InDEEP

Innovating Distributed Embedded Energy Prize

OFFICIAL RULES

October 2023: Phase II

Innovating Distributed Embedded Energy Prize (InDEEP)

Leveraging innovation methods to de-risk distributed embedded energy converters and their metamaterials for renewable wave energy technologies.

Official Rules Document

October 2023

Preface

The U.S. Department of Energy's Prize Title will be governed by 15 U.S.C. §3719 and this Official Rules document. This is not a procurement under the Federal Acquisitions Regulations and will not result in a grant or cooperative agreement under 2 CFR 200. The Prize Administrator reserves the right to modify this Official Rules document if necessary and will publicly post any such notifications as well as notify registered prize participants.

Date	Modification
3/21/2024	Changes to the Competitors Support section 3. Revision of Leaderboard scoring criteria for clarity.

List of Acronyms and Abbreviations

DEEC	distributed embedded energy converter
DEEC-Tec	distributed embedded energy conversion technologies
DEI	diversity, equity, and inclusion
DOE	U.S. Department of Energy
InDEEP	Innovating Distributed Embedded Energy Prize
NEPA	National Environmental Policy Act
R&D	research and development
TPL	technology performance level
TRIZ	Theory of Inventive Problem Solving
Wave-SPARC	Wave Systematic Process & Analysis for Reaching Commercialization
WEC	wave energy converter
WPTO	Water Power Technologies Office

Glossary

Term	Definition
DEEC	A relatively small energy transducer (often having a characteristic length less than a few centimeters) that converts one or more form(s) of energy into another and serves as a structural mechanism providing one or more methods to join and/or interconnect with other DEECs to form a resulting DEEC-Tec metamaterial.
DEEC-Tec metamaterial	A structural framework created from, or consisting of, various combinations and/or interconnections of one or more types of DEECs and whose arrangements and compositions are determined by how those DEECs are interconnected and/or structurally integrated, thereby yielding desirable properties and designed-for characteristics for the structural framework.
Techno-economic analysis	Techno-economic analyses examine costs, benefits, risks, uncertainties, and time frames to evaluate the attributes of energy technologies.
Techno-economic potential	Potential of a technology to be economically viable and competitive in the marketplace when fully developed for commercial operation.
Technology performance level	A metric that provides a holistic assessment of a wave energy converter's techno-economic performance potential.
Wave energy converter	Device that converts the motion of ocean waves into usable forms of energy, e.g., electricity.

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1 Introduction

The U.S. Department of Energy's (DOE) Water Power Technologies Office (WPTO) aims to investigate an underexplored area of wave energy technologies, build an interdisciplinary community of innovators, and generate new, precommercial wave energy converter concepts through the Innovating Distributed Embedded Energy Prize (InDEEP). This prize will challenge innovators, both inside and outside the wave energy industry, to use innovation methods that identify the techno-economic potential of novel technologies that have applications for wave energy conversion via devices called wave energy converters (WECs).

1.1 Prizes

WPTO is providing up to $2.3M in cash prizes over two years and three phases. Multidisciplinary teams are challenged to design and complete proof-of-concept testing of distributed embedded energy conversion technologies (DEEC-Tec) applicable to wave energy conversion. Competitors will receive multiple types of support throughout the prize, including training in innovation methods, office hours with commercialization experts, an introduction to DEEC-Tec, an introduction to marine energy, and more to support their success.

This version of the rules document is specifically related to Phase II of the prize, and descriptions and requirements are in the following sections. New and returning applicants are encouraged to apply.

Table 1. InDEEP Phase Awards and Descriptions

InDEEP Awards		
Phase I (closed)	*19 teams selected as winners, each receiving $15k for a total of $285k distributed.*	*Phase I was focused on concept development and team engagement. Competitors developed a 5,000-word concept paper that included the fundamental principles and the functioning of the DEEC-Tec transducers and metamaterial. Competitors completed an introductory technology performance level (TPL) assessment of their innovation.*
Phase II	**Prize pool up to $1.2M for up to 15 winners.** **Each team has the potential to win up to $80k in this phase.**	**Phase II will challenge innovators to demonstrate their concepts at the transducer level. Teams will build and laboratory test a single DEEC at the benchtop scale. The test will be assessed against performance characteristics like energy conversion, power density, and others as defined in a subsequent TPL assessment.**
Phase III	Prize pool up to $800k for up to 4 winners. Each team has the potential to win up to $200k in this phase.	In Phase III, teams will integrate DEEC transducers into a DEEC-Tec metamaterial. The test will be assessed against performance characteristics like energy conversion, power density, and others as defined in a final TPL assessment.
Applicable to all prize phases	Team Characteristics and Excellence Innovation Process	

	Technical Performance Criteria Planned Development for Future Stages

1.2 Important Dates

The following is the anticipated InDEEP Phase II and Phase III schedule:

Table 2. InDEEP Phases II and III Schedule

Anticipated Date	Milestone
November 7, 2023	Phase II submissions open
April 26, 2024	Phase II Leaderboard Eligibility Closes
May 7, 2024	Phase II close
July 2024	Phase II winner announcement and Phase III submissions open
January 2025	Phase III Leaderboard Eligibility Closes
January 2025	Phase III close
March 2025	Phase III winner announcement and awards

1.3 Eligibility and Competitors

Eligible Competitors

The competition is open only to individuals; private entities (for-profits and nonprofits); non-federal government entities such as states, counties, tribes, and municipalities; and academic institutions; subject to the following requirements:

- An individual prize competitor (who is not competing as a member of a group) must be a U.S. citizen or permanent resident.
- A group of individuals competing as one team may win, provided that the online account holder of the submission is a U.S. citizen or permanent resident. Individuals competing as part of a team may participate if they are legally authorized to work in the United States.
- Private entities must be incorporated in and maintain a primary place of business in the United States.
- Academic institutions must be based in the United States.
- DOE employees, employees of sponsoring organizations, members of their immediate families (e.g., spouses, children, siblings, or parents), and persons living in the same household as such persons, whether or not related, are not eligible to participate in the prize.
- Individuals who worked at DOE (federal employees or support service contractors) within six months prior to the submission deadline of any contest are not eligible to participate in any prize contests in this program.
- Federal entities and federal employees are not eligible to participate in any portion of the prize.

- DOE national laboratory employees cannot compete in the prize.
- Entities and individuals publicly banned from doing business with the U.S. government such as entities and individuals debarred, suspended, or otherwise excluded from or ineligible for participating in Federal programs are not eligible to compete.
- Entities identified in Department of Homeland Security (DHS) Binding Operational Directives (BOD) as publicly banned from doing business with the U.S. government are not eligible to compete. See https://cyber.dhs.gov/directives/.
- Entities and individuals identified as restricted parties on one or more screening lists of Department of Commerce, State or the Treasury are not eligible to compete. See Consolidated Screening List. https://www.trade.gov/consolidated-screening-list
- Individuals participating in a foreign government talent recruitment program[1] sponsored by a country of risk[2] and teams that include such individuals are not eligible to compete.
- Entities owned by, controlled by, or subject to the jurisdiction or direction of a government of a country of risk are not eligible to compete.
- To be eligible, an individual authorized to represent the competitor must agree to and sign the following statement upon registration with HeroX:

I am providing this submission package as part of my participation in this prize. I understand that the information contained in this submission will be relied on by the federal government to determine whether to issue a prize to the named competitor. I certify under penalty of perjury that the named competitor meets the eligibility requirements for this prize competition and complies with all other rules contained in the Official Rules document. I further represent that the information contained in the submission is true and contains no misrepresentations. I understand false statements or misrepresentations to the federal government may result in civil and/or criminal penalties under 18 U.S.C. § 1001 and § 287, and 31 U.S.C. §§ 3729-3733 and 3801-3812.

1.3.1 Applications of Interest

The Prize Administrator must conclude that all the following statements are true when applied to a submission to be considered:

- The submission satisfies laws of physics.
- The submission uses ocean wave energy.

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[1] Foreign Government-Sponsored Talent Recruitment Program is defined as an effort directly or indirectly organized, managed, or funded by a foreign government, or a foreign government instrumentality or entity, to recruit science and technology professionals or students (regardless of citizenship or national origin, or whether having a full-time or part-time position). Some foreign government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to relocate physically to the foreign state for the above purpose. Some programs allow for or encourage continued employment at United States research facilities or receipt of federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct participants not to disclose their participation to U.S. entities. Compensation could take many forms including cash, research funding, complimentary foreign travel, honorific titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

[2] DOE has designated the following countries as foreign countries of risk: Iran, North Korea, Russia, and China. This list is subject to change.

- The submission generates electricity using the domain of DEEC-Tec.
- The submission shows promise of eventually having high techno-economic potential.
- The submitted materials match the DEEC demonstrated.

If the proposed solution does not meet the above requirements, it will not be subjected to additional review, will not receive scores from the reviewers, and will not be considered for a prize under this program.

The competitor will retain all ownership of the intellectual property contained in their submission. The Prize Administrator will not utilize any proprietary information without first obtaining a license from the competitor.

1.4 Background and Purpose

WPTO enables research, development, and testing of emerging technologies to advance marine renewable energy for the generation of sustainable, reliable electricity.[3] Pertinent to InDEEP, WPTO supports unique approaches for designing wave energy technologies, including innovation methods. In addition, WPTO funds the investigation of various methods of converting ocean waves into usable energy, ranging from rigid body types, flexible body types, and distributed-embedded body types. InDEEP seeks technologies that can leverage non-force-concentrating material to transform energy into electricity using ocean waves. Solutions in early development stages and applications from any industry that could apply to ocean wave energy conversion are encouraged to participate.

WPTO has specifically chosen the prize mechanism for InDEEP to contribute to four high-level objectives within the office:

1. InDEEP aims to explore a diverse range of potentially high-impact technologies for wave energy. By employing the prize mechanism, the barrier to entry is lowered, and multiple prizes can be awarded to researchers both inside and outside the wave energy industry, supporting them with conceptualizing a variety of high-techno-economic DEEC concepts.
2. InDEEP encourages the use of systems engineering approaches and methodologies in the field of wave energy. Working in the ocean is a challenge; generating cost competitive energy is a challenge; transforming the energy of ocean waves and converting it into electricity is a challenge; scales, timelines, risks, and costs of never-been-done-before engineering systems are a challenge. Leveraging systems engineering approaches and methods at the early concept development and engineering analysis stage will generate consistent and high-performing long-term results.
3. InDEEP will make new investments in the marine energy community, targeting both existing wave energy experts and those with ideas new to the wave energy industry. Simultaneously, InDEEP will build a community of innovators working to understand how DEEC-Tec and similar technology areas can be applied to wave energy.
4. InDEEP will help prepare promising technologies for future research and maturation by proving comprehensive competitor support for every stage of technology development, from conception to building and testing.

[3] https://www.energy.gov/eere/water/advantages-marine-energy

1.5 Prize Goals

WPTO's desired outcome for InDEEP is an understanding of the landscape of innovators and potential DEEC-Tec solution providers that could apply this technology to wave energy converters in the ocean environment.

