U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

SECTION

2

Marine and Hydrokinetics Program

Foundational and Crosscutting R&D

Technology-Specific Design and Validation

Reducing Barriers to Testing

Data Sharing and Analysis

Powering the Blue Economy

MARINE AND HYDROKINETICS PROGRAM OVERVIEW

Marine and hydrokinetic (MHK) technologies are at an early stage of development due to the fundamental challenges of generating power from dynamic, low-velocity, and high-density resource while surviving in corrosive marine environments. These challenges are intensified by high costs and lengthy permitting processes associated with in-water testing. To achieve the mission and help to realize the vision, the program must support research and development (R&D) efforts that lead to significant reductions in the cost of MHK energy that enable industry to be competitive in U.S. electricity markets.

Vision

A U.S. marine and hydrokinetic industry that expands and diversifies the nation's energy portfolio by responsibly delivering power from ocean and river resources.

Mission

Conduct transformative early-stage research that advances the development of reliable and cost-competitive MHK technologies and reduces barriers to technology deployment.

The program has four core R&D activity areas, which represent its strategic approaches to addressing challenges faced by U.S. MHK stakeholders:

1. Foundational and Crosscutting R&D
2. Technology-Specific System Design and Validation
3. Reducing Barriers to Testing
4. Data Sharing and Analysis.

The MHK Program launched a public Request for Information to solicit feedback from stakeholders on its draft programmatic strategy in fiscal year (FY) 2017. Through the revised MHK Program strategy, the Water Power Technology Office (WPTO) aims to clearly communicate the rationale for and organization of possible U.S. Department of Energy (DOE)-supported hydropower marine energy R&D from now to 2030. The tables below summarize the foundation of the revised strategy: WPTO's description of U.S. MHK's challenges and the MHK Program's approaches to address such challenges.

Challenges for MHK Technology Development in the U.S.

Difficult Engineering	Installing and Operating Reliable Systems	Prolonged Design and Testing Cycles	Technology/Market Information and Supply Chains
• MHK resources have large ranges in intensity and present other fundamental difficulties for designing systems to efficiently capture usable energy, due to the unique physics of the systems. • There are open scientific and engineering questions about how devices interact with these complicated resources or with other devices, and efforts to develop validated methods to measure, model, and predict these interactions are ongoing. • Commonly accepted performance metrics are not well established to evaluate the wide range of existing technologies and drive early-stage designs toward performance improvements and cost competitiveness.	• Developing effective and efficient methods for installation, testing, O&M, and environmental monitoring are difficult due to the nature of high-energy and corrosive marine/ riverine systems, and there have been limited opportunities to improve through experimental learning. • Ships and other infrastructure necessary to deploy MHK devices and support other operations in high-energy and sometimes deep-water environments where devices will be deployed are limited and/or have not been optimized for MHK applications.	• Access to test infrastructure required for rapid iterative design improvements is limited and facilities do not exist at all necessary scales. • Permitting process are expensive and time consuming due to: ▫ Extensive requirements for environmental monitoring driven by high perceptions of risk, ▫ Limited transferability and utilization of accurate information about siting and deployment of MHK technologies, and ▫ The need for sometimes complicated coordination with numerous other existing users of ocean spaces and waterways.	• Many high value opportunities for utilizing MHK technologies are unclear due to the limited availability of information and analysis on the potential of MHK technologies in the electric sector and other maritime markets. • There is a lack of validated, pubicly-available data on the performance, costs and reliability of new MHK systems and the unique benefits which can be realized in developing these resources. • Manufacturing and supply chains for MHK applications are not well-developed and may results in long lead times and high costs for materials and components.

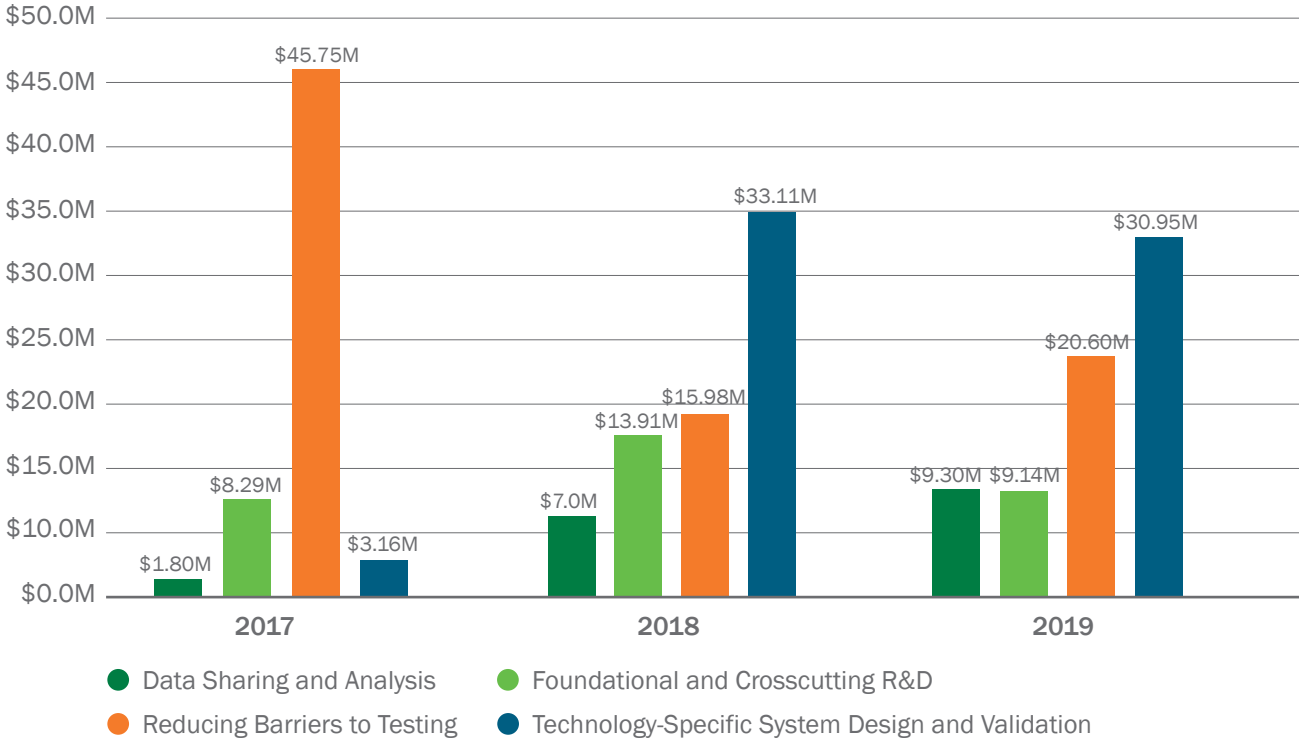
WPTO's Approaches to Address Challenges

Foundational and Crosscutting R&D	Technology-specific System Design and Validation	Reducing Barriers to Testing	Data Sharing and Analysis
• Drive innovation in components, controls, manufacturing, materials and systems with early-stage R&D specific to MHK applications. • Develop, improve, and validate numerical and experimental tools and methodologies needed to improve understanding of important fluid-structure interactions. • Improve MHK resource assessments and characterizations needed to optimize devices & arrays, and understand extreme conditions. • Collaboratively develop and apply quantitative metrics to identify and advance technologies with high ultimate techno-economic potential for their market applications.	• Validate performance and reliability of systems by conducting in-water tests of industry-designed prototypes at multiple relevant scales. • Improve methods for safe and cost-efficient installation, grid integration, operations, monitoring, maintenance, and decommissioning of MHK technologies. • Support the development and adoption of international standards for device performance and insurance certification. • Evaluate current and potential future needs for MHK-specific IO&M infrastructure (vessels, port facilities, etc.) and possible approaches to bridge gaps.	• Enable access to world-class testing facilities that help accelerate the pace of technology development. • Work with agencies and other groups to ensure that existing data is well-utilized and identify potential improvements to regulatory processes and requirements. • Support additional scientific research as needed, focused on retiring or mitigating environmental risks and reducing costs and complexity of environmental monitoring. • Engage in relevant coastal planning processes to ensure that MHK development interests are equitably considered.	• Provide original research to assess and communicate potential MHK market opportunities, including those relevant for other maritime markets (e.g., desalination, powering subsea sensors, charging for underwater vehicles). • Aggregate and analyze data on MHK performance and technology advances, and maintain information sharing platforms to enable dissemination. • Support the early incorporation of manufacturing considerations/ information into design processes. • Leverage expertise, technology, data methods, and lessons from the international MHK community and other offshore scientific & industrial sectors (e.g., offshore wind, oil and gas).

Overview of the MHK Program during this Peer Review Period

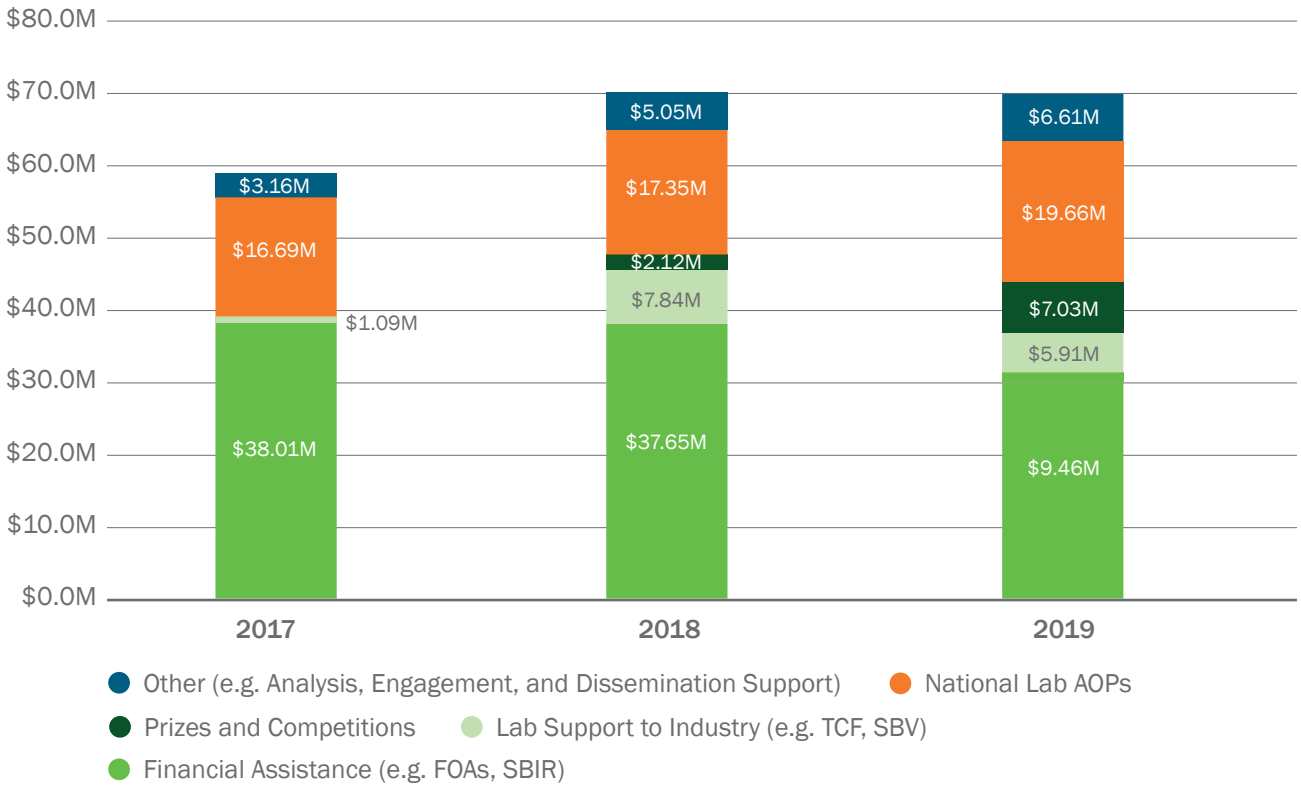
Figure 17 shows the MHK Program's spending by activity area over recent years (Fiscal Years 2017, 2018, and 2019). It should be noted that some of the projects reviewed during the 2019 WPTO Peer Review period were funded with prior year dollars (such as from FY 2016 or before). However, this chart, when viewed as a whole, best represents current and recent program funding. Due to the multi-year nature of DOE R&D program planning, some aspects of the portfolio were more heavily emphasized in a particular year. For example, WPTO awarded funding in FY 2017 to Oregon State University (OSU) for the development of a grid-connected MHK test site as the result of a funding opportunity announcement (FOA) that WPTO issued based on Congressional direction to develop a dedicated MHK test site. This explains the large spike in funding for Reducing Barriers to Testing in FY 2017.

Figure 17. MHK Program FY17-FY19 portfolio—total budget by activity area



The MHK Program leverages a variety of funding mechanisms, and the distribution by funding mechanism for FY 2017–2019 can be seen in the chart below. For descriptions of each funding mechanism, please see the Funding Mechanisms section of the Introduction.

Figure 18. MHK Program FY17–FY19 portfolio—total by budget by funding mechanism



The 2019 Peer Review looked at the first three years of WPTO as an independent office, and there were several program developments during this time period:

- **More devices in the water than ever before**: Year-on-year budget growth for the MHK Program has enabled WPTO to support more tests of marine energy technologies than previously possible. Several WPTO-funded in-water tests took place over the last few years. Most recently, the Ocean Energy 35 buoy with the Siemens Government Technologies Hydro Air Turbine arrived in Hawaii on December 1, 2019, at the Navy's Wave Energy Test Site (WETS). Also, in July 2019, the Ocean Renewable Power Company, in partnership with the Igiugig Village Council, deployed its RivGen system in the Kvichak River in Igiugig, Alaska. Multiple WPTO-funded projects are currently working toward open water tests—of which, a few are expected to begin in FY 2020 or FY 2021; for example, Verdant Power will return to the East River in 2020 to advance the development of the tidal power system and TriFrame mount.
- **The development of robust programs and facilities to support marine energy testing**: While WPTO continues to fund design development and testing efforts through FOAs, it is in the process of standing up a new program to support testing and research for marine energy technologies—the U.S. Testing Expertise and Access for Marine Energy Research (TEAMER) program. In September 2019, WPTO announced the competitive selection of the new network director, the Pacific Ocean Energy Trust. Through TEAMER, the Pacific Ocean Energy Trust will support WPTO in bringing together capabilities from universities and the national laboratory system to provide marine energy developers ready access to unique, world-class testing facilities and expertise. WPTO hopes this new program, along with the anticipated opening of the grid-connected PacWave facility, will pave the way for more marine energy testing and faster design iteration than ever before.

