InDEEP

Innovating Distributed Embedded Energy Prize

OFFICIAL RULES

July 2024: Phase III

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

July 2024

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

List of Acronyms and Abbreviations

DEEC	distributed embedded energy converter
DEEC-Tec	distributed embedded energy conversion technologies
DOE	U.S. Department of Energy
InDEEP	Innovating Distributed Embedded Energy Prize
NEPA	National Environmental Policy Act
TPL	technology performance level
TRIZ	Theory of Inventive Problem Solving
TRL	technology readiness level
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 and Phases

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 III of the prize. Phase descriptions and requirements are summarized in Table 1 and Phase III details are included in the following sections. InDEEP Phase III is only open to winners of Phase II.

Table 1. InDEEP Phase Awards and Phase Descriptions

InDEEP Phase	Awards and Dates	Description
Phase I (closed) *Team Building/Engagement and Concept Creation*	*March 22, 2023–Aug. 25, 2023* *19 teams selected as winners, each receiving $15k for a total of $285k distributed.*	*Phase I of InDEEP engaged interdisciplinary teams and incentivized the use of innovative methodologies in the development of novel DEEC-Tec concepts. This phase familiarized participants with DEEC-Tec, ocean wave energy, and the integration of these two applications to find new potential solutions.*
Phase II (closed) *Simple Prototype Proof-of-Concept*	*Nov. 7, 2023–May 7, 2024* *15 teams selected as winners, each receiving $80k for a total of $1.2M distributed.*	*Phase II was focused on innovators demonstrating their concepts at the transducer level. Teams built and tested a single DEEC at the benchtop scale. The test reflected the dynamic operational ranges of their designs and assessed performance characteristics such as energy conversion and power density. This phase marked the final opportunity for new teams to enter the prize.*
Phase III	July 29, 2024–January 27, 2025 (anticipated) Up to 4 teams will compete for a Grand Prize pool up to $800k.	*In Phase III, teams will integrate DEEC transducers into a DEEC-Tec metamaterial and test their systems. Teams will then present on their DEEC transducers and DEEC-Tec metamaterials and detail their test results against performance characteristics like energy conversion, power density, and others as defined in a final TPL assessment. At the conclusion of Phase III, all competitors will be invited to attend an in-person Final*

	Each team has the potential to win up to $200k in this phase.	*Event at a National Renewable Energy Laboratory facility in Colorado. At least one representative from each team must be present at the in-person Final Event Design Presentation for the competitor to be considered for a Phase III Grand Prize.*

1.2 Important Dates

The following is the anticipated InDEEP Phase III schedule. The dates listed in Table 2 are anticipated and subject to change.

Table 2. InDEEP Phase III Schedule

Anticipated Date	Milestone
July 29, 2024	Phase III submissions and leaderboard open
January 24, 2025	Phase III leaderboard closes
January 27, 2025	Phase III closes
March 5-7, 2025	Phase III Final Event (winner announcement and awards)

1.3 Eligibility and Competitors

Eligible Competitors

The Phase III competition is open only to winners of Phase II of this prize. At least one representative from each team must be present at the in-person Final Event Design Presentation for the competitor to be considered for a Phase III Grand Prize.

The competition is only open 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 Binding Operational Directives 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. See 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:

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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 satisfies laws of physics.
- The submission uses ocean wave energy.
- 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 and DEEC-Tec metamaterial 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 use 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]

InDEEP is expected to contribute to four high-level objectives within the WPTO 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 by conceptualizing a variety of high techno-economic DEEC concepts.
2. InDEEP encourages the use of systems engineering approaches and innovation 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 innovation 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 multidisciplinary community of diverse innovators working to understand how DEEC-Tec and similar technology areas can be applied to wave energy.
4. InDEEP will help prepare promising high potential technologies for future research and maturation by providing comprehensive competitor support for every stage of technology development, from conception to building and testing.

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 blue economy markets, such as

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

ocean observation, marine aquaculture, or seawater mining. WPTO intends to provide subsequent funding opportunities for maturing promising high techno-economic potential technologies after the prize. For additional reference material, WPTO's long-term plans are detailed in the multiyear program plan.[4]

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 WECs 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 C) 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 DEECs 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 is an emerging area of research with the potential for harvesting and converting ocean wave energy through non-force-concentrating technologies.[5]

The smallest and most fundamental technology scale is the individual DEEC, with each DEEC acting as both a small energy transducer and as a base-level structural mechanism, which was 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 assembling various types of DEEC-Tec metamaterials and other components to form a fully functioning ocean WEC. The sequence is DEECs → DEEC-Tec metamaterials → a DEEC-Tec-based WEC (see figures in Appendix B).

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.

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[4] https://www.energy.gov/eere/water/multi-year-program-plan
[5] https://www.nrel.gov/water/distributed-embedded-energy-converter-technologies.html

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.

2.1 Technology Development Trajectory and Innovation

Technology development can be charted along the technology readiness level (TRL)-technology performance level (TPL) matrix (Figure 1) 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, long development timelines, and high risks. Because iterative testing at a high TRL is expensive in the ocean wave environment, InDEEP encourages teams to leverage systems engineering methodologies early in their concept development. Devices need to have a high level of performance at the benchtop scale, yielding fewer costly iterations later on and creating systems with high techno-economic potential at the deployment scale.

InDEEP calls for innovation alongside assessment in each phase (an essential aspect emphasized in Figure 1). 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.

