x Angular Velocity

Quantifying the motion of the bodies in the WEC device will require an understanding of the displacements and the orientation of each body in the WEC device. Displacements and orientations will be analyzed to determine the time series of a relevant kinematic parameter (velocity, angular velocity, mass flow rate) for each power producing body.

Displacements and the orientations will be determined through a combination of:

---

[8] M. K. Ochi, *Ocean Waves: The Stochastic Approach*, vol. 6. Cambridge University Press, 1998.
[9] Water Wave Mechanics for Engineers and Scientists, R. G. Dean and R. A. Dalrymple, Englewood Cliffs: Prentice-Hall, Inc., ISBN 0-13-946038-1, 1984. Reprinted Singapore: World Scientific Publishing Co., ISBN 981-02-0420-5, 1991

- An optical motion tracking system, which consists of cameras, real-time software, and retro-reflective markers (that must be above the free surface), will be used to record six degree of freedom motion time series of at least one body of the device, with the potential to track more than one body. The optical motion tracking system is provided by the Prize.
- On board sensors to measure the motions of all bodies in the test area that are outside of the optical motion tracking sample volume: string pots (to measure relative displacement), gyroscope (to measure rotation). These sensors outside of the optical motion tracking sample volume will be Team-provided.

The dynamic side of the absorbed power (force, pressure, torque, etc.) will be measured through Team-provided sensors. This measurement must be made for each body that absorbs power.

From the time series of the kinematic and dynamic parameters, the instantaneous power time series will be derived. The last twenty (20) minutes of each test will be used to determine the RMS value of absorbed power in each sea state.

With the exception of markers and stantions required by the optical tracking system, the Wave Energy Prize Teams are responsible for installing on their scale model the necessary instrumentation to allow instantaneous absorbed power to be determined.

Appendix H: MASK Basin Requirements

Facility Requirements:	
Time required to clear Finalist Team Members to be present at the MASK Basin for testing	American Citizens: 2 week min; Foreign Nationals: 2 month minimum.
Information required from Team Members	Full name (will need valid US government ID to get in). Foreign Nationals will need to fill out a form (d5512-6) which needs much more information (i.e. Birth Place, DOB, current residence, purpose of visit, length of visit.)
Number of permitted Team Members	Seed funding will cover expenses for five (5) individuals per Team; number can be adjusted if need is shown, though additional Team members will not have their expenses covered.
Special security requirements for Team Members (Access to site, Escorting, Entry and exit from site, Briefing …)?	Valid and current IDs for all Team Members must be presented at the front gate. If driving on site, registration and insurance must be valid as well. Any vehicle with expired registration or insurance will not be allowed on base. American citizens will be allowed to drive on and must come straight to the test location. Foreign Nationals will require an escort at all times. Hours pre-approved for visitors are 0600-1800, if other times are needed, that will be provided at the discretion of base security.
Allowed personal materials (Laptops, Cameras, Phones, Tablets, …)	No Cameras or thumb drives. Laptops can be allowed on site, but forms will need to be filled out (2 months lead time.) Phones are allowed as long as no pictures are being taken. Tablets are to be treated like laptops. In general, the appropriate forms are required for all Personal Electronic Devices (PEDs).

Health and Safety Requirements:	
Required briefings	Daily health and safety briefing on lifting or rigging as appropriate for that days' efforts.
Materials no allowed on site (batteries, fluids, …)	No HAZMAT restricted materials. Special consideration requires review of all relevant Safety Data Sheets (SDS).
Personal Protective Equipment requirements (special footwear, safety hats, googles, Personal Floatation Device (PFD))	Recommend steel-toed shoes/boots, eye protection, Coast Guard approved PFDs.
Fire safety training/certification	Daily brief on what is going on that day and POC for emergency.

44

Catering for Team Members on site for water, tea and coffee, lunch etc.	There is no onsite catering available.

Shipping Requirements:	
Required shipping containers	Maximum of two (2) 20' containers per Team; containers must not exceed 15,000 lbs.
Security clearance required for shipping containers	None, as long as there are no HAZMAT materials; any HAZMAT materials require special processing and conditions.
Materials not allowed for use for the construction of the WEC model	Any HAZMAT materials. Special consideration requires review of all relevant Safety Data Sheets.
Materials not allowed to be stored in shipping containers	HAZMAT materials must be clearly marked with the SDS sheets visible outside the container; no explosives permitted.

Moving Scale Models into the MASK Basin Facility:	
Transportation of models on site and into the MASK Basin	All lifting and rigging will be done by Carderock personnel with Carderock-supplied materials and machinery. A forklift will lift devices and position them to be maneuvered by an overhead crane.
Requirements for model construction to assist handling and movement (Lifting fixings – design/capacity, Weight limits, Limits on dimensions of scale models, …)	To accommodate the door entering the MASK Basin, the largest dimension must be less than 8 ft. in order to maneuver in the building. Height wise, the bay door can open to 20'; Weight of individual WEC device components must not exceed forklift capacity of 2 tons.
Maximum lift of the overhead crane	Must not exceed capacity for a four (4) ton overhead crane and two 2-ton lifts on the bridge.

Requirements for fixings for lifting scale models		Minimum of two (2) lift points, with a certification of approved loads, safety factor of five (5), at a minimum, and verification that the lifting points are rated for the load. Safe Working Load specifications for each instance of lift point hardware must be provided. Carderock personnel reserve the right to not lift a body if the lift point hardware is inadequately attached to the structure or device, or there is concern about the structure's integrity during a lift operation.

Appendix I: Assessment for Technology Gate 4 and Method for Determination of Winner(s)

Following the 1/20th scale testing at the MASK Basin, Finalists will be ranked according to the **Hydrodynamic Performance Quality (HPQ)** of their 1/20th scale WEC model. This ranking will be used to determine first, second, and third place winners of the Wave Energy Prize. To be eligible for consideration for prize purses, a Team's results from 1/20th scale testing must first show that a WEC model exceeds a threshold value for ACE of **3m/$M (full-scale) based on the 1/20th scale testing.**

HPQ is dependent on the overall performance of the WEC model during the final tank testing in the MASK Basin. HPQ is dependent on:

- Performance related quantities measured during the MASK Basin test,
- Performance related events analyzed with regard to adaptive control strategies,
- Performance related events counted during the MASK Basin test, and
- Performance related observations made during the MASK Basin test.

The dominant performance related quantity within the HPQ is ACE.

As shown in **Appendix C**, a typical joint probability distribution (JPD) contains hundreds of sea states. Testing all of these sea states in a wave tank is not feasible in order to obtain an average annual capture width value. Hence only six (6) irregular wave spectra will be used to represent an individual wave climate. For illustration purposes, the Figure I1 below shows a full JPD that is color-coded with six (6) distinct regions (the black represent breaking waves and hence are not considered a region). Each region will be represented by one irregular wave spectrum (sea state) in this reduced wave climate. Each wave climate, j, is assigned a unique scaling vector, $\alpha(i,j)$, to ensure that the sum of the omnidirectional power densities for all regions are equal to the climate's total average annual omnidirectional wave power density, $\langle C_p(j) \rangle$.

47

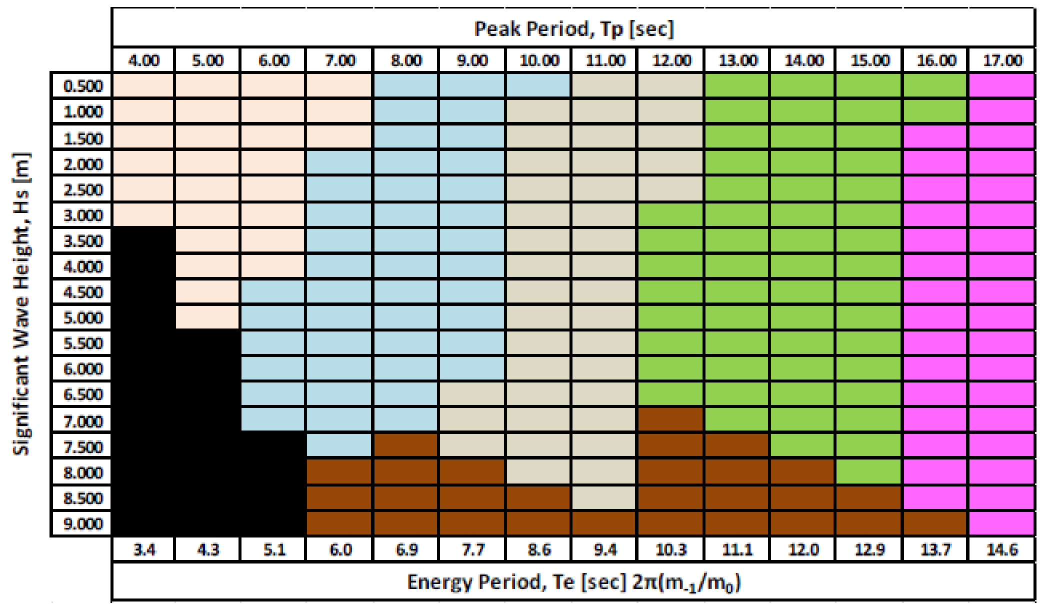


Figure I1 - JPD

Average absorbed power, $\langle AP(i)\rangle$, is measured for each of the 6 irregular wave spectra ($i = 1, 2, \ldots, 6$) that will be used to represent a full wave climate (i.e. site along the West Coast of the US). The Wave Energy Prize created a representative wave climate based on seven ($j = 1, 2, \ldots, 7$) wave climates typical of deep water locations off the West Coast of the United States. The average annual capture width, $AACW(j)$, produced in a single wave climate is calculated by summing the products of the average absorbed power produced in each IWS, $\langle AP(i)\rangle$, and a corresponding scaling factor $\Xi(i,j)$ (related to the probability of each IWS in each wave climate), and then dividing by the total annual omnidirectional wave power density, $\langle C_p(j)\rangle$:

$$AACW(j) = \frac{\sum_{i=1}^{6IWS} \langle AP(i)\rangle\, \Xi(i,j)}{\langle CP(j)\rangle}$$

The scaling factors $\Xi(i,j)$ will be revealed at the conclusion of the Wave Energy Prize.

The annual capture widths $AACW(j)$ for these seven climates are averaged to determine the annual climate capture width,

$$ACCW = \frac{\sum_{j=1}^{7climates} AACW(j)}{7}$$

48

which is divided by the characteristic capital expenditure CCE to determine the metric ACE. If the ACE equals or surpasses the threshold value of 3m/$M, then further analysis will be conducted to determine the winner.

Once the threshold has been surpassed, the additional wave spectra that were run in the basin will be considered in calculating HPQ. These additional wave spectra are the:

- Two (2) large irregular wave spectra (LIWS1 to 2)
- Two (2) realistic wind swell spectra (RWS1 to 2)

The subsequent section describes the determination of the HPQ on the basis of the ACE and taking additional performance related quantities into account.

Instead of limiting the consideration of additional hydrodynamic performance related quantities to a very small number of quantities that are comparatively measurable in all possible proposed WEC models that enter the final MASK Basin test, an approach is chosen that allows the incorporation of hydrodynamic performance-related quantities that are either quantified through the magnitude of the measurement, event count or observation. Six (6) additional criteria have been selected for incorporation into the HPQ. These criteria are shown in the following table and are described below:

Statistical Peak of Mooring Watch Circle (WC_{HPQ}): The watch circle of a device is the diameter of the area on the surface where a moored object can move about. It is not expected that every device will have a circular mooring watch circle. The major axis will be used for noncircular areas. If there is more than one mooring line, the line for which the largest major axis is recorded will be used. Mooring excursion data will be fit to a distribution and a statistical measure of the peak excursions will be determined (i.e. the absolute peak value seen in the tank will not be used).

Statistical Peak of Mooring Forces (MF_{HPQ}): The mooring forces will be measured in each mooring leg and the statistical peak value will be used in this criteria. If there is more than one mooring line, the line for which the highest statistical peak value is recorded will be used. Mooring force data will be fit to a distribution and a statistical measure of the peak excursions will be determined (i.e. the absolute peak value seen in the tank will not be used).

Statistical Peak-to-Average Ratio of Absorbed Power ($AP_{P2A,\,HPQ}$): Absorbed power data will be fit to a distribution and a statistical measure of the peak power production will be determined (i.e. the absolute peak value seen in the tank will not be used).

End-Stop Impact Events (ES_{HPQ}): The number of impact events due to travel limitations will be counted and summed per body for each power producing body. If needed an average number of impact events will then be calculated across all bodies.

Absorbed Power in Realistic Seas (RS_{HPQ}): The average absorbed power in each of the realistic sea-states will be compared to the average absorbed power in corresponding IWS seas.

Adaptive Control Effort (AC_{HPQ}): The time and energy effort required for the execution of adaptive control (e.g. configuration/structural changes) during operation of the fully developed system will be considered.