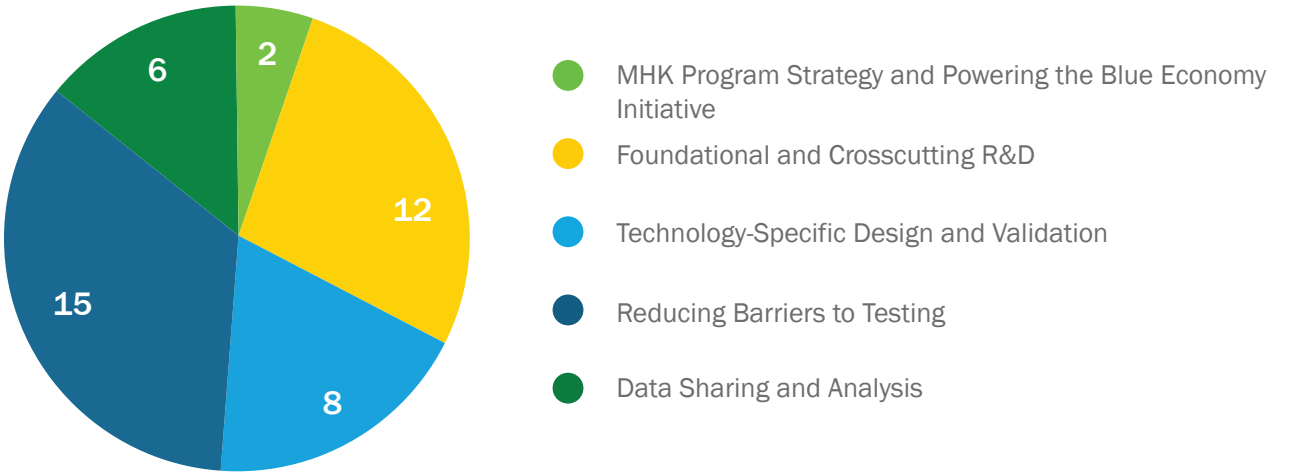
- **Advancing marine energy's potential to serve the Blue Economy**: Traditionally, international marine energy R&D has been focused on long-term cost reductions and performance improvements for grid-scale application. WPTO, while continuing to support R&D for technologies with grid applications, has also recently undertaken new efforts to explore nearer-term opportunities to reduce power constraints for other ocean-based industries and missions. In FY 2019, WPTO launched its Powering the Blue Economy Initiative (PBE), which aims to unlock opportunities for ocean science, security, and other maritime industries by exploring new applications for marine energy. Successfully leveraging marine energy technologies to address existing power challenges for other ocean sectors offers the potential to meaningfully accelerate cost reductions for marine energy systems.
    - Since releasing a foundational *Powering the Blue Economy* report, WPTO has announced two system design and build prizes and one business-case-based collegiate competition and has awarded several Small Business Innovation Research (SBIR) and FOA projects for R&D with Blue Economy applications. One of these prizes, the Ocean Observing Prize, was jointly announced with NOAA in FY 2019, with the goal of challenging innovators to integrate marine renewable energy with ocean observation systems. The other prize, the Waves to Water Prize, hopes to advance small, modular, cost-competitive desalination systems that use the power of ocean waves to provide clean drinking water for disaster recovery and for remote and coastal communities. This prize was also the first funding opportunity launched under the Water Security Grand Challenge, a White House-initiated, DOE-led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water.
- **Increased efforts to leverage a variety of funding mechanisms**: As aforementioned, the MHK Program launched its second and third prize competitions focused on developing marine energy systems in FY 2019. These build off the success of the office's first-ever prize in 2016, the Wave Energy Prize, and are well suited to achieve technology innovation goals because they can attract new ideas and incentivize collaborations. The Ocean Observing Prize was the first time the MHK Program worked this collaboratively with another federal agency to both scope and co-launch a funding opportunity.

These developments not only provide context for some of the newer approaches WPTO took during the years under review, but also preview what to expect from WPTO in future years and in the next peer review.

Organization of Tracks and Review Panels

Both the MHK Program strategy and individual projects were reviewed and scored during the 2019 WPTO Peer Review. Additionally, the reviewers scored and provided specific feedback on the future direction of PBE—a new effort that seeks to understand the power requirement of emerging coastal and maritime markets and advance technologies that could integrate marine renewable energy to relieve these power constraints and promote economic growth. Two panels of reviewers reviewed these program elements, as well as individual projects across all the MHK Program's technology areas. Figure 19 depicts the total number of MHK presentations reviewed by program and activity area.

Figure 19. MHK Program Portfolio—number of presentations by activity area



The following external experts served as reviewers for the MHK Program during the 2019 Peer Review.

Table 6. MHK Reviewers

Name	Organization	Review Panel
Elaine Buck*	European Marine Energy Centre	Foundational R&D, Technology Design, and Validation
Alex Fleming	iMetalx Group LLC	Foundational R&D, Technology Design, and Validation
Andy Hamilton	Monterey Bay Aquarium Research Institute	Foundational R&D, Technology Design, and Validation
Henry Jeffrey	The University of Edin-burgh	Foundational R&D, Technology Design, and Validation
Jim Bretl	Korvis Automation	Foundational R&D, Technology Design, and Validation
Mike Muglia	University of North Caroli-na	Foundational R&D, Technology Design, and Validation
Chris Bassett**	University of Washington	Reducing Barriers to Testing and Data Sharing
Anu Kumar	U.S. Navy, Living Marine Resources Program	Reducing Barriers to Testing and Data Sharing
Gayle Zydlewski	University of Maine	Reducing Barriers to Testing and Data Sharing
Jason Wood	SMRU Consulting	Reducing Barriers to Testing and Data Sharing
Martin Wosnik	University of New Hamp-shire	Reducing Barriers to Testing and Data Sharing
Whitney Hauer	Bureau of Ocean Energy Management - Pacific OCS Office	Reducing Barriers to Testing and Data Sharing

* MHK Program Review Chair and Panel Lead
** Review Panel Lead

Organization of the Results

The quantitative and qualitative results are summarized at the program, activity area, and project-level. Information in this section has been compiled based on the following sources and is organized as follows:

1. *MHK Program Evaluation Summary*: A summary of all hydropower reviewers' comments that provides insight into the program's strengths and weaknesses or potential issues and specific recommendations. The program review chair was responsible for drafting the program summary report in consultation with each review panel lead and all hydropower reviewers.
2. *MHK Programmatic Response*: The program's official response to the recommendations provided in the review chair's program evaluation summary.
3. *MHK Program Score Results*: The results are organized by the activity areas into which individual projects were grouped for the 2019 Peer Review. Each subsection includes each activity area's score results, an evaluation summary prepared by the review panel lead, and individual project evaluations.

MHK PROGRAM EVALUATION SUMMARY

Prepared by Elaine Buck, MHK Program Review Chair

Key Takeaways

Participating and contributing in WPTO's 2019 Peer Review provided reviewers and the general audience an in-depth understanding of the challenges that the MHK sector continues to face. The reviewers provided industry insight on project results and suggestions on potential next steps to address engineering challenges of the sector.

The U.S. MHK sector is poised to deliver significant results. The year-on-year congressional budget increases demonstrate support for MHK technologies R&D advancing toward commercialization. The outstanding professional and technical management of the MHK Program is accelerating U.S.-led MHK technology developments. DOE's national labs have contributed enormously to the development of vital tools that enable further technical breakthroughs (e.g., WaveSPARC, FlexWEC, wave energy converter (WEC) optimization, and co-design tools).

The MHK review panels fully expect advances in the performance and reliability of next-generation MHK developers. The time is now for improved integration, alignment, and focus within the existing program, while expanding access and support within PBE. Interagency collaborations with NOAA will provide a step-change in system integration and technological breakthroughs for the Blue Economy markets.

The 2019 MHK peer review chair, as an American whose international career focuses on overseeing MHK technology developments in the UK and Europe, considered it a great honor to be invited to lead this review. While the United States was not the first country to make investments in marine energy research, it is quickly becoming a leader in this field, and thus, all eyes are directed to U.S. activities and mechanisms supporting continued innovations and in-sea performance validation.

Feedback from the Review Chair to WPTO

Industry data sharing is a vital activity for each of the four MHK programmatic activity areas. The investments made to support data and information dissemination are recognized as essential and one of the strengths of the program. The *State of the Science* report is a valuable product, and the forthcoming 2020 edition will provide new and up-to-date information, while meeting WPTO's dissemination goals.

The review panel leads agreed on the necessary requirements to improve WPTO's data sharing knowledge hubs, including aligning and consolidating the databases that underpin the knowledge hubs. The main recommendation from the reviewers was to restructure the programs (Tethys, MHK Atlas, the Portal and Repository for Information on Marine Renewable Energy) that improve access to research findings, quality of information listed, and sustainability of the knowledge hubs' data management. WPTO should improve the definition of the needs case for the resource assessment portfolio. Improvement in regulatory stakeholder engagement is viewed as vital to align the needs case, while ensuring that the best available information is accessible to those stakeholders.

For the other three areas, the reviewers have the following summary recommendations.

Foundational & Crosscutting R&D/Technology Specific Design & Validation:

- Complete techno-economic assessments (WaveSPARC) on existing devices.
- Integrate lab-developed tools (such as the WEC Design Optimization tool) into existing devices where appropriate.
- Evaluate the appropriate prioritization of tidal R&D.
- Incorporate testing to standards and feedback to the International Electrotechnical Commission's System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications as a requirement for testing, such as at WETS, PacWave, and all tank testing.
- Integrate PBE objectives into existing device development projects, while not losing lessons learned from WPTO-funded developer projects focused on grid-scale application.
- More closely benchmark and ensure collaboration between funded projects with similar objectives, such as the controls projects.
- Set specific dissemination targets for all projects (e.g., the number of peer-reviewed journal papers, pipeline (CRM) of end users, and number of workshops).
- Expand and utilize additional platforms for the dissemination of tools produced through WPTO funding.

Reducing Barrier to Testing:

- Improve regulatory stakeholder engagement to align environmental, technological investments with regulatory concerns.
- Evaluate levels of investment across this activity area and opportunities to scale back support based on advances made in the field.
- Increase targeted deployments with environmental monitoring technologies developed through the program.
- Set specific dissemination targets for all projects.
- More closely benchmark and ensure collaboration between funded projects with similar objectives, such as activities supported by the Triton Initiative.

Summary of all Reviewers' Comments

Overall Impressions

Overall, the reviewers agreed that the MHK Program has a clear understanding of the near- and long-term challenges facing the industry and has developed a well-balanced program strategy to-date with objectives that were conveyed during the peer review. Long-term strategy concerns from reviewers included the integration of PBE in a manner that ensures WPTO continues to support both the longer established developers with higher technology readiness levels ("GEN1 developers" – as the reviewers called them) and newer developers with lower technology readiness levels or who may have an easier experience pivoting to Blue Economy markets (those the reviewers referred to as "GEN2 developers"). Also, the reviewers have concerns that the outstanding developments coming from the labs and environmental instrumentation portfolio have outpaced the device developers' results. There is opportunity for WPTO to refocus the program

that balances the requirements of the PBE markets, including improved integration, alignment of the enabling tools, and initiatives with the MHK technology developers.

Program Strategy and Objectives

Most reviewers agreed that most program objectives supported the sector needs, though several goals of each activity area were not necessarily realized through the GEN1 developer projects. Specifically, validating performance and reliability of systems, as well as improvement in cost-effective methods for integrated operations and maintenance (O&M). In the Reducing Barriers to Testing activity area, the goals of enabling access to test facilities, coupled with R&D aimed at reducing permitting and environmental monitoring costs, have not yet proven to improve regulatory efficiencies. Below is a selection of reviewer comments related to each aspect of the program strategy and objectives criterion used for this review.

- The program's long-term strategy, strategic approaches, and future direction were effectively conveyed during the peer review.
  - The multi-year MHK strategy document is still in draft form and needs to be finalized and published in accordance with WPTO's outreach and engagement goals of transparency, feedback, dissemination, and accurate information.
  - Concern on the future direction of the current MHK GEN1 large-scale grid program is disparate from the new PBE program.
  - As the MHK Program budgets have steadily increased over recent years, international developers will seek opportunities to work in the U.S. market. WTPO should evaluate using business models that implement business support mechanisms, as well as SBIR.
- The program's strategy reflects an understanding of the near and long-term challenges facing the industry and other stakeholders.
  - A midterm challenge is the pipeline of developers ready to test/deploy in the United States. It is expected that more international device developers will seek to enter the U.S. market, and this will require a transparent business model that international developers can adopt and set up.
  - The program strategy appears solid in advancing MHK, and reviewers would recommend emphasizing improved integration of the excellent work done by the labs into developer efforts. Projects such as WaveSPARC and the System Advisor Model (SAM) can provide needed structure to technology developments as current GEN1 developers do not have a convincing trajectory toward commercial LCOE.
  - Further investigations into novel marine energy storage approaches, flexible materials, and distributed power take-off (PTO) approaches should be included in the program.
  - The disparity between regulatory permitting and environmental assessment issues are still a challenge, and further investments in stakeholder engagement and environmental tools is necessary. Program efficiency could be improved by reducing the spending on data sharing by consolidating existing projects.
- The program invests in early-stage research to accelerate the development of innovative water power technologies, while ensuring that long-term sustainability and environmental issues are addressed.
  - The levels of investment for development of marine energy systems versus environmental monitoring technologies seem out of proportion given the relative stages of these technologies. WPTO has developed advanced supporting tools, and the office should look at where there are

opportunities to scale back in this area to refocus more resources on marine renewable energy (MRE) technology development.
    - WPTO has funded research to investigate and better understand environmental risk; however, there is not yet enough evidence that this has significantly impacted regulators' understanding of how environmental concerns are being addressed, nor has it resulted in improved regulatory efficiencies.
- The program supports efforts to validate performance and grid reliability for new technologies, develop and increase accessibility to necessary testing infrastructure, and evaluate systems-level opportunities and risks.
    - WPTO's announcement that there will be more detailed design reviews incorporating validation/verification processes will enhance program efforts to validate performance.
    - Program support to validate performance and reliability through NREL work is critical for the decision making of GEN1 further developments.
    - Funding for PacWave and TEAMER demonstrates clear focus for access to necessary testing infrastructure.
    - There is a need for a more regional approach for testing infrastructure
- The program invests taxpayer funds wisely to drive the most significant impact.
    - Taxpayer funds are distributed to a wide range of project types that reflect existing needs, but program efficiency could be improved by reducing spending on data sharing by consolidating similar data-sharing projects.
    - Concern that existing GEN1 devices that have been funded will deliver the most significant impact. Independent reviews are critical to be conducted on GEN1 developers to determine credible trajectory toward commercial LCOE.
    - Investments in material characterization, WECSim, WEC Design Response Toolbox, SAM, DTOcean, WaveSPARC, and Advanced Controls all are critical to accelerate and enable the MHK sector.

Program Portfolio

The breadth and depth of projects within the program's portfolio reflect the engineering, testing, and environmental challenges for the MHK sector. This is a strength of the program portfolio. A weakness to the portfolio is some redundancy of projects, for example, the investment in data sharing activities and overlap on environmental monitoring projects. These projects need further integration and streamlining.

The portfolio strengths stem from the projects led by the labs. One example is WPTO leveraging the Ocean Energy deployment at WETS, with the labs providing multiple instrumentation testing; this is an excellent example of value for taxpayer funds.

There is a need for more in-sea deployments and more emphasis on installation and O&M demonstrations, logistics, and supply chain needs. While facilitating developers' access to testing, the program must be ready to address potential operational challenges and advance the technologies. That means ensuring a skilled supply chain and support from the national labs.

There is a need to refocus GEN1 activities towards continued integration, focus GEN2 activities to expand disruptive technologies, and evaluate if tidal still/should be a priority for a U.S. program given progress in tidal internationally. The balance of the research priorities and allocation of resources is necessary within each of these portfolios.

PacWave does not appear to have a pipeline of technologies ready to test, and it is not clear how the site can be used for PBE-focused technologies. A programmatic emphasis on the wave resource in the Northwest has created a lack of balance across the other regional areas. The portfolio does not adequately balance research priorities or appropriately fund testing across the United States.

A weakness noted by reviewers is that WPTO did not always clearly convey the rationale for the funded projects. This is important for WPTO's role as a public R&D organization. A WPTO introduction of the FOA recipients explaining why WPTO agreed the projects aligned with the program strategy and objectives would save time during the peer review and be more useful for panel reviewers to hear. Professional and dedicated staff manage WPTO.

Program Management Approach

The significant strength of the MHK Program is the WPTO management approach and management team. Professional and dedicated staff manage WPTO. There is high confidence among reviewers that the success of the sector will be realized with the current team.

Some concerns raised on the approach are with the alignment of program objectives, implementation, and results where targets are implied (reduction of LCOE) in project portfolios and are not well quantified. One reviewer recommended the program ensure a stronger connection between strategic objectives and activities implemented to address the stated challenges of the industry. For example, if it is a programmatic objective to focus investments that will have the most significant impact to advance industry, a metric beyond LCOE reduction should be quantified. After LCOE, what is next?

The panel agreed that the WPTO team effectively communicated the priority research areas; however, it was less clear to the panel how the areas were resourced in terms of budgets identified or people resourced to support the specific research areas.

The WPTO team appears to be continuously skilling up to ensure excellent service delivery to the program, and specifically with the project awardees.

Stakeholder Engagement, Outreach, and Dissemination

The program is outstanding and effective in communications and coordination. Overall outreach is a potential weakness; however, some projects within the program have international awareness, such as DTOcean and international standards development. The program should seek further platforms available for outreach and dissemination of activities. The impact of the program results should engage wider with the international MHK community. The program's recent announcements of new programs to facilitate access to test sites and funding opportunities will attract the global market. With the inclusion of PBE, it is expected that outreach to the Blue Economy markets will bring further innovation, R&D focus, and resultant impact. The data sharing repositories/ knowledge hubs are fundamental to dissemination. However, the accessibility and quality of information need improvement. Stakeholder engagement with regulators to understand requirements is vital moving forward.