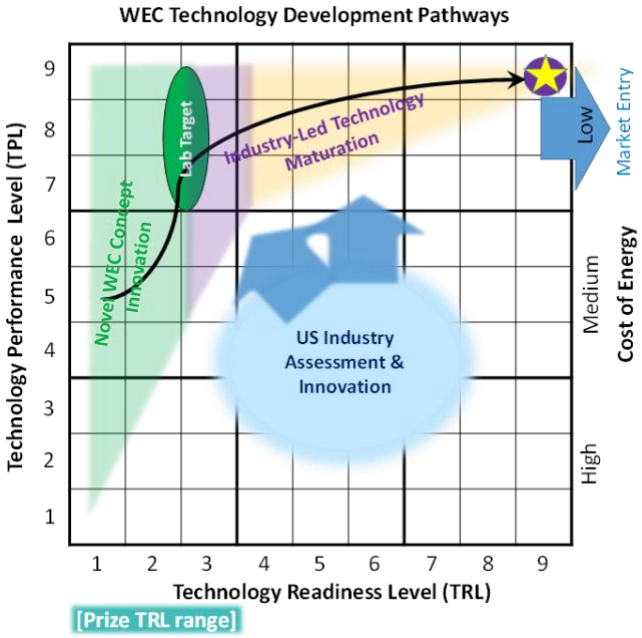

Figure 1. Technology development trajectory, comparing technology performance level and technology readiness level

2.2 Technology Performance Level 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.[6] 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.[7] Beyond supporting the design process, the final score of a TPL assessment provides a sense of the "promise/potential" a technology holds when fully matured. This includes, in addition to techno-economics, considerations of societal benefits, ability to be permitted and certified, environmental impacts, safety, and survivability.

InDEEP uses a shortened and simplified version of the full TPL assessment of a WEC as a system for the continental grid application (https://tpl.nrel.gov/). Competitors must complete a self-evaluation by responding to 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 III is included in Section 4.

As in Phase II, during Phase III the TPL assessment will contribute to the competitor's overall final score. Competitors are expected to complete a TPL assessment for their DEEC-Tec metamaterial, in which feedback from the Phase II submission has been incorporated and the team has identified any synergistic benefits from aggregating multiple DEECs into a metamaterial.

A primary technology development goal of this prize is that the winning technology concepts must demonstrate high techno-economic potential, such that the TPL assessment will contribute to scores in Phase III and be incorporated into the final pitch session. 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 44.

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 is 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, and guides 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.

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[6] 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.

[7] 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.

During the prize, competitors are asked to describe how their DEEC-Tec concept could interact with ocean waves. Although 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.

During Phases I and II, competitors referenced ocean wave parameters derived from the sea states in Bull and Dallman[8] that are representative of locations for utility electrical grid-scale WEC deployment off the U.S. West Coast and Hawaii (Appendix B).

In Phase III, competitors must describe how the parameters in Table 3 are relevant to their DEEC-Tec metamaterial, but competitors may also reference the tables used in Phase I and II to describe individual DEEC interaction parameters and wave parameters (Appendix B). Competitors developing individual DEEC designs or DEEC-Tec metamaterials outside these parameters will need to provide more explanation and justification.

Table 3. 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 1.5.

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 on the HeroX platform. During Phase III, 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 4.2.1).

[8] 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.

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 may be asked for their input on the types of support that will be the most relevant to them.

Specific to Phase III, competitors will receive access to the support listed in Table 4Table 4 in the development of their DEEC metamaterials.

Table 4. 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.
Training Sessions	Live webinars will be provided covering the following topics: • Wave Energy 3.0 • DEEC-Tec 3.0 • Innovation Methods 3.0 • TPL Assessment 3.0. Additional topics may be identified during Phase III and will be announced on the HeroX platform.

Additional support may be added later and announced on the HeroX platform.

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 Phase III Scoring and Submission Requirements

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 InDEEP TPL assessment to their DEEC-Tec metamaterial to determine the holistic 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. Additionally, the TPL assessment will be scored in this phase.

At the conclusion of Phase III, all competitors will be invited to attend an in-person Final Event at a National Renewable Energy Laboratory (NREL) facility in Colorado. During this event, competitors will

present their plans for post-prize design optimization during a Design Presentation, and share high level information related to their designs and participation in the prize to the broader DEEC-Tec community through poster presentations. A hybrid option may be available, but at least one representative from each team must be present at the in-person Final Event Design Presentation for the competitor to be considered for a Phase III Grand Prize. Competitors are responsible for all costs associated with travel. It is encouraged that competitors leverage Phase II funding to offset travel costs, as no additional funding will be provided for travel to the Final Event.

4.1 How to Enter

Follow the instructions for registering and submitting all required materials before the deadline in Table 2 or as displayed on the HeroX website. Phase III is only open to winning teams from Phase II.

4.2 Phase III Submission Requirements

All competitors will submit the required submission materials, which will be evaluated in multiple parts, as outlined in Table 5. Note that any changes to the due dates will be posted on HeroX. Submission materials will be evaluated as outlined in Section 4.2.1.

Table 5. Submission Requirements for Phase III

Item	Description	Will Be Made Public[9]	Scored Item	Due
Technical Narrative	Up to 5,000 words in length. Teams may also include up to 5 supporting drawings, images, or graphics.	No	Yes	At Phase III Close.
Phase III TPL Assessment	Read, review, and complete a simplified version of the TPL Assessment focused on the DEEC-Tec metamaterial.	No	Yes	At Phase III Close.
Test Report	A technical document that describes the test set-up needed to demonstrate DEEC-Tec metamaterial and including results from testing. This document should be updated to incorporate feedback received during Phase II.	No	Yes	At Phase III Close.
Virtual Interview and 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. Unlike in Phase II, the prize administration team will evaluate this demonstration.	No	Yes	After Phase III Close, prior to Final Event.
Final Event Design Presentation	All competitors will present to an expert review panel, discussing how the TPL informed their decisions in Phase III, what changes they saw between their Phase II and Phase III TPL assessments, and their plans for further refining	No	Yes	Slides (if applicable) due 1 week prior to Final Event

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

	their technologies after the conclusion of Phase III.			
Final Event Poster	All competitors are invited to present a poster during the in-person Final Event.	Yes	No	2 weeks prior to Final Event.