Each of these hydrodynamic performance related quantities will be allocated to a factor, I_i (Table I1) and the HPQ will be determined by multiplication of the ACE with all these factors.

$$HPQ = ACE * \{I_i(MF_{HPQ}) * I_i(WC_{HPQ}) * I_i(AP_{P2A,HPQ}) * I_i(ES_{HPQ}) * I_i(RS_{HPQ}) * I_i(AC_{HPQ})\}$$

Each of these factors may have limited beneficial, non-beneficial or no influence on the HPQ. Additionally, each factor is influenced by the other two possible wave sets, LIWS and/or RWS, in a distinct manner as is identified in the third column of the table (wave spectra weighting). The six (6) sea states (IWS 1 to 6) used to determine average annual capture width values will be used to find equivalent average annual values for any variable of interest. These average annual values will then be averaged over the seven (7) wave climates to find the average climate value for the variable, $ACXX$. The following equation illustrates this for the Mooring Quality function described above.

$$ACMF = \frac{\sum_{j=1}^{7climates} \sum_{i=1}^{6IWS} (MF(i))\alpha(i,j)}{7}$$

Performance Related Quantity	Surveillance Type [Measured, Counted, Observed, Analyzed]	Impact Factor Range Over 5 Points [(I_1), (I_2), (I_3), (I_4), (I_5)] [negative impact,..., no impact,..., positive impact]	Wave Spectra Weighting
Mooring Force: MF_{HPQ}	Measurable	[0.92, 0.96, 1.0, 1.04, 1.08]	$MF_{HPQ} = ACMF \cdot 20\% + \left(\frac{\sum_{i=1}^{2LIWS} MF(i)}{2}\right) \cdot 60\% + \left(\frac{\sum_{i=1}^{2RWS} MF(i)}{2}\right) \cdot 20\%$
Watch Circle WC_{HPQ}	Measurable	[0.96, 0.98, 1.0, 1.02, 1.04]	$WC_{HPQ} = ACWC \cdot 20\% + \left(\frac{\sum_{i=1}^{2LIWS} WC(i)}{2}\right) \cdot 60\% + \left(\frac{\sum_{i=1}^{2RWS} WC(i)}{2}\right) \cdot 20\%$

50

Statistical Peak-to-Average Ratio of Absorbed Power $AP_{P2A_{HPQ}}$	Measurable	[0.92, 0.96, 1.0, 1.04, 1.08]	$AP_{P2A_{HPQ}} = ACAP_{P2A} \cdot 60\% + \left(\frac{\sum_{i=1}^{2_{LIWS}} AP_{P2A}(i)}{2}\right) \cdot 10\% + \left(\frac{\sum_{i=1}^{2_{RWS}} AP_{P2A}(i)}{2}\right) \cdot 30\%$
End-Stop Impact Events ES_{HPQ}	Total number countable, severity observable	[0.92, 0.96, 1.0, 1.04, 1.08]	$ES_{HPQ} = ACES \cdot 40\% + \left(\frac{\sum_{i=1}^{2_{LIWS}} ES(i)}{2}\right) \cdot 20\% + \left(\frac{\sum_{i=1}^{2_{RWS}} ES(i)}{2}\right) \cdot 40\%$
Absorbed Power in Realistic Seas RS_{HPQ}	Measurable	[0.90, 0.95, 1.0, 1.05, 1.1]	$RS_{HPQ} = \frac{\left(\sum_{i=1}^{2_{RWS}} \frac{<AP(i)>_{RWS}}{<AP(i)>_{IWS}}\right)}{2}$
Adaptive Control Effort AC_{HPQ}	Analyzed	[0.92, 0.94, 0.96, 0.98, 1.0]	

Table I2 – Hydrodynamic Performance Quantities and Factors

The values of the impact factors for each hydrodynamic performance related quantity for each Finalist will be assigned by the Judging Panel. The Judging Panel will use the guidelines below in assigning these values:

Statistical Peak of Mooring Watch Circle: Small watch circles will be rewarded (I_4 and I_5) while large watch circles will be penalized (I_1 and I_2).

Statistical Peak of Mooring Forces: Small forces will be rewarded (I_4 and I_5) while large forces will be penalized (I_1 and I_2).

Statistical Peak-to-Average Ratio of Absorbed Power: Small peak-to-average ratios will be rewarded (I_4 and I_5) while large peak-to-average ratios will be penalized (I_1 and I_2).

End-Stop Impact Events: Few to no impact events will be rewarded (I_4 and I_5) while many impact events will be penalized (I_1 and I_2).

Absorbed Power in Realistic Seas: Average absorbed power values in realistic seas that do not deviate strongly from average absorbed power values in corresponding IWS seas will be rewarded (I_4 and I_5) while strong deviations will result in penalization (I_1 and I_2).

Adaptive Control: Devices that do not utilize adaptive control will not be affected, and will receive a factor of 1.0. For all devices that execute adaptive control between tests by physical interaction (e.g. by manually interacting with the device model) or through on-board equipment, time and energy effort required for the execution of adaptive control during operation of the fully developed system will be considered and will result in penalization.

Exact assignments and methodologies are dependent upon the performance of all the Finalists in the Prize, with the exception of absorbed power in realistic seas. The Judges will use the above guidelines to produce the most suitable, objective and comparable formulation for each of the Finalists, dependent on their technology in relation to the other Finalists.

Appendix J: Branding and Logo Usage Guidelines

WAVE ENERGY PRIZE

U.S. DEPARTMENT OF ENERGY

Logo Specifications Guide 2015 - 2016

53

WAVE ENERGY PRIZE

U.S. DEPARTMENT OF ENERGY

The Wave Energy Prize image is used to enhance the program's visibility and foster positive recognition in today's marketplace. These guidelines specify how the name, logo and colors are to be used to create a foundation for visual unity, impact and consistency when used in print, broadcast and electronic media.

This brief guide provides quick direction for the treatment of the Wave Energy Prize logo in a variety of situations.

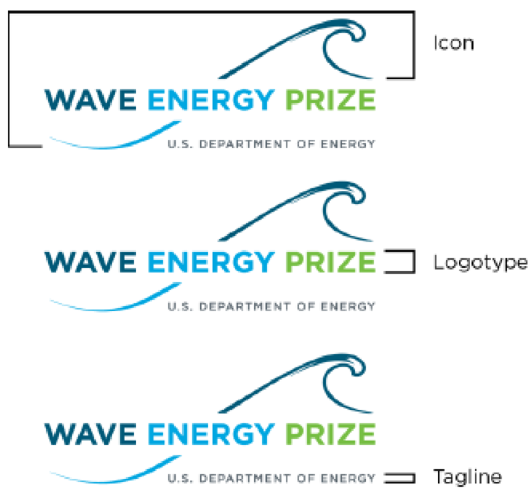
Wave Energy Prize Naming Convention

On first reference, the Prize should be referred to as the "U.S. Department of Energy Wave Energy Prize." On subsequent references, it may be referred to as the "Wave Energy Prize."

In no case shall the acronym "WEP" be used to refer to the Prize.

Logo Breakdown

This logo is composed of a representative icon, logotype and tagline.



Pantone Colors

Always use the Wave Energy Prize logo on a white background.

Pantone 308
4-color process build:
C = 100, M = 59, Y = 35
K = 16

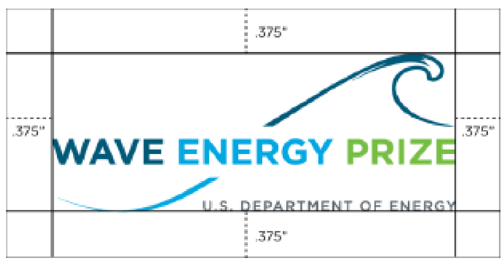
Pantone 2995
4-color process build:
C = 80, M = 12, Y = 1
K = 0

Pantone 368
4-color process build:
C = 58, M = 2, Y = 100
K = 0

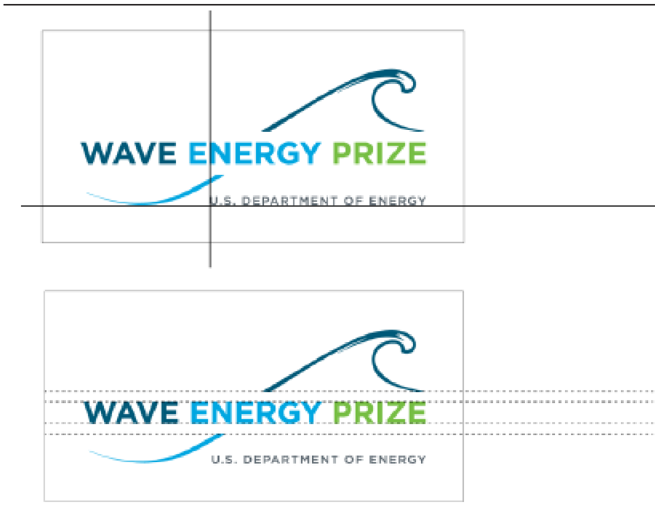
Pantone 431
4-color process build:
C = 66, M = 52, Y = 45
K = 17

Clear Space Around the Logo

Allow .375" of X (the size from the top of the logo to the bottom) spacing on all sides of the logo.



Spacing Inside the Logo



- Tagline text should always be aligned with the bottom of the icon wave and flushed with the "N" in "ENERGY."
- The spacing in between the icon wave and the logotype should always be .1".

Fonts

Do not substitute the font in the Wave Energy Prize logotype or the tagline.

Gotham Bold is the suggested typeface for the WEC logotype. There is 0 kerning.

WAVE ENERGY PRIZE

Gotham Medium is the suggested typeface for the DOE tagline with a kerning at 85pt.

U.S. DEPARTMENT OF ENERGY

Gotham Book is the suggested typeface when creating body copy to be used when creating a layout.

Other "No-Nos"

- Never change the layout of the logo to make it more horizontal by adjusting the kerning.
- Do not use the logo on a busy pattern or colored background that impairs its legibility.
- Do not stretch any part of the logo at any time.
- The format cannot be compromised: do not slant or rotate the logo in any way.
- Never use the wave icon part of the logo, nor the logotype/tagline alone.

Size and Placement of Other Logos

In some cases, the Wave Energy Prize logo may appear in conjunction with other logos. When this occurs, the other logo(s) must be one-third the width of the Wave Energy Prize logo (for horizontal logos), or half the height of the Wave Energy Prize logo (for vertical logos).

Other logos may include (but are not limited to) the U.S. Department of Energy or EERE logo, event sponsor logos, team logos, and team sponsor logos.

File Formats Available from the Wave Energy Prize

The logo was created in Adobe Illustrator version CS6 and is MAC OS formatted. The logo is also available in these formats:

- .eps
- .ai
- .jpeg (300 dpi)
- .png
- .tif (300 dpi)

In all cases other than electronic media, the EPS format must be used.

If you are unable to use EPS, you may use the .jpeg or .tif only when transparent backgrounds are not required.

If there is need for a different format, please request it and the Wave Energy Prize Administrators will send the graphic file to you.

Appendix K: Glossary

Absorbed power – Net hydrokinetic power absorbed from the wave field and available for further conversion to useful power. For example, conversion to mechanical power is the product of the dynamic (forces, pressures, torques, etc.) and kinematic (velocities, flows, rotational velocities, etc.) parameters for a hydrokinetically excited device. Power motoring with reverse power flow will reduce absorbed power.

Adaptive control – Control of overall system state typically conducted at longer time scales (not wave by wave), excluding controls of power converting forces (e.g. configuration, orientation, ballasting).

Capture Width – The power absorbed from the waves by the device in kW (kiloWatt) divided by the incident wave energy flux per meter crest width in kW/m.

CapEx – Capital Expenditure

Controllability with fast wave by wave control – Deterministic control of WEC in millisecond time scale for adaptation to instantaneous and predicted observable signals.

Controllability and adaptability with slow sea state by sea state control – Stochastic control of WEC hour time scale for adaptation to sea state.

DOE – U.S. Department of Energy

Force flow – The way forces and loads penetrate the system.

Power flow – The way power flows through the system.

Information flow – The way information (operations condition, system condition) flows through the system.

Linear resistive damping – A control strategy in which the kinematic and dynamic sides of absorbed power are linearly proportional to one another through a constant resistive term. The value of proportionality (i.e. the resistive term) can be changed on a sea state by sea state basis.

LCOE – Levelized Cost of Energy

MASK – Maneuvering and Seakeeping Basin, at the Naval Surface Warfare Center, Carderock Division in West Bethesda, MD

OpEx – Operational Expenditure

PTO Control - Direct control of power absorption via control of PTO force or PTO motion directly within the power conversion chain.

Representative Power Take Off (PTO) – Primary mechanism used to control hydrodynamic power absorption and to convert the absorbed power to useful power. This may include multiple power conversion steps. In hydrodynamic model testing this system is often represented solely with respect to its influence on the primary power absorption and conversion step. Often a simple (e.g. linear relationship) between the dynamic and kinematic components controlling the power absorption is used.

System adaptability supporting availability – The ability of a WEC device to adapt its configuration, geometry, or alignment to increase power producing availability.

TPL – Technology Performance Level

TRL – Technology Readiness Level

Wave farm infrastructure – Non WEC device parts and infrastructure, e.g. interconnectors of device umbilicals, cables to shore, grid connection, and anchoring system.

WEC – Wave Energy Converter

Total Surface Area – Total surface area (m^2) at full scale is identified as all structural surface area that is subject to loading and/or is inherent to the production of power. For this prize, only surface areas that define the profile of the device are considered (i.e. it is not the surface area of all components that are needed to physically construct a device, like the underlying girders and stiffeners).

- Included are structural surface areas below and above the water line when the system is installed with the mooring attached and in still water.
- Included is the station keeping mechanism.
- Not included are anchor lines.

12.2 Appendix 2 – Wave Energy Prize Terms and Conditions

WAVE ENERGY PRIZE
U.S. DEPARTMENT OF ENERGY

Wave Energy Prize Terms and Conditions

1. Indemnification and Liability

Any and all information provided by or obtained from the Federal Government and any agents authorized to act on behalf of the Department of Energy (DOE), including the Judging Panel, Sandia National Laboratory, National Renewable Energy Laboratory, Naval Surface Warfare Center, and the Wave Energy Prize Administrators are without any warranty or representation whatsoever, including but not limited to its suitability for any particular purpose. Upon registration, all participants agree to assume and, thereby, have assumed any and all risks of injury or loss in connection with or in any way arising from participation in this competition. Upon registration, except in the case of willful misconduct, all participants agree to and, thereby, do waive and release any and all claims or causes of action against the Federal Government and its officers, employees and agents for any and all injury and damage of any nature whatsoever (whether existing or thereafter arising, whether direct, indirect, or consequential and whether foreseeable or not), arising from their participation in the contest, whether the claim or cause of action arises under contract or tort. Upon registration, all participants agree to and, thereby, shall indemnify and hold harmless the Federal Government and its officers, employees and agents for any and all injury and damage of any nature whatsoever (whether existing or thereafter arising, whether direct, indirect, or consequential and whether foreseeable or not), which results, in whole or in part, from the fault, negligence, or wrongful act or omission of the participants or participants' officers, employees or agents.

2. Insurance

In accordance with the America COMPETES Act, the Team shall provide proof of general liability insurance of $500,000 per incident and a $1 million umbrella policy for claims by a third party for death, bodily injury, or property damage or loss resulting from an activity carried out in connection with the competition, with the Federal Government named as an additional insured under the Team insurance policy.

Additionally, the Team must agree to indemnify the Federal Government against third party claims for damages arising from or related to competition activities and for damage or loss to Government property resulting from such an activity.

All costs associated with securing this insurance is the responsibility of the Team.

Proof of the required insurance must be provided to the DOE and Wave Energy Prize Administrators by the Qualified Teams on or before September 14, 2015.