The prize will incentivize the development of novel DEEC-Tec-based concepts to meet the following goals:

- **Leverage WEC innovation methods (see Appendix B) to systematically develop DEEC-Tec concepts** that could bring value to the ocean wave energy industry.
- **Build a solver community** by engaging and facilitating collaboration between diverse innovators in the marine energy industry and related DEEC-Tec disciplines.
- **Encourage development of novel DEEC-Tec with high potential** relevant to WECs by supporting an interdisciplinary set of competitors from ideation to design.
- **Refine WEC innovation methods** to incorporate ideas beyond the field of wave energy based on feedback from the prize.

2 Distributed Embedded Energy Conversion Technology (DEEC-Tec)

DEEC-Tec is an emerging area of research with the potential for harvesting and converting ocean wave energy through non-force-concentrating technologies.[4]

The smallest and most fundamental technology scale is the individual DEECs, with each DEEC acting as both a small energy transducer and as a base-level structural mechanism, which is the focus of Phase II.

The next technology level is DEEC-Tec metamaterials, which are made from many individual DEECs that are, for example, interconnected, layered, meshed, and/or composited together. This is the focus of Phase III.

The last and largest technology level, which is beyond the scope of this prize, is a whole structure made from the assemblage of various types of DEEC-Tec metamaterials and other components to form a fully functioning ocean wave energy converter (WEC). The sequence is DEECs > DEEC-Tec metamaterials > a DEEC-Tec-based WEC. (see Figures 1–3).

[4] https://www.nrel.gov/water/distributed-embedded-energy-converter-technologies.html

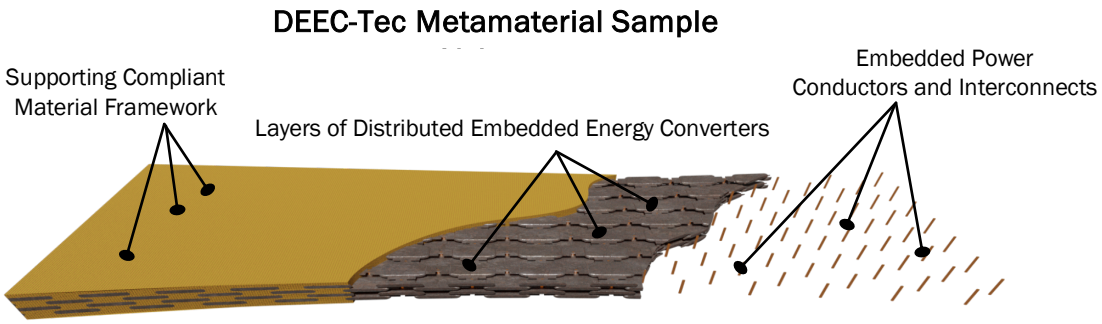

Figure 1. A sample volume: Illustrating the basic use of individual distributed embedded energy converters to create a DEEC-Tec metamaterial. This sample volume has sections where components of the metamaterial are removed, aiming to clarify the constituent components making up a generic DEEC-Tec metamaterial. To the far left of the illustration, all constituent components are present. In the middle section, the supporting compliant material framework is removed. In the right section, both the supporting compliant framework and the individual DEECs are removed. In this way, the illustration showcases how the combined semicontinuous nature of DEECs creates a DEEC-Tec metamaterial.

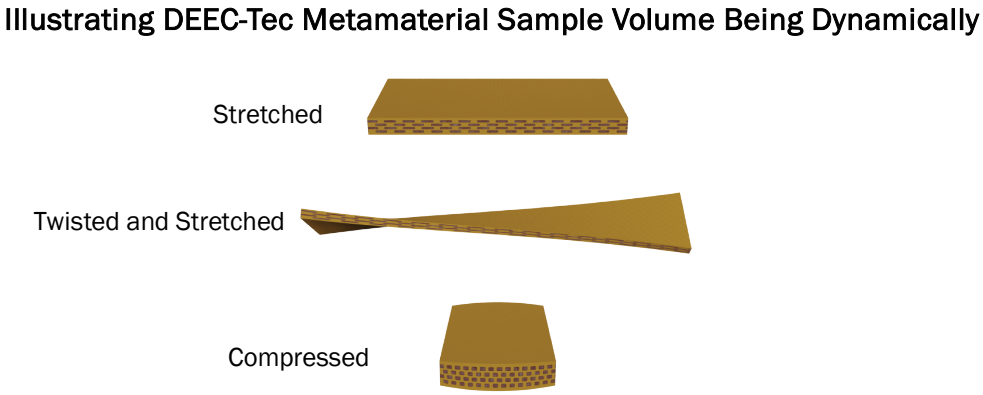

Figure 2. Principal manner of operation: illustrating DEEC-Tec metamaterial sample volume being dynamically deformed by some external source of energy

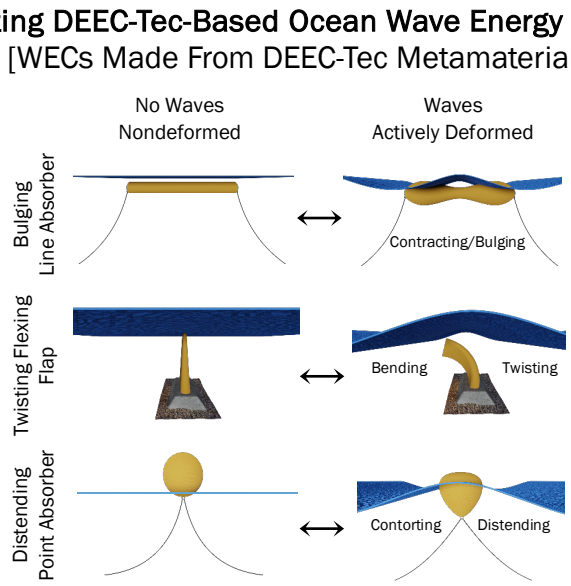

Figure 3. Three possible DEEC-Tec-based WEC archetypes showcasing their nondeformed and dynamically deformed states. The yellow flexible bodies of each archetype represent DEEC-Tec metamaterials. Note: Nothing is to scale; the archetype figures and scene are solely illustrative.

Though the WEC itself is out of scope for the prize, it may be useful for competitors to consider the attributes a high-potential DEEC-Tec-based WEC would have:

1. The capacity for harvesting and converting energy from a wide variety of ocean wave conditions.
2. The potential for energy conversion throughout an ocean WEC's structure, as opposed to concentrating and converting energy via a centralized transmission and/or generator.
3. Reduced critical failure modes and maintenance needs due to DEEC-Tec's innate redundancy. If parts of an ocean WEC structure based on DEEC-Tec fail, the majority of the many DEECs making up that structure could still function.

High techno-economic potential DEEC-Tecs identified through InDEEP will inform future WPTO-funded research. The prize intends to lay the foundation for innovations eventually meant for electricity generation at the utility grid scale, but just as WECs are outside of the scope of the prize, so is transmission of energy from the WEC to the shore. The prize is a part of broader arc of WPTO-funded research into the potential of DEEC-Tec. DEEC-Tec can be applicable to multiple market areas, ranging from utility grid ocean wave energy conversion "farms" to market areas found in the blue economy, such as ocean observation, marine aquaculture, or seawater mining. WPTO intends to provide subsequent funding opportunities for maturing promising technologies after the prize. For additional reference material, WPTO's long-term plans are detailed in the multiyear program plan.[5]

[5] https://www.energy.gov/eere/water/multi-year-program-plan

2.1 Technology Development Trajectory and Innovation

Technology development can be charted along the technology readiness level (TRL)-technology performance level (TPL) matrix (Figure 4) from ideation (left) to market entry (right). Increasing TRL without focusing on performance early in the context of wave energy, however, has led to high costs. Because iterative testing at a high TRL is expensive in the ocean wave environment, InDEEP encourages teams to leverage systems engineering methodologies in their concept development. Devices need to have a high level of performance at the benchtop scale, yielding fewer costly iterations later on, creating systems with high techno-economic potential at the deployment scale.

Therefore, an essential aspect emphasized in Figure 4 is the role of innovation alongside assessment (blue ellipse) in a development process targeting high-TPL system solutions at low TRL. Flexibility of system fundamentals at low TRL is a valuable and important ingredient to successful high-TPL development, and this flexibility must be fully embraced and capitalized on in the development process.[6]

InDEEP calls for innovation alongside assessment in each phase. Operating in the ocean is inordinately expensive and challenging compared to terrestrial technologies, and this approach is intended to help reduce some of those costs and risks early on.

For innovating DEECs, competitors are free to choose any innovation technique or method that best suits their development process. Some example structured innovation frameworks that may be pursued are described in Appendix B.

[6] Weber, J. 2012. "WEC Technology Readiness and Performance Matrix – Finding the Best Research Technology Development Trajectory." Presented at the 4th International Conference on Ocean Energy, Dublin, Ireland, Oct. 17–19, 2012.

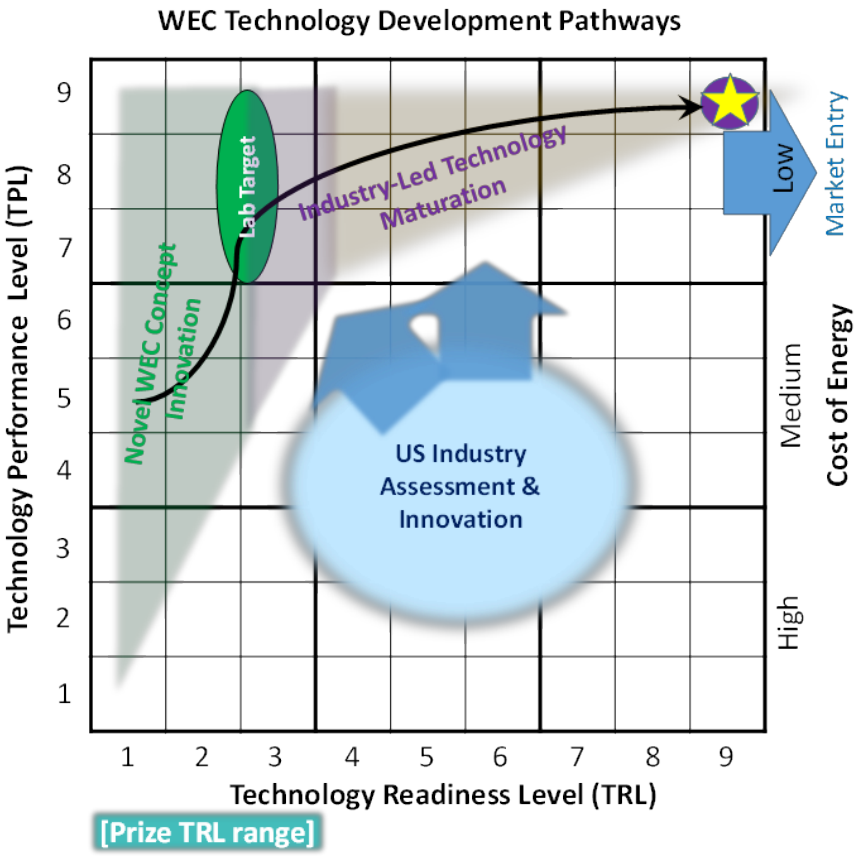

Figure 4. Technology development trajectory, comparing TPL and TRL

2.2 Technology Performance Level (TPL) Assessment

A major element of the prize is introducing competitors to, and supporting them through, holistic assessments of their technology concept starting early in the innovation process. It is generally understood that the majority (~80%) of the cost, impact, and environmental drivers are locked into the design/product within the first ~20% of the technology design and development process.[7] Assessments performed early and often can help with awareness about potential technology challenges and opportunities for improvement as early as possible. Such awareness can inform innovations and technology adjustments when design considerations are more flexible and can ultimately save developers time and money.[8] Beyond supporting the design process, the final score of a TPL assessment provides a sense of the "promise/potential" a technology holds if fully matured. This includes, in addition to techno-economics, considerations of societal benefits, ability to be permitted and certified, environmental impacts, safety, and survivability.