The MHK Program Outreach and Engagement Strategy was communicated at peer review. WPTO should continue to optimize each goal in specific areas:

- Transparency: Project/portfolio impacts need to be precise; i.e., 'X was done, Y was achieved, and Z is what is learned.' Project performers (developers) need guidance on how to present this effectively, so immediate quantification of impacts is realized. The national labs have made significant traction in this area.

- Feedback: Engage regulators to understand their needs and environmental concerns. Incorporate this feedback into the environmental monitoring portfolio.
- Dissemination: Maximize impact by increasing international use and dissemination of tools, as well as program opportunities for international engagement, and expanding use of outreach platforms (such as university networks and social media).
- Objective and accurate information: Improve access to and quality of knowledge hubs.

All the above recommendations will maximize the MHK Outreach and Engagement Strategy.

MHK PROGRAMMATIC RESPONSE

Prepared by Tim Ramsey, MHK Program Manager

Overview

The MHK Program would like to thank the reviewers for the significant time and effort they contributed to this review. The program was honored to work with each of the reviewers and grateful that they shared their expertise. WPTO gained invaluable insights and has already started to incorporate some of the recommendations into our program strategy. The U.S. marine energy community will benefit for years to come thanks to the hard work and dedication of the reviewers. The MHK Program thanks the reviewers for their many positive comments on the quality of the WPTO staff. We are very proud of the team and acknowledge that the success of the program reflects their hard work and professionalism. Overall, reviewers outlined several areas for improvement in (1) clearly communicating metrics and goals, (2) incorporating detailed design reviews, techno-economic assessments, and standards, (3) incentivizing more lab-industry partnerships, and (4) effectively disseminating information and lessons learned. The following sections outline the program's response to the reviewers' key recommendations to the program and the most prevalent comments received for PBE and each individual activity area.

Recommendation 1: Clearly communicate metrics and goals

The MHK Program agrees with the reviewers' feedback that the program must better define metrics and goals across our portfolio, and the team is focused on adding specificity to the program's long-term goals and ensuring these are reflected in project-level goals. The program is working to re-baseline the current LCOE for marine energy technologies and to update our long-term LCOE reduction targets in accordance with the Government Performance and Results Act. We will continue to work closely with partners both within the United States and internationally on LCOE goals, as well as on new metrics and the appropriate use of such metrics. For example, the program is engaged in a metrics coordination project with the International Energy Agency (IEA)-Ocean Energy Systems (OES). This task, OES Task 12, addresses the ongoing need to define consistent evaluation criteria to assess progress in several critical target areas of ocean energy technology development. The overall objective of Task 12 is to establish a common international technology evaluation framework for technology developers, investors, and other funders to use. WPTO plans to incorporate Task 12 results into our own program and project planning.

In addition to improving metrics and goals across the portfolio, the office will also work over the next year to better evaluate impacts of WPTO-funded projects, better communicate progress made against stated goals, and disseminate these impacts and progress more broadly to industry. To help the project teams do the same, the program is developing a standard framework for a logic model designed to help PIs clearly define and articulate project activities, outputs, outcomes, and impacts, as well as how these align with the program's strategy and approach. WPTO envisions this logic model to serve as both a project management and communication tool that can inform project plans and help better identify meaningful and appropriate data and metrics to monitor and measure. We will pilot the logic model with several project teams in FY 2021 and further encourage PIs to integrate impact-focused thinking into the project lifecycle.

Recommendation 2: Detailed design reviews, techno-economic assessments, and standards

The program recognizes the need for more detailed design reviews and overall techno-economic assessments, and we intend to better incorporate quantifiable metrics and international standards into future rigorous

reviews. Through EERE Active Project Management best practices, the program requires one go/no-go review or critical design review per year on most projects, with an emphasis on projects that are large, complex, and/or include testing as part of their scope of work. We will work to add more rigor to our required milestones and these reviews to focus on results rather than simply project progression. We will ensure that the metrics developed for these decision points reflect the program's metrics and long-term LCOE reduction goals which, as mentioned above, we are working to update. Additionally, the program has funded NREL and SNL to support the development of technology performance levels (TPLs), which are used as a metric to quantify techno-economic performance potential of WEC technologies at an early stage of development. The program will encourage and support additional TPL assessments on WEC technology development projects to inform the program of the overall techno-economic potential of different designs. The program will also consider expanding the use of TPLs to current energy converters.

Based on reviewer comments during the previous WPTO peer review in 2017, the program has already emphasized the development and implementation (to include third-party certification) of international standards for the marine energy industry. We have increased our support through collaboration with the International Electrotechnical Commission (IEC) Technical Committee 114 (TC 114) to develop technical specifications that will lead to standards for marine energy devices. The program has and will continue to cite technical specifications and standards in FOAs and require funded project teams to design to and adhere to these requirements throughout the project period. Recipients are required to demonstrate this adherence during go/no-go decisions and critical design reviews. The program has also initiated formal design reviews, utilizing subject matters experts from the labs and industry, for wave energy device designs planned for operations at PacWave. Finally, the program is investigating the opportunity to consult an independent engineering firm to perform third-party cost audits during award selection and subsequent design reviews to better inform the techno-economic assessment of funded technologies. The program plans to use these tools to evaluate project potential during selection and project success throughout the period of performance, including go/no-go reviews, to inform program decisions to continue, redirect, or sunset work.

Recommendation 3: Incentivize more lab-industry partnerships

We appreciate the reviewers' comments that they were impressed with the quality of work from the national labs and, in particular, industry-lab partnerships. We heard the reviewers found the lab-developed tools in the Foundational and Crosscutting R&D activity area to be of great value to technology developers, and they witnessed great results when technology developers leveraged these resources. We agree with the reviewers' recommendation to continue supporting collaborative partnerships, as we recognize the national labs are a great resource for the marine energy industry—both to the program (by supporting technical design reviews and assessments) and to technology developers (by partnering on device design and performance assessments).

The program continues to leverage the labs' capabilities for greatest impact to the industry, and we will continue to encourage and facilitate partnerships between labs and industry. For example, when appropriate, WPTO will consider setting aside funding specifically for labs to support selected FOA awardees. Another avenue for lab-industry collaboration will be through the recently established TEAMER program. TEAMER will bring together capabilities from universities and the national labs to provide marine energy developers ready access to unique, world-class testing facilities, expertise, and tools. We also envision the TEAMER program to help increase awareness and lead to greater adoption of lab-developed tools.

Recommendation 4: Effective dissemination of information and lessons learned

We thank the reviewers for acknowledging that the program is already doing extensive outreach and engagement to help the marine energy industry (for example, building new partnerships with Blue Economy stakeholders); however, we also agree that more work is always needed to further facilitate transparency and sharing of information, data, and lessons learned. Outreach and engagement, including dissemination, is critical to WPTO's R&D mission.

We will continue to prioritize outreach and engagement efforts, including dissemination, across the entire portfolio. In particular, we are focused on maintaining active communication with the marine energy community so that they are aware of and can contribute to the direction of the many tools and resources WPTO has developed for their benefit. One way we facilitate this for U.S. marine energy developers is through monthly presentations to the Marine Energy Council. WPTO organizes these monthly briefings during Marine Energy Council member meetings so that industry partners are better informed of capabilities and work ongoing at the labs and with other partners. We have heard from industry members that this series has improved their understanding of specific projects and tools and even facilitated new partnerships. Additionally, the recently established TEAMER program will provide another avenue to facilitate more industry and national lab collaboration, creating lessons learned and new data that will be made publicly available as soon as possible.

While maintaining consistent engagement with the U.S. marine energy community, the program is also exploring new information sharing strategies that can help us target new audiences. In 2019, WPTO stood up a public webinar series to highlight new program announcements, such as open funding opportunities, newly funded projects and their intended impacts, and project milestones. We always provide a question and answer (Q&A) session at the end of each webinar for listeners to directly engage with WPTO staff. We see this as a good vehicle for stakeholders—whether new to the program or not—to learn about the portfolio and its current direction and priorities, and we have seen many organizations that we have not already worked with participate in these webinars. To respond to the reviewers' recommendation to focus more on sharing lessons learned, WPTO can start by leveraging this webinar series, while also considering other avenues. We are also developing a 2019 Accomplishments Report to highlight project milestones and lessons learned over the last year. We intend to publish this document in the coming months and update the publication annually. Lastly, we began ramping up our support to increase video and media coverage of projects, especially projects involving in-water tests, and we will disseminate these products so the public can visually follow the deployment.

Powering the Blue Economy

The program thanks the reviewers for their supportive comments on the PBE effort. The reviewers stated the launch of PBE could ultimately help the marine energy industry test more devices, gain more in-water experience, and reduce costs, which are major objectives and motivations behind the initiative. WPTO would like to address two elements of our PBE strategy that reviewers specifically called out that will determine PBE's impact: (1) our outreach to Blue Economy partners and (2) how PBE activities complement R&D for grid-scale systems.

We appreciate the reviewers' recognition of how much stakeholder outreach we and our partners have already done to stand up the PBE effort. We will continue to engage Blue Economy stakeholders, both to inform research pathways and to better connect developers and researchers with the ultimate end users of the

technologies they seek to develop. The national laboratories are directly surveying potential end users in Blue Economy markets to understand the energy requirements of their existing technologies (for example, ocean observing systems). These insights will directly inform PBE R&D pathways. At the same time, customer discovery tasks are being incorporated into all competitive solicitations; for example, we emphasized co-development (meaning the marine energy power take off (PTO) unit being designed/developed holistically with the overall end use system) through a recent SBIR/STTR solicitation, and we require all current prize and competition participants to engage end users and identify their needs. Also, as part of the prize portfolio, the program will continue to engage end users, investors, and other commercial partners in the review of prize submissions. We will also invite these organizations to convening events—like the finals of prize competitions—to help amplify the technologies developed in the PBE portfolio.

Additionally, the program is engaging other federal partners in PBE to leverage their expertise and tap into their broader networks, with NOAA as a key partner from the beginning of the effort and more recently, the U.S. Department of Commerce's Economic Development Administration.

While reviewers were overwhelmingly supportive of PBE, we also recognize some concerns over how PBE might impact developers interested in grid-scale devices; specifically, reviewers questioned whether PBE would ultimately be a benefit or a distraction to these developers. The PBE portfolio is meant to complement grid-scale efforts, not replace or redirect them. As an example, since the launch of PBE, the program launched a FOA (FY 2019 FOA DE-FOA-0002080) through which we funded four projects to develop full system designs that will be ready for fabrication, deployment, and prototype testing at the DOE-funded PacWave-South test site.

Foundational and Crosscutting R&D

WPTO appreciated the reviewers' comments that projects funded in our program's Foundational and Crosscutting R&D activity area have achieved innovation in controls, components, and systems with impressive results from the lab projects overall. These types of projects are selected and funded based on their potential to reduce costs and address difficult engineering challenges faced broadly by the industry. As an example, a major programmatic focus is on controls research, where studies have shown that advances can provide significant increases in energy capture (on the order of 200%–300%). To maximize the impact of these projects, the program will continue to encourage and actively facilitate dissemination of results and adoption by industry stakeholders as appropriate.

Technology-Specific Design and Validation

The program notes the concerns by reviewers that several technology development projects had notable challenges, which many believe are largely due to the few U.S. deployments to date. The program agrees with this assessment and the suggestion to create more opportunities for developers to share lessons learned during installation, operation, and maintenance (IO&M) activities. We fully agree that in-water testing is critical to gather the experience needed to drive down costs in system performance and IO&M. Some studies have shown that IO&M can account for greater than 45% of the lifetime costs of a commercial marine energy project. The program previously supported a FOA focused on durability and survivability (DE-FOA-0001310), which had a topic area focused on reducing uncertainty regarding the cost of IO&M. Three projects were selected under that topic area, one of which (the Igiugig Village Council) has already entered the operations phase of the project. Through this project, we are starting to capture IO&M lessons learned, and we will ensure dissemination of the results to the greatest extent possible. Also, the program's

FY 2019 FOA (DE-FOA-2080) included a topic area focused on IO&M cost reductions for current energy converters operating in riverine environments. Lastly, we will ensure that analysis, data, and lessons learned from TEAMER-supported activities, including IO&M information, will be disseminated broadly, and we will strongly consider prioritizing IO&M cost reduction measures within future work.

Reducing Barriers to Testing

WPTO appreciates the reviewers' strong support for the Triton Initiative, including positive comments on testing planned at WETS in Hawaii and an overarching statement that PNNL's provision of facility and technical support for industry-led projects is an effective use of funding and critical for the industry. The program thanks the reviewers and will continue to support the Triton project and additional testing at WETS.

The reviewers advocated for WPTO to focus on translating our marine energy environmental R&D into regulatory outcomes. They also encouraged the program to consider how regulators interpret the findings from our environmental research portfolio and whether monitoring tools would ultimately be accepted for monitoring needs. While DOE does not make regulations, we recognize these impacts can only be realized if the findings and tools are widely disseminated and used. To address this, a new project focused on developing an MHK environmental permitting toolkit was initiated in 2019. The toolkit will include a spatial, regulatory, and document database of the latest science and informational resources to help users rigorously and efficiently identify potential impacts of a proposed project. As regulators will be the primary end user for this toolkit, they are providing direct engagement and guidance to the project team during development.

The reviewers provided several recommendations on how to maximize the impact of our Reducing Barriers to Testing portfolio through coordination with offshore wind. WPTO has a strong historical relationship with DOE's Wind Energy Technologies Office (WETO), and we will continue to seek opportunities to partner on common technical and environmental research, such as the development of standards for environmental monitoring technologies.

An overarching recommendation from the reviewers that stuck out to WPTO was the suggestion to consider opportunities to better streamline regulatory R&D based on (1) recommendations from the permitting analysis projects led by PNNL and SNL and (2) the advanced state or environmental monitoring technologies relative to marine energy systems. All future work will be prioritized based on the cost/timeline reduction potential and the needs of the industry, as well as the insights gained from ongoing projects led by PNNL, SNL, and Kearns and West.

PacWave

As the first full-scale, grid-connected test facility in the U.S., PacWave is a large and important project for WPTO and the MHK industry. Reviewers overwhelmingly agreed that they recognized the importance of PacWave to the MHK Program's goals and to the industry. We heard from reviewers that WPTO should work with the PacWave team to produce a white paper that documents best practices and captures lessons learned from their permitting process. We agreed that this would be valuable and have since contracted PNNL to lead this effort for the program. The key questions we received from reviewers were about 1) how PacWave related to our PBE work, 2) whether there will be enough of a pipeline of devices to test at the facility, and 3) the potential for additional cost overruns and schedule delays. Although Blue Economy applications will not be the primary focus of the facility, certain elements will support PBE. Regarding the future pipeline question, the program recognizes the importance of a robust pipeline of devices across all stages of development, both for the needs of PacWave and the health of the marine energy industry. The program has supported

early stage development of marine energy devices for several years and will continue to prioritize effective utilization of the nation's first permanent, grid-scale test facility. Lastly, the reviewers acknowledged potential for additional cost overruns and schedule delays. Since the peer review, the PacWave team has finalized the cost estimate and Congress provided an additional $26 million for the PacWave test facility. Based on this increased commitment from Congress, the PacWave team has finalized the site design and moved toward facility construction.

Data Sharing and Analysis

The reviewers provided important feedback on our program's Data Sharing and Analysis work; we agree that we need to assess some of our investments and approaches in this area, and we commit to reexamining our data strategy overall. Of the comments received, the recommendations that stuck out most to us were that the program should consider (1) more efficient and effective means to collect, organize, and analyze high-quality data and the storage needs/implications for such data; (2) whether PRIMRE, in its current form, has helped address marine energy data challenges; and (3) developing metrics to quantify the impact of this work that are more meaningful than the number of downloads of datasets or visits to a site.

Data collection and impactful dissemination is critical to WPTO's R&D mission. The program recognizes the need to better collect, organize, and analyze high-quality data for device testing and performance, environmental data streams, and lessons learned (especially from in-water testing experiences). We fully recognize that the impact of the data created, and lessons learned from WPTO-funded R&D will only be impactful if they are easily accessible, broadly disseminated, and used. We will continue to assess areas for improvement, including methods to more systematically document lessons learned, across the portfolio. When we start new programs, we do so with these critical goals driving our actions. For example, we are expecting TEAMER to create new data that could be informative for other marine energy developers and researchers. Therefore, we stood up a TEAMER Technical Board who are currently developing a test plan template to ensure data is collected in a consistent, repeatable manner and adheres to relevant technical specifications and standards. We envision that best practices to collect, organize, and analyze data will be developed by the Technical Board. In addition, through the Kearns & West MHK toolkit award, the project team is engaging regulatory agencies in discussions around the use cases for datasets WPTO collects and makes available, including environmental data. These activities will inform programmatic decisions moving forward with respect to better collecting, organizing, and analyzing data.