1

3. Eligibility

To be eligible to win a prize under the Wave Energy Prize, an individual or entity:

a) Shall have successfully registered to participate in the Wave Energy Prize;
b) Shall have complied with all the requirements under this section;
c) In the case of a private entity, shall be incorporated in and maintain a primary place of business in the United States, and in the case of an individual, whether participating singly or in a group, shall be a citizen or permanent resident of the United States;
d) May not be a Federal entity or Federal employee acting within the scope of their employment;
e) May not be a DOE employee, employee of Wave Energy Prize sponsoring organizations, members of their immediate family (spouses, children, siblings, parents), or persons living in the same household as such persons, whether or not related;
f) Federal grantees may not use Federal funds to participate in COMPETES Act challenges;
g) Federal contractors may not use Federal funds from a contract to participate in COMPETES Act challenges or to fund efforts in support of a COMPETES Act challenge; and,
h) An individual or entity shall not be deemed ineligible because the individual or entity used Federal facilities or consulted with Federal employees during a competition if the facilities and employees are made available to all individuals and entities participating in the competition on an equitable basis.

In addition, a team must have a single legal individual representing the entire team. This individual will be designated the Team Leader. The Team Leader is responsible for providing and meeting all submission and evaluation requirements.

4. Use of the Department of Energy (DOE) Logo

If a Team wishes to use the DOE logo, it must first obtain permission from DOE. The DOE will determine if the usage is appropriate, and determine any special usage conditions. Please note that use of the Wave Energy Prize logo is included in the Prize Rules. The permission process can be initiated via the link below:

http://energy.gov/management/office-management/employee-services/graphics/doe-logo-seal-and-word-mark

5. Team Representations and Warranties

The Team hereby represents and warrants that:

a) It is free to enter into this competition without the consent of any third party and has the capability to fully perform its obligations as stipulated by the Wave Energy Prize Rules and Terms and Conditions;
b) It is validly existing and duly organized in the state or jurisdiction of its incorporation;
c) It is not a party to (and it agrees that it shall not become a party to) any agreement, obligation, or understanding that is inconsistent with the Terms and Conditions or might limit or impair the

DOE's or Wave Energy Prize's rights or the Team's obligations under the Wave Energy Prize Rules or Terms and Conditions;

d) There is no suit, proceeding, or any other claim pending or threatened against the Team, nor does any circumstance exist, to its knowledge, which may be the basis of any such suit, proceeding, or other claim, that could limit or impair the Team's performance of its obligations pursuant to Wave Energy Prize Rules or Terms and Conditions;

e) It will not infringe, violate, or interfere with the Intellectual Property, publicity, privacy, contract or other right of any third party in the course of performance of this agreement or cause the DOE, Wave Energy Prize, or their agents to do any of the same;

f) It will sign a Limited Purpose Cooperative Research and Development Agreement with the Naval Surface Warfare Center, Carderock Division, to allow Team members to be present at and equipment to be brought to the MASK Basin for testing;

g) It and its facilities will be subject to the National Environmental Policy Act (NEPA) per the DOE's NEPA compliance responsibility. (For additional background on NEPA, please see DOE's NEPA website, at http://nepa.energy.gov/);

h) It will comply with all applicable laws, rules, and regulations in performing under these Terms and Conditions; and

i) It meets the eligibility requirements set forth by the America COMPETES Act, and provided in Section 3 of these Terms and Conditions.

6. Wave Energy Prize Representations and Warranties

The Wave Energy Prize makes the following limited representations and warranties: (1) it is capable of paying out the seed funding and prize purse(s) outlined in the Wave Energy Prize Rules; (2) it will treat and judge all Teams who enter the Wave Energy Prize in a non-preferential and equal manner; and (3) it will use best efforts to ensure all information provided by the Team as part of a "Team Submission" and in accordance with the reporting requirements of Section 7 (below) remains strictly confidential;(4) it understands that the prize offer is limited by the Terms and Conditions and Prize Rules; (5) awards made under the Wave Energy Prize do not constitute procurement; (6) the final decisions of the Judging Panel are binding and may not be challenged by the participating Teams.

The Wave Energy Prize make no express warranties of any kind as to the design feasibility, constructability, safety, licensing, launch, commercial operating, and/or commercial sale of the Team's wave energy conversion (WEC) devices or technology. Except as expressly set forth in these Terms and Conditions, the Wave Energy Prize disclaim any and all warranties, express or implied in connection with the offering of the Wave Energy Prize.

7. Confidentiality of Team Submissions and Data/Test Results Usage

All technical information submitted by the Team to the Wave Energy Prize Administrators for the purpose of competing in the Prize will remain confidential, if marked as proprietary, except for data that will be publicly releasable, as set forth below. Unmarked data delivered to Wave Energy Prize Administrators will be made publicly available as the Wave Energy Prize Administrators and DOE deem appropriate. The submitted technical information and data will be used by the Wave Energy Prize Administrators, and the designated Judging Panel, to assess the WEC devices proposed by the competing teams, and ultimately rank the technologies for the purpose of continuation in and purse placement for the Wave Energy Prize.

All associated data and test results derived from the analysis and testing of Team submissions will be delivered to the Wave Energy Prize Administrators, who will deliver them to the DOE. The Wave Energy Prize Administrators will publish scores, rankings and test results following assessments at all Technology Gates on the public Wave Energy Prize website.

During and after the Prize, data and information that may be made publicly available—at the DOE's sole discretion—includes scores and rankings following each Technology Gate, test results and associated data, videos and/or photos of participant devices either static and/or dynamic, including but not limited to:

- **Registration Application –** The type of device noted in application and a description of its proposed working principles, geometry and dimensions, and materials.
- **Technology Gate 1** - Scores and rankings from the assessment of the Technical Submission from all Registered Teams, taken from the Judging Panel's assessment of the Technology Performance Level.
- **Technology Gate 2** - Scores, rankings and data generated by the up to 20 Qualified Teams throughout the assessment process:
    - Numerical model predictions of performance at full scale for the waves to be used in the 1/50th scale tests and 1/20th scale tests and a description of the numerical model provided by Teams (as described in the Wave Energy Prize Rules).
    - Power Take Off characteristics for 1/50th scale WEC concepts.
    - Data collected by the Data Acquisition System during 1/50th scale testing. This includes the time series of scale model displacements and any quantities derived from the time series; the time series of those appropriate parameters that characterize the average absorbed power by the 1/50th scale WEC model (such as Force/Velocity, Pressure/Mass Flow, Torque/Angular Velocity); data on the actual wave climate experienced by the 1/50th scale model during these tests and any analysis of these data, such as of absorbed power.
    - Reports produced by the Small Scale Test Facility, which include data analyses and comparisons of numerical modelling results at full scale and actual test results at 1/50th scale, scaled to full scale.
    - Analyses by the National Renewable Energy Laboratory (NREL) and Sandia National Laboratory (SNL) of Average Climate Capture Width per Characteristic Capital Expenditure and parameters that define it (as described in the Wave Energy Prize Rules).
    - Scores and rankings derived from the revised Technical Submission, utilizing the Technology Performance Level assessment that reflect new data and analyses arising from/through Technology Gate 2.
    - Videos taken of the testing at 1/50th scale.

WAVE ENERGY PRIZE
U.S. DEPARTMENT OF ENERGY

- **Technology Gate 3 –** Announcement of the Finalists to be tested at the MASK Basin including the following information from the required submission:
    - Photos and/or videos of technology to be used on the public website for promotional purposes.
- **Technology Gate 4** - Scores, rankings and data generated by the up to 10 Finalist Teams throughout the assessment process:
    - Data collected by the Data Acquisition System during 1/20th scale testing. This includes the time series of scale model displacements and any quantities derived from the time series; the time series of those appropriate parameters that characterize the average absorbed power by the 1/20th scale WEC model (such as Force/Velocity, Pressure/Mass Flow, Torque/Angular Velocity); data on the actual wave climate experienced by the 1/20th scale model during these tests and any analyses of these data, such as of absorbed power.
    - Analyses by NREL and SNL of Average Annual Capture Width and of Average Climate Capture Width/Characteristic Capital Expenditure achieved in 1/20th scale tests and scaled to full scale.
    - Data and analyses associated with the determination of the Hydrodynamic Performance Quality as described in Appendix I, Assessment for Technology Gate 4 and Method for Determination of Winner(s,) of the Wave Energy Prize Rules, including physical measurements, observations and counted events from 1/20th scale testing.
    - Scores and rankings derived from the revised Technical Submission, utilizing the Technology Performance Level assessment that reflect new data and analyses arising from/through Technology Gate 4.
    - Videos taken of the testing at 1/20th scale.

8. Intellectual Property Ownership

All intellectual property associated with team submissions, as required to participate in the Wave Energy Prize, remains the sole property of the submitting team. The DOE and Wave Energy Prize Administrators take no interest in the intellectual property submitted to the Wave Energy Prize without the written consent of the submitting Team. Teams must disclose and properly identify and label all information and/or data that the Team deems proprietary. Data marked as proprietary will not be disclosed to the public except as described in Section 7, above. All data submitted to the Prize Administration Team, will be made available to the DOE and parties authorized to act on behalf of the DOE. By accepting these Terms and Conditions, participants consent to the use of data submitted to the Wave Energy Prize Administrators and DOE consistent with the Wave Energy Prize Rules and Terms and Conditions.

9. Relationship of the Parties

Nothing contained in these Terms and Conditions is intended to create, nor constitute, any relationship between the DOE, nor the Prize administrators, with the Team. Participation in the Wave Energy Prize does not imply any form of sanction or support of the Team by the DOE and Wave Energy Prize Administration, nor does it grant either Party any authority to act as agent, nor assume or create any obligation, on behalf of the other Party.

10. Wave Energy Prize Rules Acknowledgement

The Team hereby acknowledges receipt and understanding of all rules and requirements established for the Wave Energy Prize as set forth in the Wave Energy Prize Rules document that may be amended throughout the duration of the competition as appropriate. The participant agrees to comply with: (1) the Wave Energy Prize Rules; (2) additional relevant Prize -related documents that may be issued by the DOE or Wave Energy Prize administration; (3) any amendments or revisions to the Wave Energy Prize Rules and related documents issued by the DOE or the Wave Energy Prize administration; and (4) all official interpretations of the Prize Rules made by or on behalf of the DOE.

☑ I, the Team Leader, on behalf of my Team, acknowledge and accept the Terms and Conditions stipulated above for the Wave Energy Prize. Acceptance of the Wave Energy Prize Terms and Conditions constitutes consent to delivery of data and test results as required by the Wave Energy Prize Administrators, and the use and public release of those data consistent with the Wave Energy Prize Rules.

12.3 Appendix 3 – Media Coverage of the Wave Energy Prize

Below is a summary list of all the media coverage of the Prize along with a web link to the original article. A complete hard copy of each article can be found in a separate document entitled "Coverage_of_the_Wave_Energy_Prize"

World Maritime News
WEC Prize Competition registration date set (Jan. 27, 2015)
http://tidalenergytoday.com/2015/01/27/wec-prize-competition-registration-set-for-april-15/

Solar Thermal Magazine
Official Registration for the DOE Sponsored Wave Energy Prize Opens April 2015 (Jan. 28, 2015)
https://solarthermalmagazine.com/2015/01/28/official-registration-doe-sponsored-wave-energy-prize-opens-april-2015/

Ecopreneurist
Wave Energy Prize Challenge Seeks to Halve the Cost (Feb. 4, 2015)
http://ecopreneurist.com/2015/02/03/wave-energy-prize-challenge-seeks-to-halve-the-cost/

Clean Technica
Wave Energy Prize Aims To Cut Costs Of Wave Energy Production In Half (Feb. 10, 2015)
http://cleantechnica.com/2015/02/10/wave-energy-prize-aims-cut-costs-wave-energy-production-half/

AltEnergyMag
What is the Wave Energy Prize? (Feb. 16, 2015)
http://www.altenergymag.com/emagazine/2015/02/us-department-of-energys-wave-energy-prize/2406

ClimateSpectator
Surf's up – can wave energy rise to the challenge in Australia? (Feb. 19, 2015)
https://www.businessspectator.com.au/article/2015/2/20/renewable-energy/surfs-%E2%80%93-can-wave-energy-rise-challenge-australia

Renewable Energy World
Wave and Tidal Energy in 2015: Finally Emerging from the Labs (Feb. 25, 2015)
http://www.renewableenergyworld.com/rea/news/article/2015/02/wave-and-tidal-energy-in-2015-finally-emerging-from-the-labs

Green Living Ideas
The Future of Wave Power (March 2, 2015)
http://greenlivingideas.com/2015/02/03/future-of-wave-power/

World Maritime News
Public comments open for Wave Energy Prize Rules Draft (March 17, 2015)
http://tidalenergytoday.com/2015/03/17/public-comments-open-for-wave-energy-prize-rules-draft/

Hydro World
Energy Department prize challenge incentivizes wave energy conversion next generation ideas (April 2, 2015)
http://www.hydroworld.com/articles/2015/04/energy-department-prize-challenge-incentivizes-wave-energy-conversion-next-generation-ideas.html

Ocean News and Technology
U.S. Department of Energy Looks to Revolutionary Innovation for Harnessing Wave Energy (April 22, 2015)
https://www.oceannews.com/feature-story/2015/04/22/april-editorial-focus-doe

Hydro World
DOE looking for tech boom with new Wave Energy Prize (April 27, 2015)
http://www.hydroworld.com/articles/2015/04/doe-looking-for-tech-boom-with-new-wave-energy-prize.html

EIN News
Energy Department Launches Competition to Drive Innovations in Wave Energy (April 27, 2015)
http://www.einnews.com/pr_news/262296974/energy-department-launches-competition-to-drive-innovations-in-wave-energy

Solar Thermal Magazine
U.S. DOE Launches Competition to Drive Innovations in Wave Energy (April 27, 2015)
https://solarthermalmagazine.com/2015/04/27/u-s-doe-launches-competition-to-drive-innovations-in-wave-energy/

Domestic Fuel
DOE Announces Wave Energy Prize (April 28, 2015)
http://domesticfuel.com/2015/04/28/doe-announces-wave-energy-prize/

reNews
US floats wave prize (April 28, 2015)
http://renews.biz/87739/doe-floats-wave-price/

Tidal Energy Today
US DoE launches Wave Energy Prize competition (April 28, 2015)
http://tidalenergytoday.com/2015/04/28/us-doe-launches-wave-energy-prize-competition/