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[7] Ulrich, Karl T., and Scott A. Pearson. 1993. "Does Product Design Really Determine 80% of Manufacturing Cost?" Working Paper #3601-93. Cambridge, MA: Massachusetts Institute of Technology. https://dspace.mit.edu/bitstream/handle/1721.1/47202/doesproductdesig00ulri.pdf.

[8] Weber, Jochem, Daniel Laird, Ronan Costello, Ben Kennedy, Jesse Roberts, Diana Bull, Aurelien Babarit, Kim Nielsen, and Claudio Bittencourt Ferreira. 2017. "Cost, Time, and Risk Assessment of Different Wave Energy Converter Technology Development Trajectories: Preprint." Golden, CO: National Renewable Energy Laboratory. NREL/CP-5000-68480. https://www.nrel.gov/docs/fy17osti/68480.pdf.

InDEEP uses a short and simplified version of the full TPL assessment of a wave energy converter as a system (https://tpl.nrel.gov/). Competitors must complete a self-evaluation by responding to a dozen questions pertaining to aspects that might ultimately impact capabilities in the areas of cost of energy, investment opportunity, societal benefits, and safety and function. Competitors have the option to leverage external third-party support, including but not limited to Wave Venture and Ramboll through office hours (see Section 3, Competitor Support). Information on the relevant questions and structure of the assessment for Phase II is included in Section 5.

Numerical scores from the TPL assessment did not contribute to competitors' final scores in Phase I but will contribute to scores in Phase II. A primary technology development goal of this prize is that the winning technology concepts must demonstrate high techno-economic potential. This means that competitors must demonstrate that they have considered—at least at a high level—the various aspects of the technology that contribute to a high-scoring TPL assessment. The considerations and risk mitigation strategies that the teams have incorporated into these critical development characteristics are included in the evaluation criteria that teams will be scored on in Section 5.

2.3 Technology Interaction With Ocean Waves

This prize seeks technologies that will facilitate the conversion of ocean wave energy into electricity using DEEC-Tec. Developing a full WEC is a major investment and beyond the scope of this prize. Competitors are incentivized to innovate in DEEC-Tec to build a foundation for future WEC development. The following section provides a base level of knowledge for all competitors, regardless of their technical background, guiding the development of wave energy-relevant DEEC-Tec concepts.

Please note the following tables represent (1) utility-scale wave conditions and (2) interactions of wave energy with individual and aggregated DEEC-Tec concepts.

During the prize, competitors are asked to describe how their DEEC-Tec concept will interact with ocean waves. While some DEEC-Tec concepts might directly convert the motion of waves to electricity, it is possible that some wave-energy-driven DEEC-Tec concepts may precondition or alter the incoming wave field in some manner to optimize power production, and thus do not need to be constrained one-to-one by the motion of the waves. For example, wave amplitudes and/or frequencies can be influenced by the metamaterial or other components of a WEC structure. This information is provided so competitors can look ahead to future phases but was not required in Phase I.

Table 3 Table 3 gives ocean wave parameters derived from the sea states in Bull and Dallman[9] and are representative of locations for utility electrical grid-scale WEC deployment off the U.S. West Coast and Hawaii. Table 4 and

[9] Bull, D., and A. Dallman. 2017. "Wave Energy Prize Experimental Sea State Selection." *Proceedings of the ASME 2017 36th International Conference on Ocean, Offshore and Arctic Engineering, OMAE2017*, Trondheim, Norway, June 25–30, 2017. V010T09A025. ASME. https://doi.org/10.1115/OMAE2017-62675.

Table 5 describe possible parameter values that individual DEECs and DEEC-Tec metamaterials, respectively, could encounter when interacting with the prescribed ocean wave conditions.

Competitors must describe how these parameters are relevant to their concept submission, but only need to reference how at least one of the tables below influenced their concept design. Participants developing individual DEEC designs outside these parameters are welcomed, but such designs will require a greater explanation and justification.

Table 3. Wave Parameters

Number	Parameter	Units	Range
1	Frequency of oscillation	Hz	0.03–0.3
2	Amplitude of oscillation of displacement (water surface, water particle)	m	0.2–6
3	Amplitude of oscillation of velocity (water surface, water particle)	m/s	0.2–4
4	Amplitude of oscillation of hydrodynamic pressure	kPa	2.5–60
5	Average energy flux per unit of area perpendicular to wave direction	kW/m^2	2–12

Table 4. Individual DEEC Interaction Parameters

Number	Parameter	Units	Range
1	Frequency; f_F	Hz	$0 < f_F \leq 100$
2	Force Amplitude; *F*	kN	$0 < F \leq 200$
3	Pressure Amplitude; *P*	kPa	$0 < P \leq 1000$
4	Flow Amplitude; *u*	m/s	$0 < u \leq 10$

Table 5. DEEC-Tec Metamaterial Guideline Parameters

Number	Parameter	Units	Range
1	Frequency	Hz	0.01–3.0
2	Displacement Amplitude	m	0.1–3.0
3	Fluid Flow Velocity Amplitude	m/s	0.01–10.0
4	Deformation rate/strain	%	5–300
5	Pressure Amplitude	kPa	1–100
6	Average Energy Flux per projected cross section area	kW/m^2	0.1–20

3 Competitor Support

InDEEP will offer a range of opportunities to support teams throughout all phases of the prize. These opportunities will help teams achieve their full potential by supporting the goals of the prize, noted in Section 1.4.

As we anticipate that many competitors are new to the marine energy industry and/or DEEC-Tec, the Prize Administrator has compiled relevant materials and trainings to help teams familiarize themselves with these disciplines. A list of existing materials and recorded webinars is available in Appendix C. Additional trainings, webinars, networking opportunities, and office hour sessions will be available throughout the prize and will be communicated on the prize's online platform on HeroX. Office hours will also be provided on specific topics where competing teams could use additional support.

Power Connectors support all active prize competitors. The Power Connectors will provide direct support, webinars, and trainings for the benefit of all the teams. Competitors will be asked for their input on the types of support that will be the most relevant to them. Support provided in Phase II will be shaped around needs of the competing teams.

Specific to Phase II, competitors will receive access to the support listed in Table 6. Support Available to CompetitorsTable 6 in the development of their DEEC transducer:

Table 6. Support Available to Competitors

Support Tasks	Detailed Execution
Mentorship	Provide direct, one-on-one support for competitors in: • **Commercialization**. Concepts sought in this prize are early-stage, so this support will focus on early considerations in concept design for a stronger long-term strategy. • **Innovation approach**. Because concepts are early-stage, competitors are expected to leverage an innovation approach to help them consider the long-term impacts of early design decisions and explain the use of the innovation approach in their submission. • **Wave Energy**. Competitors are expected to bring expertise from other industries, so the focus of this support will be on transitioning that expertise to its relevance in wave energy.

	As a part of the prize, competitors have the option to create a video of their system and test setup and develop a preliminary test plan. The mentorship resources are prepared to provide feedback on the concept and the test plan anticipating this will impact the competitor's submission in Phase II.
Patent Search	Competitors will have access to resources related to understanding the current state of the art: • **Patent Search.** Competitors can provide an overview of their concept and a supporting organization will search existing patent documentation to determine the novelty of the idea and opportunities for new patents. • **Feedback.** Following the search, the competitors will receive feedback on the potential patentability of the project given other existing patents in the United States.

Updates on training sessions, mentorship contacts, and office hours will be posted on the HeroX platform periodically, and competitors are encouraged to leverage these opportunities. Leaderboard points are awarded for interacting with the Power Connector competitor support (see Section 5.3.2).

After the technologies with the strongest techno-economic potential are selected, WPTO may provide follow-on support to competitors to further mature these technologies through other opportunities beyond this prize for funding or voucher support, subject to appropriations.

4 Prize Stages

4.1 PHASE I: Team Building/Engagement and Concept Creation

March 22, 2023–Aug. 25, 2023

Phase I results: 19 awards made at $15k each, for a total of $285k distributed.

Teams created an initial concept, submitted a technical narrative representing their idea and the innovation process that led them to the solution, and completed a simplified Phase I version of a TPL assessment, defined in Section 2.2, to represent the performance level of the concept. Awards supported work leading up to Phase II.

Phase I of InDEEP was designed to engage interdisciplinary teams and incentivize the development through use of innovative methodologies of novel DEEC-Tec concepts. Teams had the opportunity to attend trainings in ocean wave energy innovation and assessment tools to support building a multidisciplinary team with a range of backgrounds and disciplines needed to develop their wave-energy-relevant DEEC-Tec concepts. This stage familiarized participants with DEEC-Tec, ocean wave energy, and the integration of these two applications to find new potential solutions. There was a focus on teaming and collaboration, and competitors were scored on the diversity of expertise represented.

4.2 PHASE II: Simple Prototype Proof-of-Concept

Nov. 7, 2023–May 7, 2024

Anticipated Awards: Up to 15 awards at up to $80k each.

Phase II of InDEEP is designed to provide a pathway for competitors to demonstrate a single, unit-level transducer—an individual DEEC. Phase II will challenge innovators to build and test their concepts at the individual DEEC level by demonstrating the DEEC's energy transducer and structural mechanisms. Teams will build and test a single DEEC at the benchtop scale in a laboratory or other

physical setting. The test will reflect the dynamic operational ranges of their designs and will be assessed against performance characteristics such as energy conversion and power density. Participants will apply a simplified Phase II version of a TPL assessment. The competitors' TPL assessment, scored by the reviewers for process adherence and used in combination with the technical narrative and test report to assess technology viability in this phase. This phase will be the final opportunity for new teams to enter the prize. Collaboration will still be an important scored element of this phase, but focus will now be on proof-of-concept for the technology.

4.3 PHASE III: Complex Prototype (Design Optimization)

July 2024–January 2025 (anticipated)

Anticipated Awards: Up to 4 at up to $200k each.