The reviewers expressed some concerns about the PRIMRE project, a multi-lab effort to improve the discoverability and use of data produced from MHK Program-funded R&D. Currently, these data are collected and stored in many ways. The PRIMRE project is still relatively new and, at the time of the peer review, some functions had not yet been realized. As the project is still under development, construct and function can still be modified as appropriate. Nevertheless, we understand the reviewers' concerns around PRIMRE, and we are reassessing our data strategy overall while working to beef up our team's data science expertise.

Lastly, we heard from reviewers that the program staff and project teams supporting marine energy data sharing need better metrics to quantify the impact of this work. We fully agree with this sentiment, as the impact of knowledge sharing is not adequately reflected by metrics such as number of visits to a site. Developing meaningful metrics for websites, databases, and communications work is a challenge for anyone working in these fields. The standard logic model WPTO is developing will help projects, including data sharing projects, to better define and articulate project activities, outputs, outcomes, and impacts. The function of the logic model will also inform project management plans and help better identify meaningful and appropriate data and metrics to monitor and measure.

MHK PROGRAM SCORE RESULTS

This section provides an overview of the scoring for the MHK Program strategy, all projects within the MHK Program, and PBE. Reviewers evaluated the MHK Program strategy and PBE on the following, equally weighted criteria: (1) program strategy and objectives; (2) program portfolio; (3) program management approach; and (4) stakeholder engagement, outreach, and dissemination. Reviewers provided scores on a scale of 1 ("unsatisfactory") to 5 ("superior") for each criterion and were also asked to answer unscored, supplemental questions for each program or strategic initiative, which are outlined in Appendix B. A summary of the reviewers' responses to the unscored, supplemental questions were incorporated into the MHK Program Evaluation Summary. Figure 20 summarizes the weighted score of the MHK Program strategy and average reviewer score according to each program evaluation criteria.

In addition, reviewers were asked to evaluate a set of WPTO's projects, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each project on the following specific criteria: (1) project objectives, impacts, and alignment with the program strategy; (2) end user engagement and dissemination strategy; (3) management and technical approach; (4) technical accomplishments and progress; and (5) future work. Project scoring involved weighting the evaluation criteria based on each project's category—sunsetting/completed, ongoing, or new—which was based upon a project's start and/or end date. Reviewers were asked to comment on the strengths and weaknesses behind their scoring and to provide recommendations that they felt that the office should consider. Figure 21 summarizes the average score of all projects within each activity area, the average score of all MHK projects, the average PBE strategy score, and the average program strategy score.

Figure 20. Average reviewer score of the MHK Program Strategy by program evaluation criteria

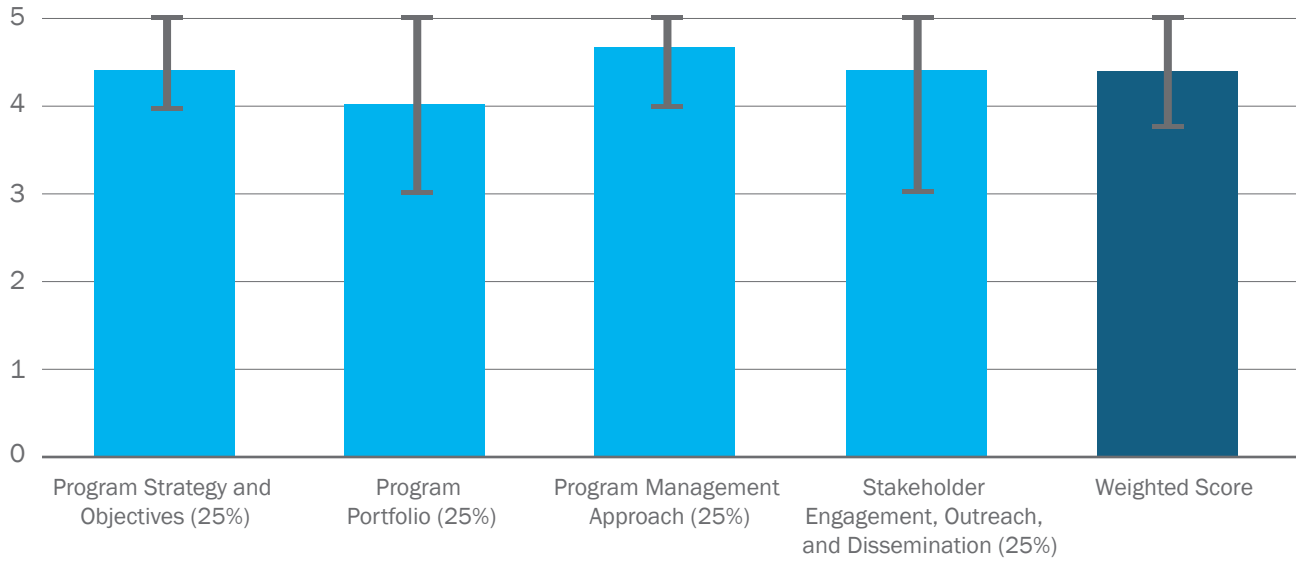
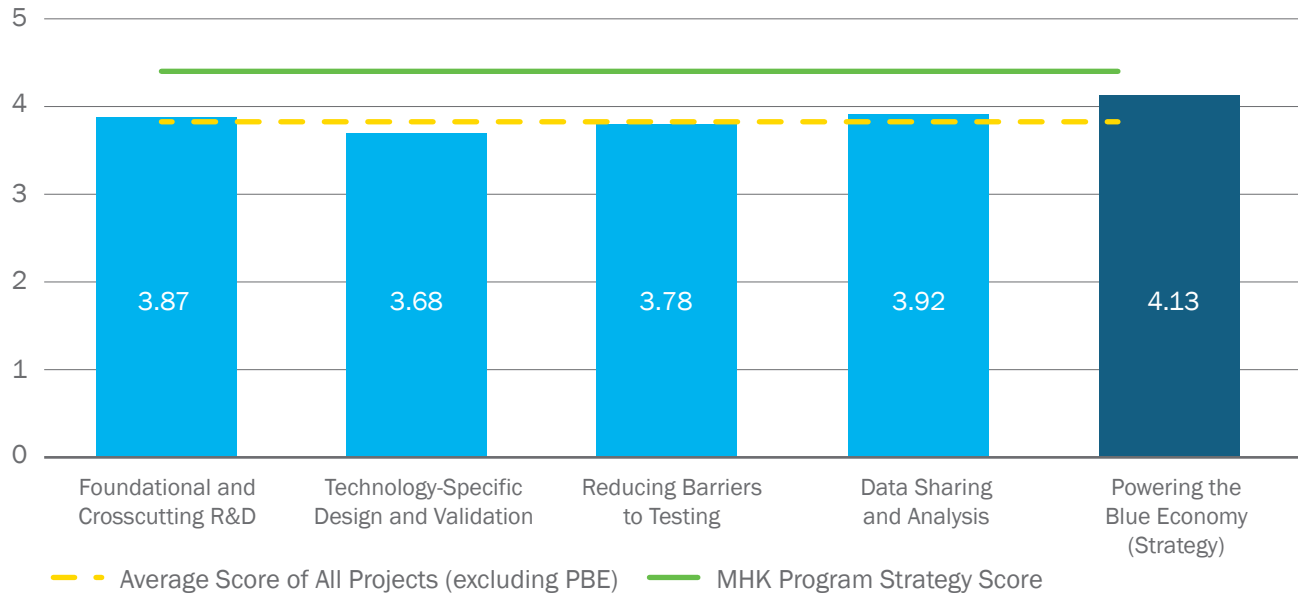


Figure 21. Average weighted score by MHK Program activity area



Note: Of the 41 projects reviewed in the MHK portfolio, the number of projects reviewed per activity area include: Foundational R&D—12 (29%); Design and Validation—8 (19%); Testing—15 (37%); Data—6 (15%).

Organization of Activity Area and Project Results

The results are organized by the activity areas into which individual projects were grouped for the 2019 Peer Review. Each subsection (i.e., activity area) includes the following components:

1. *Activity Area Score Results*: This chart depicts the average weighted score for each project in each activity area.
2. *Activity Area Summary Report*: This consists of a summary of the review panel's comments that provides insight into the activity area's strengths and weaknesses or potential issues and specific recommendations. Review Panel Leads were responsible for drafting activity area evaluation summaries in consultation with the full review panel and Program Review Chair. Consensus among the reviewers was not required, and reviewers were asked to include differences of opinion and dissenting views within the report.
3. *Project Evaluations*: These are individual project reports, which constitute 2–3-page reports summarizing the results of each project evaluated during the review process. Each report includes the following elements:
    a. *Project Name and Work Breakdown Structure (WBS) Number or Award Agreement*: The full project name is listed as the heading, with the identifying code underneath in parentheses. Project evaluations for each activity area are ordered by WBS number, followed by award agreement number, from lowest to highest.
    b. *Weighted Project Score*: Each project's average weighted score is stated numerically. A bar chart depicts the average scores for each evaluation criterion, as well as the range of scores given to the project by the individuals within the Review Panel. The chart also indicates the average value for each evaluation criterion across all projects within the activity area.

c. *Summary Table*: Each report provides reference information about the project, including the recipient organization, PI name, project dates, project type, and funding values.
   i. *Recipient*: The recipient indicates the organization tasked with leading the project (this may include multiple organizations in situations where the project has more than one recipient).
   ii. *Principle Investigator*: The PI is the individual affiliated with the recipient organization who is assigned to lead the project.
   iii. *Project Category*: Each project is categorized as sun-setting, ongoing, or new, based on its start/end date.
   iv. *Project Type*: There are many types of projects within the WPTO portfolio, but this review focused primarily on two types of projects: (1) AOPs, which are core R&D projects performed by DOE's national laboratories, and (2) projects awarded through a funding opportunity announcement, which are indicated in this table by listing the FOA's name or number.
   v. *Funding*: Each project includes total costed and total authorized. Total costed is the budget executed during the full peer review period (from FY17 through Q2 of FY19). Total authorized for AOPs is the sum of prior year (FY16) carryover and budget authorized during the full peer review period (from FY17 through Q2 of FY19). Total authorized for FOAs is the total DOE negotiated award amount, including amounts allocated to sub-recipients.
   vi. *Project Descriptions*: Project descriptions are compiled from the project summaries that the PIs submitted for each project.
   vii. *Summary of All Reviewers' Comments*: Reviewers were responsible for consolidating and summarizing all reviewer comments on their assigned projects, in consultation with the Review Panel Leads and Program Chairs. These project evaluation summaries were edited only for grammar and clarity. In a limited number of cases, reviewer remarks deemed inappropriate or irrelevant were excluded from the final report.

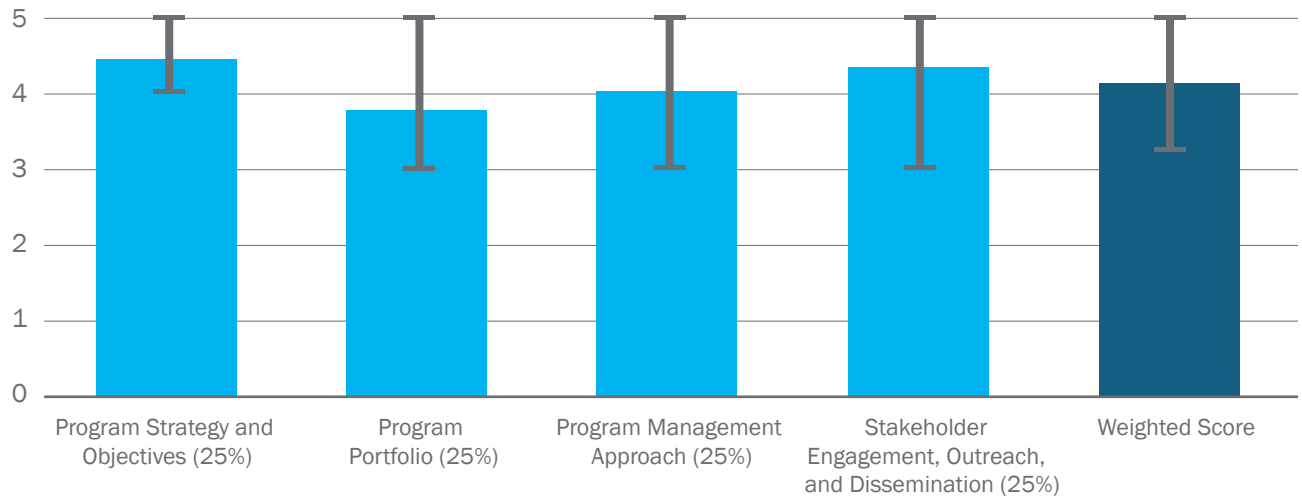
Powering the Blue Economy

This section provides full evaluation results for PBE and its strategy, as well as the lead reviewer's summary of reviewer comments in response to the program evaluation criteria.

PBE Score Results

Figure 22 summarizes the weighted score of the PBE strategy and average reviewer score according to each program evaluation criteria. The program evaluation criteria and the unscored, supplemental information are outlined in Appendix B. A summary of the reviewers' responses to the unscored, supplemental questions were incorporated into the below PBE Summary Report.

Figure 22. Average reviewer score of the PBE strategy by program evaluation criteria



PBE Summary Report

Prepared by the PBE Lead Reviewer

Feedback from the Review Panel to WPTO

The reviewers agreed that the long-term goals and objectives of PBE were clearly communicated. WPTO presentations, panel discussions, and reports conveyed the direction of the WPTO to address the near-term opportunities for MHK. The consensus is that PBE is a good track for WPTO to pursue.

The connection between PBE and a path to grid-scale power was not clear to the reviewers. Additionally, the role in existing testing centers and grid-scale investments for PBE was also questioned. This primarily included whether PacWave was still going to be essential for PBE support and success. Reviewers agreed that the increasing focus on PBE should not result in a lack of support for past efforts toward grid-scale development, which includes modeling, test centers, and devices. However, reviewers did note that TEAMER was seen as a well-poised facilitator of PBE.

The reviewers provided feedback on market-specific opportunities, as well. The consensus of the reviewers was that WPTO place more emphasis on aquaculture. There were several counter views on whether autonomous underwater vehicle docking, specifically on improvements to docking, should be a goal of PBE or funded by DOE. Some thought this should be an early focus, while others recommended that investment in this technology fell outside of the WPTO mandate. Counter examples include "the areas of Ocean

Observation and Underwater Vehicle Charging go hand in hand and should be pursued concurrently," and "these costs, like advancing AUV [autonomous underwater vehicle] docking technology, cannot and should not be supported by WPTO," with the latter being in the minority. In its objectives, WPTO doesn't appear to prioritize novel storage solutions for power at sea. There should be more emphasis on finding novel clean storage solutions at sea, as storage is just as essential as energy production.

Most reviewers were concerned that there is still not enough of an understanding of the size and scale of market opportunities across the Blue Economy for marine energy developments and found that this should be investigated further as soon as possible.

Lab support and integration will be essential for success, and reviewers recommended that this collaboration build on past successful efforts at integrating the labs. Additionally, reviewers recommended synchronizing with efforts of other funding agencies, like the work with IOOS, and they cited multiple agencies, like NSF, NOAA, and USAID, and private big private industry partners like Teledyne.

Summary of all Reviewers' Comments

Overall Impressions

The PBE direction was viewed positively by the reviewers. Specific concerns that were addressed by all reviewers included available markets; metrics for markets; and the balance between previous investment in grid power and test facilities. There were differences of opinion about whether autonomous underwater vehicle development docking/recharging should be a focus, and a consensus on increasing the priority of activities that support aquaculture development.

Program Strategy and Objectives

There was strong consensus among reviewers that the program's PBE long-term strategy, strategic approaches, and future direction was effectively conveyed during the peer review. The program has demonstrated funding opportunities that align with near-term PBE opportunities. Examples of these funding activities were SBIR awards, the Waves to Water prize, and the Marine Energy Collegiate Competition. This new track for DOE fits well within other governmental program mandates that are already being conducted in close collaboration with DOE. This includes specifically NOAA IOOS, NSF, and the U.S. Coastal Research Program (which includes USACE and the U.S. Geological Survey) for resilient coasts. These agencies present many new opportunities for the program to fill data gaps by powering instruments with micro to small scale power needs.

