# WAVE ENERGY PRIZE

## Frequently Asked Questions

### Q1: What is wave energy?

A1: Wave energy is one form of marine renewable energy. Wave energy converts the energy in highly predictable ocean waves into electricity using a range of different technologies. Wave energy conversion (WEC) devices are in the early stages of technological development, and there are currently hundreds of potentially viable technologies in this emerging industry as researchers and developers seek to prove their technologies' viability.

### Q2: How much potential does wave energy have as a viable alternative energy source in the United States?

A2: With more than 50 percent of the U.S. population living within 50 miles of coastlines, there is vast potential to provide clean, renewable electricity to communities and cities across the United States using wave energy. It is estimated that the technically recoverable wave energy resource is estimated to range between 898-1,229 terawatt hours (TWh) per year, distributed across Alaska, the West Coast, the East Coast, the Gulf of Mexico, Hawaii, and Puerto Rico. Developing just a small fraction of the available wave energy resource could allow for millions of American homes to be powered with this clean, reliable form of energy. For context, approximately 90,000 homes could be powered by 1 TWh per year. Extracting just 5% of the technical resource potential in the United States could result in wave energy powering five million American homes.

### Q3: Are there examples of wave energy systems in use in other parts of the world?

A3: The Marine and Hydrokinetic Technology Database on the Open Energy Information (OpenEI) website (openei.org) provides information on wave energy projects, both in the United States and around the world. You can also find information on wave energy systems in other parts of the world in the International Energy Agency's Ocean Energy Systems annual report. Each year, the Energy Department (DOE) and several other countries contributes to the report which provides an overview of worldwide ocean energy developments.

### Q4: What are the challenges to developing wave energy resources, and how will the Wave Energy Prize help solve some of the problems?

A4: One challenge is that wave energy devices are not yet cost competitive with other means of generating electricity. Thus, DOE sees an important opportunity in reducing the cost of wave energy so it can contribute to the nation's clean energy supply. The Wave Energy Prize is one way to encourage the development of more efficient WEC devices, which in turn will reduce the cost of wave energy and make it competitive with traditional energy solutions.

## Q5: Why did DOE decide to do a prize challenge focused on wave energy?

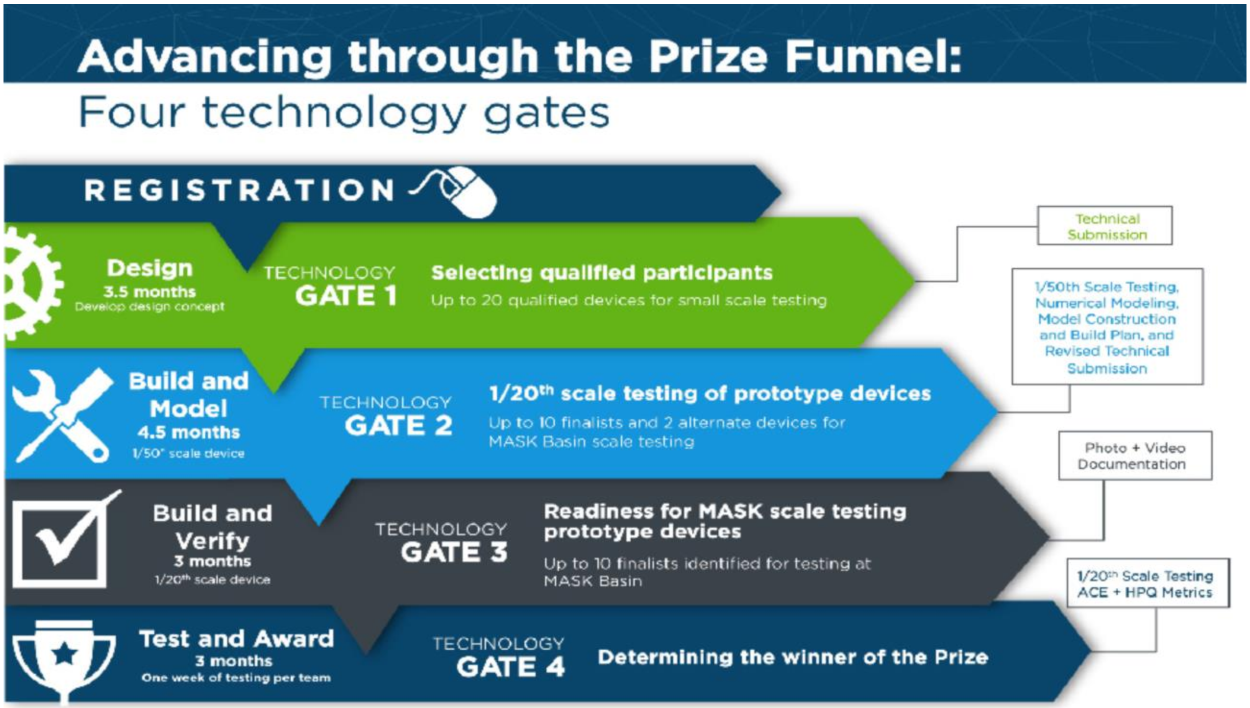
A5: Wave energy offers a substantial resource to deliver renewable energy to the United States. The wave energy sector is in its early stages of development, and the diversity of the technologies makes it hard to evaluate the most technically and economically viable solutions. DOE sought to use a prize competition to help dramatically improve the performance of WEC devices, providing a pathway to game-changing reductions in the cost of wave energy. Prize competitions set a high technical bar for participants to be eligible, facilitating rapid advancements in technical innovations at a relatively low cost to the sponsoring agency. The Wave Energy Prize aims to attract next generation ideas by offering a prize purse and providing an opportunity for testing at the nation's most advanced wave-making facility, the Naval Surface Warfare Center Carderock's Maneuvering and Seakeeping (MASK) Basin in Maryland.