Phase III will challenge successful teams from Phase II to demonstrate their individual DEECs as DEEC-Tec metamaterials. This stage will require teams to interconnect and integrate their individual DEEC prototypes built in the prior stage to demonstrate the resulting functionality of their created DEEC-Tec metamaterial. Participants will also apply the full TPL assessment to their DEEC-Tec metamaterial to determine how much energy could be converted and, correspondingly, the techno-economic potential of their design. The focus of this stage will be the development of precommercial prototypes. The competitor will describe the process by which they integrated their DEECs into a metamaterial, including resolution of design trade-offs and targeting required operational ranges. The TPL assessment will be scored in this phase.

WPTO may provide follow-on funding after this phase to continue the development of promising technologies, subject to appropriations.

5 Phase II Scoring and Submission Requirements

5.1 How to Enter

Follow the instructions for registering and submitting all required materials before the deadline in Table 79 or as displayed on the HeroX website. Competitors can also form teams or find partners through the platform and/or teaming events described in Competitor Support (Section 3).

5.2 Important Dates

All dates outlined for the Prize phases are anticipated and subject to change. Final dates will be posted on HeroX.

Table 7. Important Dates

Anticipated Date	Milestone
November 7, 2023	Phase II submissions open
April 26, 2024	Phase II Leaderboard Eligibility Closes
May 7, 2024	Phase II close
July 2024	Phase II winner announcement and Phase III submissions open
January 2025	Phase III Leaderboard Eligibility Closes
January 2025	Phase III close
March 2025	Phase III winner announcement and awards

5.3 Phase II Submission Requirements

Table 8. Submission Requirements

Item	Description	Will Be Made Public[10]	Scored Item
Summary Slide	Individual slide representing public-facing concept and team description.	Yes	No
Technical Narrative	Up to 5,000 words in length. Teams may also include up to 5 supporting drawings, images, or graphics.	No	Yes
Phase II TPL Assessment	Read, review, and complete a simplified version of the TPL Assessment.	No	Yes
Test Report	A test report the competitor has completed that includes sufficient detail to replicate the work.	No	Yes
Leaderboard Submissions	Continuous engagement activities scored for application period. Opportunities provided on HeroX platform.	Yes	Yes
Live Virtual DEEC Demonstration	Competitors will be required to attend a virtual meeting with the Prize Administrator demonstrating testing process and validating the test results in the Test Report and Technical Narrative.	No	Yes

5.3.1 Unscored Submission Components

Submission Summary Slide

The Submission Summary Slide is a slide describing the competitor's approach and the anticipated impact of the submission. It will be made public. The Submission Summary Slide will not contribute to the overall score but is a required submission. Requirements are as follows:

- The competitor must make a public-facing, one-slide submission summary that contains technical details but can be understood by general audiences. Competitors are encouraged to use any format they would like to represent this information, as there is no template. Any text must be readable in a standard printout and conference room projection.

5.3.2 Scored Submission Components

All scored submission components will be scored on how well the competitor addresses the statements in each criterion; each statement (described below) will be scored by reviewers on the following 0–5 scale:

0	1	2	3	4	5

[10] Competitors who do not want any documents not already intended to be public-facing must mark them according to the instructions in 0 (Section A.11).

Strongly Disagree/Does Not Address	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree/Fully Addresses

The following table explains the manner in which the scores for each submission will be calculated. The maximum possible points are earned if each scored statement receives a maximum score of 5. The total points earned in each criterion are then weighted to the percentage of the total score, as defined.

Table 9. Submission Scoring Criteria

Submission Component	Potential Points	% of Total Score
Technical Narrative	115	67%
Criterion 1: Team Characteristics and Excellence	*35*	
Criterion 2: Innovation Process	*30*	
Criterion 3: Viability of the Concept	*25*	
Criterion 4: Planned Development for Phase III	*25*	
Phase II TPL Assessment	20	12%
Criterion 1: Assessment Process	*15*	
Criterion 2: Technology Promise	*5*	
Test Report	20	12%
Leaderboard Submissions	15	9%
Criterion 1: Team Characteristics and Excellence	*5*	
Criterion 2: Innovation Process	*5*	
Criterion 3: Viability of the Concept	*5*	
Live Virtual DEEC Demonstration	*Pass/Fail Qualification*	
TOTAL	**170**	**100%**

Technical Narrative

The scored Technical Narrative, which describes the solution approach, is the primary component of the submission and should provide a clear description of the concept. The Technical Narrative should provide responses to the scoring statements outlined in the following table of evaluation criteria. Competitors can use up to 5,000 words and up to five supporting images, figures, or graphs to populate the template available on HeroX.

The following table suggests content and provides the Scoring Statements, which are the criteria used to evaluate the Technical Narrative. The suggested content bullets are only suggestions to guide responses; competitors decide where to focus their responses.

Table 10. Technical Narrative Evaluation Criteria

Technical Narrative Criterion 1: Team Characteristics and Excellence

Suggested Content Competitor Provides	Scoring Statements (Scored on 0–5 Scale)
• Briefly outline formation/origin of the team and how the team incorporates a diverse makeup, including disciplines, backgrounds, experience, industries, and sectors. • Describe the team's background in systems engineering and innovation methodologies, and the specific methodologies in which the team has expertise. • Briefly outline what work was contributed by each team member and highlight successful collaborations. Focus on how non-ocean wave energy specialists were introduced to ocean wave energy. • Describe how you have shared information with other InDEEP teams.	• The team has diverse expertise and incorporates that expertise to support the successful development of their concept. • The competitor has demonstrated a background in systems engineering and/or innovation methodologies as a core part of the team. • The competitor has clearly demonstrated how they have collaborated with other teams and/or other professionals to further mature this nascent industry.
• Evaluate your current team and the technical gaps missing to successfully develop the proposed concept. • Propose an approach and/or support mechanisms offered that the team intends to leverage to resolve these technical gaps in the next phase.	• The competitor has provided a thoughtful and accurate assessment for current technical gaps and areas of expertise, and their intended plan is likely to resolve these gaps. • The competitor demonstrates an ability to leverage multidisciplinary skillsets through teaming arrangements and collaborations to create a well-rounded team.
• Describe how the team will cultivate a culture of inclusion to ensure all team member's contributions are considered and facilitates team excellence. • Describe potential challenges the team may face in creating an inclusive environment and making accommodations for team members, and how the team plans to address those challenges.	• The competitor has clearly outlined a plan to cultivate a culture of inclusion, seek out diverse perspectives, and effectively consider all team member's contributions. • The team has a clear plan to accommodate a diverse team and any team members' specific needs.
Technical Narrative Criterion 2: Innovation Process	
Suggested Content Competitor Provides	**Scoring Statements (Scored on 0–5 Scale)**
• Describe the research and/or literature search conducted to inform the team's understanding of the current state of the technology and previous related work. • Outline the starting point for your innovation (i.e., did you start with an underperforming system and seek to improve it, did you start with a preexisting solution from another industry that is newly applied to wave energy, did you start with a requirements statement and ideate an entirely new solution, or something else?). • Outline the systems engineering methodology, including a description of the innovation technique(s) used. Examples of different systems engineering approaches are included in Appendix B.	• The competitor demonstrates a thorough understanding of the current state of the technology, any lessons learned from another domain they have incorporated into the technology development, and/or how their concept fits into the industry. • The competitor clearly describes the innovation technique used, a description of how they iterated on the proposed concept, and their plans to rigorously apply an effective systems engineering methodology going forward. • The competitor has effectively leveraged the innovation technique and the systems engineering approach to balance the weaknesses identified for the TPL assessment. • The competitor has clearly identified the design trade-offs and described how they

	used an innovation technique to resolve those trade-offs in their concept design.
• Describe your vision to mature the concept and what you need to guide your innovation process, during and after the prize.	• The competitor has clearly described their vision to mature the concept and what they need to guide their innovation process during and after the prize.
• Outline the target or requirements that you seek to meet.	• The competitor has clearly described the targets or requirements they seek to meet, and how those targets or requirements will advance their technology closer to commercialization.
Technical Narrative Criterion 3: Viability of the Concept	
Suggested Content Competitor Provides	**Scoring Statements (Scored on 0–5 Scale)**
• Describe what energy goes into your DEEC, the energy transformation(s) that occur, and the net useful energy output. • Describe what parameters (directions, magnitudes, frequencies, etc.) influence the efficiencies of the energy conversion for your individual DEEC. • Describe any mechanisms that transform, influence, augment, enhance, boost, and/or filter the energy the DEEC encounters. • Describe how individual DEECs interact and whether they are independent and redundant. • Provide a set of drawings or sketches representing the individual DEEC geometry, size and their deformation or other changes during operation. (These drawings or sketches could include simple geometric profile drawings of the individual DEEC.)	• The competitor clearly describes the energy conversion steps performed by their DEEC. • The competitor clearly describes a valid concept for a DEEC. • The reviewer is confident in the overall viability of the concept (0 or 5).
• Develop a concept storyboard to represent how the DEEC-Tec metamaterial will generate useful energy.	• The competitor clearly demonstrates how the individual DEEC and the DEEC-Tec metamaterial will operate together. • The competitor's concept has the potential to effectively operate and be integrated into a DEEC-Tec metamaterial.
Technical Narrative Criterion 4: Planned Development for Phase III	
Suggested Content Competitor Provides	**Scoring Statements (Scored on 0–5 Scale)**
• Building from the concept descriptions developed in Technical Narrative Criteria 1–3, describe the plans to overcome the identified challenges in the technology development path. • Analyze the impact of your project design based on the potential environment or community it would be located in, including any relevant assessments of target audiences and/or end users.	• The competitor has clearly described a plan for the development of the DEEC-Tec metamaterial in Phase III using an innovation method and outcomes from the TPL assessment. • The competitor has clearly described the potential impact of their project on the environment or community it would be located in, including any relevant assessments of target audiences and/or end users.
• Develop a Phase III Gantt chart, schedule, and work breakdown structure.	• The competitor has provided detailed plans for proceeding with the development of the proposed concept in the next phase.

• Provide a separate risk register for project management and technology risks (see the Marine and Hydrokinetic Technology Development Risk Management Framework[11]). • Outline risk management approach to project design, including a description for how the planned work will reduce missing information and reduce risks and increase prospects of successful outcome.	• The competitor identifies risks and the challenges in maturing the technology and has plans that are likely to manage these identified risks.
• Propose what would be needed to successfully test the metamaterial on site at a national lab in Phase III	• The competitor understands how they could execute a successful test in person at a national lab

Phase II TPL Assessment

The TPL Assessment to be completed in Phase II is a required, scored submission component designed to help inform the development of a competitor's concept and measure its potential/promise when commercially ready. Competitors will be scored on the quality of the work put into the assessment process and the overall techno-economic promise of their technology rather than on the quantitative results from the TPL Assessment. Reviewers will perform an independent TPL Assessment using the information provided by the competitors. Specific questions to be are included in **Error! Reference source not found.**, and a template is available on HeroX. When filling in the template, the suggested length of justification and background information is 250 words per question.

Teams are encouraged to leverage the support mechanisms provided when completing the TPL assessment (Section 3) and receive feedback both on the associated score and the justification for that score. As noted in the Leaderboard Scoring section that follows, teams can earn points for engaging support organizations during their development process.