The link from PBE to utility scale MHK generation is less clear and should be detailed more, considering a portfolio that supports past and current investments in grid-scale technology, while still facilitating this new PBE direction and fully utilizing the labs for making connections between the two tracks where they exist. The program invests taxpayer funds wisely to drive the greatest impact, but impact needs to be defined and evaluated for this initiative early.

Program Portfolio

There was nearly unanimous consensus among the reviewers that PBE being so young makes it more difficult to assess, from a portfolio perspective, as there are few PBE funded projects currently. The Waves to Water prize was viewed favorably as a first step, as was the upcoming Ocean Observing prize. But in general, the reviewers viewed PBE as a positive perspective portfolio direction, but with few examples to fully evaluate the program portfolio.

The minority dissention and critical comments from individual reviewers of the PBE approach noted that the allocation of resources could not be evaluated, as the associated budget for PBE development or plans for PBE activities were not shared. It was also unclear the relationship between presumably niche lower-power MHK devices and grid-scale devices. However, it was noted that there are certainly lessons to be learned from smaller-scale devices that apply to grid-scale development. Some investigation of the relationship between these two programmatic themes is warranted early. And, it appeared from the peer review during open discussions that developers are still not fully aware of WPTO support mechanisms and view collaboration with labs (IP) as a barrier.

Program Management Approach

There was strong consensus, with only minority dissent, in support for the program team among reviewers. This is a unique team of capable people to manage and execute this new PBE initiative, which has been constructed over the last 5 years. Reviewers were impressed with the program leadership, initiative, and team camaraderie. A specific example that reviewers commended was the collaboration and cross-pollination of funding opportunities between DOE and NOAA IOOS. Attendance by several WPTO leadership staff at the decadal Ocean Observing meeting in Hawaii tangibly demonstrated a motivated attempt to understand the needs and opportunities in the observing community early. One exception to consensus was given in a minority opinion, "[t]he vision of the powering the blue economy was clear, but the management approach to implement the vision was vague." While one reviewer noted that the portfolio was, "somewhat unfocused," another noted that, "overall the team is very focused, motivated and with budget behind them empowered to make a success of PBE."

Several reviewers noted the team is focused on priority research areas that could create the greatest impact on new technology and industry advancement, and the team is effectively communicating what these areas are and how the program is allocating resources. Reviewers noted that the program team demonstrates the professional and technical capabilities needed to identify, monitor, and guide its portfolio of projects, but that while operations and oversight procedures are in place to ensure efficient direction of office activities—both internally and with project awardees—it could be strengthened.

Stakeholder Engagement, Outreach, and Dissemination

Reviewers shared opinions that at this early stage, program efforts at stakeholder engagement, outreach, and dissemination for PBE were positive. But at this early stage of PBE, it is difficult to evaluate the stewardship of tax dollars; however, reviewers have confidence in the WPTO team to do so effectively based on past performance. The program provides access to accurate and objective information and data that can help to accelerate industry development and inform decision makers, which will be important for PBE. Like the feedback in other areas, reviewers suggested other agencies (e.g., USAID, NSF, and NOAA) that could be engaged to further understand the PBE markets. And reviewers did include additional recommended partners and engagement strategies.

Reviewers recommended that WPTO investigate ways to disseminate information more broadly. This included reaching beyond its current website; conducting workshops with additional stakeholders; utilizing other platforms like Udemy, Coursera, and TEDx for disseminating to a global community; and working with leaders on PBE—for example, with Silvia Earl on how her ocean exploration campaign should align with the PBE objectives for ocean observation or with Professor Lienhard for desalination. One reviewer suggested leveraging events, such as the Institute of Electrical and Electronics Engineers' Oceanic Engineering Society

Marine Technology Society Offshore Technology Conference, to amplify PBE and connect with new stakeholders.

Another reviewer suggested that WPTO send delegates to IOOS regional associations like SECOORA/MACOORA to learn about their needs and facilitate and collaborate on relevant funding opportunities. Most of the regional associations have annual meetings where WPTO staff would have an opportunity to engage with researchers to learn about specific needs within those regions.

It was also suggested that the program have early engagement with companies like Teledyne, specifically their Webb, RDI, and Benthos branches. Additional companies that reviewers suggested for potential collaboration included Seabird, Edgetech, and RBR. These companies produce many of the ocean observing instruments in use. Determining their power needs, and the potential for MHK to grow their capabilities may help to craft even more relevant funding opportunities. Additionally, another reviewer suggested reaching out to Siemens on their BlueVault Energy Storage and Subsea Power Grid.

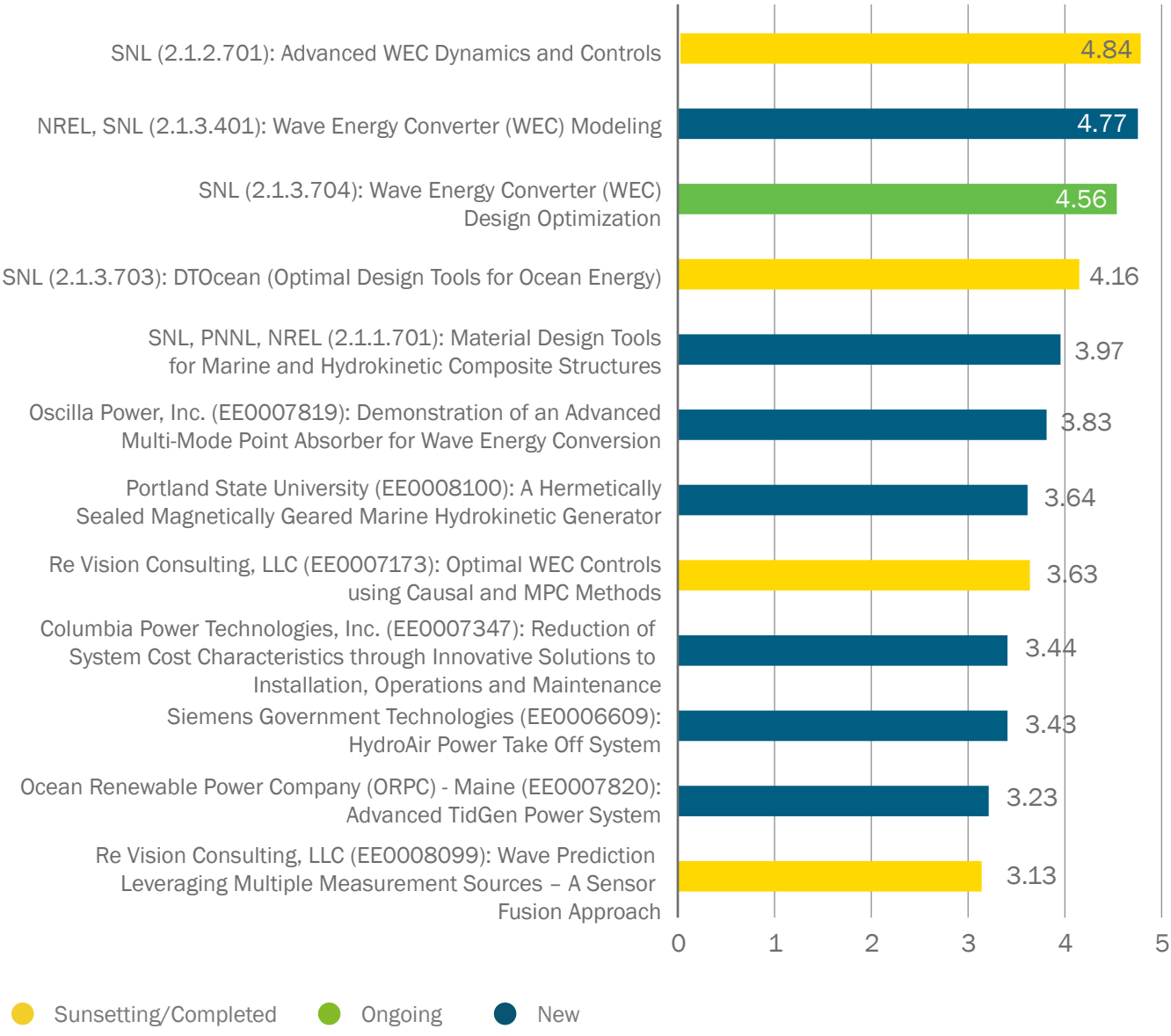
Foundational and Crosscutting R&D

This section provides an overview of the scoring for all projects within the Foundational and Crosscutting R&D activity area (see Figure 23); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

Activity Area Score Results

Name	Average Weighted Score of All Projects
Foundational and Crosscutting R&D	**3.87**

Figure 23. Foundational and crosscutting R&D activity area—average weighted score by project



Activity Area Summary Report

Prepared by the Review Panel Lead

Feedback from the Review Panel to WPTO

The Foundational and Crosscutting R&D activity area encompassed projects presented and focused on the development of controls, device subsystems (i.e., generators), PTOs, components, materials, the preparation for WEC/TEC tank/in-sea performance testing, O&M methodologies, modeling, and design tools all targeting the reduction of LCOE. The foundational knowledge and data disseminated from the portfolio of projects are vital to future technology breakthroughs, improvements in device performance, and LCOE reduction. Several excellent examples of projects led by the labs were presented and scored highly. The panel agreed that the new market requirements, as addressed in PBE, should be well defined and integrated under the Foundational and Crosscutting R&D program activity area. The panel agreed that the portfolio's impact and technical progress to the sector, including end user engagement and dissemination, are areas WPTO should improve upon, with recommendations described below.

Program Impact and Technical Progress

One reviewer recommended that, where there is a discrepancy in panel comments and scores, WPTO evaluate the comments on the specific project impact and progress. Reviewers agreed overall that the developer (GEN1) projects had conflicting evidence demonstrating impact to the sector; for example, a common comment on individual projects was that "it is not fully clear the impact that this particular device adds to improving significant cost reduction and performance improvement that is required in the ocean energy sector overall."

With the introduction of the PBE initiative and incorporation into the MHK program, it appears that GEN1 developers have opportunities to deliver lower-cost, smaller-scale devices that can power markets within the Blue Economy, such as ocean observation or remote communities. Most of the GEN1 developers did mention how they could impact these markets. The concern is how they pivot into a new technology development program that does not integrate the lessons learned during full-scale development. The reviewers recommended that, if possible, WPTO incorporate PBE objectives into GEN1 developer projects and in a manner that ensures the lessons learned are not lost, even if it is to deliver a proposal for lower-cost design options at kW scale utilizing remaining budgets. It is crucial for the GEN1 developers to demonstrate their capability to deliver into Blue Economy markets.

The panel consistently agreed that WPTO should implement more detailed design reviews and overall have labs lead technology assessments with GEN1 developers that determine whether each design has a credible path to a competitive LCOE or not. The outputs of key lab projects should be integrated much earlier into GEN1/GEN2 design projects. For example, the outputs of the materials project should inform potential component design and the WEC optimization tool presented by SNL. A reviewer commented, 'Sandia's involvement and not doing it in an intellectual vacuum by bringing in developers is the right kind of symbiosis the MHK industry desperately needs to be successful.'

Another recommendation is to ensure lessons learned are in a standard format within WPTO project peer review presentations. Identifying common events/effects/causes is vital to the sector not repeating mistakes.

WPTO should ensure that work is accessible to the whole sector to avoid duplication of efforts. For example, the optimal WEC controls/MPC methodology is vital to work, but the comment by the project performer that

'recovery on the cost-share before they are willing to make the model predictive controls (MPC) work open source' fundamentally limits impact and progress at the program level.

Another recommendation is that projects winding down, such as the WEC-Sim and DTOcean projects, should have a long-term sustainability plan with ownership and support continued at the lab level. WPTO should ensure that the WEC design optimization tool is embedded/utilized with all GEN2 funded WEC developers.

Program Dissemination/End User Engagement

Regarding dissemination strategies and end user engagement presented throughout the projects, a reviewer recommended that dissemination targets are set by WPTO and communicated. For example, the number of expected peer-reviewed journal papers on foundational R&D projects. Reviewers also recommended that WPTO support end user engagement workshops so that business to business opportunities are realized.

Reviewers recommended that further engagement with international community for development, engagement, and implementation of the SNL WEC design optimization tool is critical for further uptake in the MHK sector.

Dissemination of the lab tools into university courses or on other online learning platforms will increase tool utilization and learnings. One reviewer expressed interest in seeing facilities added to easily direct the tool to evaluate performance based on real sea spectra. This utility will be significant for the PBE effort because two-parameter spectra commonly lose details that are relevant at a smaller scale.

Lab modeling and controls work should be disseminated and opportunistically integrated with other GEN1/GEN2 developers/PBE developers. The panel recommend that WPTO assess the controls projects to determine the state of the art or use the SNL advanced WEC dynamic and control tool as the standard for which other WEC tools are benchmarked.

Summary of All Reviewers' Comments

Overall Impressions

The projects presented under the Foundational and Crosscutting R&D activity area demonstrated key outputs toward innovation in controls, components, and systems, with impressive results from the lab projects overall. For example, all reviewers agreed that the work on controls and modeling done by SNL and NREL was driving innovations ahead of developers' abilities, and thus it was critical to realign the work done to accelerate Oscilla, Columbia Power Technologies, Ocean Renewable Power Company (ORPC), and Siemens/OE (which the reviewers referred to as the GEN1 developers).

The reviewers agreed in varying degrees on the developer/industry projects in how well the projects conveyed their progress, how those projects impacted the challenges facing the industry, and, most importantly, how those projects supported the program to validate performance and grid reliability for new technologies. For example, regarding PTO developments with potential innovation for other WEC technologies, a reviewer stated, "It is not fully clear the impact that (a) particular device adds to improving significant cost reductions and performance improvements that is required in the sector overall." Another example was on a developer's design approach with late-stage changes to designs that limit the potential of the technology. "It is not clear what the overall benefit is of the particular technology compared to more conventional (devices)." Reviewers did have concerns on specific devices' PTO applicability with other WECs or the scalability for different applications.

All reviewers agreed that all developers presented under this activity area did require an investigation or assessment by WPTO to determine if each of the device designs has a credible path to a competitive LCOE. A defined LCOE is fundamental to achieving the program strategy that identifies and advances technologies with the highest potential.

The significant disagreement from reviewers was on consultancy projects' progress and impact on innovation. For example, the consultancy project on optimal controls methodology using predictive control and feedback versus the lab project on prediction-less control methodologies. Both deliver on the objectives for foundational R&D. However, the impact is unclear for the sector. Which one will drive WEC performance to competitive LCOE?

Program Strategy and Objectives
All reviewers agreed that the Foundational and Crosscutting R&D are demonstrates a strategic approach for MHK sector development focused on overcoming difficult engineering. The program efficiently demonstrated a portfolio of projects that align with driving innovation in components, controls, manufacturing, materials, and systems; developing tools and methodologies; and aggregating analyses of the MHK device performance and technology advances. Less evident at the program portfolio level was the number of collaborative development and application of quantitative metrics projects.

At the program level, reviewers agreed that the projects addressing modeling and design optimization tools worked toward the goal of early-stage research that accelerates the development of innovative technologies. Examples of this include the Advanced WEC dynamics and controls and WEC design optimization tool.

The program has significant international reach with uptake in the researcher community on the tools developed, such as WEC-SIM and DTOcean tools.

The panel agreed that the program does fund the efforts to validate the performance and grid reliability for new technologies. However, a more integrated lab approach with GEN1 developers is necessary to support the efforts to validate performance and, most importantly, assess the successful technology trajectory toward a competitive LCOE. The reviewers expressed concerns that the taxpayer investment made compared to GEN1 developer results will continue to depress investor confidence.

Program Portfolio
The reviewers all agreed that the lab modeling and design tools developed aligned well with the program strategy and objectives needed to improve understanding between WEC structure and fluid dynamics.

Most challenging to the program strategy and objectives was the delivery of the device-specific projects and their progress. Most reviewers agreed that the GEN1 developer results emphasize the challenges facing the sector and do not demonstrate effectively how to overcome those challenges. For example, the integration challenges with a PTO and WEC structure individually designed as subsystems. Each of the GEN1 developer projects included objectives to drive down LCOE. However, reviewers are skeptical of the ultimate results toward those targets.