## Q6: What is the prize timeline– how long will it last, when did it kick off, etc.?

A6: The Wave Energy Prize is a 20-month design-build-test competition. Ninety-two teams registered for the Prize beginning in April 2015. Of these, 66 submitted technical submissions and 20 were named official Qualified Teams in August 2015. The Qualified Teams revised their technical submissions, completed numerical modeling, participated in small-scale testing and drafted a Model Design and Construction Plan, all of which were reviewed by a panel of judges to identify the finalists. Nine official Finalist teams and two Alternates were announced on March 1, 2016. All nine Finalists passed through Technology Gate 3 and will test their 1/20$^{th}$ scale prototypes at the MASK Basin beginning in August 2016. Winner(s) will be announced in November 2016. A complete list of prize phases can be found on the Wave Energy Prize website.

## Q7: What steps are required of Prize participants?

A7: Participants in the Wave Energy Prize will design, build, numerically model, and test prototypes of a WEC device at the 1/50$^{th}$ and 1/20$^{th}$ scales. Prototypes should at least double the state of the art performance based on energy capture and cost of current WEC devices.




## Q8: What types of participants do you anticipate being drawn to the prize?

A8: DOE envisioned a diverse group of Wave Energy Prize competitors, including corporations, small businesses, professional engineers, students, and entrepreneurs. It is open to all U.S. entities, which include U.S. persons and companies as well as foreign companies that are incorporated in and maintain a primary place of business in the United States.

## Q9: What does a successful team look like?

A9: Successful teams will require skills in mechanical engineering, structural engineering and finite element analysis, computational fluid dynamics for numerical wave modeling, electrical engineering and controls, and systems-level optimization.

## Q10: Why did DOE choose to test wave climates typically found off the West Coast of the United States?

A10: For large-scale commercial harnessing of wave power, it is best to have a good wave climate in deep water located close to shore and close to markets with a large demand for power. The West Coast of the United States fits all of these conditions. Furthermore, there exist long-term wave climate data sets for deep water environments off the West Coast, which provide a detailed understanding of average annual wave climates and wave directionality necessary for the rigorous testing program to be employed in the Wave Energy Prize. While the performance of the WEC devices off the West Coast is of primary importance, results of device performance from the sea states reproduced at the MASK Basin may be used to determine device performance in locations with early market opportunities, such as Hawaii and Alaska.

## Q11: Do the rules and criteria for this competition eliminate certain types of devices?

A11: 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 17-39 kilowatt (kW) per meter. 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.

## Q12: The test metric is Average Climate Capture Width per Characteristic Capital Expenditure, or ACE. What is that and why is it being used?