Table 11. Phase II TPL Assessment Outline

Number	TPL Question	Impacted Capability
1	Assuming your concept has shown functionality during benchtop testing, what, if any, additional changes will it need to function in the intended ocean deployment environment?	Cost of Energy, Investment Opportunity, Safety and Function
2	How difficult are the components to source? Are they made of specialty material (e.g., very high cost, unknown properties for use/environment, or specially made/ordered)?	Cost of Energy
3	How many conversion steps are there within the DEEC? How many times is the form of the energy significantly changed? What is the design average combined energy conversion efficiency? What are the energy densities, power densities, etc.?	Cost of Energy
4	Are components custom-manufactured outside of expected or common practices? This could include custom parts, nontypical manufacturing processes, and non-commercial-off-	Cost of Energy

[11] Snowberg, David, and Jochem Weber. 2015. *Marine and Hydrokinetic Technology Development Risk Management Framework*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-63258. https://www.osti.gov/biblio/1225914.

	the-shelf components where commercial-off-the-shelf components are common.	
5	What expertise is needed from the workforce (dependent on material type, level of tolerances that must be achieved, specialized safety, customized molds)?	Cost of Energy
6	What are the known failure modes and frequency of failure for DEECs and their components? What is the level of confidence for failure modes and frequency? What are the consequences of failure?	Cost of Energy, Investment Opportunity
7	Are any material types used rare or located only in particular parts of the world? What material types are vulnerable to price fluctuations?	Investment Opportunity
8	Are new manufacturing capabilities or new workforce expertise needed to manufacture the DEECs?	Investment Opportunity
9	Are the components recyclable?	Beneficial to Society
10	Has a safety philosophy been incorporated into the design process?	Safety and Function
11	Is there a threat to human health and safety during any life cycle stage?	Safety and Function
12	Will an abrupt disconnection of the external power input put the DEECs at risk of damage?	Safety and Function

Table 12. TPL Assessment Evaluation Criteria

TPL Assessment Criterion 1: Assessment Process	
Suggested Content Competitor Provides	**Scoring Statements (Scored on 0–5 Scale)**
• Fully completed TPL assessment using the template provided on HeroX with scores, justification, and background information filled in.	• The competitor has provided an accurate assessment of the TPL of their technology. • The competitor clearly understands the strengths and weaknesses of the technology that the TPL is trying to communicate. • The competitor has a plan to address weaknesses through innovations, technology adjustments, and/or mitigation strategies.
TPL Assessment Criterion 2: Technology Promise	
Suggested Content Competitor Provides	**Scoring Statements (Scored on 0–5 Scale)**
• Fully completed TPL assessment that thoroughly addresses each TPL question within the template. The competitor's TPL assessment, along with the technical narrative, will be used by the reviewers to perform an independent TPL assessment. The self-assessed numerical scores will not be included in the final score.	• Based on TPL assessment, the technology demonstrates high techno-economic potential.

Test Report

The test report clearly explains the process the competitor followed to test the individual DEEC in 15–20 pages. The test report should be complementary to (but not duplicate) the technical narrative and should provide concrete details on the prototype, the testing process, and results of the testing.

Specific information required for the Test Report is listed in Table 13.

Teams are encouraged to leverage the support mechanisms provided when completing the test report (Section 3) and receive feedback on both their early plan and their final document. As noted in the Leaderboard Scoring section that follows, teams can earn points for engaging support organizations during their development process.

The scored test report should be heavily guided by the questions included above and deliver responses to the scoring statements outlined in the following table of evaluation criteria.

Table *13*: Test Report Evaluation Criteria

Test Report Scoring Criteria	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**

• Description of the individual DEEC prototype, including any complementary information that will help the Prize Administrator understand how the prototype was built and how it functions. Description must include:
  ○ Materials used for the prototype, represented in both a list and in engineering drawings.
  ○ Specific configurations that need to be considered for the device to be tested.
• Description of the testing process, written as a repeatable process. Description must include:
  ○ Test setup, including specific parameters and variables considered in the test and applicable ranges (frequencies, displacements, strains, voltages, currents, etc.).
  ○ Identification of operational values for the input ranges in Tables 3–5, or representative substitutes.
  ○ Any materials needed to hold/fix the DEEC in place.
  ○ Description for how inputs and outputs are measured, including instrumentation, sensors, change-over time, run duration(s), and overall timing of the test.
	• The competitor has adequately described the prototype, including the necessary materials, the fabrication process, and a clear explanation for how it functions.
	• The competitor has adequately described the testing process, to a degree that it is reproduceable.
	• The competitor has clearly described the theory behind the design of the system and quantified how they have achieved the results of the test.
	• The competitor has included an adequate description of the test results that is an accurate reflection of the anticipated performance and other relevant characteristics for the system.

○ Any post-processing and/or filtering. ○ Associated testing standards (ISO, IEEE, IEC, ASTM, etc.) if applicable. • Explanation of the physics represented in the testing process. Explanation may include: ○ Degree(s) of freedom during the testing process (translation, rotation, etc.). ○ Ranges of magnitude of applied forces and motions, (time variance of oscillation and deformation such as stretching/squishing and moments, etc.). ○ Description of the power conversion principle and the conversion of the original energy form into the desired useful energy form, including unique characteristics of the DEEC. ○ Description of the parameters that can be used to control the properties of the DEEC (if applicable). ○ Time-varying characteristics, continuous or discrete. • Full description of the test results, including: ○ Specific mechanical input and electrical output. ○ Net electrical power generated. ○ Conversion efficiency. ○ All sensing, signal treatment, and data acquisition relevant to the results.	

Leaderboard Submissions

The leaderboard, hosted on HeroX, is a representation of engagement throughout Phase II. The final scores represented on the public-facing leaderboard will contribute directly to the final numerical score a competitor receives on their submission. Individual scoring components are included in the following table, and teams can receive up to 5 points per scoring criteria, for a maximum of 15 additional points, that will be calculated and weighted into final scores for their appropriate category.

Specific engagement activities will be offered on the HeroX platform directly and updates will be shared on the leaderboard as teams complete these activities. Teams will not earn points for these activities prior to completing the initial eligibility confirmation. To sign up for the leaderboard, click Solve this Challenge in HeroX and submit a Leadership Eligibility Form. Eligibility criteria can be found in Section 1.2. It is the responsibility of the team to notify the Prize Administrator to transition points

to another team, should teams pursue partnerships and a change in the team captain whose name is associated with these engagement changes.

Table 14. Leaderboard Scoring

Leaderboard Criterion 1: Team Characteristics and Excellence	
Required Submissions to Earn Points	**Scoring Statements (Scored on 0–5 Scale)**
• (2) Earn one point for attending each Power Connector event for a maximum of two points • (1) Provide a recommendation on the InDEEP forum for a conference or journal relevant to InDEEP • (1) Complete a short questionnaire providing information on the test set up needed in Phase III (space constraints, power requirements, etc.) • (1) Complete a short questionnaire providing feedback on available prize support mechanisms, and what would be useful going forward (vouchers, Power Connectors, etc.)	• *Activities are pre-scored on public-facing leaderboard.* The team leverages educational tools and support mechanisms provided by Prize Administrator to better understand key prize elements and build the prize community.
Leaderboard Criterion 2: Innovation Process	
Required Submissions to Earn Points	**Scoring Statements (Scored on 0–5 Scale)**
• (1) Complete the TPL Assessment questionnaire, to be provided on HeroX. • (1) Attend the TPL training • (1) Engage on the HeroX forum, asking questions or responding to questions others have posted. • (2) Earn one point for each office hour session attended with competition mentors, as noted in Section 3, for a maximum of two points. Provide feedback during sessions about numerical modeling and benchtop test challenges and/or software tools that have helped to progress the concept. Share any thoughts on resources needed to prepare for Phase III.	• *Activities are pre-scored on public-facing leaderboard.* The team leverages educational tools and support mechanisms provided by Prize Administrator to better understand key prize elements.
Leaderboard Criterion 3: Viability of the Concept	
Required Submissions to Earn Points	**Scoring Statements (Scored on 0–5 Scale)**
• (1) Attend the second level of training on wave energy. Dates and link to be provided on the HeroX platform. • (1) Attend the second level of training on DEEC-Tec. Dates and link to be provided on the HeroX platform. • (1) Attend the second level of training on innovation methods. Dates and link to be provided on the HeroX platform. • (2) Hold a focus group with a diverse set of stakeholders to gather feedback on the viability of the concept. Send a post-meeting summary to InDEEP@nrel.gov.	• *Activities are pre-scored on public-facing leaderboard.* The team leverages educational tools and support mechanisms provided by Prize Administrator to advance the viability of their concept.

Live Virtual DEEC Demonstration

A Live Virtual DEEC Demonstration will be scheduled with eligible competitors shortly following the close date of Phase II and will be administered via a streaming service. This Live Virtual Demonstration will be conducted by the Prize Administrator, technical subject matter experts from national laboratories and DOE, and any other necessary legal representatives as appropriate. This demonstration will serve as a qualification for Phase III, so **materials submitted must match the DEEC demonstrated.**

In this meeting, the Prize Administrator will evaluate critical design components and system functionality. The Prize Administrator will have reviewed the Test Report and Technical Narrative in advance. The purpose of this meeting will be to validate consistency between the submitted materials and the functionality of the system in a demonstration setting, and to ensure adherence to the functional requirements outlined in Tables 3–5.

Live Virtual DEEC Demonstration meetings are expected to run for one hour and cover the following:

- Team introductions.
- Device outside of the test apparatus.
- Standalone test apparatus.
- Device in the test apparatus.
- Device in the test apparatus being stimulated.
- Quantitative results from the test performed that align with the materials submitted.
- Questions from the Prize Administrator related to the test or submitted materials.

Teams will not be directly scored on the outcomes of the Live Virtual DEEC Demonstration, but this will instead serve as a qualification for a team's ability to compete in Phase III. Following the demonstration, competitors will have an opportunity to respond to any feedback provided by the review team during and immediately following the meeting. A final determination on qualification for Phase III will be made resulting from the demonstration. For the safety of competitors, facility staff, and prize staff, during the Phase III in-person testing this decision is final and cannot be appealed.

Teams are encouraged to leverage the support mechanisms provided when preparing for the Live Virtual DEEC Demonstration (Section 3) and do a dry run and/or receive feedback on the demonstration. As noted in the Leaderboard Scoring section, teams can earn points for engaging support organizations during their development process.

6 How Winners Are Determined

The Prize Administrator screens all completed submissions and, in consultation with DOE, assigns reviewers to independently score the applicable content of each submission. The reviewers will be composed of federal and nonfederal subject matter experts. Reviewers will review submissions in each phase according to the described evaluation criteria. The Prize Administrator will tally the scores based on the scoring criteria described and the outcomes from the public-facing leaderboard.