Power Systems Design
Energy Department launches competition to drive innovation in wave energy (April 28, 2015)
http://www.powersystemsdesign.com/energy-department-launches-competition-to-drive-innovation-in-wave-energy

The Maritime Executive
Energy Department Launches Wave Energy Prize Competition (April 28, 2015)
http://www.maritime-executive.com/pressrelease/energy-department-launches-wave-energy-prize-competition

ECO Magazine
Funding: Over $2 Million in Wave Energy Prizes (April 29, 2015)
http://www.ecomagazine.com/news-briefs/funding-over-2-million-in-wave-energy-prizes.html

International Water Power & Dam Construction
Registration open for US DOE's Wave Energy Prize (April 29, 2015)
http://www.waterpowermagazine.com/news/newsregistration-open-for-us-does-wave-energy-prize-4565344

AltEnergyMag
Department of Energy Wave Energy Prize Kicks Off Annual NHA/IMREC Conference (April 29, 2015)
http://www.altenergymag.com/news/2015/04/28/department-of-energy-wave-energy-prize-kicks-off-annual-nhaimrec-conference-/19757/

HydroWorld
NHA 2015 Annual Conference Special Edition Newscast (May 2, 2015)
http://www.hydroworld.com/topics/m/video/104661581/nha-2015-annual-conference-special-edition-newscast.htm

Targeted News Service
DOE Establishes $2 Million in Prizes for Wave Energy Concepts (May 3, 2015)
http://targetednews.com/display_story.php?s_id=1203666

Southeast Green
Energy Department Launches Competition to Drive Innovations in Wave Energy (May 4, 2015)
http://www.southeastgreen.com/index.php/news/washington-dc/13347-energy-department-launches-competition-to-drive-innovations-in-wave-energy

Voice of America
US Energy Agency Announces Wave Energy Prize Competition (May 4, 2015)
http://www.voanews.com/content/department-of-energy-wave-energy-prize-competition/2748293.html

Big News Network
US Energy Agency Announces Wave Energy Prize Competition (May 4, 2015)
http://www.bignewsnetwork.com/index.php/sid/232546711

CleanTechnica
Registration Open For The New Wave Energy Prize Competition (May 9, 2015)
http://cleantechnica.com/2015/05/09/registration-open-new-wave-energy-prize-competition/

Hydro World
DOE offers prize challenge for wave energy conversion ideas (May 20, 2015)
http://www.hydroworld.com/articles/hr/print/volume-34/issue-4/departments/marine-hydrokinetics.html

Tidal Energy Today
Wave Energy Prize extends registration deadline (June 15, 2015)
http://tidalenergytoday.com/2015/06/15/wave-energy-prize-extends-registration-deadline/

Hydro World
DOE looks for tech boom with new Wave Energy Prize announcement (June 29, 2015)
http://www.hydroworld.com/articles/hr/print/volume-34/issue-5/departments/marine-hydrokinetics.html

Tidewater Current
Virginia Joins Wave Energy Competition (July 6, 2015)
http://www.tidewatercurrent.com/2015_summer/energy.html

Domestic Fuel
Wave Energy Prize Entrants Move Forward (July 7, 2015)
http://energy.agwired.com/2015/07/07/wave-energy-prize-entrants-move-forward/

Popular Science
For The First Time, Waves Are Adding Power To The U.S. Grid (July 7, 2015)
http://www.popsci.com/waves-are-adding-power-grid-hawaii/

Business Insider
The US just tapped into a surprising source of renewable energy for the first time (July 8, 2015)
http://www.businessinsider.com/hawaii-is-using-waves-to-power-homes-for-the-first-time-2015-7/

Fierce Energy
Water water everywhere, but is it too soon for wave energy? (July 8, 2015)
http://www.fierceenergy.com/story/water-water-everywhere-it-too-soon-wave-energy/2015-07-08

Hydro World
More than 90 teams enter U.S. DOE's Wave Energy Prize program (July 8, 2015)
http://www.hydroworld.com/articles/2015/07/more-than-90-teams-enter-u-s-doe-s-wave-energy-prize-program.html

Phys.org
Wave energy device is watched for clean power in Hawaii (July 9, 2015)
http://phys.org/news/2015-07-energy-device-power-hawaii.html

Tidal Energy Today
US Wave Energy Prize: Race-on for 92 teams (July 13, 2015)
http://tidalenergytoday.com/2015/07/13/us-wave-energy-prize-race-on-for-92-teams/

OffshoreWIND.biz
USD 2 Mln Wave Energy Prize Attracts 92 Teams (July 13, 2015)
http://www.offshorewind.biz/2015/07/13/usd-2-mln-wave-energy-prize-attracts-92-teams/

HydroWorld
COER competition could help marine hydrokinetic development (July 27, 2015)
http://www.hydroworld.com/articles/2015/07/coer-competition-could-help-marine-hydrokinetic-development.html

energybiz
Wave energy test rolling forward in Hawaii (July 28, 2015)
http://www.energybiz.com/article/15/07/wave-energy-test-rolling-forward-hawaii

E&E News (ClimateWire)
Infant U.S. wave-to-energy industry looks to build more testing facilities (Aug. 7, 2015)
http://www.eenews.net/stories/1060023142/

Virginia Public Radio
West Coast Waves Promise Clean Power (Aug. 12, 2015)
http://wvtf.org/post/west-coast-waves-promise-clean-power#stream/0

HydroWorld
DOE selects 20 teams to advance in Wave Energy Prize program (Aug. 14, 2015)
http://www.hydroworld.com/articles/2015/08/doe-selects-20-teams-to-advance-in-wave-energy-prize-program.html

HydroWorld
Hydro Headlines Weekly Newscast (Aug. 14, 2015)
http://www.hydroworld.com/index.html

Virginia Public Radio
Virginia Company A Leader in Marine Energy (Aug. 14, 2015)
http://wvtf.org/post/virginia-company-leader-marine-energy#stream/0

Marine Technology News
Twenty Teams Vie for Wave Energy Prize (Aug. 14, 2015)
http://www.marinetechnologynews.com/news/twenty-teams-energy-prize-519330

Tidal Energy Today
US Wave Energy Prize advances 20 teams to next stage (Aug. 17, 2015)
http://tidalenergytoday.com/2015/08/17/us-wave-energy-prize-advances-20-teams-to-next-stage/

renews
DoE picks top wave devices (Aug. 17, 2015)
http://renews.biz/93779/doe-picks-top-wave-devices/

AltEnergyMag
Twenty Teams Advancing to Next Phase of the Wave Energy Prize (Aug. 17, 2015)
http://www.altenergymag.com/news/2015/08/17/twenty-teams-advancing-to-next-phase-of-the-wave-energy-prize-/21037/

MIT Sea Grant Program
MIT Sea Grant led team advances to next phase of the Wave Energy Prize Contest (Aug. 17, 2015)
http://seagrant.mit.edu/press_releases.php?nwsID=509

Oregon Wave Energy Trust
Twenty Teams Advancing to Next Phase of the Wave Energy Prize (Aug. 17, 2015)
http://oregonwave.org/news/twenty-teams-advancing-to-next-phase-of-the-wave-energy-prize/

offshoreWIND.biz
20 Teams Qualify for DOE Wave Energy Prize (Aug. 17, 2015)
http://www.offshorewind.biz/2015/08/17/20-teams-qualify-for-doe-wave-energy-prize/

Renewable Energy Focus
Twenty teams advancing to next phase of the Wave Energy Prize (Aug. 20, 2015)
http://www.renewableenergyfocus.com/view/42782/twenty-teams-advancing-to-next-phase-of-the-wave-energy-prize/

Popular Science
A New Energy Plant In Hawaii Generates Power From Ocean Temperature Extremes (Aug. 24, 2015)
http://www.popsci.com/new-energy-plant-hawaii-uses-ocean-temperatures

renews
M3 Wave eyes energy prize (Aug. 25, 2015)
http://renews.biz/94338/m3-wave-eyes-energy-prize/

Tidal Energy Today
M3 Wave to unveil NEXUS wave energy device (Aug. 25, 2015)
http://tidalenergytoday.com/2015/08/26/m3-wave-to-unveil-nexus-wave-energy-device/

Sea Technology
92 Teams Submit Technical Description of WECs to DOE (August 2015)
http://www.sea-technology.com/news/mar_resources.php

Hydro Review
DOE's Wave Energy Prize narrowed to 20 teams (Sept. 17, 2015)
http://www.hydroworld.com/articles/hr/print/volume-34/issue-7/departments/marine-hydrokinetics.html

Hydro World
Lignum Vitae North America donates bearings to teams in the Wave Energy Prize Challenge (Sept. 23, 2015)
http://www.hydroworld.com/articles/2015/09/lignum-vitae-donates-bearings-to-teams-in-the-wave-energy-prize-challengeb.html

AltEnergyMag
Technical Summaries of Wave Energy Prize Qualified Teams (Oct. 1, 2015)
http://www.altenergymag.com/article/2015/09/technical-summaries-of-wave-energy-prize-official-qualified-teams/21560

EnergyBiz Magazine
Wave Energy Test Rolling Forward in Hawaii (Fall 2015)
http://www.energybiz.com/magazine/article/433323/wave-energy-test-rolling-forward-hawaii

Tidal Energy Today
Sea Potential prepares DUO wave energy converter for testing (Nov. 3, 2015)
http://tidalenergytoday.com/2015/11/03/sea-potential-prepares-duo-wave-energy-converter-for-testing/

Tidal Energy Today
AWP backs out of Wave Energy Prize (Nov. 5, 2015)
http://tidalenergytoday.com/2015/11/05/awp-backs-out-of-wave-energy-prize/

renews
Atlantic quits DoE competition (Nov. 5, 2015)
http://renews.biz/100364/atlantic-quits-doe-competition/

Tidal Energy Today
Another company withdraws from Wave Energy Prize (Nov. 11, 2015)
http://tidalenergytoday.com/2015/11/11/another-company-withdraws-from-wave-energy-prize/
Tidal Energy Today
Sea Potential performs wet tests on DUO WEC (Nov. 26, 2015)
http://tidalenergytoday.com/2015/11/26/sea-potential-performs-wet-tests-on-duo-wec/

The Weather Channel
Harnessing Wave Energy for Power (Dec. 11, 2015)
http://www.weather.com/tv/shows/amhq/video/harnessing-wave-energy-for-power

Tidal Energy Today
Atlas Ocean concludes scaled WEC testing (Dec. 15, 2015)
http://tidalenergytoday.com/2015/12/15/atlas-ocean-concludes-scaled-wec-testing/

Tidal Energy Today
USA: UMaine wave energy testing underway (Dec. 18, 2015)
http://tidalenergytoday.com/2015/12/18/usa-umaine-wave-energy-testing-underway/

National Geographic
8 Tech Breakthroughs of 2015 That Could Help Power the World (Dec. 29, 2015)
http://news.nationalgeographic.com/energy/2015/12/151228-eight-tech-breakthroughs-that-could-help-power-the-world/

Tidal Energy Today
Wave Energy Prize: Teams to finish scaled testing end of January (Jan. 4, 2016)
http://tidalenergytoday.com/2016/01/04/wave-energy-prize-teams-to-finish-scaled-testing-end-of-january/

The Straits Times
8 Tech Breakthroughs of 2015 That Could Help Power the World (Jan. 10, 2016)
http://www.straitstimes.com/opinion/8-tech-breakthroughs-in-2015-that-could-help-power-the-world/

NYU ScienceLine
A new paradigm for renewable energy (Jan. 17, 2016)
http://scienceline.org/2016/01/a-new-paradigm-for-renewable-energy/

Tidal Energy Today
VIDEO: AquaHarmonics' scaled WEC testing (Jan. 25, 2016)
http://tidalenergytoday.com/2016/01/25/video-aquaharmonics-scaled-wec-testing/

Tidal Energy Today
VIDEO: Oscilla Power's Triton WEC (Jan. 27, 2016)
http://tidalenergytoday.com/2016/01/27/video-oscilla-powers-triton-wec/

Engineering News Record
Three Firms Test Wave-Power Models at UMaine's 'W2' Lab (Jan. 28, 2016)
http://www.enr.com/articles/38716-three-firms-test-wave-power-models-at-umaines-w2-lab/

Virginia Tech News
Squid-inspired wave energy converter turns ocean's power into electricity (Feb. 12, 2016)
http://www.vtnews.vt.edu/articles/2016/02/021216-ictas-waveenergyprize.html

AltEnergyMag
U.S. Department of Energy's Wave Energy Prize Announces Finalist Teams (March 1, 2016)
http://www.altenergymag.com/news/2016/03/01/us-department-of-energy%E2%80%99s-wave-energy-prize-announces-finalist-teams/22995

Hydro World
DOE announces Wave Energy Prize finalists (March 1, 2016)
http://www.hydroworld.com/articles/2016/03/doe-wave-energy-prize-announces-finalists.html

MarineLink
Finalists Complete for $2 Mln Wave Energy Prize (March 1, 2016)
http://www.marinelink.com/news/finalists-complete-energy405952.aspx

Pete Danko Clean Energy News & Commentary
Two Oregon Teams Reach Wave Energy Prize Finals (March 1, 2016)
http://petedanko.net/two-oregon-teams-reach-wave-energy-prize-finals/

Maritime Global News
Finalists Complete for $2 Mln Wave Energy Prize (March 1, 2016)
http://maritimeglobalnews.com/news/finalists-complete-energy-prize-c34nrs

Oregon Wave Energy Trust
Energy Department Announces Finalists Vying for $2.25 Million Wave Energy Prize (March 1, 2016)
http://oregonwave.org/news/energy-department-announces-finalists-vying-for-2-25-million-wave-energy-prize/

Tidal Energy Today
Wave Energy Prize unveils finalist teams (March 2, 2016)
http://tidalenergytoday.com/2016/03/02/wave-energy-prize-unveils-finalist-teams/

Renews
Finalists eye Wave Energy Prize (March 2, 2016)
http://renews.biz/101765/finalists-eye-doe-wave-energy-prize/

Network World
Energy Dept. sets 9 finalists for $2.25M wave energy prize (March 2, 2016)
http://www.networkworld.com/article/3040323/data-center/energy-dept-sets-9-finalists-for-2-25m-wave-energy-prize.html