One project was presented that fit the objective to improve resource assessment and characterization. Reviewers had varying comments on the significance of this project and how the wave prediction tool utilizing marine radar will ultimately impact resource characterization necessary at small and array scale. Overall, there were positive comments about the consultancy projects regarding their novel approaches. For example, "no one has been able to implement MPC on a WEC device at sea…important milestone and impact

for the MHK community...this is essential work at does have the opportunity to benefit all scales of wave energy converters."

All reviewers agreed that the organization of the project and program approaches were effectively conveyed. Most reviewers questioned how the foundational and crosscutting R&D program will be impacted by PBE strategy as presented. Will the innovation in components, for example, as developed by GEN1 developers, be scalable for a smaller size, lower power requirement device? It is a challenge to the program portfolio to balance the research priorities effectively without loss to the lessons learned and innovations developed through the projects.

Program Management Approach
All reviewers agreed that the WPTO program team is highly competent and energetic in the delivery of the program. The team is focused on creating the most significant impact to advance the sector, and it is evident when the project manager effectively engages and influences the developer projects that bring them closer to successful outcomes. Examples include the insertion of lab support into developer projects, such as the NREL instrumentation of the OE buoy to obtain and validate vital performance data. The program team has demonstrated strong professional and technical capabilities, including active portfolio management.

Stakeholder Engagement, Outreach, and Dissemination
The reviewers agreed that the program does provide access for project performers to disseminate data and report results. However, the reviewers have concerns about how effectively the project performers are utilizing the repositories. There is a concern that the data repositories have high-level information only. There are some useful sites where the number of hits and downloads on the open-source tools are effectively utilized, but qualifying how the access is helping to accelerate the industry and inform decision makers is less evident.

The WPTO peer review process is an excellent example of maximizing R&D impact, while demonstrating sound stewardship of taxpayer funds. The active promotion of the Foundational and Crosscutting R&D portfolio, while encouraging transparent feedback from stakeholders attending the peer review week is vital to the success of the MHK program.

It is essential for WPTO to reach a wider international audience and present on program developments. The peer review week should not encourage the same attendees with the same 'faces' repeatedly, which could lead to 'group think.'

The keynote presentations from Conservation X Labs and Greentown Labs were excellent examples of outreach to stakeholders. These stakeholders have excellent platforms for disseminating results of the WPTO program, including access for the MHK sector to capitalize on Greentown Lab programs. Involving other similar stakeholders is a 'new' networking service WPTO can offer to the MHK product development sector.

Project Evaluations

MATERIAL DESIGN TOOLS FOR MARINE AND HYDROKINETIC COMPOSITE STRUCTURES

(WBS #: 2.1.1.701)

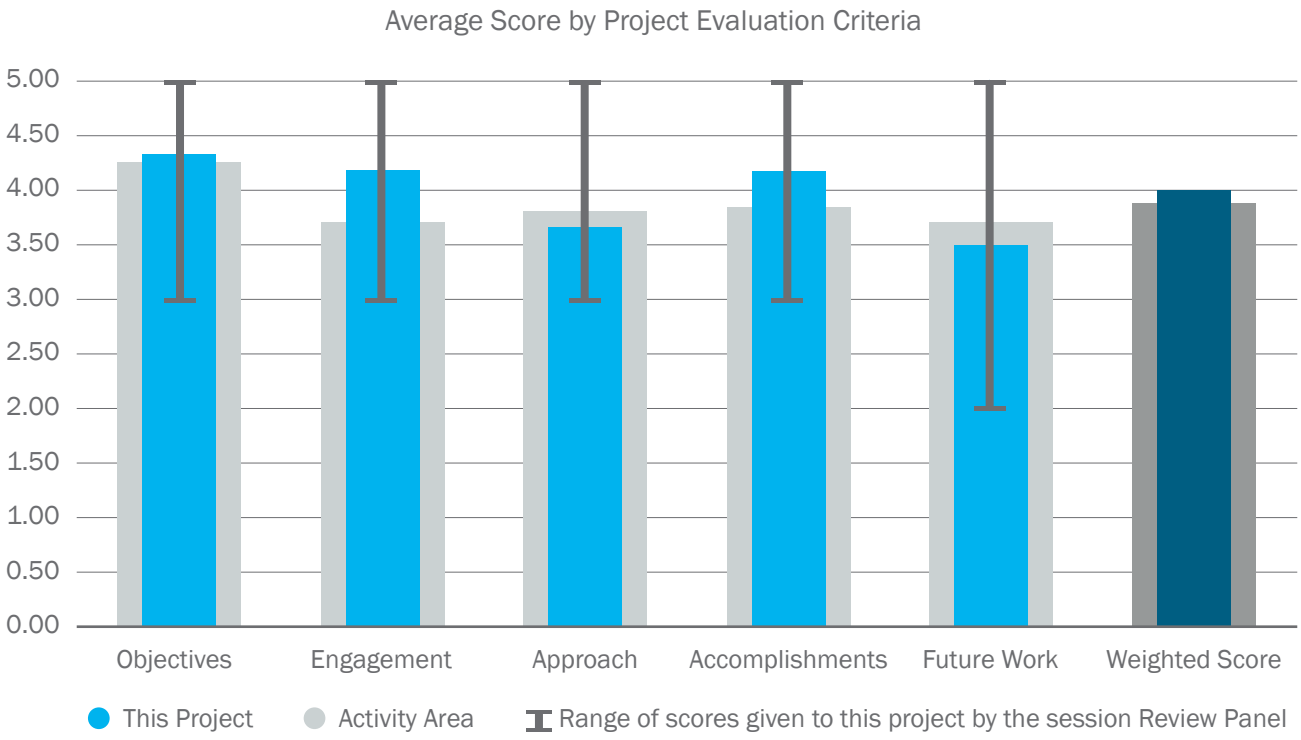
Recipient:	SNL, PNNL, and NREL
Principal Investigator:	Bernadette Hernandez-Sanchez
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$1,866K
Total Costed:	$1,194K

Project Description

MHK technologies manufactured with composites are promising to increase efficiency and improve levelized cost of energy (LCOE) metrics; however, composites in marine energy applications are largely untested. During a composites workshop that the project team conducted in 2015, the community voiced a need to better understand composite materials and structure performance properties related to MHK conditions. Therefore, the project goal is to reduce risk/uncertainty in using composite designs by demonstrating their potential advantages. Through this project, the team plans to: (1) assess industry supplied coupons for biofouling, loads, and corrosion; (2) identify relevant substructures for fabrication/testing; and (3) provide descriptive resources of materials properties (database/best practices handbook) and solutions addressing industry's priority needs.

Weighted Project Score: 4.0

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

Reviewers generally ranked this project in the average-to-good range, and they thought it served a useful purpose within the program. It was specifically noted that building a database for MHK materials is a significant contribution to the MHK community.

Reviewers made several suggestions on ways to improve the project. One reviewer suggested that the project team should have collaborated with specific partners that had several years of experience with materials in the marine environment. The reviewer stated "I would have liked to see more involvement from Penn State Applied Research Laboratory as I have worked with them in the past on these issues, and they have a significant repository of composite designs that may or may not be shared from the U.S. Department of Defense (DOD) customer. Additionally, Navy Carderock should have been involved to leverage their materials group and long history in characterizing these materials to fully realize the impact of government R&D dollars."

In the project summary/bio, the technical approach mentions that in comparison to international efforts —e.g., the European Marine Energy Centre (EMEC), the French Research Institute for Exploitation of the Sea (IFRMER), and Wave Energy Scotland (WES)—this program is focused on performance testing of glass and carbon fiber reinforced composites (coupons to subcomponents), coatings, and carbon-metal interconnects. It would be important to either align with or discuss differences between the international efforts at EMEC, IFRMER and WES. Reviewers recommended that this is further detailed in follow-on work in 2020 and shared via webinar with EMEC, IFREMER, and WES.

This project comes about as close as any to a material science effort in the WPTO portfolio. While it is useful work, it is not the type of effort that is liable to provide a breakthrough advance that will have a transformational change on the technology. Nevertheless, for its goals, the effort is well run and provides a central place for work involving the long-term and fatigue testing of components and materials. This is useful and could lead to incremental improvements in the devices being developed. Fatigue, corrosion, and biofouling are common problems with ocean-deployed equipment, and it's not entirely clear to one reviewer that WPTO needs this project in the program.

What are the range of environmental parameters investigated? In Particular, some details about various salinities and temperatures for testing scenarios would be valuable and quite relevant.

Project Objectives, Impacts, and Alignment with the Program Strategy

Reviewers felt that this project had a significant impact on MHK development and generally agreed that it aligned with program strategies. The performers have engaged with several industry and lab partners to evaluate community needs. Insofar as the number of relatively advanced industry partners listed, the performers have established communications that help the project provide meaningful and immediate impacts to developers.

Building a database for MHK materials is a significant contribution to the MHK community. Many small developers do not understand the impact of seawater on fatigue lives of steel components, which may be reduced by half from in-air material characterizations. Solid load case generation and a material database are the foundation of successful MHK designs for factors of safety to arrive at cost-competitive LCOE.

This project looks to replace incumbent steel with composite and hybrid structures. Most MHK devices have remained as steel structures due to more mature fabrication methods, the relative low materials and

manufacturing costs, wide availability of resources, and greater characterization of steel alloys' performance in marine environments.

There was, however, one less favorable view of the impact of this project: "The project performers have worked to identify areas to study but, in the end, [this project] doesn't appear to be filling a critical hole in the WPTO project portfolio. A lot of what's being studied applies to a lot of ocean deployed equipment and the specific testing and study details device developers face may or may not be covered by this study."

End User Engagement and Dissemination Strategy

Reviewers rated the end user engagement strategy from average to good, noting that the project performers have clearly described the rationale for the stakeholder/end user engagement strategy, as well as dissemination plans for project results and information. However, it appears that the results disseminated are to a smaller audience within the MHK sector.

Final results will be published in public databases (OpenEI, SNL, and Tethys), and incremental results have been shared through telecons, webinars (EPRI, Marine Energy Council), presentations (Institute for Advance Composites Manufacturing Innovation and Marine Energy Technology Symposium), and workshops (Water Power Week) to inform beneficiaries of progress.

They have also reached beyond their immediate partners to request input through DOE facilitated webinars, workshops at conferences, and a planned publication. Several specific dissemination examples were provided, but the reviewers would have appreciated a list.

The only potential challenge with the dissemination effort could be due to user error. Following the link that provides the Materials and Structures Database for download, one reviewer filled out the user form (noting that it didn't provide an academic user community option) and attempted to download the database. Nothing happened, and the reviewer was redirected to fill out the form again.

Management and Technical Approach

A recurring theme among the reviewers was to see longer term testing provided. There were a myriad of suggestions given by reviewers for improvement in this area

Reviewers were concerned that there was no discussion of potential risks to projects. One reviewer made the insightful comment that longer-term tests on materials would make a very valuable contribution to developers who could not afford the time and investment to do this on their own.

It would be important to either align with or discuss differences between the international efforts at EMEC, IFRMER and WES. Reviewers recommended that the project team provide more details in follow-on work in 2020 and share dissemination with webinar with EMEC/IFREMER, WES would be appropriate.

One reviewer suggested that a more rigorous characterization of the testing environments should have been presented, stating that testing for biofouling and corrosion presents challenges that were not immediately addressed in the technical approach. For example, what were the salinity ranges for the corrosion tests? Various water bodies in ocean environments vary widely in salinity from ~33 practical salinity units to above 36 practical salinity units. Also, temperature and different biological communities that are present/absent in different water masses can have profound effects on the amount of biofouling. Clearly, all water bodies can't be tested, but were these affects considered in some of the tests? It would be helpful to define the water mass/community/temperature/salinity of some of these tests.

The reviewers also felt that international MHK developers should have been solicited for input. The project performers have identified a project management plan that includes well-defined milestones and adequate methods for addressing potential risks, though again, the risks were not well described.

Technical Accomplishments and Progress

Reviewers ranked the technical accomplishments and progress of this project from average to good. They noted that based on the project management plan, the project performers have made progress in reaching their objectives. The project performers described their most important accomplishments in achieving milestones, reaching technical targets, and overcoming technical barriers. Additionally, the project performers have clearly described the progress since the last review period, and they did a good job of describing outcomes and progress on the tests.

Reviewers suggested that this knowledge should be evaluated with GEN2 developers who are incorporating composites into their designs. The project results described that moisture diffusion within the laminate affects the longitudinal and transverse mechanical behavior. Project performers observed similar degradations in strength and an increase in failure strain across almost all the 33 industry supplied material systems tested.

Reviewers generally agreed that milestones appear to have been met, but the project team is not monitoring program health as to what the critical success factors are in what is required for MHK developers to be commercially viable. Reviewers noted that characterizing the test coupons is not enough and that this program would benefit from U.S. Navy support. The project performers have described their most important accomplishments in achieving milestones, reaching technical targets, and overcoming technical barriers.

Future Work

One common theme among about half the reviewers was that risks and mitigation strategies were not presented, and a vision for integration into future projects was not well established. Future work is only focused on the first half FY 2020. It would be good to see engagement/collaboration with a range of European Union-funded materials projects. About half of the reviewers ranked future work favorably, considering that the perception was that this project is wrapping up.

One reviewer questioned if a component reliability database can be reverse engineered, prioritizing components that could be made from composite materials without limited/lower failure risk. Another reviewer suggested that the team establish a cost versus performance database.

ADVANCED WEC DYNAMICS AND CONTROLS

(WBS #: 2.1.2.701)

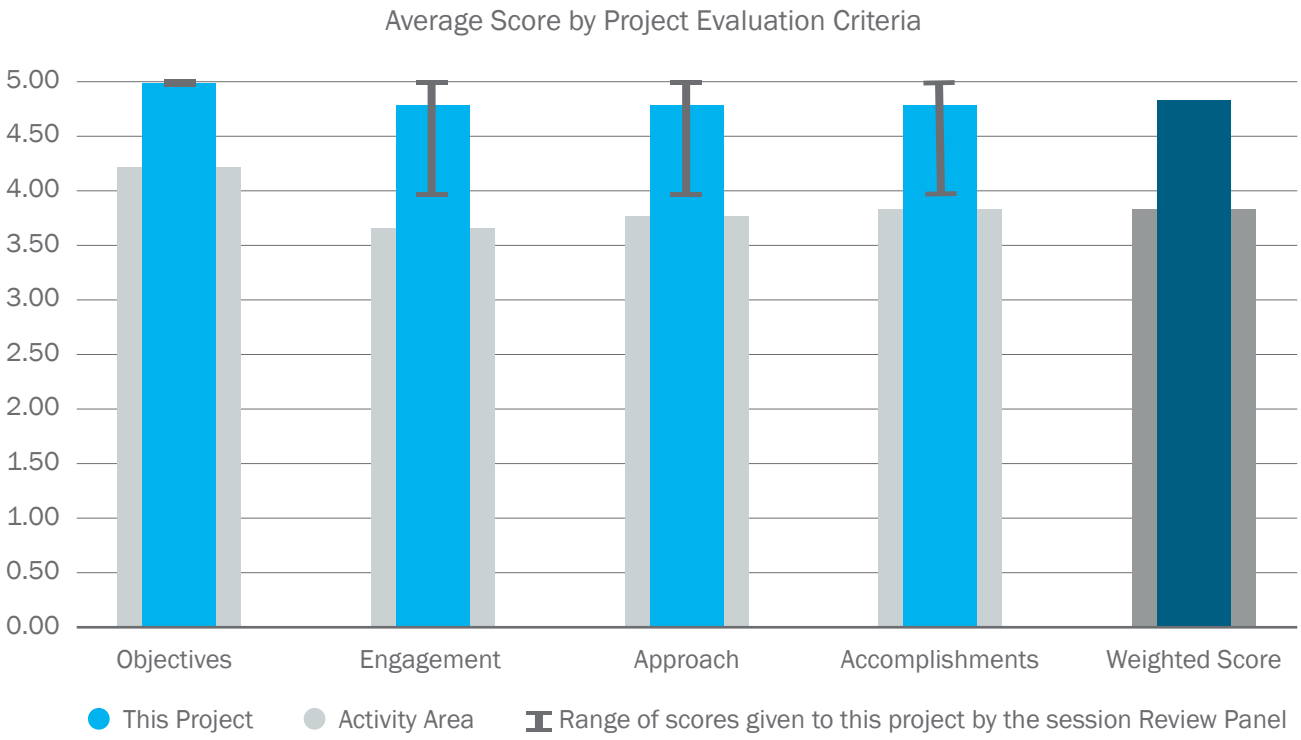
Recipient:	SNL
Principal Investigator:	Ryan Coe
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$3,528K
Total Costed:	$2,983K

Project Description

Numerous studies have shown that advanced control of a wave energy converter (WEC) PTO can provide significant increases (on the order of 200%–300%) in WEC energy absorption. These increases can lead to reductions in the LCOE, both by increasing energy generation and decreasing loading. SNL's Advanced WEC Dynamics and Controls project is focused on transitioning control design approaches from simplified paper studies to application in full-scale devices. By leveraging a wide range of dynamics and controls, robotics, modeling, and testing expertise, this project has delivered on its goal, producing broad dissemination products (webinars, workshops, journal and conference papers, and open-source data sets) and providing a direct benefit to individual WEC developers through industry collaboration projects.