4.2.1 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
Strongly Disagree/Does Not Address	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree/Fully Addresses

Table 6 explains the manner by 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 6. Submission Scoring Criteria

Submission Component	Potential Points	% of Total Score
Phase III Technical Narrative	**80**	**32%**
Criterion 1: Team Characteristics and Excellence	5	
Criterion 2: Innovation Process	30	
Criterion 3: Viability of the Concept	25	
Criterion 4: Future Plans to Mature Technology	20	
Phase III TPL Assessment	**15**	**6%**
Test Report	**20**	**8%**
Leaderboard Submissions	**15**	**6%**
Virtual Interview and Demonstration	**40***	**16%**
Final Event Design Presentation	**80**	**32%**
Criterion 1: Lessons Learned and Potential	20	
Criterion 2: End-Use Application	10	
Criterion 3: Future Plans	15	
Reviewer Recommendation	35	
TOTAL	**250**	**100%**

*Competitors scores are multiplied by 2 for a total of 40 possible points.

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[10] available on HeroX.

Table 7 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 7. Technical Narrative Evaluation Criteria

Technical Narrative Criterion 1: Team Characteristics and Excellence	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**
• Evaluate your current team and identify the technical gaps missing (potentially from TPL assessments or other means) 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.	• The competitor demonstrates an ability to leverage multidisciplinary skill sets to foster a well-rounded team and a path forward to fill these gaps and further optimize their capabilities.

Technical Narrative Criterion 2: Innovation Process	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**
• 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 C. • Describe your vision to mature the concept and what you need to guide your innovation process, during and after the prize. • Describe how systems engineering approaches, TPL insights, engagement of competitor support, and use of innovation methodologies influenced your design thinking in a way that increased the likelihood of the long-term success of your technology.	• The competitor clearly describes the innovation technique(s) used and how they iterated on the proposed concept. • The competitor has effectively leveraged the innovation technique(s) and the systems engineering approach(es) to balance the weaknesses identified by the TPL assessment. • The competitor has clearly described how TPL and systems engineering methodologies informed their design and resulted in improvements (via design changes or updated metrics). • 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. • The competitor has clearly described their vision to mature the concept and what they need to guide their innovation process after the prize.

[10] To assist teams, the Prize Administrator is providing an elective template to illustrate the information needed to evaluate whether teams meet minimum requirements in the associated critical success factors. Teams are not required to use this template and may submit using any form or format of their choosing. All submissions should address the substantive measures outlined in the template and described in this Rules document.

	• The competitor has provided a thoughtful and accurate assessment of current technical gaps and areas of expertise and how their intended plan is likely to resolve these gaps.

Technical Narrative Criterion 3: Viability of the Concept	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**
• Describe how your plans for innovation are relevant to a DEEC-Tec metamaterial and not just innovation of the individual DEECs. • Describe what energy goes into your DEEC-Tec metamaterial, the energy transformation(s) that occur, and the net useful energy output. • Describe which parameters were chosen (in Table 3) and their influence on the efficiencies of the energy conversion for your DEEC-Tec metamaterial, or, if you are using alternative parameters, identify and justify those here. • Describe any mechanisms that transform, influence, augment, enhance, boost, and/or filter the energy the DEEC-Tec metamaterial encounters. • Provide a set of drawings or sketches representing the DEEC-Tec metamaterial geometry, size, and deformation or other changes during operation. (These drawings or sketches could include simple geometric profile drawings of the DEEC-Tec metamaterial.) • Develop a concept storyboard to represent how individual DEECs interact with each other within the DEEC-Tec metamaterial and how the DEEC-Tec metamaterial generates useful energy. • Describe how test results provided the evidence that there is a likely pathway to long-term viability of your concept.	• The competitor clearly describes the energy conversion steps performed by their DEEC-Tec metamaterial. • The competitor clearly describes a valid concept for a DEEC-Tec metamaterial. • The competitor clearly demonstrates how the individual DEEC and the DEEC-Tec metamaterial will operate together. • The competitor has provided easily understood drawings, sketches, and a storyboard that explain the interactions between the individual DEECs and DEEC-Tec metamaterial and how useful energy is being generated and transferred. • The competitor's concept has the potential to effectively operate as a DEEC-Tec metamaterial.

Technical Narrative Criterion 4: Future Plans to Mature Technology	
Suggested Content Competitor Provides	**Each Statement Scored on a 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. • Identify how continued use of systems engineering approaches, TPL insights, and use of innovation methodologies will influence your future plans in a way that increases the likelihood of the long-term success of your technology.	• The competitor has clearly described a plan for the development of the DEEC-Tec metamaterial post prize using an innovation method and addressing risks identified in the TPL assessment. • The competitor has identified future avenues for advancement of their DEEC-Tec metamaterial, such as through an applicable testing network/in-house capabilities/partnering.