Inside Climate News
Not Just Riding the Waves, These Competitors Seek to Harness Their Energy (March 7, 2016)
http://insideclimatenews.org/news/06032016/wave-energy-power-department-energy-contest-renewable-climate-change

Belfast News Letter
Pure Marine on the crest of a US wave (March 8, 2016)
http://www.newsletter.co.uk/news/ni-business-news/pure-marine-on-the-crest-of-a-us-wave-1-7259575#ixzz42KDbbuE0

News Channel 10 (CA – CBS affiliate)
SEWEC Named Finalist in U.S. Department of Energy's Wave Energy Prize (March 8, 2016)
http://www.newschannel10.com/story/31414156/sewec-named-finalist-in-us-department-of-energys-wave-energy-prize

Renewable Energy World
DOE Announces Wave Energy Prize Finalists (March 9, 2016)
http://www.renewableenergyworld.com/articles/hydro/2016/03/doe-wave-energy-prize-announces-finalists.html

EERE Network News
Energy Department Announces Finalists Vying for Wave Energy Prize (March 9, 2016)
http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=22185

International Water Power and Dam Construction
Nine teams get to final of US Govt's Wave Energy Prize (March 11, 2016)
http://www.waterpowermagazine.com/news/newsnine-teams-get-to-final-of-us-govts-wave-energy-prize-4836614?utm_source=twitterfeed&utm_medium=twitter

Seacoastonline.com
York business a finalist in National Wave Energy Contest (March 15, 2016)
http://www.seacoastonline.com/article/20160315/NEWS/160319536

IHS Engineering 360
Wave Energy: Chasing the Big One (March 17, 2016)
http://insights.globalspec.com/article/2312/wave-energy-chasing-the-big-one

Tidal Energy Today
Waveswing America gears up for June WEC testing (March 25, 2016)
http://tidalenergytoday.com/2016/03/25/waveswing-america-gears-up-for-june-wec-testing/

Tidal Energy Today
Oscilla Power to test wave device in July (April 1, 2016)
http://tidalenergytoday.com/2016/04/01/oscilla-power-to-test-wave-device-in-july/

Fosters.com
Harnessing the ocean (April 3, 2016)
http://www.fosters.com/article/20160403/NEWS/160409904

Energy Harvesting Journal
Finalist in wave energy prize competition (April 13, 2016)
http://www.energyharvestingjournal.com/articles/9325/finalist-in-wave-energy-prize-competition

Tidal Energy Today
Who's judging technology competing for Wave Energy Prize? (April 15, 2016)
http://tidalenergytoday.com/2016/04/15/whos-judging-technology-competing-for-wave-energy-prize/

Hydro Review
Update on DOE's Wave Energy Prize (April 2016)
http://www.hydroworld.com/articles/hr/print/volume-35/issue-3/articles/update-on-doe-s-wave-energy-prize.html

Sea Technology Magazine
Catalyzing Advancements in Ocean Energy (April 2016)
http://www.sea-technology.com/news/archives/2016/soapbox/soapbox0416.php

Marine Technology Reporter
The Chase for $2m Prize (April 2016)
http://www.marinetechnologynews.com/magazine

Amped Up!
Wave Energy Prize Inspires Innovation (March/April 2016)
http://energy.gov/sites/prod/files/2016/04/f30/amped_up_vol_2_number_2.pdf

Tidal Energy Today
Sea Potential works on DUO WEC optimization (May 5, 2016)
http://tidalenergytoday.com/2016/05/05/sea-potential-works-on-duo-wec-optimization/

GTown Radio
Planet Philadelphia Podcast (May 6, 2016)
http://planetphila.weebly.com/podcasts

Tidal Energy Today
Waveswing America starts WEC construction (May 10, 2016)
http://tidalenergytoday.com/2016/05/10/waveswing-america-starts-wec-construction/

Hydro World
Hydro Headlines Weekly Newscast (May 12, 2016)
http://www.hydroworld.com/topics/m/video/115149031/www-2016-m3-wave-llc.htm?eid=326856542&bid=1404872

Tidal Energy Today
Introducing Mocean Energy's hinged raft WEC (May 13, 2016)
http://tidalenergytoday.com/2016/05/13/introducing-mocean-energys-hinged-raft-wec/

Utility Dive
Making waves: DOE reboots marine hydrokinetic energy program to push commercialization (May 18, 2016)
http://www.utilitydive.com/news/making-waves-doe-reboots-marine-hydrokinetic-energy-program-to-push-commer/419200/

Tidal Energy Today
Wave Energy Prize Teams presented at Waterpower Week (May 20, 2016)
http://tidalenergytoday.com/2016/05/20/wave-energy-prize-teams-presented-at-waterpower-week/

Clean Technica
Waves & Tides Star As DOE Rekindles Marine Hydrokinetic Energy Program, Targeting Commercialization (May 20, 2016)
http://cleantechnica.com/2016/05/20/waves-tides-star-as-doe-rekindles-marine-hydrokinetic-energy-program/

Tidal Energy Today
SEWEC starts WEC assembly process (May 23, 2016)
http://tidalenergytoday.com/2016/05/23/sewec-starts-wec-assembly-process/

Renewable Energy World
Award-winning Wave Energy (June 1, 2016)
http://www.renewableenergyworld.com/articles/print/volume-19/issue-6/departments-columns/hydro-here-and-now/award-winning-wave-energy.html

The Energy Times
West Coast Ocean Power Surge (June 3, 2016)
http://tdworld.com/news/west-coast-ocean-power-surge-0

Tidal Energy Today
Wave Energy Prize recap ahead of TG3 review (June 17, 2016)
http://tidalenergytoday.com/2016/06/17/wave-energy-prize-recap-ahead-of-tg3-review/

Tidal Energy Today
Video: Harvest Wave Energy scale WEC testing (June 20, 2016)
http://tidalenergytoday.com/2016/06/20/video-harvest-wave-energy-scale-wec-testing/

University of California News
From the test tank to the open ocean: Wave energy's make-or-break moment (June 20, 2016)
http://universityofcalifornia.edu/news/calwave

Tidal Energy Today
Waveswing America makes waves in Iowa (June 23, 2016)
http://tidalenergytoday.com/2016/06/23/waveswing-america-makes-waves-in-iowa/

Materials Science Research Bulletin
Challenge prize offer unique opportunities for materials innovation (July 2016)
(no link)

Tidal Energy Today
Finalists move ahead in Wave Energy Prize (July 4, 2016)
http://tidalenergytoday.com/2016/07/04/finalists-move-ahead-in-wave-energy-prize/

Portland Business Journal
Portland startup's wave invention lands on national stage (July 21, 2016)
http://www.bizjournals.com/portland/blog/sbo/2016/07/portland-startups-wave-invention-lands-on-national.html

Tidal Energy Today
Triton WEC heads to Carderock (July 22, 2016)
http://tidalenergytoday.com/2016/07/22/triton-wec-heads-to-carderock/

Solar Thermal Magazine
Wave Energy Prize Team Updates (July 25, 2016)
https://solarthermalmagazine.com/2016/07/25/wave-energy-prize-team-updates/

Tidal Energy Today
Video: AquaHarmonics to test at Carderock end of August (July 28, 2016)
http://tidalenergytoday.com/2016/07/28/video-aquaharmonics-to-test-at-carderock-end-of-august/

HydroWorld
DOE to fund test facility for U.S. waters as Wave Energy Prize competition continues (August 2, 2016)
http://www.hydroworld.com/articles/2016/08/doe-to-fund-test-facility-for-u-s-waters-as-wave-energy-prize-competition-continues.html

Oregon Best
M3 Wave to be First in the Water as Part of DOE Wave Prize Competition (Aug. 2, 2016)
http://oregonbest.org/news-events/news/item/news/News/action/detail/story/m3-wave-to-be-first-in-the-water-as-part-of-doe-wave-prize-competition/

Tidal Energy Today
M3 Wave to Test NEXUS Next Week (Aug. 3, 2016)
http://tidalenergytoday.com/2016/08/03/m3-wave-to-test-nexus-next-week/

Tidal Energy Today
Video: Test tank for Wave Energy Prize finalists (Aug. 9, 2016)
http://tidalenergytoday.com/2016/08/09/video-test-tank-for-wave-energy-prize-finalists/

Tidal Energy Today
Video: M3 Wave tests wave energy device in MASK Basin (Aug. 16, 2016)
http://tidalenergytoday.com/2016/08/16/video-m3-wave-tests-wave-energy-device-in-mask-basin/

Salon.com
Is blue the new green? Wave power could revolutionize the renewable-energy game (Aug. 27, 2016)
http://www.salon.com/2016/08/27/is-blue-the-new-green-wave-power-could-revolutionize-the-renewable-energy-game/

Navy News Service
Carderock Supports Energy Innovation with Wave Energy Prize Tests (Aug. 29, 2016)
http://www.navy.mil/submit/display.asp?story_id=96431

OSTP Blog
Prizes Creating "Waves" in the Energy Sector (Aug. 31, 2016)
https://www.whitehouse.gov/blog/2016/08/31/prizes-creating-waves-energy-sector

Belfast Telegraph
Scheme gives Northern Ireland tech companies the chance to pitch directly to Prince Andrew (Sept. 6, 2016)
http://www.belfasttelegraph.co.uk/business/news/scheme-gives-northern-ireland-tech-companies-the-chance-to-pitch-directly-to-prince-andrew-35022835.html

Tidal Energy Today
Video: Ongoing Wave Energy Prize WECs testing (Sept. 9, 2016)
http://tidalenergytoday.com/2016/09/09/video-ongoing-wave-energy-prize-wecs-testing/

WUSA-9 (CBS affiliate)
Teams compete to find clean energy using the ocean's waves (Sept. 15, 2016)
http://www.wusa9.com/news/local/maryland/teams-compete-to-find-clean-energy-using-the-oceans-waves/319286887

Providence Journal
Providence energy developer's DUO device is a finalist for $1.5M award (Sept. 18, 2016)
http://www.providencejournal.com/news/20160918/providence-energy-developers-duo-device-is-finalist-for-15m-award

Tidal Energy Today
Wave energy testing at Carderock nears conclusion (Sept. 28, 2016)
http://tidalenergytoday.com/2016/09/28/wave-energy-testing-at-carderock-nears-conclusion/

PDQ@RWU
Architecture Student Collaborates on Wave Energy Project Competing for $1.5 Million (Oct. 5, 2016)
http://pdq.rwu.edu/news/architecture-student-collaborates-wave-energy-project-competing-15-million

Product Design & Development
Can Department of Energy Prize Encourage the Proliferation of Wave Energy Projects? (Oct. 12, 2016)
https://www.pddnet.com/news/2016/10/can-department-energy-prize-encourage-proliferation-wave-energy-projects

White House Blog
Advancing the Frontiers of Clean Energy Innovation (Oct. 13, 2016)
https://www.whitehouse.gov/blog/2016/10/12/advancing-frontiers-clean-energy-innovation

Eureka Alert!
Wave energy researchers dive deep to advance clean energy source (Oct. 13, 2016)
https://www.eurekalert.org/pub_releases/2016-10/ddoe-wer101316.php

AZO Cleantech
Sandia Engineers Try to Optimize Performance of Wave-Energy Converters (Oct. 14, 2016)
http://www.azocleantech.com/news.aspx?newsID=23758

Tidal Energy Today
White House Frontiers Conference welcomes wave energy (Oct. 20, 2016)
http://tidalenergytoday.com/2016/10/20/white-house-frontiers-conference-welcomes-wave-energy/

WRAL TechWire
Triangle startup Harvest Wave Energy draws White House attention (+ video) (Oct. 28, 2016)
http://wraltechwire.com/triangle-startup-harvest-wave-energy-draws-white-house-attention-video-/16170724/

Tidal Energy Today
Wave Energy Prize winner to be unveiled mid-November (Nov. 1, 2016)
http://tidalenergytoday.com/2016/11/01/wave-energy-prize-winner-to-be-unveiled-mid-november/

Portland Business Journal
Portland wave energy team snags a coveted $1.5M prize (Nov. 16, 2016)
http://www.bizjournals.com/portland/news/2016/11/16/portland-wave-energy-team-snags-a-coveted-1-5m.html

renews
AquaHarmonics wins wave prize (Nov. 16, 2016)
http://renews.biz/104946/aquaharmonics-scoops-us-wave-prize/

Voice of America
Team Wins $1.5 Million for Wave Energy Device (Nov. 17, 2016)
https://www.youtube.com/watch?v=mvFe1RXWKgU

Tidal Energy Today
AquaHarmonics scoops $1.5M US wave prize (Nov. 17, 2016)
http://tidalenergytoday.com/2016/11/17/aquaharmonics-scoops-1-5m-us-wave-prize/

Navy News Service
Carderock Division Hosts Wave Energy Prize Innovation Showcase (Nov. 17, 2016)
http://www.navy.mil/submit/display.asp?story_id=97733

UC Newsroom
CalWave rides Wave Energy Prize (Nov. 17, 2016)
https://www.universityofcalifornia.edu/news/uc-startup-rides-coveted-wave-energy-prize

HydroWorld
DOE names AquaHarmonics winner of US$1.5 million in Wave Energy Prize competition (Nov. 17, 2016)
http://www.hydroworld.com/articles/2016/11/doe-names-aquaharmonics-winner-of-us-1-5-million-in-wave-energy-prize-competition.html

Utility Dive
Wave energy developer AquaHarmonics wins DOE $1.5M prize (Nov. 17, 2016)
http://www.utilitydive.com/news/wave-energy-developer-aquaharmonics-wins-doe-15m-prize/430633/

Marine Technology News
Wave Energy Prize's $1.5 Million Winner Announced (Nov. 17, 2016)
http://www.marinetechnologynews.com/news/energy-prize-million-winner-541493

KATU-2 (Portland, OR)
Portland wave-energy company wins grand prize in USDOE competition (Nov. 17, 2016)
http://katu.com/news/local/portland-wave-energy-company-wins-1st-place-in-usdoe-prize

SeeNews Renewables
AquaHarmonics wins USD-1.5m wave energy grant from US DOE (Nov. 17, 2016)
https://renewables.seenews.com/news/aquaharmonics-wins-usd-1-5m-wave-energy-grant-from-us-doe-547346

Kallanish Energy
AquaHarmonics wins $1.5 million Wave Energy Prize (Nov. 18, 2016)
https://www.kallanishenergy.com/2016/11/18/aquaharmonics-wins-1-5-million-wave-energy-prize/

