Wave Energy Prize Rules

4.25.16 R3

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:

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

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:

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

	• 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**	

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
- 3nd 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**.

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

- 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:

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

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).

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														
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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

- 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:

- 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.

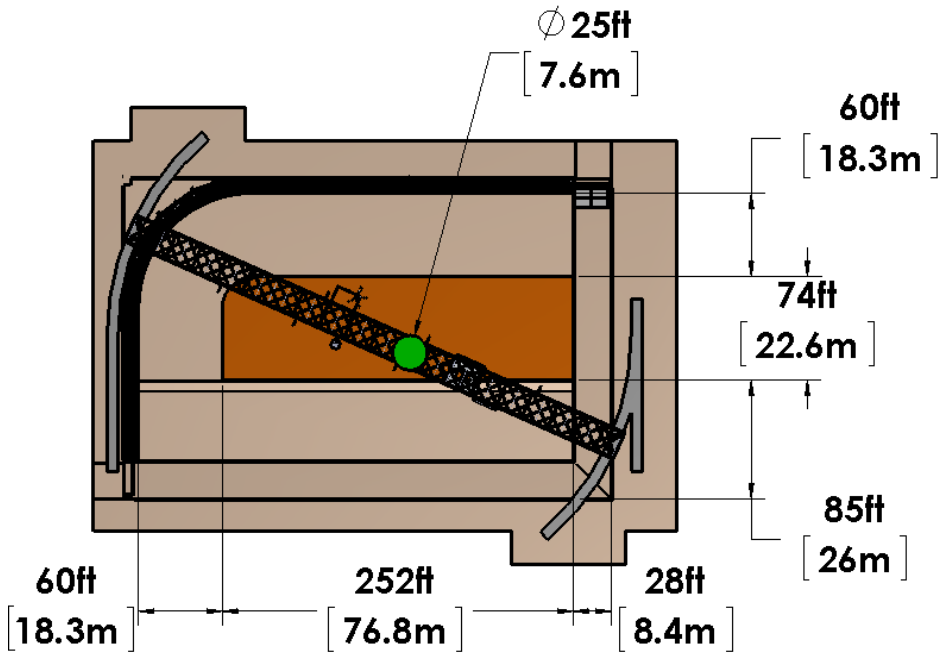


Figure F1 – Representative Test Area

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.

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.

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, $\langle C_p(j) \rangle$.