• Identify plans for further advancement of the DEEC-Tec metamaterial. • Identify opportunities to improve DEEC-Tec metamaterial post prize. • 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 of how the planned work will reduce missing information, reduce risks, and increase prospects of successful outcome.	• The competitor has identified future plans to take their DEEC-Tec metamaterial towards commercialization. • The competitor identifies risks and the challenges in maturing the technology and has plans that are likely to manage these identified risks.

Phase III TPL Assessment

The TPL Assessment to be completed in Phase III 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, using the criteria outlined in Table 9. The self-assessed numerical scores will not be included in the final score. Specific TPL questions to be included are in Table 8 and a template[12] 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 in Table 11, teams can earn points for engaging support organizations during their development process.

Table 8. Phase III TPL Assessment Questions

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

[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.

[12] To assist teams, the Prize Administrator is providing an elective template to illustrate the information needed to evaluate whether teams meet minimum requirements in the associated critical success factors. Teams are not required to use this template and may submit using any form or format of their choosing. All submissions should address the substantive measures outlined in the template and described in this Rules document.

3	How many conversion steps are there within the DEEC-Tec metamaterial? 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-the-shelf components where commercial-off-the-shelf components are common.	Cost of Energy
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 DEEC-Tec metamaterial 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 DEEC-Tec metamaterial?	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 DEEC-Tec metamaterial at risk of damage?	Safety and Function
13	Is there any synergistic amplification of benefits from connecting multiple DEECs together in a DEEC-Tec metamaterial? And how does that scale with the number of DEECs?	Cost of Energy
14	Can the metamaterial also function as an actuator?	Cost of Energy, Safety and Function

Table 9. TPL Assessment Evaluation Criteria

TPL Assessment Criterion: Assessment Process	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**
• Fully completed TPL assessment that thoroughly addresses each TPL question with scores, justification, and background information.	• 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 assessment conveys. • The competitor has a plan to address weaknesses through innovations, technology adjustments, design changes, and/or mitigation strategies.

Test Report

The test report clearly explains the process the competitor followed to test the DEEC-Tec metamaterial 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.

The test report should include the following components in sufficient detail to address the scored statements listed in Table .

Description of DEEC-Tec metamaterial, including:

- Materials used for the metamaterial, 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, including:

- 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 Table 3, or representative substitutes.
- Any materials needed to hold/fix the DEECs as a metamaterial.
- Description of how inputs and outputs are measured, including instrumentation, sensors, change-over time, run duration(s), and overall timing of the test.
- Any post-processing and/or filtering.
- Associated testing standards (ISO, IEEE, IEC, ASTM, etc.) if applicable.

Explanation of the physics represented in the test process, including:

- 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-Tec metamaterial.
- Power estimates and/or calculations.
- Description of the parameters that can be used to control the properties of the DEEC-Tec metamaterial (if applicable).
- Time-varying characteristics, continuous or discrete.

Description of test results, including:

- Specific amount of energy entering the DEEC-Tec metamaterial.
- The DEEC-Tec metamaterial energy output.
- Net electrical power generated.

- Conversion efficiency.
- All sensing, signal treatment, and data acquisition relevant to the results.

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 in Table 11, 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 of the evaluation criteria outlined in Table 10.

Table 10. Test Report Evaluation Criteria

Test Report Evaluation Criteria	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale**
• Describe the DEEC-Tec metamaterial, including any complementary information that will help the Prize Administrator understand how the metamaterial was built/assembled and how it functions. • Describe the testing process, written as a repeatable process. • Explain the physics represented in the testing process. • Provide a full description of the test results.	• The competitor has adequately described the DEEC-Tec metamaterial, 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 repeatable. • 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.

Leaderboard Submissions

The leaderboard, hosted on HeroX, is a representation of engagement throughout Phase III.

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 Table 11, and teams can receive up to 5 points per scoring criterion, for a maximum of 15 additional points.

Specific engagement activities will be offered on the HeroX platform directly and updates will be shared on the leaderboard as teams complete these activities. The leaderboard scores are not a reflection of teams' overall place in the prize. In Phase III, competitors do not need to complete the leaderboard eligibility form prior to earning points. It is the responsibility of the competitor to notify the Prize Administrator if they notice discrepancies in expected scores or in the displayed team name. It is also the responsibility of the competitor to notify the Prize Administrator of any changes to their team throughout the phase that may impact tracking of engagement.

Leaderboard activities are prescored based on the maximum points identified in Table 11. The team leverages educational tools and support mechanisms provided by the Prize Administrator to better understand key prize elements and build the prize community.

Table 11. Leaderboard Scoring

Leaderboard Points Breakdown and Descriptions of Activities	
Maximum Number of Points	**Description of Activity**
5	Earn one point per instance for attending a Power Connector event, such as a Power Connector hosted webinar, office hours, or one-on-one meeting. For a maximum of five points. Check the HeroX platform for these opportunities.
3	Earn one point per instance for engaging on the HeroX forum, such as asking questions or responding to questions others have posted. For a maximum of three points.
1	Complete a short questionnaire providing feedback on available prize support mechanisms (vouchers, Power Connectors, etc.). Link to be provided on the HeroX platform.
1	Attend the training on TEAMER. Dates and link to be provided on the HeroX platform.
1	Attend the training on applying for future funding opportunities. Dates and link to be provided on the HeroX platform.
1	Attend the third level of training on wave energy. Dates and link to be provided on the HeroX platform.
1	Attend the third level of training on innovation methods. Dates and link to be provided on the HeroX platform.
1	Attend the third level of training on DEEC-Tec. Dates and link to be provided on the HeroX platform.
1	Attend the third level of training on TPL Assessments. Dates and link to be provided on the HeroX platform.