Weighted Project Score: 4.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers were unanimous on this project's value to the program and its alignment with objectives. The performers presented clear, dense descriptions of the main objectives of the project along with their use. One reviewer thought that this project provided the best benefit per dollar of all spends in the MHK program. The presentation provided powerful content, lending a clear view to the importance of applying this tool as early as possible in the design cycle.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were unanimous with regards to the project's clear alignment with program strategy and objectives. The performers presented clear, dense descriptions of the main objectives of the project along with their use. Fundamental lessons learned also described 'prediction less controllers' and 'the most central example of this principle is this project's pursuit of feedback-based controllers. This approach is suboptimal only by perhaps 10% to an approach based on prediction, but unlike a prediction-based controller, is fully realizable today without expensive sensors or cutting-edge research on wave prediction.'

The outputs of this effort provide developers strong tools to support the co-design of PTO control and the physical WEC topology. This ability provides an extremely valuable asset for reducing costs and providing design guidance earlier in the design cycle.

End User Engagement and Dissemination Strategy

The reviewers unanimously agreed the project team had a solid end-user engagement and dissemination strategy, addressing all the objectives for this criterion. Performers believe that their work has no value if it isn't disseminated well, and their approach demonstrates the emphasis they put on dissemination. The summary shows clear evidence of strong end user engagement through industry collaborations. Practices and plans include clear pathways/events defined for dissemination and user feedback, including open-source, online databases and results, journal publications, workshops, webinars, and online support. One reviewer wrote, "Sandia's involvement and not doing it in an intellectual vacuum by bringing in developers is the right kind of symbiosis the MHK industry desperately needs to be successful."

Management and Technical Approach

The management approach of multi-lab partners' endeavors to leverage strengths across different organizations and the output of the project shows that they have succeeded. A Well-organized team that has leveraged the best of America from Navy Carderock maneuvering and seakeeping basin facilities, OSU, and Michigan Tech. Again, one reviewer wanted to see this tool pointed at a thorough failure mode and effects analysis. Reviewers recognized that the presenters focused on LCOE as a strength for the project outputs, helping the industry focus on practical technology advancement. The focus on device-agnostic evaluation was also recognized as a clear strength for this project, providing the MHK industry with some much needed ability to focus on practical comparisons.

Technical Accomplishments and Progress

The performers provided a brief description of accomplishments, along with evidence of outputs sprinkled through the earlier sections of the summary. Further details were clearly given in an impactful presentation, including the following:

- Improved experimental testing and system identification methods
- Fully realizable "prediction less" control capable of rivaling performance of prediction-based controllers
- WEC array and multi-modal device modeling and control
- Open-source datasets (most popular on MHK DR).

WAVE ENERGY CONVERTER (WEC) MODELING

(WBS #: 2.1.3.401)

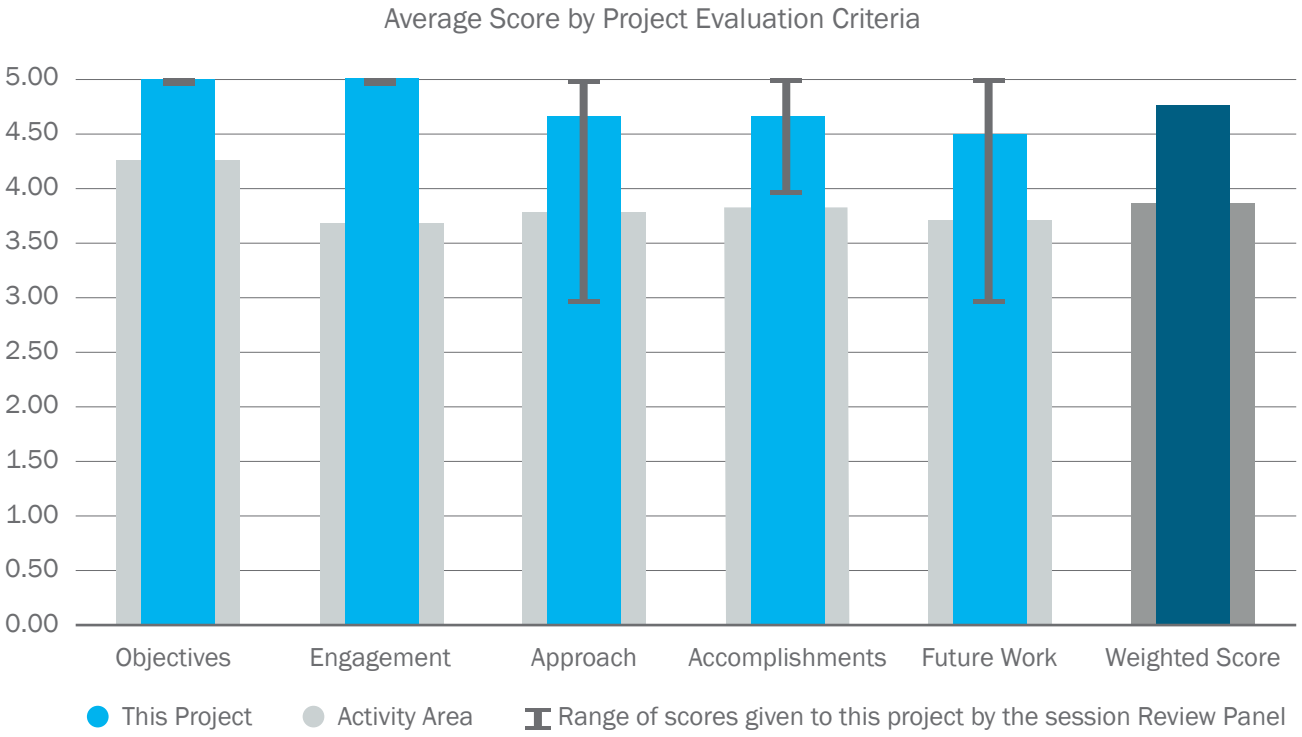
Recipient:	NREL and SNL
Principal Investigator:	Yi-Hsiang Yu
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$3,639K
Total Costed:	$3,295K

Project Description

This project supports the modeling capabilities to improve device performance and reduce costs for the wave energy industry. This includes the development, release, maintenance, and application of a suite of customizable open-source tools for WEC design and analysis and extreme condition modeling, i.e., Wave Energy Converter SIMulator (WEC-Sim) and WEC Design Response Toolbox. The effort also includes the application of these tools, putting the developed tools into practice, through numerical modeling support for the Wave Energy Prize and an industry support task to evaluate the design load and survivability of three industry-developed WECs. The project also supports international collaborations, including the IEA-OES Task 10 code verification and validation, IEC TC 114 standard development, and the WEC control competition.

Weighted Project Score: 4.8

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers were unanimous on this project's value to the program and its alignment with WPTO's stated objectives. One reviewer wrote that the efforts of NREL and SNL and the extended team are critical to the certification and commercialization of WEC devices. This team has made good choices in the software infrastructure and approach, and dissemination and uptake are clear from the GitHub activity. The team appeared to be aware of the challenges faced when modeling these systems, and they are continuing to add features to make their tool more general. The reliance on MATLAB does add a bit of cost to the user, but access to MATLAB is far from an onerous requirement, and the benefits to building on that mature and well-supported environment outweigh these costs. A reviewer mentioned failure modes and effects analysis (FMEA) and trade studies that they hope to see explored within the tool. While all reviewers gave high marks for dissemination, it was mentioned that the team might evaluate putting WEC-Sim on a wider educational platform, like Coursera or Udemy.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were unanimous with regards to the project's clear alignment with program strategy and objectives. Both the summary and presentation gave clear and concise details on the use and application of WEC-Sim, and they laid out the path for users to engage with and utilize the tool. One reviewer wrote that NREL and SNL have done a great job collaborating and lifting the WEC community with their efforts in developing these open-source tools, opening up the possibility for other nascent wave energy technology. Another reviewer noted that tools application to various scales gives it depth of utility for the Powering the Blue Economy (PBE) effort.

End User Engagement and Dissemination Strategy

Again, there was unanimous agreement on the efforts for all three points under this criterion. The project summary clearly addresses all three of the above points. They show clear examples of their success with engaging end users, supporting their training, and providing ongoing support and reacting evolving needs. The project team is working hard to engage their users and the open-source dissemination of their work appears effective, as evidenced by the healthy GitHub activity and the other download metrics presented. They provide clear details regarding the users of WEC-Sim and demonstrate clear goals to continue engaging and growing the user base. The project objectives and impacts section of the summary clearly describes the rationale for the stakeholder/end user engagement strategy and how project results and information have been/are planned to be disseminated.

Management and Technical Approach

The management approach of multi-lab partners' endeavors to leverage strengths across different organizations, along with project outputs, show that they have succeeded. Collaboration with industry partners ensures that relevant outputs reach both the end user and the industry as a whole. One reviewer felt that there could be more detail provided on the expected performance of the tool compared to other industry tools and model scale versus full scale.

The technical approach of developing on a widely used platform such as MATLAB is a clear benefit to many. The inherent lack of propriety and the open-source strategy of code dissemination gives this software a significant advantage over a commercially available solution. Providing validated wave tank models and databases is a gift to the industry and has demonstrated that it has provided benefits.

Technical Accomplishments and Progress

The technical accomplishments and progress are clearly demonstrated in the key milestone descriptions provided. This team has done a good job of balancing capability and complexity, resulting in a usable tool that seems expandable into more challenging areas, such as the inclusion of mooring cable dynamics. The reliance on MATLAB programming language is a slight barrier to acceptance but also comes with the benefits of that mature and well-supported computational environment. As the team mentioned, Python would be the second choice and would be less expensive to operate, but the use of MATLAB shouldn't be too big of a hurdle for most users.

Future Work

Efforts in the development of the tool are winding down, while the efforts to use the tool are ramping up. These efforts are defined under different projects in the review. The future work set out in this summary does show focus in planning for the future use, maintenance, and improvement of the tool. It would be concerning if this focus was not maintained. One reviewer expressed interest in seeing facilities added to easily direct the tool to evaluate performance based on real sea spectra. This utility will be significant for the PBE effort because 2-parameter spectra commonly lose details that are relevant at smaller scale.

DTOCEAN (OPTIMAL DESIGN TOOLS FOR OCEAN ENERGY)

(WBS #: 2.1.3.703)

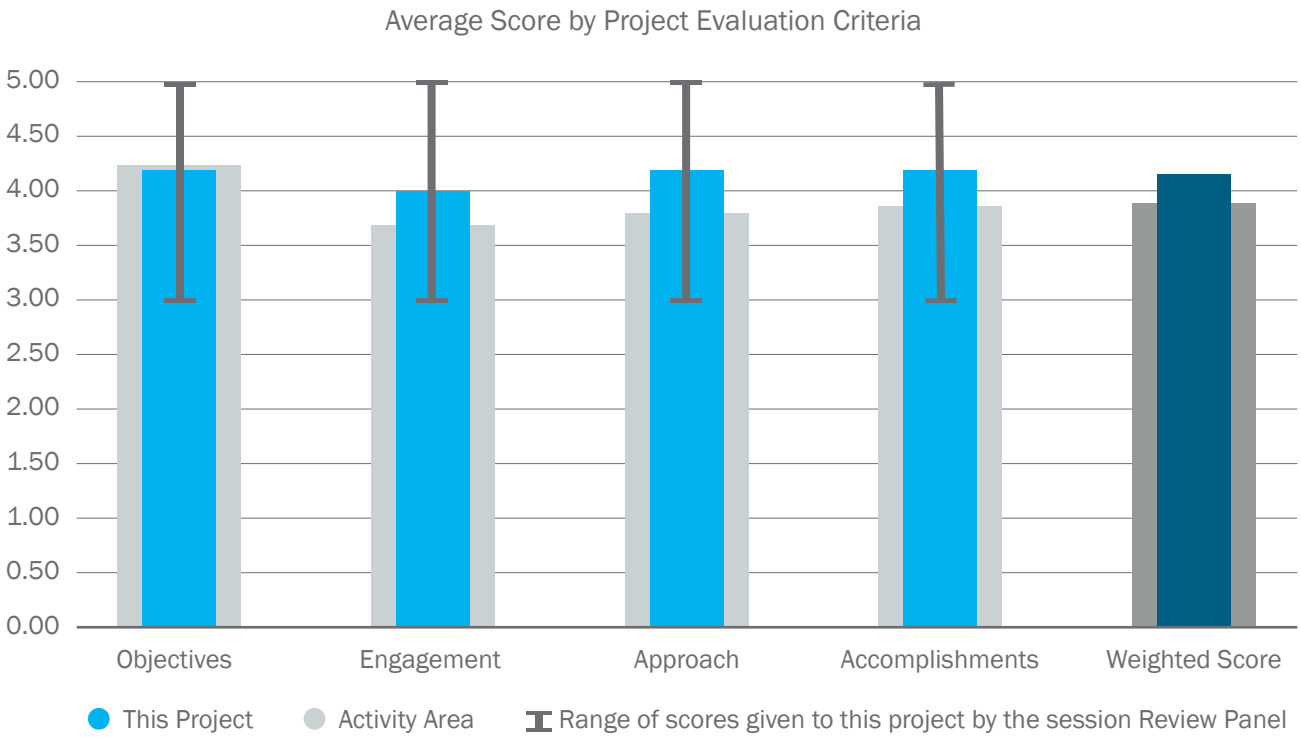
Recipient:	SNL
Principal Investigator:	Jesse Roberts
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$148K
Total Costed:	$122K

Project Description

The DTOcean project pioneered a new, open-source collaborative development model for wave and tidal array design tools that considers the entire ocean energy farm throughout its lifecycle. The software helps to find optimal array designs that minimize the LCOE and identify cost drivers, allowing the industry to progress toward economic viability. DTOcean was an international collaboration between 18 European institutions and SNL. DTOcean was funded under the Seventh Framework Programme (FP7), which bundles all research-related European Union (EU) initiatives together under a common umbrella.

Weighted Project Score: 4.2

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

This project was reviewed favorably by the reviewers. The general consensus was that this project is contributing to and leveraging an international effort, so it is valuable for the resources being committed. Two concerns were voiced: (1) that as a tool for array planning, it is out in front of the development of wave-energy devices; (2) that activity (downloads and contributions) on the GitHub site is relatively low, indicating a lack of engagement. With the project ending and without active maintenance, it seems that use of this tool is unlikely to expand.

Project Objectives, Impacts, and Alignment with the Program Strategy

In this category, the project received high scores from the reviewers, which were supported by comments indicating the reviewers felt this type of whole-plant modeling software has values and could benefit both developers and researchers who would like to study tradeoffs in plant design. For instance, one reviewer stated: "This project is widely applicable to MHK array design for wave and tidal array design in several different environments worldwide and is highly relevant for advancing commercial applications." One lower scoring reviewer commented that this was predicated on concern that this tool is too ambitious in modeling all aspects of a wave-energy system and would have a hard time being useful.

End User Engagement and Dissemination Strategy

Reviewers generally scored this high, commenting that the online presence of the tool was well established, with particular attention being paid to the YouTube tutorials. In general, the reviewers' comments answered the question of whether or not the performers had identified their dissemination strategy, but they stayed away from judging the effectiveness of that strategy, possibly indicating the effectiveness was not that clear. Typical comments were non-committal; for example, "The project performers have identified who will benefit from this project and how the success of the project will advance the industry or meet the needs of specific stakeholder/ end user groups."