The Prize Administrator has identified the following additional processes that may be used in the determination of winners. Outcomes from these processes are optional but can be used in the consideration of winner selection. These processes include:

- **Virtual interviews.** WPTO, at its sole discretion, may decide to hold virtual interviews with a subset of competitors in each phase. Selected finalists will be invited to present, explain, and answer questions pertaining to the functionality of their approach. This will be done in a virtual format. The interviews will be held prior to the announcement of winners and will

serve to help clarify questions the reviewers or judges may have. Participating in interviews is not required, and interviews are not an indication of a competitor's likelihood to win.

- **Final determination.** The director of WPTO is the judge of the competition and will make the final determination. Final determination of winners by the judge will take the reviewers' scores, the leaderboard scores, any interview findings, and the judge's review and program policy factors in 0 into account.

Approximately 45 days after the contest closes, the Prize Administrator will notify winners and request the necessary information to distribute cash prizes. The Prize Administrator will then publicly announce winners.

COMPETITORS THAT DO NOT COMPLY WITH THE ADDITIONAL REQUIREMENTS IN 0 MAY BE DISQUALIFIED.

Appendix A. Additional Terms and Conditions

A.1 Requirements

Your submission for InDEEP is subject to the following terms and conditions:

- You must post the final content of your submission or upload the submission form online by 5 p.m. ET on May 7, 2024, before the prize's Phase II submission period closes. Late submissions or any other form of submission may be rejected.
- All submissions that you wish to protect from public disclosure must be marked according to the instructions in Section 10 of Appendix A (Section A.10). Unmarked or improperly marked submissions will be deemed to have been provided with unlimited rights and may be used in any manner and for any purpose whatsoever.
- You must include all the required elements in your submission. The Prize Administrator may disqualify your submission after an initial screening if you fail to provide all required submission elements. Competitors may be given an opportunity to rectify submission errors due to technical challenges.
- Your submission must be in English and in a format readable by Microsoft Word or Adobe PDF. Scanned hand-written submissions will be disqualified.
- Submissions will be disqualified if they contain any matter that, in the sole discretion of the U.S. Department of Energy or the National Renewable Energy Laboratory (NREL), is indecent, obscene, defamatory, libelous, and/or lacking in professionalism, or demonstrates a lack of respect for people or life on this planet.
- If you click "Accept" on the HeroX platform and proceed to register for any of the prizes described in this document, these rules will form a valid and binding agreement between you and DOE and are in addition to the existing HeroX Terms of Use for all purposes relating to these contests. You should print and keep a copy of these rules. These provisions only apply to the prize described here and no other prize on the HeroX platform or anywhere else.
- The Prize Administrator, when feasible, may give competitors an opportunity to fix nonsubstantive mistakes or errors in their submission packages.
- As part of your submission to this prize, you will be required to sign the following statement:

> I am providing this submission package as part of my participation in this prize. I understand that the information contained in this submission will be relied on by the federal government to determine whether to issue a prize to the named competitor. I certify under penalty of perjury that the named competitor meets the eligibility requirements for this prize competition and complies with all other rules contained in the Official Rules document. I further represent that the information contained in the submission is true and contains no misrepresentations. I understand false statements or misrepresentations to the federal government may result in civil and/or criminal penalties under 18 U.S.C. § 1001 and § 287, and 31 U.S.C. §§ 3729-3733 and 3801-3812.

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A.2 Verification for Payments

The Prize Administrator will verify the identity and role of all competitors before distributing any prizes. Receiving a prize payment is contingent upon fulfilling all requirements contained herein. The Prize Administrator will notify winning competitors using provided email contact information for the individual or entity that was responsible for the submission. Each competitor will be required to sign and return to the Prize Administrator, within 30 days of the date on the notice, a completed NREL Request for ACH Banking Information form and a completed W9 form (https://www.irs.gov/pub/irs-pdf/fw9.pdf). In the sole discretion of the Prize Administrator, a winning competitor will be

disqualified from the competition and receive no prize funds if: (i) the person/entity does not respond to notifications; (ii) the person/entity fails to sign and return the required documentation within the required time period; (iii) the notification is returned as undeliverable; (iv) the submission or person/entity is disqualified for any other reason.

In the event of a dispute as to any registration, the authorized account holder of the email address used to register will be deemed to be the competitor. The "authorized account holder" is the natural person or legal entity assigned an email address by an Internet access provider, online service provider, or other organization responsible for assigning email addresses for the domain associated with the submitted address. All competitors may be required to show proof of being the authorized account holder.

A.3 Teams and Single-Entity Awards

The Prize Administrator will award a single U.S. dollar amount to the designated primary submitter, whether consisting of a single or multiple entities. The primary submitter is solely responsible for allocating any prize funds among its member competitors or teammates as they deem appropriate. The Prize Administrator will not arbitrate, intervene, advise on, or resolve any matters or disputes between team members or competitors.

A.4 Submission Rights

By making a submission and consenting to the rules of the contest, a competitor is granting to DOE, the Prize Administrator, and any other third parties supporting DOE in the contest, a license to display publicly and use the parts of the submission that are designated as “public” for government purposes. This license includes posting or linking to the public portions of the submission on the Prize Administrator or HeroX applications, including the contest website, DOE websites, and partner websites, and the inclusion of the submission in any other media worldwide. The submission may be viewed by the DOE, Prize Administrator, and judges and reviewers for purposes of the contests, including but not limited to screening and evaluation purposes. The Prize Administrator and any third parties acting on their behalf will also have the right to publicize competitors’ names and, as applicable, the names of competitors’ team members and organization, which participated in the submission on the contest website indefinitely.

By entering, the competitor represents and warrants that:

1. Competitor’s entire submission is an original work by competitor and competitor has not included third-party content (such as writing, text, graphics, artwork, logos, photographs, likeness of any third party, musical recordings, clips of videos, television programs or motion pictures) in or in connection with the submission, unless (i) otherwise requested by the Prize Administrator and/or disclosed by competitor in the submission, and (ii) competitor has either obtained the rights to use such third-party content or the content of the submission is considered in the public domain without any limitations on use.
2. Unless otherwise disclosed in the submission, the use thereof by Prize Administrator, or the exercise by Prize Administrator of any of the rights granted by competitor under these rules, does not and will not infringe or violate any rights of any third party or entity, including, without limitation, patent, copyright, trademark, trade secret, defamation, privacy, publicity, false light, misappropriation, intentional or negligent infliction of emotional distress, confidentiality, or any contractual or other rights;
3. All persons who were engaged by the competitor to work on the submission or who appear in the submission in any manner have:

a. Given the competitor their express written consent to submit the submission for exhibition and other exploitation in any manner and in any and all media, whether now existing or hereafter discovered, throughout the world;

b. Provided written permission to include their name, image, or pictures in or with the submission (or, if a minor who is not competitor's child, competitor must have the permission of the minor's parent or legal guardian) and the competitor may be asked by the Prize Administrator to provide permission in writing;

c. Not been and are not currently under any union or guild agreement that results in any ongoing obligations resulting from the use, exhibition, or other exploitation of the submission.

A.5 Copyright

Each competitor represents and warrants that the competitor is the sole author and copyright owner of the submission; that the submission is an original work of the competitor or that the competitor has acquired sufficient rights to use and to authorize others, including DOE, to use the submission, as specified throughout the rules; that the submission does not infringe upon any copyright or any other third-party rights of which the competitor is aware; and that the submission is free of malware.

A.6 Contest Subject to Applicable Law

All contests are subject to all applicable federal laws and regulations. Participation constitutes each participant's full and unconditional agreement to these Official Contest Rules and administrative decisions, which are final and binding in all matters related to the contest. This notice is not an obligation of funds; the final award is contingent upon the availability of appropriations.

A.7 Resolution of Disputes

DOE is solely responsible for administrative decisions, which are final and binding in all matters related to the contest.

Neither DOE nor the Prize Administrator will arbitrate, intervene, advise on, or resolve any matters between team members or among competitors.

A.8 Publicity

The winners of these prizes (collectively, "winners") will be featured on the DOE and NREL and other related websites.

Except where prohibited, participation in the contest constitutes each winner's consent to DOE's and its agents' use of each winner's name, likeness, photograph, voice, opinions, and/or hometown and state information for promotional purposes through any form of media worldwide, without further permission, payment, or consideration.

A.9 Liability

Upon registration, all participants agree to assume any and all risks of injury or loss in connection with or in any way arising from participation in this contest. Upon registration, except in the case of willful misconduct, all participants agree to and, thereby, do waive and release any and all claims or causes of action against the federal government and its officers, employees, and agents for any and all injury and damage of any nature whatsoever (whether existing or thereafter arising, whether direct, indirect, or consequential, and whether foreseeable or not), arising from their participation in the contest, whether the claim or cause of action arises under contract or tort.

In accordance with the delegation of authority to run this contest delegated to the judge responsible for this prize, the judge has determined that no liability insurance naming DOE as an insured will be

required of competitors to compete in this competition per 15 USC 3719(i)(2). Competitors should assess the risks associated with their proposed activities and adequately insure themselves against possible losses.

A.10 Records Retention and Freedom of Information Act

All materials submitted to DOE as part of a submission become DOE records and are subject to the Freedom of Information Act. The following applies only to portions of the submission not designated as public information in the instructions for submission. If a submission includes trade secrets or information that is commercial or financial, or information that is confidential or privileged, it is furnished to the Government in confidence with the understanding that the information shall be used or disclosed only for evaluation of the application. Such information will be withheld from public disclosure to the extent permitted by law, including the Freedom of Information Act. Without assuming any liability for inadvertent disclosure, DOE will seek to limit disclosure of such information to its employees and to outside reviewers when necessary for review of the application or as otherwise authorized by law. This restriction does not limit the Government's right to use the information if it is obtained from another source.

Submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

The submission must be marked as follows and identify the specific pages containing trade secrets, confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data:**
>
> Pages [list applicable pages] of this document may contain trade secrets, confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes. [End of Notice]

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Trade Secrets, Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, each line or paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets.

Competitors will be notified of any Freedom of Information Act requests for their submissions in accordance with 29 C.F.R. § 70.26. Competitors may then have the opportunity to review materials and work with a Freedom of Information Act representative prior to the release of materials. DOE does intend to keep all submission materials private except for those materials designated as "will be made public."

A.11 Privacy

If a competitor chooses to provide HeroX with personal information by registering or completing the submission package through the contest website, they understand that such information will be transmitted to DOE and may be kept in a system of records. Such information will be used only to respond to them in matters regarding your submission and/or the contest unless they choose to receive updates or notifications about other contests or programs from DOE on an opt-in basis. DOE and NREL are not collecting any information for commercial marketing.

A.12 General Conditions

DOE reserves the right to cancel, suspend, and/or modify the contest, or any part of it, at any time. If any fraud, technical failure, or any other factor beyond DOE's reasonable control impairs the integrity or proper functioning of the contests, as determined by DOE in its sole discretion, DOE may cancel the contest. Any performance toward contest goals is conducted entirely at the risk of the competitor, and DOE shall not compensate any competitors for any activities performed in furtherance of this prize.

Although DOE may indicate that it will select up to several winners for each contest, DOE reserves the right to only select competitors that are likely to achieve the goals of the program. If, in DOE's determination, no competitors are likely to achieve the goals of the program, DOE will select no competitors to be winners and will award no prize money.