Live Virtual DEEC-Tec Metamaterial Demonstration

A Live Virtual DEEC-Tec Metamaterial Demonstration will be scheduled with eligible competitors shortly following the close date of Phase III and will be administered via a videoconferencing service, similar to Phase II. This Live Virtual DEEC-Tec Metamaterial 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.

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.

Live Virtual DEEC-Tec Metamaterial 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, and confirmation that the results are aligned with the materials submitted.

- Questions from the Prize Administrator related to the test or submitted materials.

Competitors will be scored on the outcomes of the Live Virtual DEEC-Tec Metamaterial Demonstration based on the evaluation criteria in Table 12. Following the demonstration, competitors will have an opportunity to respond to any feedback provided by the review team during and immediately following the meeting.

Table 12. Live Virtual DEEC-Tec Metamaterial Demonstration Evaluation Criteria

Live Virtual DEEC-Tec Metamaterial Demonstration Evaluation Criteria	
Suggested Content Competitor Provides	**Each Statement Scored on a 0–5 Scale***
• A screen-shared file/website with a high level introduction of the team and agenda outlining the planned demonstration. • A live video via the videoconference call of the DEEC-Tec metamaterial outside the test apparatus. • A live video via the videoconference call of the test apparatus. • A live video via the videoconference call of the DEEC-Tec metamaterial inside the test apparatus. • A live video via the videoconference call of the DEEC-Tec metamaterial inside the test apparatus being stimulated. • A live video via the videoconference call of the results of the stimulation of the DEEC-Tec metamaterial inside the test apparatus. • A screen-shared file/website/video relevant to communicating the test performed, results, or DEEC-Tec metamaterial technological properties.	• The competitor sufficiently presented the DEEC-Tec metamaterial outside of the test apparatus and answered any reviewer questions. • The competitor sufficiently presented the standalone test apparatus and answered any reviewer questions. • The competitor sufficiently demonstrated the device in the test apparatus being stimulated. • The competitor showed quantitative results being produced of a similar output and range to those included in the technical narrative and/or test report.

*The total score competitors receive in this section will be multiplied by 2 for a maximum of 40 points available.

Competitors are encouraged to leverage the support mechanisms provided when preparing for the Live Virtual DEEC-Tec 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.

Final Event Design Presentation

During the Final Event, competitors will be in person and present on progress made during Phase III as well as their DEECs, DEEC-Tec metamaterials, and overall design concept to a panel of expert reviewers. A hybrid option may be available, but at least one representative from each team must be present at the in-person Final Event Design Presentation for the competitor to be considered for a Phase III Grand Prize. Competitors are responsible for all costs associated with travel. It is encouraged that competitors leverage Phase II funding to offset travel costs, as no additional funding will be provided for travel to the Final Event.

The Design Presentation should convey how the team met the goals of the prize listed in Section 1.5. There is no specific template for the presentation. Competitors may bring slides, videos, or physical materials (such as their DEEC or DEEC-Tec metamaterial) to help them present their designs. Any videos must not exceed a combined total of 5 minutes. Any DEECs or DEEC-Tec metamaterials must not be energized.

Competitors will be asked to upload any final presentation materials to a cloud-based storage website prior to the in-person Final Event to ensure materials can be downloaded to presentation computers in advance. Instructions and deadlines will be sent to competitors and posted on the HeroX platform.

During the closed-door design presentation, competitors will have 30 minutes for their Design Presentation followed by up to 30 minutes of reviewer Q&A. Following the Q&A, reviewers will evaluate the presentation by scoring the following statements on a scale of 0-5. Reviewers will assign scores based on how well competitors address the evaluation criteria and questions in Table 13.

Table 13. Final Event Design Presentation Evaluation Criteria

Design Presentation Criterion 1: Lessons Learned and Potential	
Guiding Questions: What innovation technique(s) and systematic engineering approach(es) did you take while refining your DEEC-Tec metamaterial in Phase III? How did your team apply lessons learned from the TPL assessment to your final design or plan to apply them to further iterations? How did your team incorporate ideas or feedback provided throughout the prize?	
Suggested Content Competitor Provides	**Each Statement Scored on a 0 to 5 Scale**
• Describe the innovation technique(s) and systematic engineering approach(es) used to refine and/or improve the DEEC-Tec metamaterial. • Provide evidence of how the TPL assessment insights and lessons learned have been applied or will be applied to the final design or future design iterations of the DEEC-Tec metamaterial. • Provide evidence of how you have incorporated feedback received during the prize from either competitor support options and/or reviewers to refine and/or improve your DEEC-Tec concept.	• The competitor has effectively leveraged the innovation technique(s) and the systems engineering approach(es) to refine and/or improve the DEEC-Tec metamaterial. • The competitor has provided meaningful evidence on how the insights and lessons learned from the TPL assessment have been applied or will be applied to the final design or future design iterations of the DEEC-Tec metamaterial. • The competitor has presented a novel DEEC-Tec metamaterial that has high techno-economic potential, as evidenced by the TPL assessment. • The competitor has provided meaningful evidence that they incorporated feedback received during the prize from either competitor support options and/or reviewers to refine and/or improve their DEEC-Tec concept.

Design Presentation Criterion 2: End-Use Application	
Guiding Question: How could the proposed technology be applied to ocean wave energy conversion?	
Suggested Content Competitor Provides	**Each Statement Scored on a 0 to 5 Scale**
• A discussion on how the proposed technology could be applied to ocean wave energy conversion and would bring value to the ocean wave energy industry. • A discussion of any additional areas of application, related to marine energy conversion or beyond, which might be of interest to WPTO (not scored).	• The competitor has clearly discussed how the proposed technology could be applied to ocean wave energy conversion. • The competitor's technology demonstrates high potential to bring value to the ocean wave energy industry.