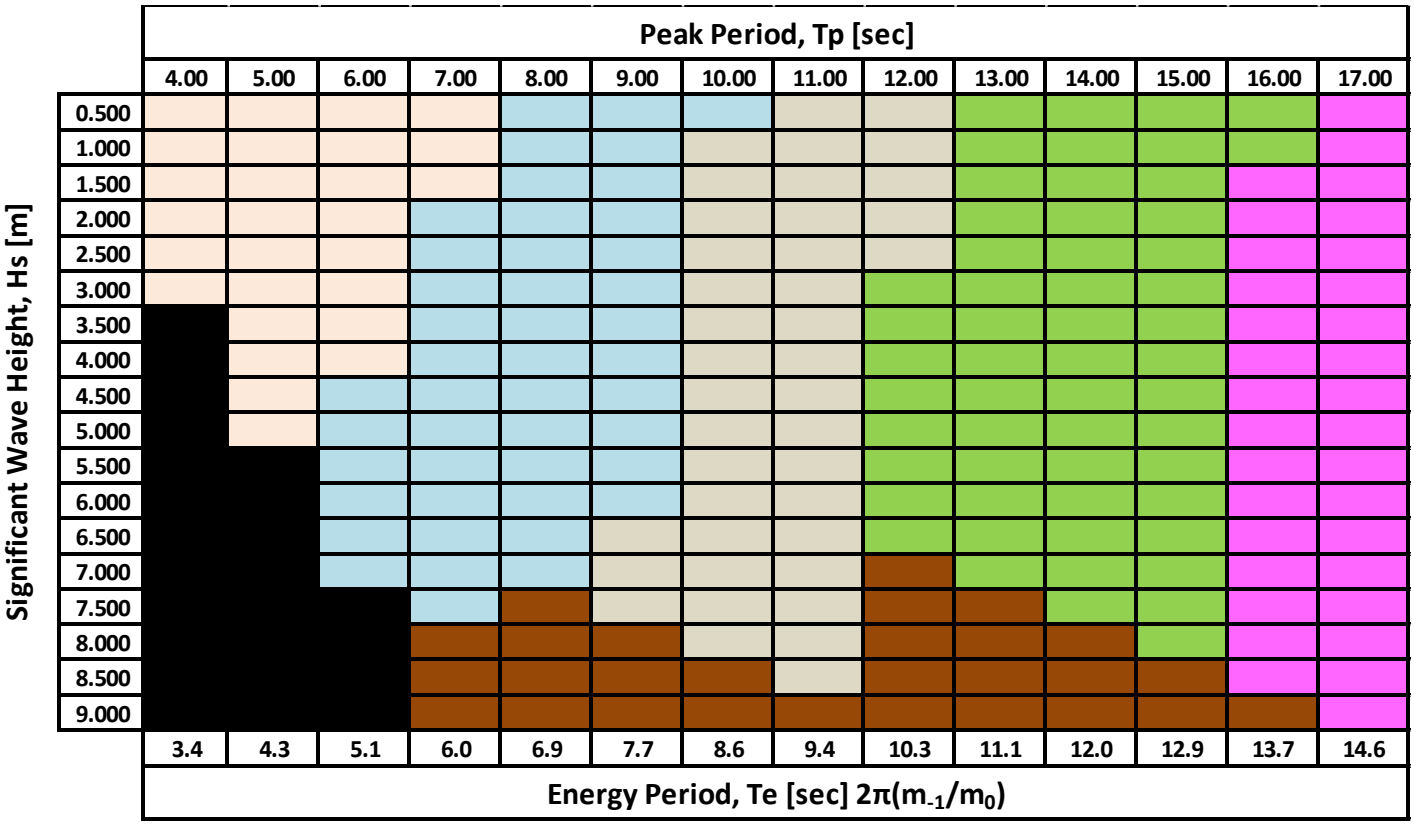


Figure I1 - JPD

Average absorbed power, $\langle AP(i)\rangle$, is measured for each of the 6 irregular wave spectra ($i = 1, 2, \dots, 6$) 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 ($j = 1, 2, \dots, 7$) 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, $\langle C_p(j)\rangle$:

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

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,

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

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.

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

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]	$MF_{HPQ} = ACMF \cdot 20\% + \left(\frac{\sum_{i=1}^{2_{LIWS}} MF(i)}{2}\right) \cdot 60\% + \left(\frac{\sum_{i=1}^{2_{RWS}} MF(i)}{2}\right) \cdot 20\%$
Watch Circle WC_{HPQ}	Measurable	[0.96, 0.98, 1.0, 1.02, 1.04]	$WC_{HPQ} = ACWC \cdot 20\% + \left(\frac{\sum_{i=1}^{2_{LIWS}} WC(i)}{2}\right) \cdot 60\% + \left(\frac{\sum_{i=1}^{2_{RWS}} WC(i)}{2}\right) \cdot 20\%$

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

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.

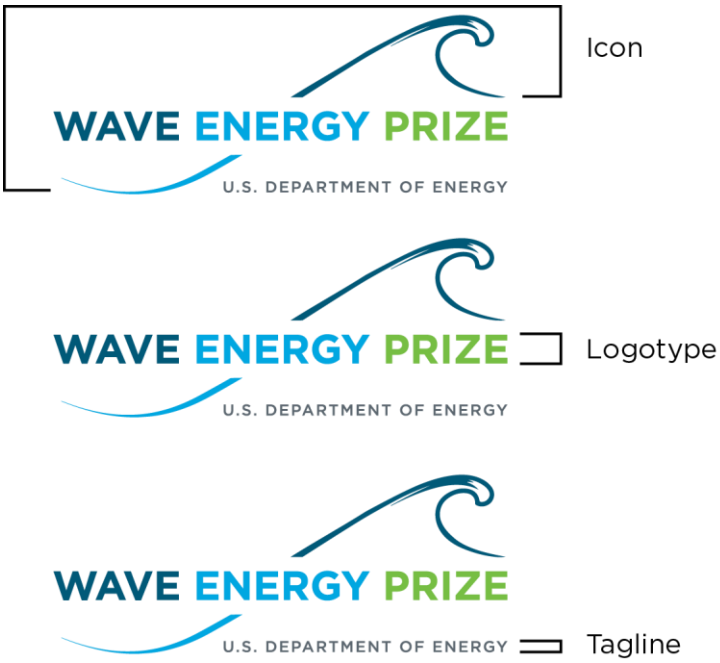
Wave Energy Prize Naming Convention

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

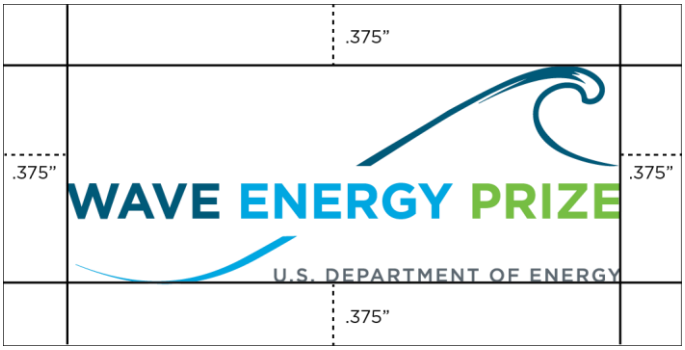
Pantone 2995
4-color process build:
C = 80, M = 12, Y = 1
K = 0

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

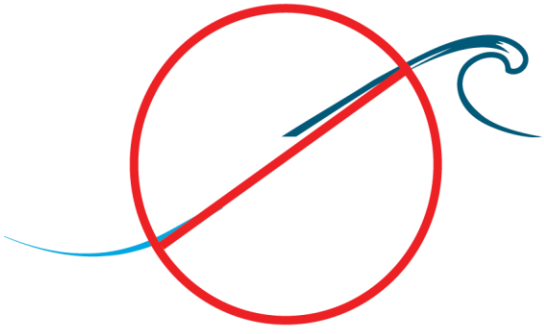
Gotham Medium is the suggested typeface for the DOE tagline with a kerning at 85pt.

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.