A12: The ACE metric has been selected by the Wave Energy Prize as a reduced content metric appropriate for comparing low Technology Readiness Level WEC concepts when there is insufficient or unreliable data to enable an actual calculation of the levelized cost of energy (LCOE). It has been determined that the total surface area adjusted for material cost tracks most closely to capital cost, which is the most important LCOE driver for WEC devices today, along with annual energy production (AEP). The two components that comprise the ACE ratio are defined as follows:

- **Average Climate Capture Width** = This is the numerator of ACE. It is the absorbed power of the device in kW divided by the wave energy flux per meter crest width in kW/m. Thus, a device with a higher capture width absorbs 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** = This is the denominator of ACE. Total Surface Area s($m^2$) x Representative Structural Thickness (m) x Density of Material(s) ($kgm^{-3}$) x Cost of Manufactured Material per unit Mass ($\$kg^{-1}$)

## Q13: Why is the goal to double the energy captured from ocean waves?

A13: DOE believes that the doubling ACE is an aggressive yet necessary (and achievable) target to meet for long term LCOE reduction. If a device or devices developed during the Wave Energy Prize were to meet or exceed this goal, it would represent a ground-breaking advancement over current devices. If further developed through other opportunities for innovation (in aspects not targeted in the Prize, like operations and maintenance) and learning, and real-world experience, these devices could produce the kind of radical technology leap required to deliver cost-competitive wave power.

Leveraging results from DOE's MHK Reference Model Project, the Wave Energy Prize has determined that the value ACE on average for today's state-of-the-art technologies is 1.5 meters per million dollars (m/$M), in typical deep water locations off the West Coast of the United States.

To achieve the ambitious goal established by DOE and promote the necessary revolutionary advancements in WEC technologies, an ACE threshold value of 3m/$M has been established and will be used to determine key decisions during the Wave Energy Prize's final Technology Gate. At the final gate, testing at 1/20$^{th}$ scale, WECs must achieve this threshold to be eligible to win a monetary prize.

## Q14: What kinds of devices will participants actually have to submit to win the Prize? What will be measured in testing?

A14: Participants will design, build, numerically model, and test 1/50th and 1/20th scale devices in different stages of the Prize. It is important to note that the actual electricity production from the devices will not be measured in the Prize. This is because WEC power take off and generator systems cannot be adequately scaled down to the 1/50th and 1/20th scales. Instead, dynamic and kinematic sides of absorbed power—as a proxy for electricity generation—of the WEC devices will be measured. The exact measurements of the kinematic and dynamic sides will vary based on device type (maybe force and velocity, or pressure and flow, etc.) however they will need to be measured at each absorption point. All measurements in the MASK Basin are specified in Appendix F.

## Q15: How much will the winner of the Wave Energy Prize receive in terms of the cash prize?

A15: Prize purses available to the winner(s) of the Wave Energy Prize will be:

- Grand Prize Winner: Team ranked the highest after testing of the 1/20$^{th}$ scale WEC device model at the Carderock MASK Basin - $1,500,000

- 2$^{nd}$ Place Finisher: Team ranked second after testing of the 1/20$^{th}$ scale WEC device model at the Carderock MASK Basin - $500,000

- 3$^{rd}$ Place Finisher: Team ranked third after testing of the 1/20$^{th}$ scale WEC device model at the Carderock MASK Basin - $250,000

To be eligible to win a monetary prize purse, a team's 1/20$^{th}$ scale device must surpass the ACE threshold of 3m/$M. The judging panel will rank all teams whose devices achieve th threshold and assess their overall performance using the Hydrodynamic Performance Quality (HPQ), a holistic measure to evaluate the reliability of devices.

## Q16: Will the Wave Energy Prize provide funding for teams to develop their WEC concepts?

A16: The Wave Energy Prize provided seed funding (financial support) to the Finalists (up to $125,000) and Alternates (up to $25,000). This seed funding was provided for costs associated with 1) the build of the 1/20$^{th}$ scale models, 2) the shipment of the 1/20$^{th}$ scale models, and 3) travel for participating in the testing process.