DOE may conduct a risk review, using Government resources, of the competitor and project personnel for potential risks of foreign interference. The outcomes of the risk review may result in the submission being eliminated from the prize competition. This risk review, and potential elimination, can occur at any time during the prize competition. An elimination based on a risk review is not appealable.

A.13 Program Policy Factors

While the scores of the expert reviewers will be carefully considered, it is the role of the prize judge to maximize the impact of contest funds. Some factors outside the control of competitors and beyond the independent expert reviewer scope of review may need to be considered to accomplish this goal. The following is a list of such factors. In addition to the reviewers' scores, the below program policy factors may be considered in determining winners:

- Geographic diversity and potential economic impact of projects
- Whether the use of additional DOE funds and provided resources are nonduplicative and compatible with the stated goals of this program and the DOE mission generally
- The degree to which the submission exhibits technological or programmatic diversity when compared to the existing DOE project portfolio and other competitors
- The level of industry involvement and demonstrated ability to accelerate commercialization and overcome key market barriers
- The degree to which the submission is likely to lead to increased employment and manufacturing in the United States or provide other economic benefit to U.S. taxpayers
- The degree to which the submission will accelerate transformational technological, financial, or workforce advances in areas that industry by itself is not likely to undertake because of technical or financial uncertainty
- The degree to which the submission supports complementary DOE funded efforts or projects, which, when taken together, will best achieve the goals and objectives of DOE
- The degree to which the submission expands DOE's funding to new competitors and recipients who have not been supported by DOE in the past
- The degree to which the submission enables new and expanding market segments
- Whether the project promotes increased coordination with nongovernmental entities for the demonstration of technologies and research applications to facilitate technology transfer.

A.14 National Environmental Policy Act (NEPA) Compliance

This prize is subject to the National Environmental Policy Act (NEPA) (42 U.S.C. § 4321, et seq.). NEPA requires federal agencies to integrate environmental values into their decision-making

processes by considering the potential environmental impacts of their proposed actions. For additional background on NEPA, please see DOE's NEPA website at http://nepa.energy.gov/.

While NEPA compliance is a federal agency responsibility and the ultimate decisions remain with the federal agency, all participants in the Inclusive Energy Innovation Prize will be required to assist in the timely and effective completion of the NEPA process in the manner most pertinent to their participation in the prize competition. Participants may be asked to provide DOE with information on fabrication and testing of their device such that DOE can conduct a meaningful evaluation of the potential environmental impacts.

A.15 Definitions

Prize Administrator means both the Alliance for Sustainable Energy operating in its capacity under the Management and Operating Contract for NREL and [Program Office Name]. When the Prize Administrator is referenced in this document, it refers to staff from both the Alliance for Sustainable Energy and WPTO staff. Ultimate decision-making authority regarding prize matters rests with the Director of WPTO.

A.16 Return of Funds

As a condition of receiving a prize, competitors agree that if the prize was made based on fraudulent or inaccurate information provided by the competitor to DOE, DOE has the right to demand that any prize funds or the value of other non-cash prizes be returned to the government.

ALL DECISIONS BY DOE ARE FINAL AND BINDING IN ALL MATTERS RELATED TO THE PRIZE.

Appendix B. Innovation Methods

InDEEP will leverage WPTO investment into tools that help empower the marine energy community to achieve significant improvement in techno-economic performance of wave energy technologies. One specific WPTO-funded project focusing on these goals is Wave-SPARC (Systematic Process & Analysis for Reaching Commercialization), which incorporates lessons learned from earlier iterations of wave energy technologies to develop and test innovation methods for the acceleration of U.S. wave energy technology development.[12] Wave-SPARC developed a detailed systems engineering approach that simultaneously balances around 100 cost and performance drivers, or the functional requirements and capabilities for WECs. As such, Wave-SPARC has created publicly accessible innovation methods and assessment tools new to the wave energy sector. Their intent is to help guide technology development trajectories to successful outcomes in less time, at less overall cost, and with less encountered risk.

Operating in the ocean is inordinately expensive and challenging as compared to terrestrial technologies, and this approach is intended to help reduce some of those costs and risks early on. As part of InDEEP, competitors will be required to demonstrate their innovation method used in the development of their concept.

The following are five innovation methods included to provide a broader perspective into techniques or approaches that may be pursued in support of concept development for InDEEP. This list is not intended to be comprehensive, and competitors are encouraged to leverage any of the innovation methods listed or any other that suits their technology development process.

B.1 TIPS/TRIZ (Theory of Inventive Problem Solving)

TRIZ is an abbreviation of the Russian term *Theoria Resheneyva Isobretatelskehuh Zadach* (TRIZ), and in English, is referred to as Techniques for Inventive Problem Solving (TIPS). Many innovation methods provide little guidance on the development of solutions and often lean on tradition and/or intuitive methods. In contrast, TRIZ provides clear guidance on the development of potential problem solutions based on the problem statement and eventually to be evaluated by the assessment method. This central part, the ideation, is based on the evidence of decades of successful inventions.

Surveying an enormous number of successful patents, Altshuller identified that a plethora of problem statements can, in a generalized form, be brought back to a finite and much smaller number of problem formulations. Furthermore, it was possible to reduce the number of processes that lead to the inventive solutions to a representative 40 inventive principles. Finally, TRIZ provides clear guidance toward the most appropriate inventive principles for the generalized problem statements through the TRIZ Contradiction Matrix. Thus, the TRIZ methodology covers all three components of problem formulation, ideations and solution assessment of the technology innovation process as depicted in in Figure B-1.

Figure B-1. High-level core components of the innovation process

[12] https://energy.sandia.gov/programs/renewable-energy/water-power/projects/wave-sparc/

B.2 Double Helix Innovation Methodology

The Double Helix Innovation Method was developed by Colin Keogh[13] to be a simple multistage, highly iterative innovation process that is usable by a wide range of people in different fields. The methodology was developed with the following requirements in mind; A Simple Multistage Process; Highly Iterative Nature; Smooth Stage Transitions; Built-in Reviews; Clear Directional Guidance; Clear Start and End Points; Clear, Easy to Follow Visuals; Avoiding Overly Complex Models; Grouping of Useful Tools; Separation of Phases and Steps; Assessment of Current Positioning, and; Flexibility to Adapt. The method borrows and adapts tools from other more established innovation methodologies and builds a new decision management structure around these tools.

B.3 Axiomatic Design

Axiomatic Design (AD) Theory is an attempt to integrate pieces of systems engineering, lean manufacturing, and other more established but piecemeal approaches into a single framework. AD is a formal design methodology that helps designers structure their thoughts and the design process in a systematic and rational way. This, in turn, is intended to reduce trial-and-error in the design process, increase design productivity, and improve the quality of the result. At its core, AD theory considers coupled systems to be the least desirable because coupling increases the complexity of the system.

B.4 Ethnographic Design

The ethnographic design methodology is centered around the idea that fully understanding a culture/society/community is a vital part of the design process. The ethnographic method aims to understand the future users of a design or service and helps designers work on idea generation, concept development, and implementation. Ethnographic design methodology highlights the importance of designing devices to suit the needs of the community they will eventually serve. Different communities inherently have different energy needs due to the climate in which they live, the amount of daylight available to them, the natural resources they are reliant on, local economics, and their energy availability. Communities in warmer climates may rely more heavily on refrigeration for food storage, whereas communities in colder climates would benefit more from providing energy to lighting systems. Connecting marine energy with ethnographic design methodology requires understanding the different energy needs of communities which utilize (or could benefit from) marine energy systems.

B.5 Quality Function Deployment

Being founded upon a customer driven inventive methodology, Quality Function Deployment (QFD) is an approach guided by the “voice-of-the-customer.” In large part, this means QFD seeks to capture customer requirements (for a desired type of technology) by way of customer interviews, focus groups, contextual inquiry, interviews, ethnographic techniques, conjoint analysis, etc. QFD, therefore, seeks to translate directly from qualitative customer requirements to quantitative engineering requirements to drive innovation.

[13] Keogh, C. 2020. “Development of a Novel Methodology for Applied Innovation Practice,” Ph.D. thesis. University College Dublin.

Appendix C. Training Resources

Marine Energy Reading Materials

- Grid Value proposition of marine energy: PNNL Grid Value Proposition of Marine Energy PNNL-31123
- Comprehensive review of the wave energy research and commercialization environment: A review of wave energy technology from a research and commercial perspective, Guo and Ringwood (2021) (https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/rpg2.12302)
- Wave Energy technology brief by Dave Hume: https://theliquidgrid.com/marine-clean-technology/wave-energy-converters/
- Waves and wave energy brief explanations: Wave Energy and Wave Changes with Depth | manoa.hawaii.edu/ExploringOurFluidEarth
- The WPTO MHK101 PowerPoint – will be shared with competitors
- 2-page fact sheet describing wave energy converter archetypes (2013) - A Primer on Wave Energy (oregonstate.edu)
- State of the Science Executive summary to understand environmental impacts and research: OES-Environmental-2020-State-of-the-Science-Executive-Summary_final_hr.pdf (pnnl.gov)
- WPTO Powering the Blue Economy report – for a broad overview, Ch. 1 Introduction and Ch. 11 Summary and Conclusions (2019): Powering the Blue Economy Report | Department of Energy
- Podcast episode feat. Pacific Northwest National Laboratory researcher Andrea Copping, broad overview on all types of marine energy: The Energy Transition Show with Chris Nelder: Marine Energy [abridged] on Apple Podcasts
- Wave and Tidal Energy (*paywall)*: https://www.wiley.com/en-ie/Wave+and+Tidal+Energy-p-9781119014492
- Handbook of Ocean Wave Energy, Editors: Arthur Pecher and Jens Peter Kofoed, Springer, 2017, https://link.springer.com/book/10.1007/978-3-319-39889-1

DEEC-Tec

- DEEC-Tec overview: How Wave Energy Could Go Big by Getting Smaller | News | NREL
- DEEC-Tec report: Distributed Embedded Energy Converters for Ocean Wave Energy Harvesting: Enabling a Domain of Transformative Technologies: Preprint (nrel.gov)
- DEEC-Tec webinar (2022): WPTO R&D Deep Dive Webinar Series: Distributed Wave Energy - YouTube
- Flexible membrane structures for wave energy harvesting: a review (2021): https://www.sciencedirect.com/science/article/abs/pii/S1364032121007590
- Distributed Embedded Energy Converter Technologies Overview: https://www.nrel.gov/water/distributed-embedded-energy-converter-technologies.html

Wave-SPARC materials

- Technology Performance Level Assessment Tool: https://tpl.nrel.gov/
- Wave-SPARC: Systematic Process and Analysis for Reaching Commercialization Overview (NREL): https://www.nrel.gov/water/wavesparc.html
- Wave-SPARC: Systematic Process and Analysis for Reaching Commercialization Overview (Sandia): https://energy.sandia.gov/programs/renewable-energy/water-power/projects/wave-sparc/
- D. Bull, R. Costello, A. Babarit, K. Nielsen, C. B. Ferreira, B. Kennedy, R. Malins, K. Dykes, J. Roberts, and J. Weber. “Systems Engineering Applied to the Development of a Wave Energy