Design Presentation Criterion 3: Future Plans	
Guiding Question: What is your plan following the conclusion of this prize?	
Suggested Content Competitor Provides	**Each Statement Scored on a 0 to 5 Scale**
• Plans for any further development and/or optimization of the DEEC and/or DEEC-Tec metamaterial following the conclusion of this prize. (Examples might include: efficiency of conversion, difficulty of manufacturing, etc.) • An identification of remaining technological challenges that would need to be resolved before the DEEC-Tec metamaterial could be applied in a high potential energy conversion application and plans to overcome those challenges. • A discussion of how the competitor intends to ensure a well-rounded team and/or collaborate with others (partners, stakeholders, etc.) to take the DEEC and DEEC-Tec metamaterial further and towards commercialization.	• The competitor has clearly described reasonable plans for further development and/or optimization of the DEEC and/or DEEC-Tec metamaterial. • The competitor has clearly identified remaining technological challenges that would need to be resolved before the DEEC-Tec metamaterial could be applied in a high potential energy conversion application and sufficient plans to overcome those challenges. • The competitor has identified future plans to ensure a well-rounded team and/or collaborate with diverse stakeholders to take the DEEC and DEEC-Tec metamaterial further and towards commercialization.

Lastly, following the Design Presentation, the review panel will make a final recommendation for funding using the evaluation criteria listed in Table 14.

Table 14. Reviewer Recommendation Evaluation Criteria

Design Presentation Reviewer Recommendation	
Suggested Content Competitor Provides	**This Statement Scored as a 'Yes' or 'No', with 'Yes' being 35 points and 'No' being 0 points.**
• There is no direct corresponding submission requirement for this score. Rather, it is an	• The competitor has demonstrated the highest quality response to all questions asked, presented materials responsive to

overall assessment of all materials submitted and/or presented in Phase III. • The design presentation should convey how the competitor met the goals of the prize listed in Section 1.5.	the prize goals, and should be considered for a Grand Prize.

4.2.2 Unscored Submission Components

Final Event Poster

During the in-person Final Event, posters will be on display publicly. As a part of a solver community, competitors will have the opportunity to share information about their technology to other InDEEP competitors, national laboratory staff, and DOE staff.

Posters should at a high-level convey how the team met the goals of the prize listed in Section 1.5. In the poster, the team should describe their experience in Phase III and answer the following questions:

- How did the competitor leverage WEC innovation methods to systematically develop their individual DEEC and/or DEEC-Tec metamaterial?
- How did the competitor engage or collaborate with others in the marine energy industry and/or related DEEC-Tec disciplines?
- How could the DEEC and/or DEEC-Tec metamaterial be of high potential relevance to WECs and the marine energy industry?
- How has the competitor refined WEC innovation methods to incorporate ideas beyond the field of wave energy?

Although there are no specific scoring criteria for the poster, it will be evaluated as part of the entire submission package. Posters should not include proprietary information. More information on potential templates and logistics will be provided ahead of the Final Event.

4.3 Final Event Logistics and Information

It is expected that all competitors will have at least one representative available in person at the InDEEP Final Event. Competitors are responsible for all costs associated with travel. It is encouraged that competitors leverage Phase II funding to offset travel costs, as no additional funding will be provided for travel to the Final Event. We encourage all competitors from any phase to participate and information on preregistration and site entry requirements will be posted on HeroX. Travel will not be reimbursed by DOE or the Prize Administrator.

The Final Event date is subject to change, but is **tentatively scheduled for March 5-7, 2025**, and changes to these dates will be announced as soon as possible. The Final Event will be held in Colorado at either the National Renewable Energy Laboratory South Table Mountain campus in Golden, Colorado, or at the National Renewable Energy Laboratory Flatirons campus in Boulder, Colorado. This event is intended to provide a venue for competitors to highlight their successes, connect and network, learn from each other, and gain knowledge and resources for further technology development.

If the Final Event cannot take place in person for any reason, we may shift the event to a virtual format. Details about the type of event will be provided to all competitors.

5 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 include 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 listed in Appendix A.13 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 APPENDIX A 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 January 27, 2025, before the prize's Phase III 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 U.S. DOE Water Power Technologies Office. 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. Distributed Embedded Energy Conversion Technology

B.1 Distributed Embedded Energy Conversion Technology (DEEC-Tec) Sequences

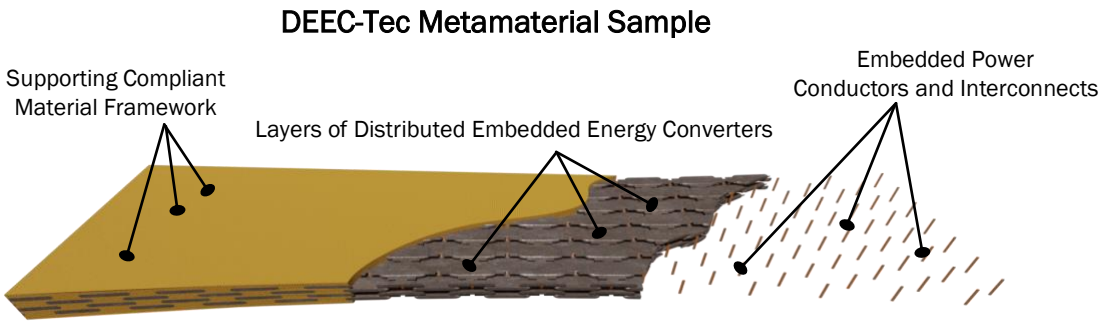


Figure B-1. A sample volume: Illustrating the basic use of individual distributed embedded energy converters to create a distributed embedded energy conversion technology (DEEC-Tec) metamaterial. This sample volume has sections where components of the metamaterial are removed, aiming to clarify the constituent 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 distributed embedded energy converters (DEECs) are removed. In this way, the illustration showcases how the combined semicontinuous nature of DEECs creates a DEEC-Tec metamaterial.