## Q17: In the rules, multiple Technology Gates are mentioned. What is a Technology Gate and what is the purpose?

A17: 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) distinct 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)

### Q18: Why did DOE decide to focus this prize on deep water devices?

A18: Driving down the cost of harnessing wave energy and deploying wave energy technologies at a large commercial scale and requires proximity to close-to-shore markets as well as high wave energy resources. Further, the rigorous testing program of the Wave Energy Prize that targets this cost reduction requires a detailed understanding of average annual wave climates and wave directionality. The West Coast of the United States not only has the right market size and wave energy resource, but DOE has long-term wave climate data sets for deep water environments off the West Coast necessary for the Prize testing program.

### Q19: What stage of the prize are the teams at now?

A19: The Wave Energy Prize has passed through the third of four Technology Gates, and the official Finalist Teams are now preparing for Technology Gate 4.

### Q20: What has DOE observed so far about the teams and their technologies?

A20: So far, the Wave Energy Prize is demonstrating early successes as a number of the teams are proposing truly innovative technologies and several have demonstrated a potential to achieve the ACE threshold and thus exceed DOE's stated program goal. The innovations being proposed are in geometry and shape, material, energy absorption and conversion capabilities, and, importantly, control systems. Further, the official Finalist Teams demonstrate great diversity. Of the teams moving forward in the competition, we have teams representing existing wave energy developers, start-ups, and universities. The common thread is their willingness to think outside the box and their dedication to the idea of bringing viable WEC technologies to the clean energy mix.

### Q21: How many teams registered for the Prize? How many are still in the running?

A21: Of the 92 teams that registered for the Wave Energy Prize, 66 submitted the technical submissions required to pass Technology Gate 1. Of these 66, the Wave Energy Prize judges identified 20 teams to continue in the competition as official Qualified Teams. After the announcement of the Qualified Teams, three teams withdrew from the competition. The Wave Energy Prize judges evaluated the remaining 17 submissions at Technology Gate 2 and identified nine Finalists and two Alternates to proceed to

Technology Gate 3. The nine Finalist Teams all proceeded through the third technology gate and will be testing their 1/20th scale WEC prototypes at the MASK Basin beginning in August 2016.

### Q22: What are the remaining teams doing now?

A22: The nine official Finalist Teams are preparing for Technology Gate 4, which will begin in August 2016.

### Q23: Where did the small-scale tank testing occur?

A23: The Wave Energy Prize judges assigned each Qualified Team a small-scale tank facility for 1/50th scale testing based on which facility would be the best fit for each team's proposed technology. Small-scale devices were tested in wave tanks at Oregon State University, Stevens Institute of Technology, the University of Iowa, the University of Maine, and the University of Michigan.

### Q24: What is Hydrodynamic Performance Quality (HPQ)?

A24: It is on the basis of HPQ that the teams will be ranked in the final round of testing. ACE forms the basis of HPQ. Determining ACE requires knowledge of the power absorbed by the WEC in a West Coast deployment climate and the Characteristic Capital Expenditure needed to build the WEC. Much more can be learned about a device's overall performance by monitoring other aspects of the WEC's performance—such as the degree of its motion and processing the testing data—to understand not just a WEC's average performance, but also its responses to infrequent events. Six hydrodynamic performance-related quantities will be determined through data processing for each device tested in the MASK Basin:

- One that measures the area swept by the device in its motions;
- One that examines the maximum loads on the device's mooring;
- One that measures the fluctuations in the devices absorbed power;
- One that counts impact events;
- One that quantifies the device's absorbed power in realistic seas; and,
- One that examines the amount of energy used by the device for controls.

Each of these quantities will be allocated to a factor and the HPQ of a device will be established by multiplying the ACE metric with the factors allocated to each quantity. For more details on HPQ and how it is calculated, please see the Prize Rules.

### Q25: What are Characteristic Capital Expenditure (CCE) and Representative Structural Thickness (RST)?

A25: The ACE metric is a proxy for LCOE, the denominator of which—CCE— corresponds to a cost metric of the WEC. It is calculated as shown below:

**Characteristic Capital Expenditure (CCE)** = Total Surface Area ($m^2$) x Representative Structural Thickness (m) x Density of Material(s) ($kg/m^3$) x Cost of Manufactured Material per unit Mass ($/kg) for all applicable materials.

RST is the thickness of relevant load-bearing materials used to determine the total structural mass when multiplied by the surface area of each material. The RST can be visualized as a single uniform thickness obtained by melting down all of the structural components of a WEC then “casting” the shape of the WEC with a constant wall thickness.