Farm," Sandia National Laboratories. Albuquerque, NM, USA. SAND2017-4507, Version 1.01, April 2017, https://www.osti.gov/biblio/1365534
- Weber (2012). "WEC Technology Readiness and Performance Matrix – finding the best research technology development trajectory". International Conference on Ocean Energy, Dublin, Ireland. October 17-19, 2012. https://www.icoe-conference.com/publication/wec_technology_readiness_and_performance_matrix_finding_the_best_research_technology_development_trajectory/
- Bull et al. "Scoring the Technology Performance Level (TPL) Assessment". European Wave and Tidal Energy Conference, Cork, Ireland. Aug 27 – Sep 1, 2017. <https://www.osti.gov/servlets/purl/1456719>, https://www.osti.gov/servlets/purl/1469052

Supplementary Materials Beyond the Scope of the Prize

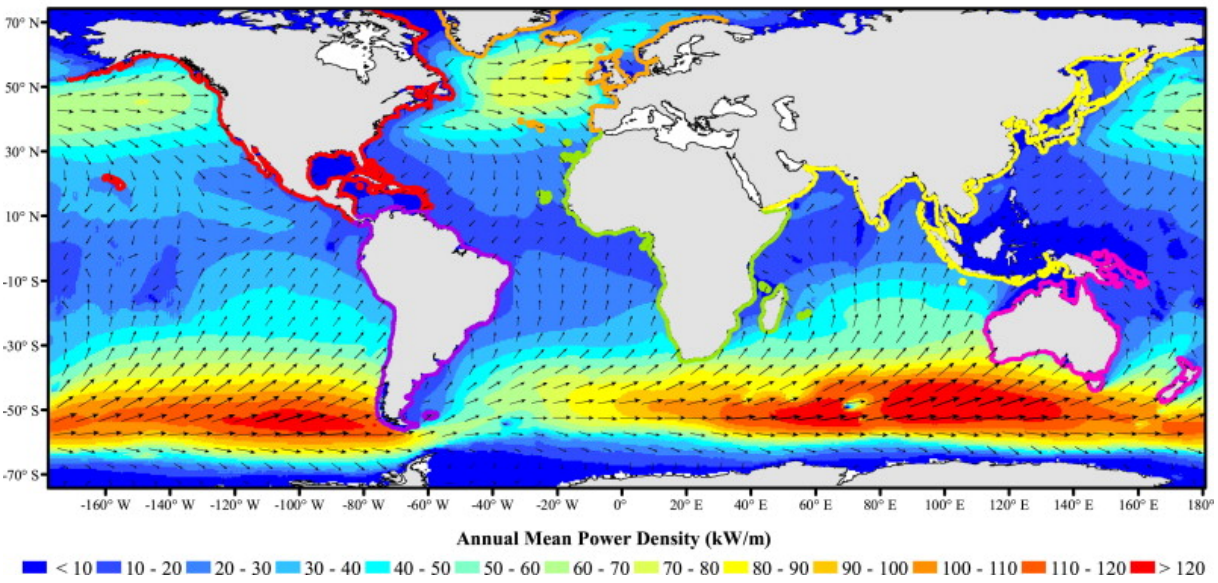
- PRIMRE code hub at https://openei.org/wiki/PRIMRE/Software.
- WEC Sim videos and training: https://wec-sim.github.io/WEC-Sim/master/user/webinars.html
- Falnes, Johannes; Kurniawan, Adi. (2020) Ocean waves and oscillating systems : linear interactions including wave-energy extraction. Cambridge University Press. 2020. ISBN 9781108481663, https://www.cambridge.org/core/books/ocean-waves-and-oscillating-systems/8A3366809DE5C1F916FF87F36C55C459.
- C Mei Chiang (MIT), Michael Stiassnie (Technion-Israel Institute of Technology, Israel), and Dick K-P Yue (MIT). (July 2005) Theory and Applications of Ocean Surface Waves, Advanced Series on Ocean Engineering, Section 8.9 Power Absorption by Floating Bodies, https://doi.org/10.1142/5566
- Systematic innovation with TRIZ and xTRIZ, http://www.xtriz.com/
- A framework for disruptive innovation in an industry where everything is innovative: https://www.diva-portal.org/smash/get/diva2:858101/FULLTEXT01.pdf.
- Books and/or information for innovation techniques, conceptualization strategies, and design discovery:
    - 40 Principles: TRIZ Keys to Technical Innovation [ISBN-13 : 978-0964074033]
    - Trizics: Teach yourself TRIZ, how to invent, innovate and solve "impossible" technical problems systematically [ISBN-13 : 978-1456319892]
    - TRIZ For Dummies [ISBN-13 : 978-1119107477]
    - Solve It!: The Mindset and Tools of Smart Problem Solvers [ISBN-13 : 978-3903386037]
    - Critical thinking, Logic & Problem Solving: The Ultimate Guide to Better Thinking, Systematic Problem Solving and Making Impeccable Decisions with Secret Tips to Detect Logical Fallacies [ISBN-13 : 979-8363860713]

Appendix D: Supplemental Market and Technology Background

Market Opportunities

Marine energy resources—such as waves, tides, and ocean currents—are abundant, geographically diverse, energy dense, predictable, and complementary to other renewable energy resources.[14] More than 50% of the U.S. population lives within 50 miles of coastlines, where there is vast potential to provide clean, renewable electricity to communities and cities. WPTO has identified the full potential for future electricity production from our nation's water resources.[15]

Of these resources, wave energy is the most abundant and geographically diverse marine energy resource in the United States. To give an idea of the global wave power potential, the annual mean wave power density globally is shown in Figure D-1Figure D-1. However, it is also the most complex and expensive resource from which to harness energy. This complexity has resulted in a range of wave energy converter designs in the industry.[16] While this diversity can enable systems to be optimized for specific markets and locations, it comes at the price of supply chain availability and cost and complicates workforce training. The materials and manufacturing costs for devices harnessing energy from waves, along with performance and reliability improvements yet to be realized for WECs result in high-cost devices. Because of these challenges, WPTO is motivated to identify high-potential, early-stage solutions to these challenges to improve the efficiency of WECs and reduce costs, ultimately leading to widespread market adoption, energy generation, and other benefits.



[14] https://www.energy.gov/eere/water/advantages-marine-energy
[15] U.S. Department of Energy, "Marine Energy Resource Assessment and Characterization." https://www.energy.gov/eere/water/marine-energy-resource-assessment-and-characterization.
[16] Different wave energy converter technologies: https://openei.org/wiki/PRIMRE/MRE_Basics/Wave_Energy

Figure D-1. Annual mean wave power density and annual mean best direction[17]

There is also significant deployment potential out to 2050 and beyond and many reasons why continued investment in marine renewables can be important for long-term U.S. climate goals. Given the trajectory of continuing cost reductions and the historical progress of innovation for other renewable technologies, up to 50 GW of marine energy capacity could be added in the United States by 2050. Modeling efforts also show that to achieve long-term 2050 clean energy goals while also meeting America's growing energy needs, the pace of renewables deployment will need to continue accelerating past 2040, and relatively newer technologies—like marine energy—may be well positioned to support ambitious long-term targets.

Technology Development

A distributed embedded energy converter (DEEC) is a relatively small device that acts as both an energy transducer and a structural mechanism. A DEEC's energy transducer converts an external energy source—such as structural bending, hydraulic pressures, shock loads, pneumatic pressures, etc.—into more usable forms of energy, e.g., electricity. A DEEC's structural mechanism not only houses a DEEC's energy transducer, but also enables a DEEC to interconnect and/or embed with many other DEECs to form, in aggregate, a DEEC-Tec metamaterial. These DEEC-Tec metamaterials could be used to build ocean WECs—structures that harvest and convert ocean wave energy throughout the structure itself.

The prize begins with concept development in Phase I, followed by a benchtop proof-of-concept of an individual DEEC in Phase II, then a combination of individual DEECs to form a DEEC-Tec metamaterial in Phase III. Various innovation methods are introduced in Appendix B with the goal of generating new DEEC-Tec concepts. The outcomes of the prize are intended to be precommercial DEEC-Tec metamaterials relevant to wave energy devices with high techno-economic potential. WPTO intends to provide future support after the prize to develop these concepts and move them along the commercialization pathway for both near-term applications in a range of industries and long-term applications in grid-scale marine energy.

In addition to understanding the potential of DEEC-Tec, WPTO aims to build an interdisciplinary solver community with knowledge and expertise to address opportunities and challenges specific to DEEC-Tec. Through this prize, WPTO will support competitors through access to experts in marine energy, DEEC-Tec, and more. Experience with wave energy converters is not required to compete. WPTO has identified the following technologies that have potential to be transferable to wave energy, but this list is not intended to be comprehensiveFigure D-2. Ideas not identified on this list are encouraged, and concepts already in use in wave energy are also encouraged to participate.

Though this prize focuses on wave energy applications for DEEC-Tec, DEEC-Tec are relevant to a variety of industries. Because this prize seeks to engage innovators in a range of disciplines, technology development achieved within this prize may be relevant to other industries beyond wave energy and support de-risking this development in multiple areas.

[17] Gunn, K., and Stock-Williams, C. 2012. "Quantifying the global wave power resource." Renewable Energy, 44:296–304. https://doi.org/10.1016/j.renene.2012.01.101.

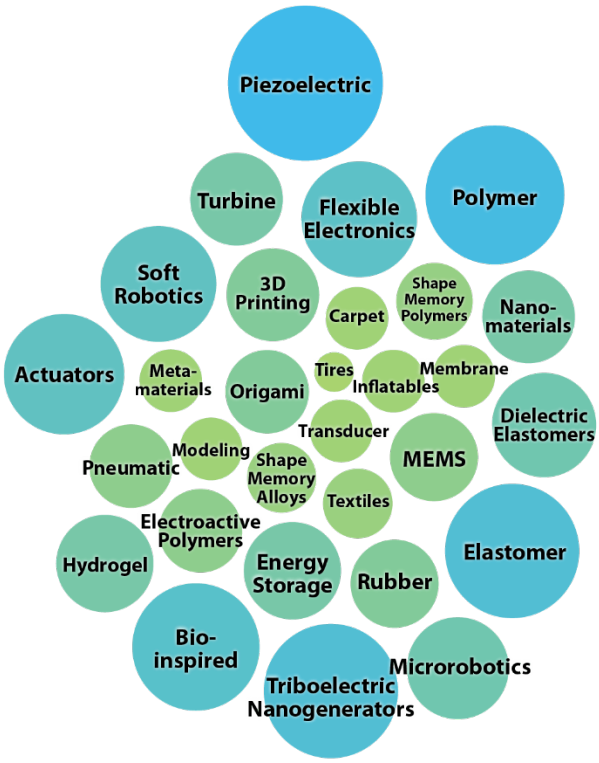


Figure D-2. Potential technology areas that could be transferrable to wave energy. This is not intended to be comprehensive but serves as example areas of interest.