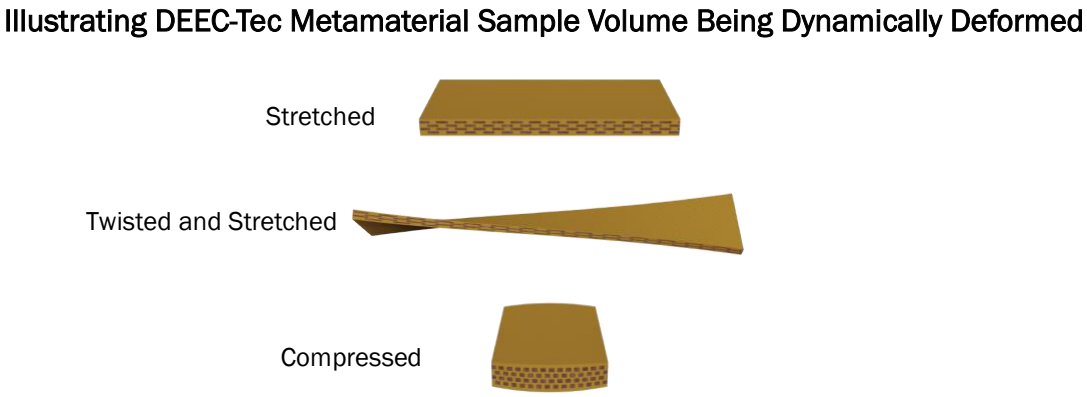


Figure B-2. Principal manner of operation: illustrating distributed embedded energy conversion technology metamaterial sample volume being dynamically deformed by some external source of energy.

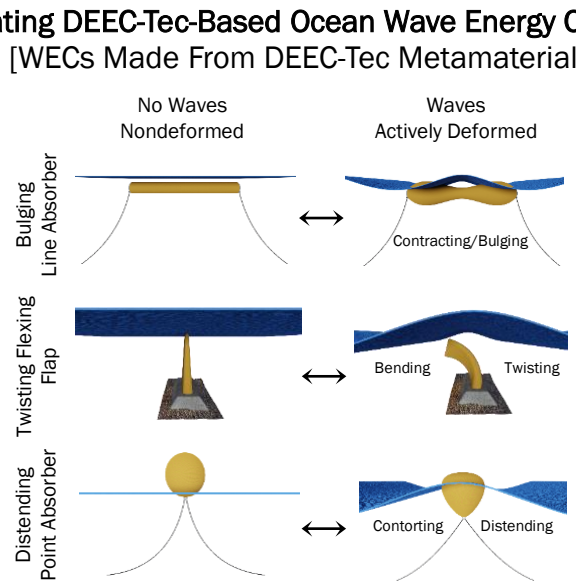


Figure B-3. Possible distributed embedded energy conversion technology (DEEC-Tec)-based wave energy converter archetypes showcasing their nondeformed and dynamically deformed states. The yellow flexible bodies of each archetype represent DEEC-Tec metamaterials. Note: Nothing is to scale; the archetype figures and scene are solely illustrative.

B.2 Wave Parameters and Individual DEEC Interaction Parameters

Table 15. Wave Parameters

Number	Parameter	Units	Parameter Value 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 16. Individual Distributed Embedded Energy Converter 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	$0 < u \leq 10$

Appendix C. Innovation Methods

The Innovating Distributed Embedded Energy Prize (InDEEP) will leverage the Water Power Technologies Office (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.[13] Wave-SPARC developed a detailed systems engineering approach that simultaneously balances around 100 cost and performance drivers or the functional requirements and capabilities for wave energy converters. 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 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 the 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.

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

TRIZ is an abbreviation of the Russian term *Theoria Resheneyva Isobretatelskehuh Zadach*, that 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, by the assessment method. This central part, the ideation, is based on evidence from 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 the technology innovation process of problem formulation, ideations, and solution assessment as depicted in in Figure C-1.

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

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

C.2 Double Helix Innovation Methodology

The Double Helix Innovation Method was developed by Colin Keogh[14] 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.

C.3 Axiomatic Design

Axiomatic design theory is an attempt to integrate pieces of systems engineering, lean manufacturing, and other more established but piecemeal approaches into a single framework. Axiomatic design 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, Axiomatic design theory considers coupled systems to be the least desirable because coupling increases the complexity of the system.

C.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 that use (or could benefit from) marine energy systems.

C.5 Quality Function Deployment

Being founded upon a customer driven inventive methodology, quality function deployment is an approach guided by the “voice-of-the-customer.” In large part, this means quality function deployment 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. Quality function deployment, therefore, seeks to translate directly from qualitative customer requirements to quantitative engineering requirements to drive innovation.