Clean Technica
Giant Floating Frisbee Wins $1.5 Million Wave Energy Grant From DOE (Nov. 18, 2016)
https://cleantechnica.com/2016/11/18/giant-floating-frisbee-wins-1-5-million-wave-energy-grant-doe/

The Maritime Executive
Over $2 Million for Wave Energy Winners (Nov. 18, 2016)
http://www.maritime-executive.com/article/over-2-million-for-wave-energy-winners

Tolerance.ca
Team Wins $1.5 Million for Wave Energy Device (Nov. 18, 2016)
http://www.tolerance.ca/ArticleExt.aspx?ID=332086&L=en

***KBND* (radio)**
Portland Company Wins Wave Energy Tech Grant (Nov. 18, 2016)
http://kbnd.com/kbnd-news/regional-news/280552

ExecutiveBiz
AquaHarmonics Wins DOE Wave Energy Converter Devt Competition (Nov. 21, 2016)
http://blog.executivebiz.com/2016/11/aquaharmonics-wins-doe-wave-energy-converter-devt-competition/

Portland Business Journal
The breakthrough that won the $1.5M Wave Energy Prize for Portland's AquaHarmonics (Nov. 22, 2016)
http://www.bizjournals.com/portland/news/2016/11/22/the-breakthrough-that-won-the-1-5m-wave-energy.html

Daily Energy Insider
Energy Department awards AquaHarmonics Wave Energy Prize (Nov. 22, 2016)
https://dailyenergyinsider.com/industry/2339-energy-department-awards-aquaharmonics-wave-energy-prize/

Planetsave
Wave Energy Converter Prize is Awarded to AquaHarmonics (Nov. 23, 2016)
http://planetsave.com/2016/11/23/wave-energy-converter-technology-development-prize-awarded-aquahamonics/

ENGINEERING.com
Two Guys in a Garage Win $1.5M Wave Energy Prize (Nov. 27, 2016)
http://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/13782/Two-Guys-in-a-Garage-Win-15M-Wave-Energy-Prize.aspx

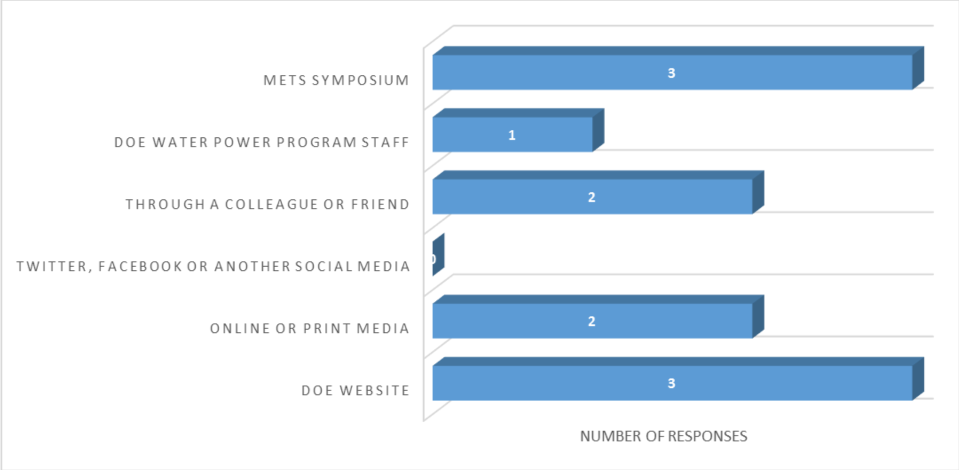
E&E News
2016 — the end or beginning of an era for marine energy? (Nov. 28, 2016)
http://www.eenews.net/stories/1060046254

Interesting Engineering
Garage Project Garners $1.5 Million Energy Award (Nov. 29, 2016)
http://interestingengineering.com/garage-project-garners-1-5-million-award/

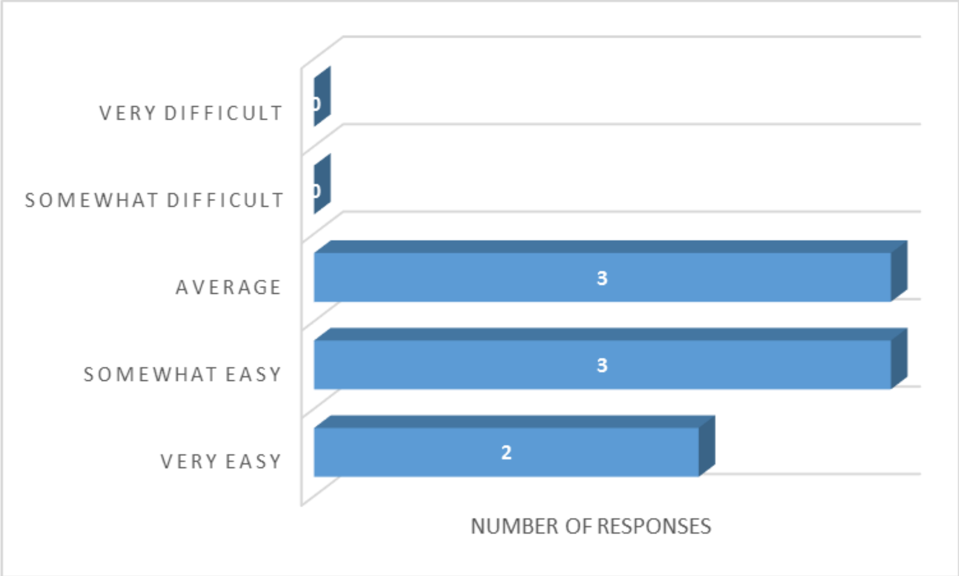
Energy Harvesting Journal
AquaHarmonics wins wave energy prize (Nov. 30, 2016)
http://www.energyharvestingjournal.com/articles/10286/aquaharmonics-wins-wave-energy-prize

12.4 Appendix 4 – Wave Energy Prize Finalist Closeout Interview Results

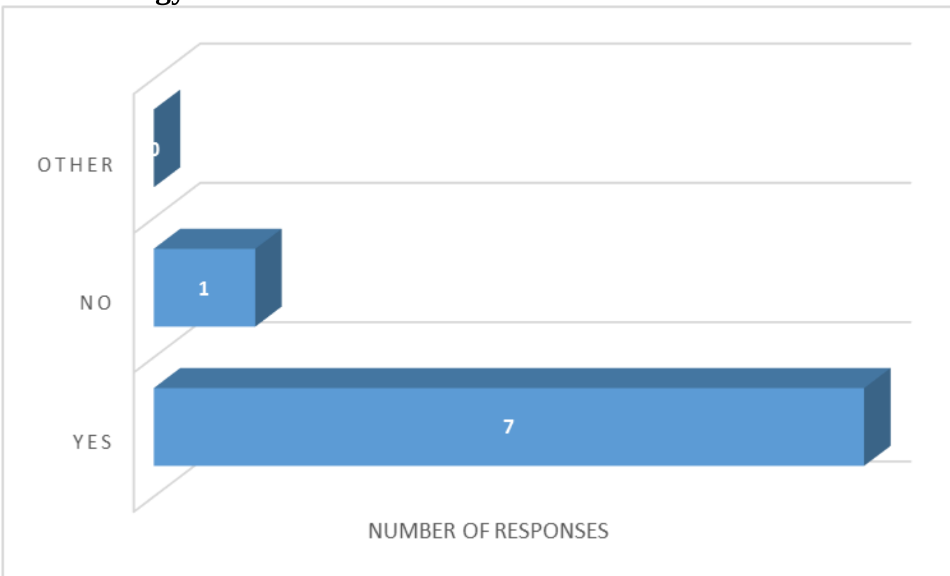
1. **How did you learn about the Wave Energy Prize? Please select all that apply.**



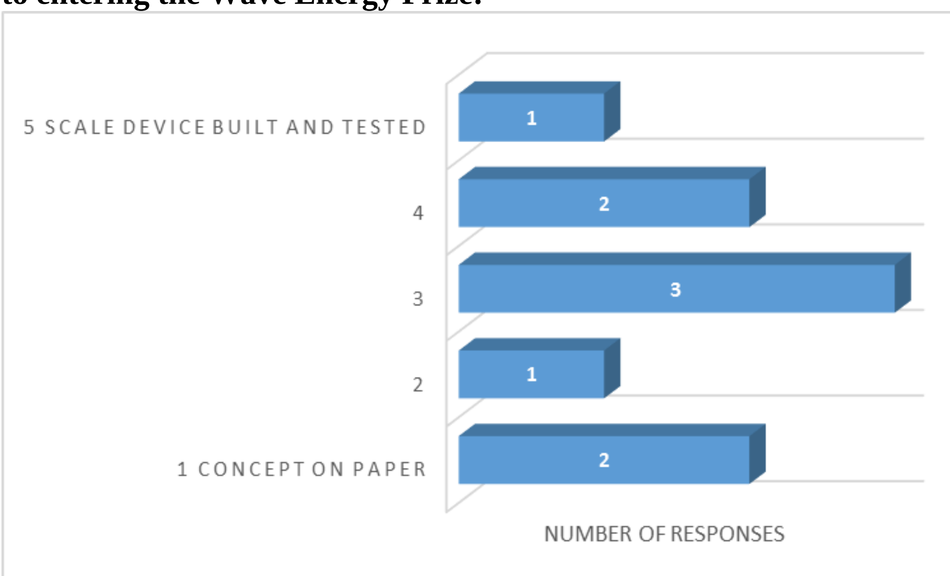
2. **How would you rate the process to register for the Wave Energy Prize?**



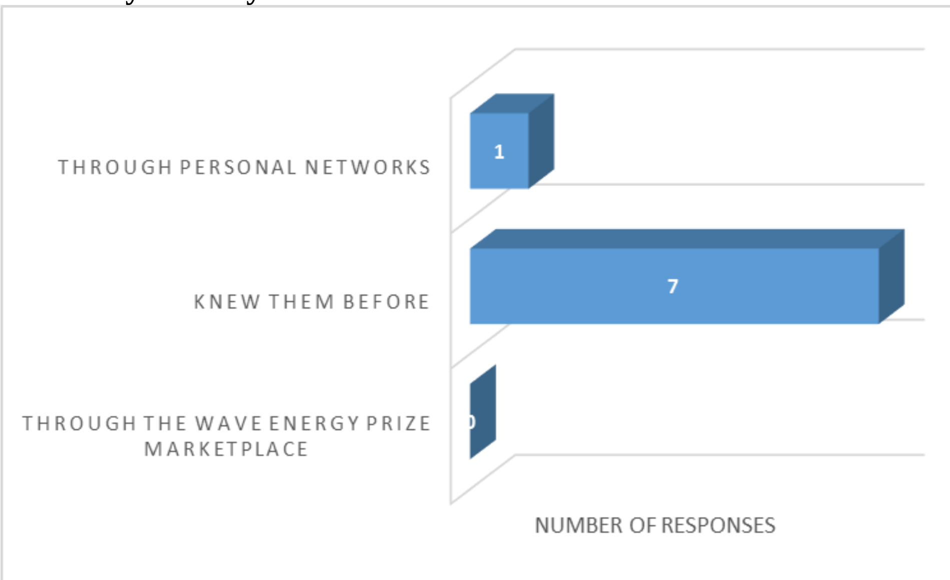
3. **Were you actively participating in a project to develop a new WEC at the time the Wave Energy Prize was announced?**



4. **On a scale of 1-5, with 1 being low (concept on paper) and 5 being high (scale device built and tested), rate the level of development of your WEC concept prior to entering the Wave Energy Prize:**



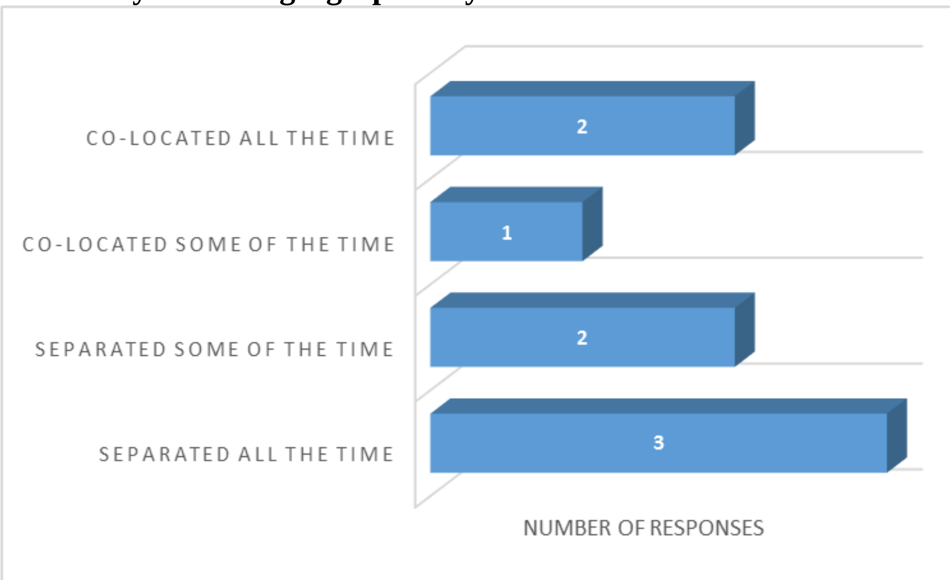
5. **How did you find your team/teammates?**



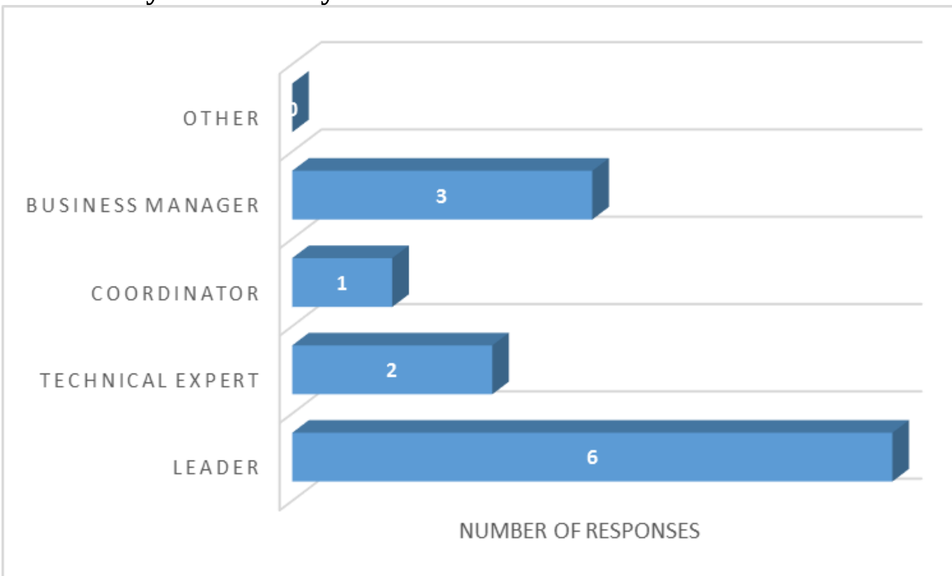
6. **Which technical skills were needed at start of competition? Did this change along the way? List the technical specialties of your team members, and describe how your team grew during the Prize.**

   Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

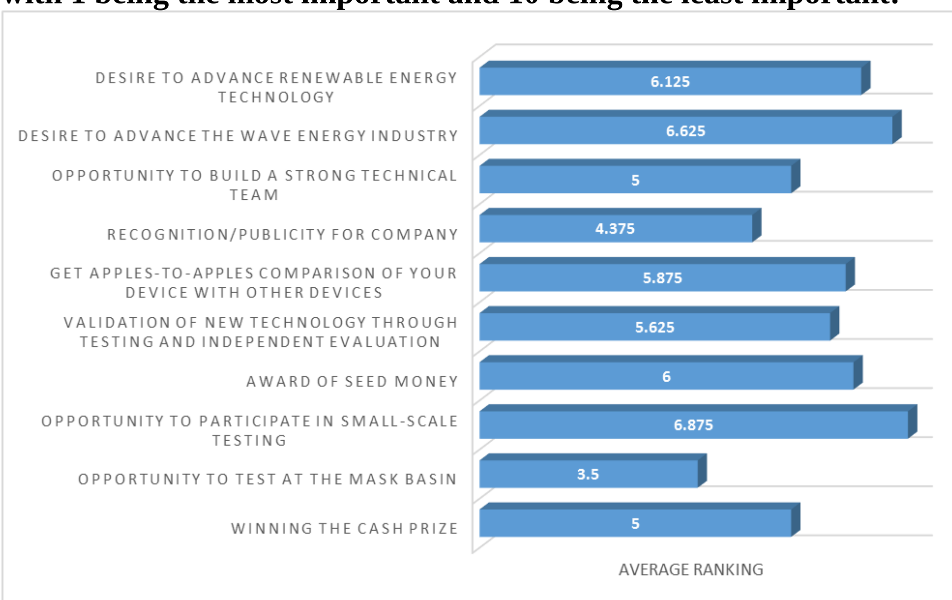
7. **How was your team geographically co-located or distributed?**



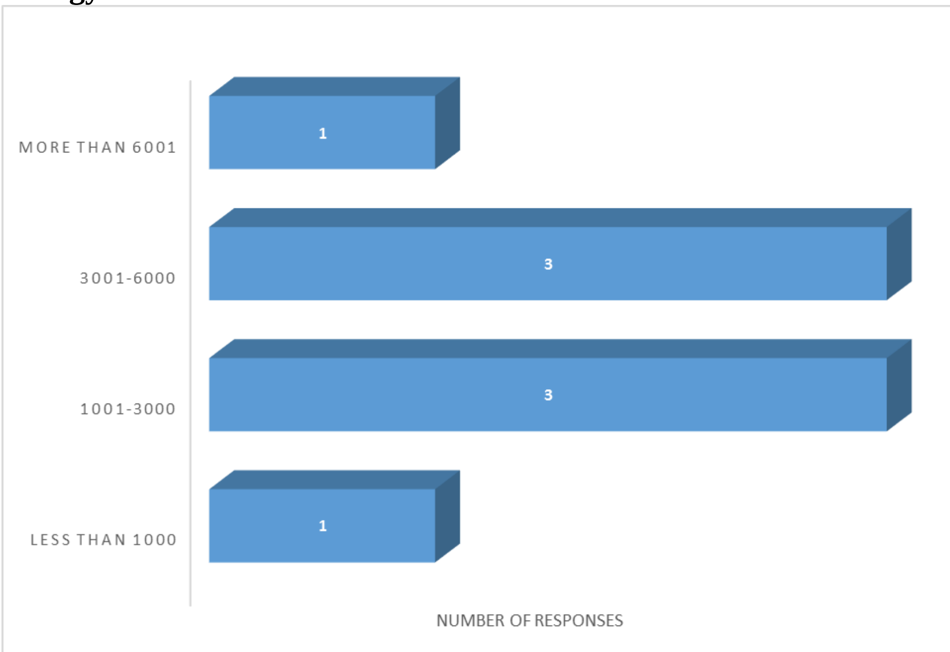
8. What was your role on your team?



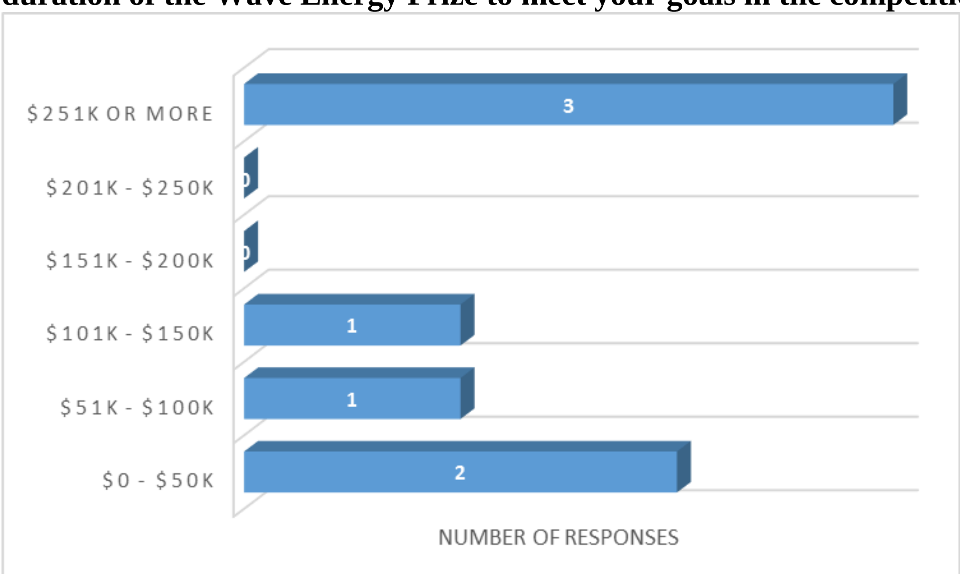
9. Rank the following reasons for your participation in the Wave Energy Prize, with 1 being the most important and 10 being the least important:



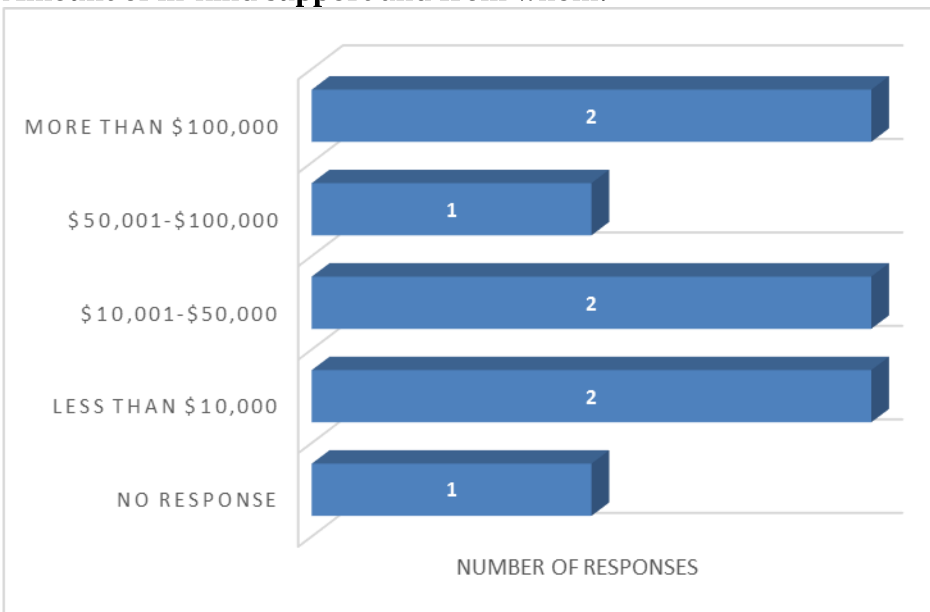
10. In total, how many hours of work (including team meetings, discussion, emails, design work, testing, etc.) would you estimate your team spent on the Wave Energy Prize?



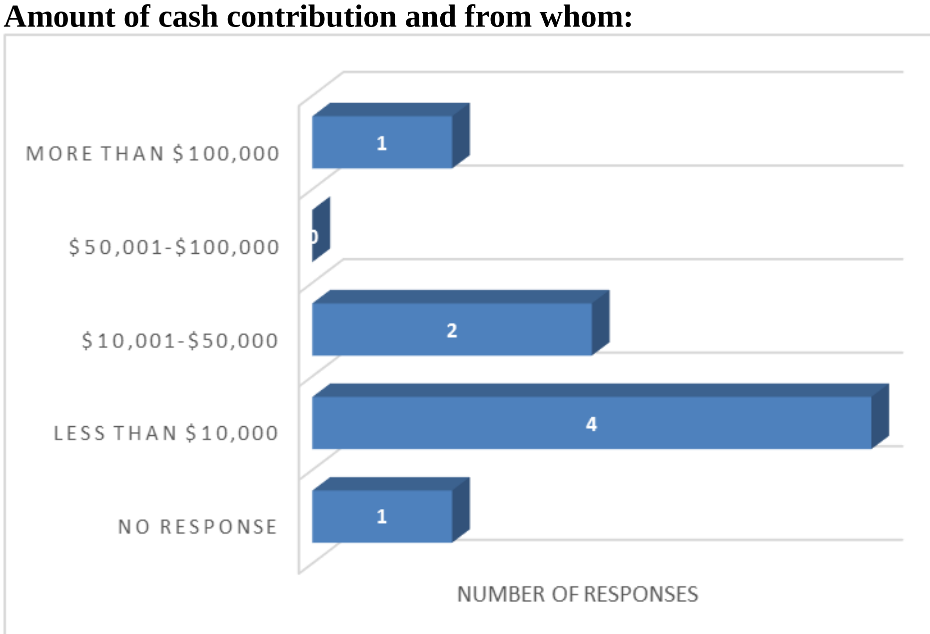
11. Above and beyond the seed funding provided by DOE, about how much investment was spent to design, develop, build and test your concept over the duration of the Wave Energy Prize to meet your goals in the competition?



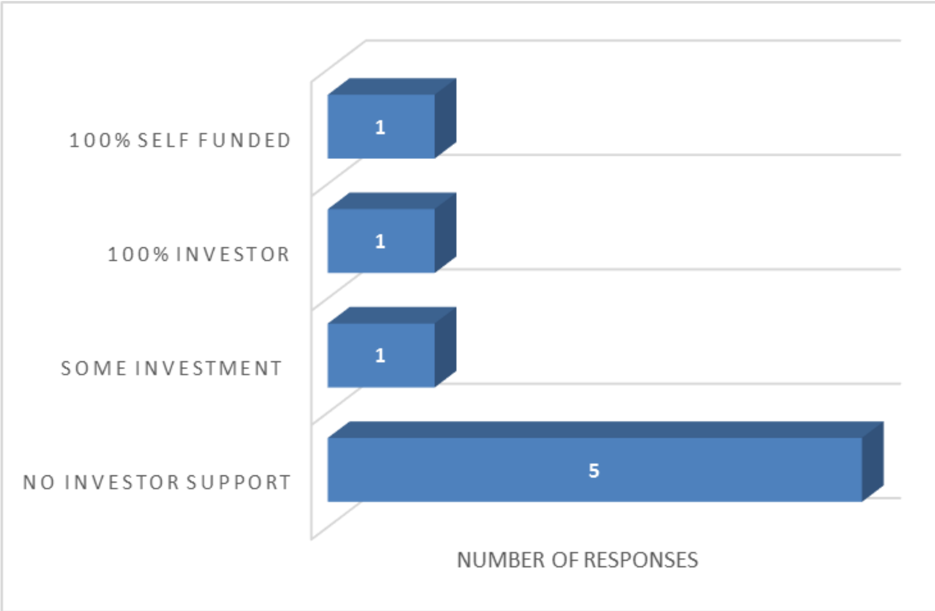
12. Amount of in-kind support and from whom:



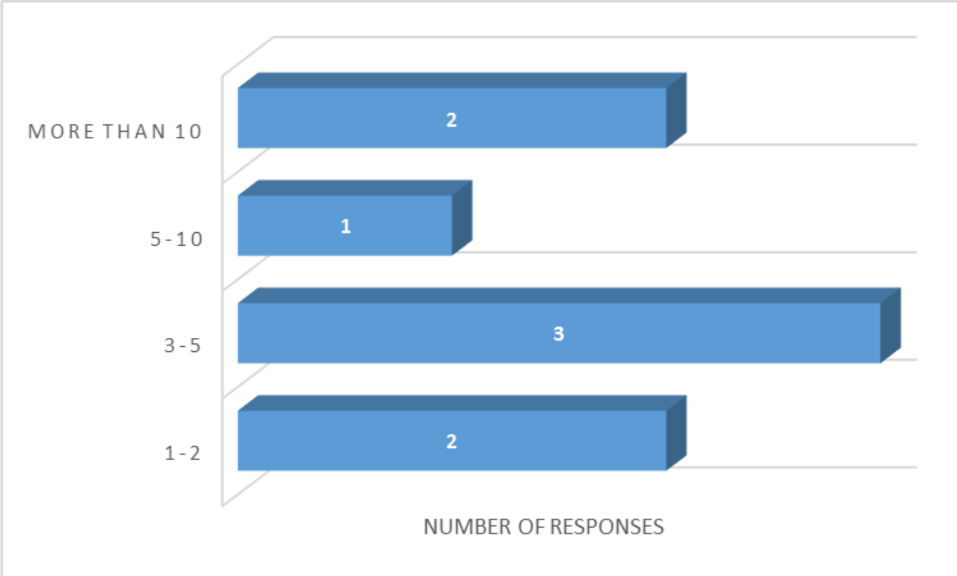
13. Amount of cash contribution and from whom:



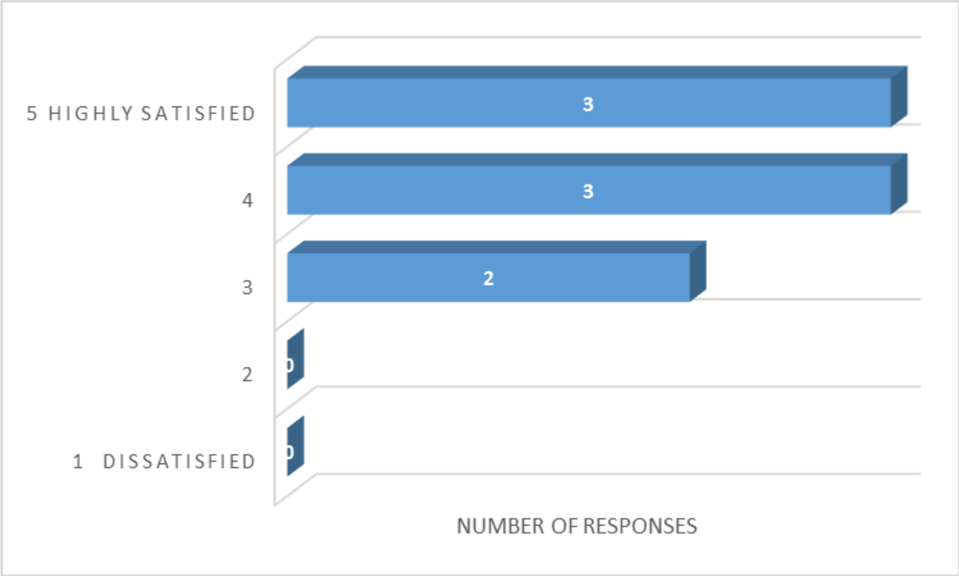
14. Amount of investor contribution and from whom:



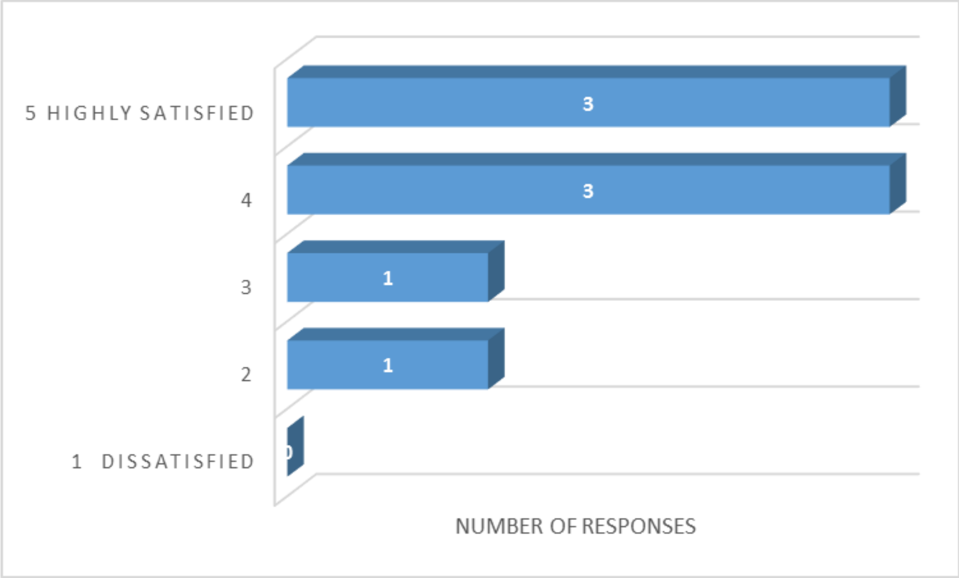
15. How many different design concepts or configurations did your team explore before the final submission? (A change in a concept or configuration would be something that would trigger, for example, the need to run a numerical model on the configuration, or the need to rebuild a key component of your device.)



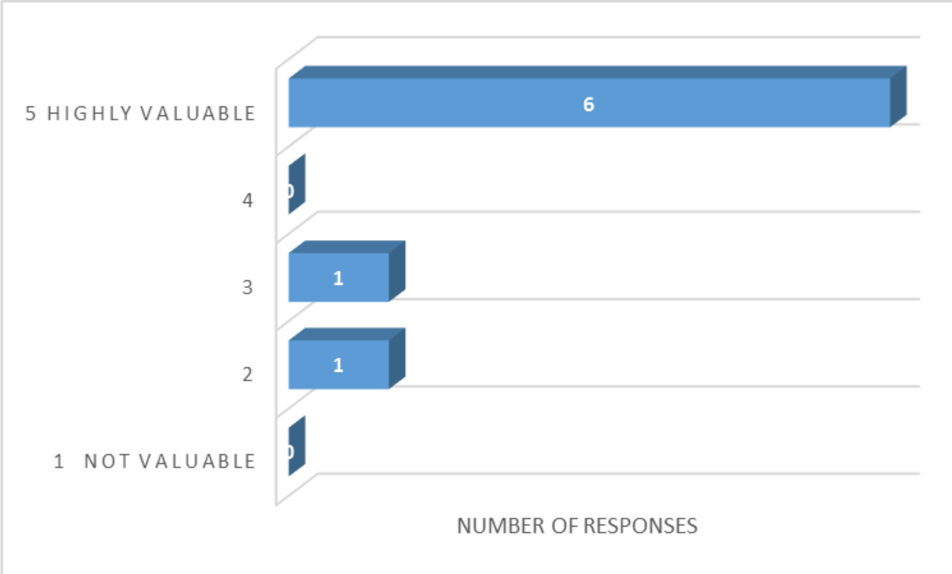
16. Please rate your experience, with 1 being dissatisfied and 5 being highly satisfied, with small-scale testing (and if you are willing to share, name your small-scale testing facility in the comments section):



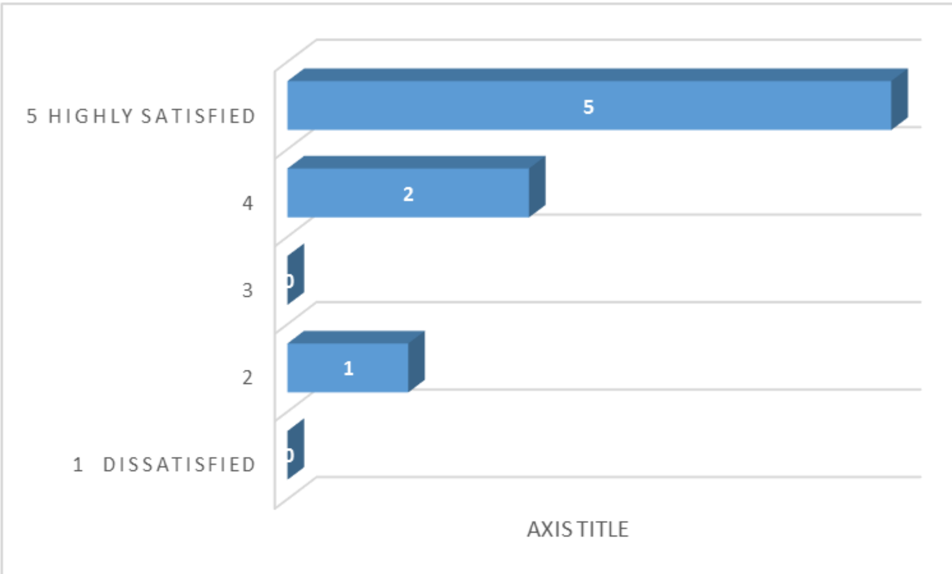
17. Please rate your experience, with 1 being dissatisfied and 5 being highly satisfied, with testing at the MASK Basin:



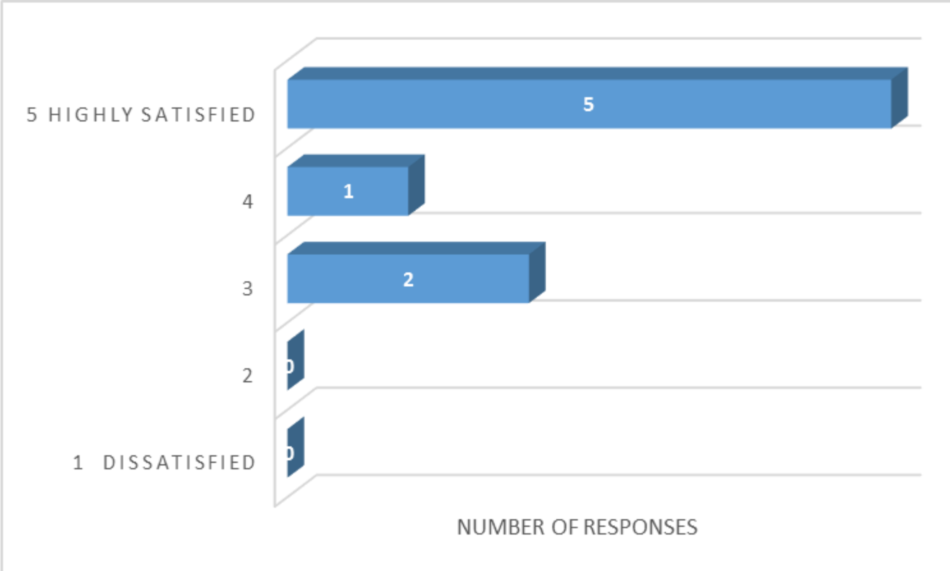
18. How valuable do you see the data that was gathered during testing at the MASK Basin, with 1 being not valuable at all and 5 being highly valuable?



19. Please rate your experience with the overall administration of the Wave Energy Prize.



20. How satisfied were you with the support you received via email, team website, and phone calls/conferences/webinars throughout the Wave Energy Prize?



21. Please describe your overall experience in the Wave Energy Prize.

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

22. Please describe your next steps regarding the development of your WEC technology. In what areas do you believe you need additional support? What are the roadblocks you believe you will encounter in the next phase of development?

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

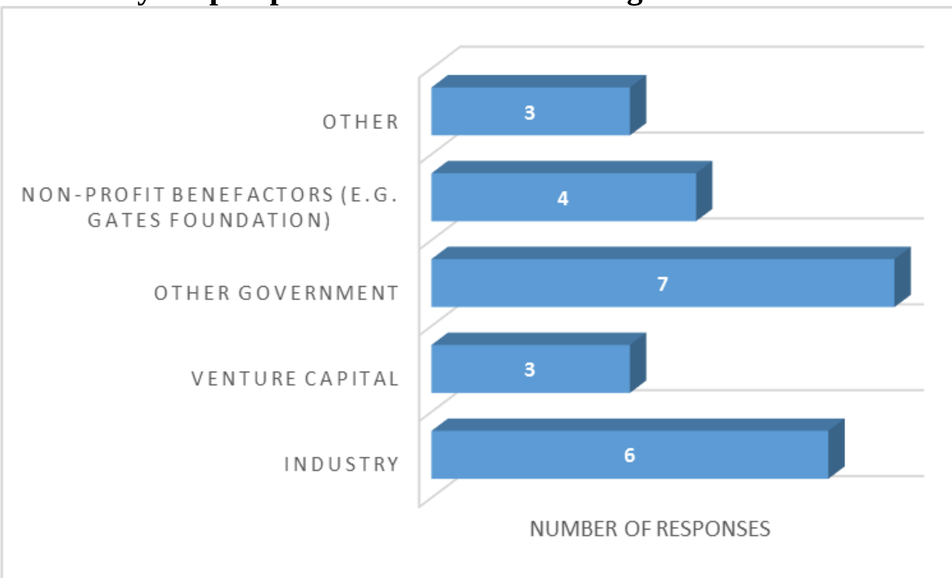
23. How did you leverage emerging technologies-like 3D printing, big data processing, cloud computing, etc.-or technical areas in designing, building, or testing your device?

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

24. **How did the Prize metrics help your technological development? How will they help future innovation for your device and the wave energy industry?**

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

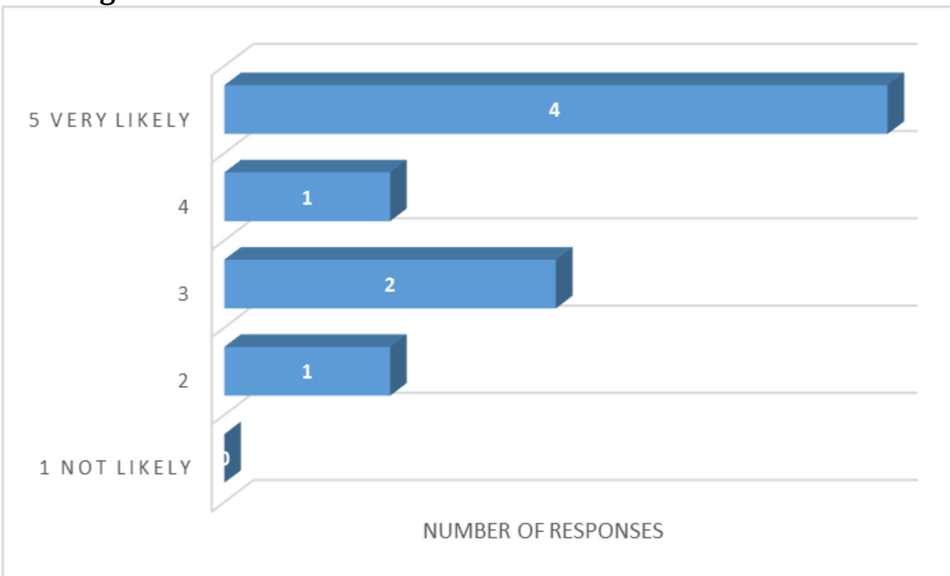
25. **What are your prospects for non-DOE funding?**



26. **What are your plans for disseminating/publishing the results of your participation in the Wave Energy Prize to enable follow-on innovators to build on your ideas?**

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.

27. How likely would you be to participate in potential future DOE prizes or challenges?



28. Any other comments?:

Because teams were not notified when providing responses that data would be released publically, and comments are not able to be anonymized/aggregated, no interview response data to this question is available.