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

Appendix D. 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 by 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 InDEEP Wave Energy 101 PowerPoint and Recording
- 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)
- Water Power Technologies Office 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
- The InDEEP Wave Energy 201 PowerPoint and Recording

DEEC-Tec

- Distributed embedded energy conversion technologies (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
- The InDEEP DEEC-Tec 101 PowerPoint and Recording
- The InDEEP DEEC-Tec 201 PowerPoint and Recording

Wave-SPARC materials

- Technology Performance Level (TPL) 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
- The InDEEP Innovation Methods 101 PowerPoint and Recording
- The InDEEP Innovation Methods 201 PowerPoint and Recording
- The InDEEP TPL 101 PowerPoint and Recording
- The InDEEP TPL 201 PowerPoint and Recording

Supplementary Materials Beyond the Scope of the Prize

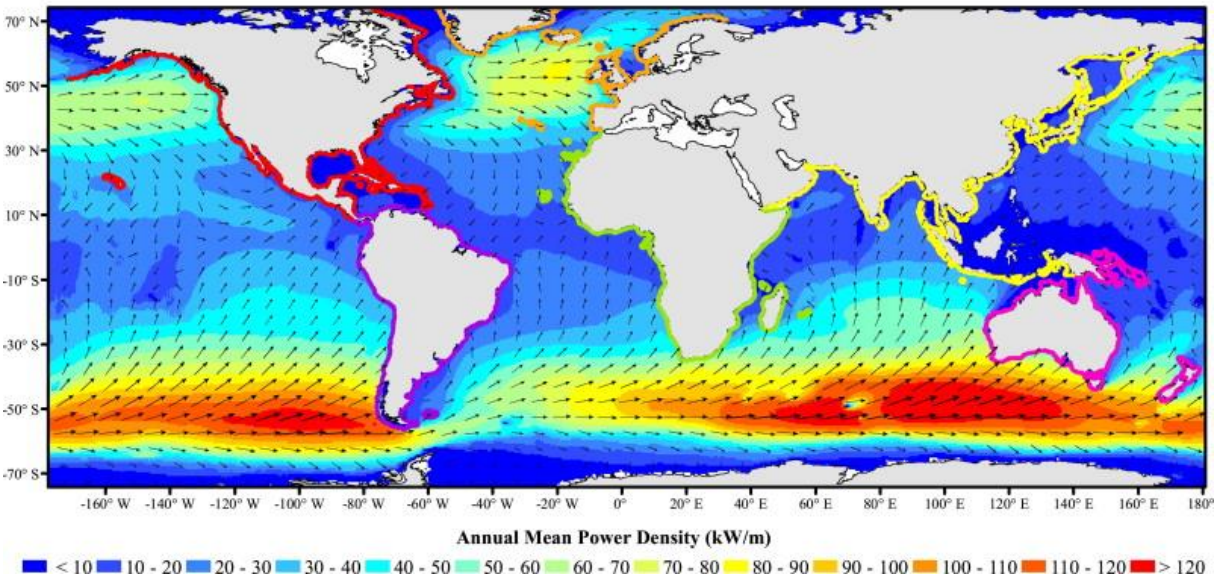
- PRIMRE code hub: https://openei.org/wiki/PRIMRE/Software.
- Wave Energy Converters Sim videos and training: https://wec-sim.github.io/WEC-Sim/master/user/webinars.html
- Falnes, Johannes; Kurniawan, Adi. (2020) Ocean waves and oscillating systems: linear interactions including wave-energy extraction. 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.[15] 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. The U.S. Department of Energy's Water Power Technologies Office (WPTO) has identified the full potential for future electricity production from our nation's water resources.[16]

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-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.[17] Although 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 wave energy converters (WECs) result in high-cost devices. 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.



[15] https://www.energy.gov/eere/water/advantages-marine-energy
[16] U.S. Department of Energy, "Marine Energy Resource Assessment and Characterization." https://www.energy.gov/eere/water/marine-energy-resource-assessment-and-characterization.
[17] 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[18]

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 distributed embedded energy conversion technologies (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 technologies in Figure D-2 as having the potential to be transferable to wave energy. This list of technologies is not intended to be comprehensive, however, and ideas not identified on this list are encouraged. Participants can also expand on concepts already in use in wave energy.

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.

[18] 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.

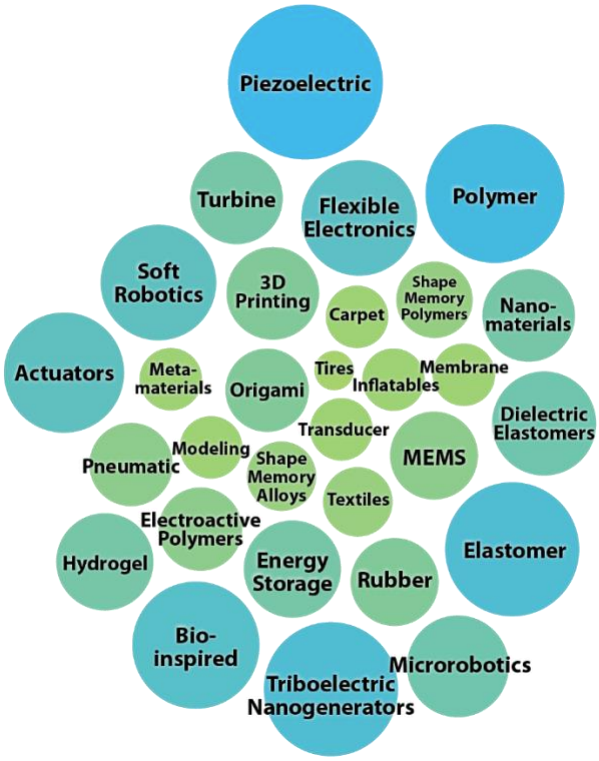


Figure D-2. Potential technology areas that could be transferrable to wave energy. This is not intended to be comprehensive but serves as example areas of interest.