Management and Technical Approach

Reviewers noted repeatedly that this is a large international collaboration, which is somewhat dictating the management approach. Most comments were positive, with some dissatisfaction expressed regarding the lack of risk identification and management.

Technical Accomplishments and Progress

More than half of the reviewers made a point to note that the project objectives were met and that the project has made a significant contribution to the code base. The clear list of technical accomplishments in both the written and presented materials was noted. Also evident in the comments was a concern about both the impact of this code, as well as the prospects for maintaining it as the project ends. For instance, "Not clear how DTOCEAN tool will be maintained once DTOCEAN+ suite of tools is delivered? Where will the maintenance and site be held?"

WAVE ENERGY CONVERTER (WEC) DESIGN OPTIMIZATION

(WBS #: 2.1.3.704)

Recipient:	SNL
Principal Investigator:	Ryan Coe
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	$280K
Total Costed:	$64K

Project Description

The DTOcean project pioneered a new, open-source collaborative development model for wave and tidal array design tools that considers the entire ocean energy farm throughout its lifecycle. The software helps to find optimal array designs that minimize the LCOE and identify cost drivers, allowing the industry to progress toward economic viability. DTOcean was an international collaboration between 18 European institutions and SNL. DTOcean was funded under the Seventh Framework Programme (FP7), which bundles all research-related European Union (EU) initiatives together under a common umbrella.

Weighted Project Score: 4.6

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.

Summary of all Reviewers' Comments

Overall Impressions

The reviewers were unanimous on this project's value to the program and its alignment with objectives. The performers presented clear, dense descriptions of the main objectives of the project, along with their use. The presentation showed the importance of considering the complete system when optimizing design and, in particular, the effect that advanced active control has on the LCOE design space for a WEC. One powerful slide showed two surfaces, one showing power absorbed and the other representing LCOE or an analogous metric. The PI went on to state the profound insight that the future needed to embrace exploring the space between such surfaces.

One reviewer expressed concern that developers might be technically challenged to exploit the tool. This suggests that continued support from labs in using the tools should be maintained. Another suggested expanding the budget to include potential other partners who can help support development. The reviewers recommended that the project team engage with the international community for development/engagement/implementation of the optimization tool.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were unanimous with regards to the project's very strong alignment with strategy and objectives. The project performers demonstrated clear and deep consideration of the use and application of the project's output. They provided a high-level roadmap of how successful implementation of the outputs can impact LCOE. The presenters were able to update the presentation with a late breaking slide showing two surfaces, one showing power absorbed and the other representing LCOE or an analogous metric. The striking feature of the graphic was that the peak in power production did not align with the LCOE peak. A tool that allows for the relatively quick exploration of such spaces is very impactful.

End User Engagement and Dissemination Strategy

The point of the project is to disseminate as widely as possible. Reviewers rated this effort pretty highly, but there is some concern that developers may be challenged technically to take full advantage of the toolset. Performers believe that their work has no value if it isn't disseminated well, and their approach demonstrates the emphasis they put on dissemination. The summary shows clear evidence of strong end user engagement through industry collaborations. Practices and plans include clear pathways/events defined for dissemination and user feedback, including open source, online databases and results, journal publications, workshops, webinars, and online support. A few reviewers recommended the project team solidify engagement with more developers to establish the tool's base for industry use, and the project summary the SNL team provided did show that the next phase of the project has that effort as a major focus.

Management and Technical Approach

The collaborative management approach focusing the efforts of OSU and SNL is appropriate for this project. Reviewers recognized that the project team's focus on LCOE was a strength for the project outputs, helping the industry focus on practical technology advancement.

The project leverages the co-design framework to help support the industry as it wrestles with the extremely complex task in optimizing for the marine environment. One reviewer noted the impact of the following statement, 'Users will be able to iterate WEC geometry and controls systems computationally, using efficient pseudo-spectral modeling, to improve design concepts as they are still being ideated.' A clear timeline shows project milestones.

Technical Accomplishments and Progress

The progress discussed shows the team to be on time with expectations at this point.

Details of the present state of development are clear. The performers provided a brief description of accomplishment, along with evidence of outputs sprinkled through the earlier sections of the summary.

Future Work

The future work section is a little thin, but discussion in the earlier sections clearly describes the intention behind the highlights shown. Some added details on conference presentations, webinars, and the industry partner collaboration would have been helpful.

HYDROAIR POWER TAKE OFF SYSTEM

(WBS #: EE0006609)

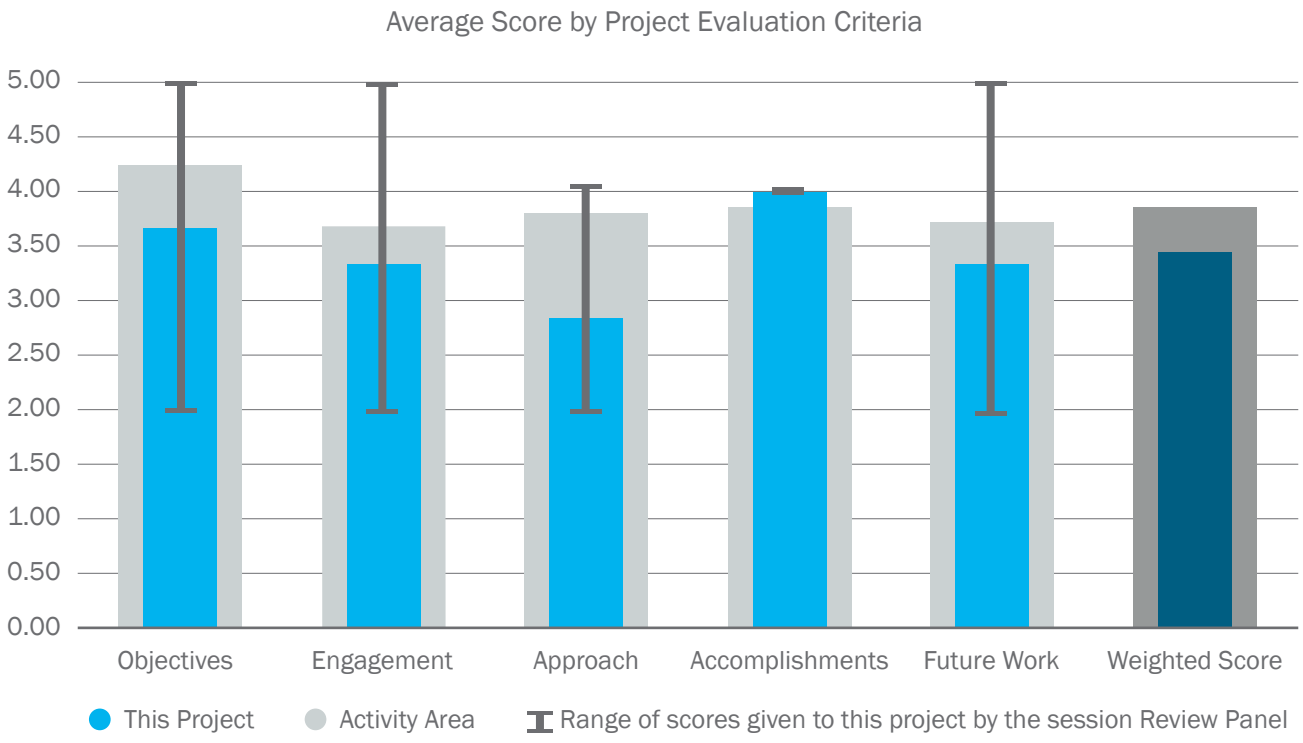
Recipient:	Siemens Government Technologies
Principal Investigator:	Rod Blunk
Project Type:	FOA 848: Marine and Hydrokinetic System Performance Advancement
Project Category:	Ongoing Projects
Total Authorized:	$6,807K
Total Costed:	$5,521K

Project Description

The project's objective is to design, construct, and test a full-scale, 500-kW HydroAir turbine and Power Take Off (PTO). Optimally, the project team planned to design the HydroAir turbine PTO to utilize the volumetric airflow and pressure transmitted from an Oscillating Water Column on the Ocean Energy (OE) buoy with planned deployment at the Navy's grid-connected WETS in late FY 2019. The project hopes to provide industry understanding on innovation in the turbine design to improve reliability, availability, and efficiency by using composite materials for maritime application. Additionally, the project team planned to leverage commercially available components such as off the shelf generators and variable frequency drives and other components where possible to enable transition from prototype to production capability for commercial applications.

Weighted Project Score: 3.4

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

This project produced an impressive piece of hardware that is just now entering operational use, so the results should be available soon and enable a fuller review. It is not entirely clear whether the design of this turbine and the design of the buoy, which will be installed together, were carefully coordinated. The presentation indicated that there are some design and control unknowns that will be adjusted or at least studied during the upcoming deployment. The summary and presentation did not address the workings of this device or why it is expected to be superior to devices fielded in the past.

Project Objectives, Impacts, and Alignment with the Program Strategy

This project aligns with programmatic goals. However, it is not clear how applicable this PTO is to various WECs or what the scalability of this PTO is for different applications. This is foundational R&D, but it is not crosscutting. The plan for design and validation is sound and aligns well with the program's strategic initiatives.

End User Engagement and Dissemination Strategy

The project performer did not do a sufficient job describing beneficiaries of this technology by providing specific examples. The ocean power industry they quoted is very general and does not show end user engagement. Additionally, it was not clear as to how a number of different technologies currently being developed will benefit from this PTO. Potential clients are identified, but no specific examples of collaborations with such clients were provided.

Management and Technical Approach

The performers sufficiently described their subcontractor relationships and have a technically sound approach to get this PTO tested at WETS. The project schedule was presented, and most milestones have been met. However, potential challenges during deployment and testing have not been clearly communicated.

Technical Accomplishments and Progress

All reviewers agreed that this team did succeed in designing and building the device. That major accomplishment should not be underestimated. However, it was not fully clear how this design improves existing turbines in this space.

Future Work

The project plans only describe steps for testing at WETS, but they did not cover length of time or decommissioning discussions after testing. Therefore, it is not fully clear how the post-test lessons learned will be handled/processed.

OPTIMAL WEC CONTROLS USING CAUSAL AND MPC METHODS

(WBS #: EE0007173)

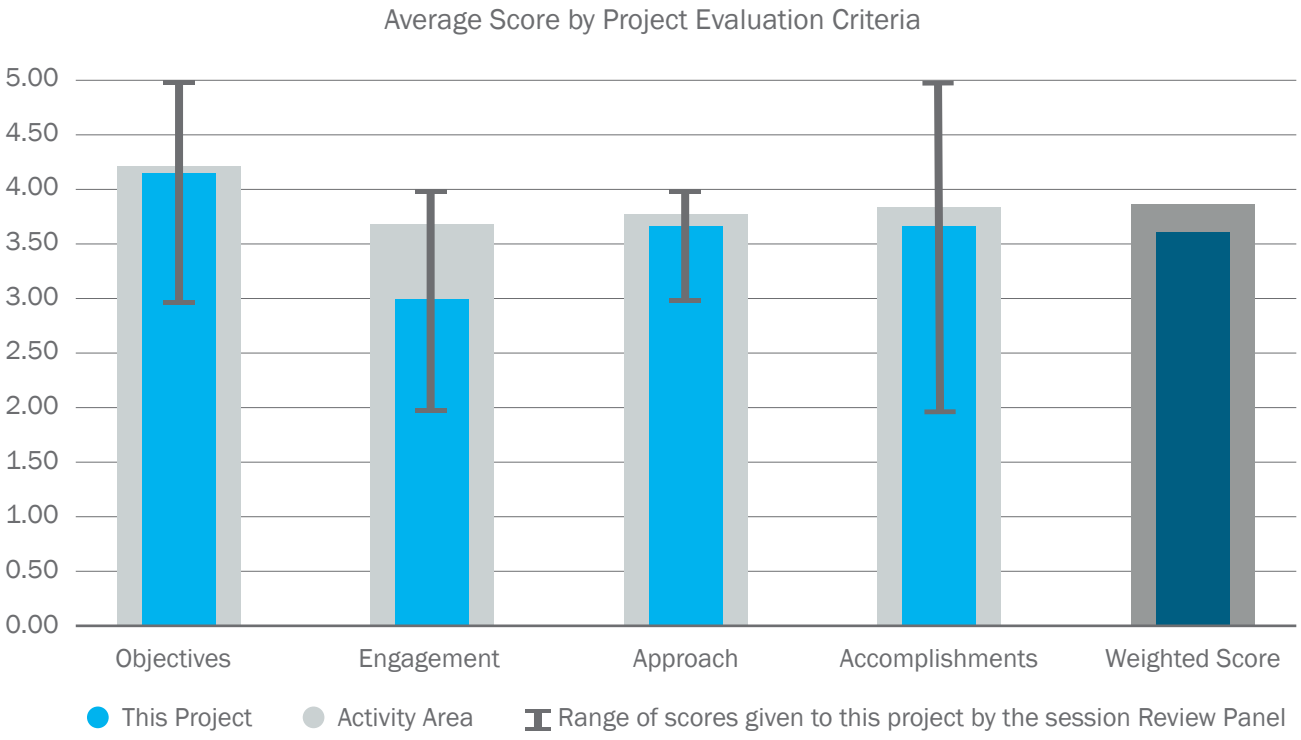
Recipient:	Re Vision Consulting
Principal Investigator:	Mirko Previsic
Project Type:	FOA 1182: Marine and Hy-drokinetic Systems Perfor-mance Advancement II (SPA II): Component Metric Validation
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$3,124K
Total Costed:	$2,927K

Project Description

The overarching project objective is to fully develop and validate an optimal controls framework that can subsequently be applied widely to different WEC devices and concepts. Optimal controls of WEC devices represent a fundamental building block for WEC designers that must be considered as an integral part of every stage of device development. Using a building-blocks approach to optimal controls development, this effort will result in the full development of a feed-forward and feed-back control approach and a wave prediction system. Phase I focused on numerical offline optimization and validation using wave tank testing of three industry partners' WEC devices, including CalWave, Ocean Energy, and Resolute Marine Energy. These industry partnerships allowed the project team to identify optimal control strategies for these different WEC topologies at different maturity levels. Phase II focuses on demonstrating an integrated control system on an at-sea prototype that is to be custom-built and maturing the hardware and software required to successfully run our advanced controls code frameworks on at-sea systems. A secondary focus during phase II is to adapt our systems identification, controls, and wave-prediction frameworks to become more robust and comprehensive in respect to RT capability, robustness, and reliability.

Weighted Project Score: 3.6

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

A project in an important/enabling topic for WECs. It is not fully clear how transferable this project's approach will be to the wider sector and other WECs. Reviewers suggested that the DOE ensures the work is accessible to the whole sector to avoid any duplication of effort.

Project Objectives, Impacts, and Alignment with the Program Strategy

The project performers have presented the relevance of this project and how the successful completion of the project will advance the state of technology and the viability of any commercial WEC applications. Optimal controls leveraging MPC and causal (feedback) control strategies have the potential to significantly improve the economic viability in most WEC devices under development. This is a clear fit with the program to ensure the optimal performance of WECs.

End User Engagement and Dissemination Strategy

Three WEC topologies were identified, but there were no testimonials on how well the MPC control framework worked to enhance WEC performance. There was also no further mention of the project team engaging with other WEC developers. Key comments do indicate that 'significant challenges and advances need to be made before commercial uptake.' It appears that engagement is rather limited; the other key message is that Re Vision would seek cost recovery on the cost share before they are willing to make the MPC controls work open source. The performers do a good job engaging with several different WEC developers early, but do not present future dissemination strategies for engaging a wider WEC community that might benefit from the use of this tool.

Management and Technical Approach

A project management plan and schedule were described with milestones. Cost over runs were identified. The team also provided a clear discussion on the challenges and next steps to achieve success.

Technical Accomplishments and Progress

The project performers have made significant progress toward getting their MPC implemented in at-sea testing with device developers. The 8-kW device at-sea testing has been completed successfully. The progress is clearly presented in the table of schedules and milestones. Tank testing has been completed.

REDUCTION OF SYSTEM COST CHARACTERISTICS THROUGH INNOVATIVE SOLUTIONS TO INSTALLATION, OPERATIONS AND MAINTENANCE

(WBS #: EE0007347)

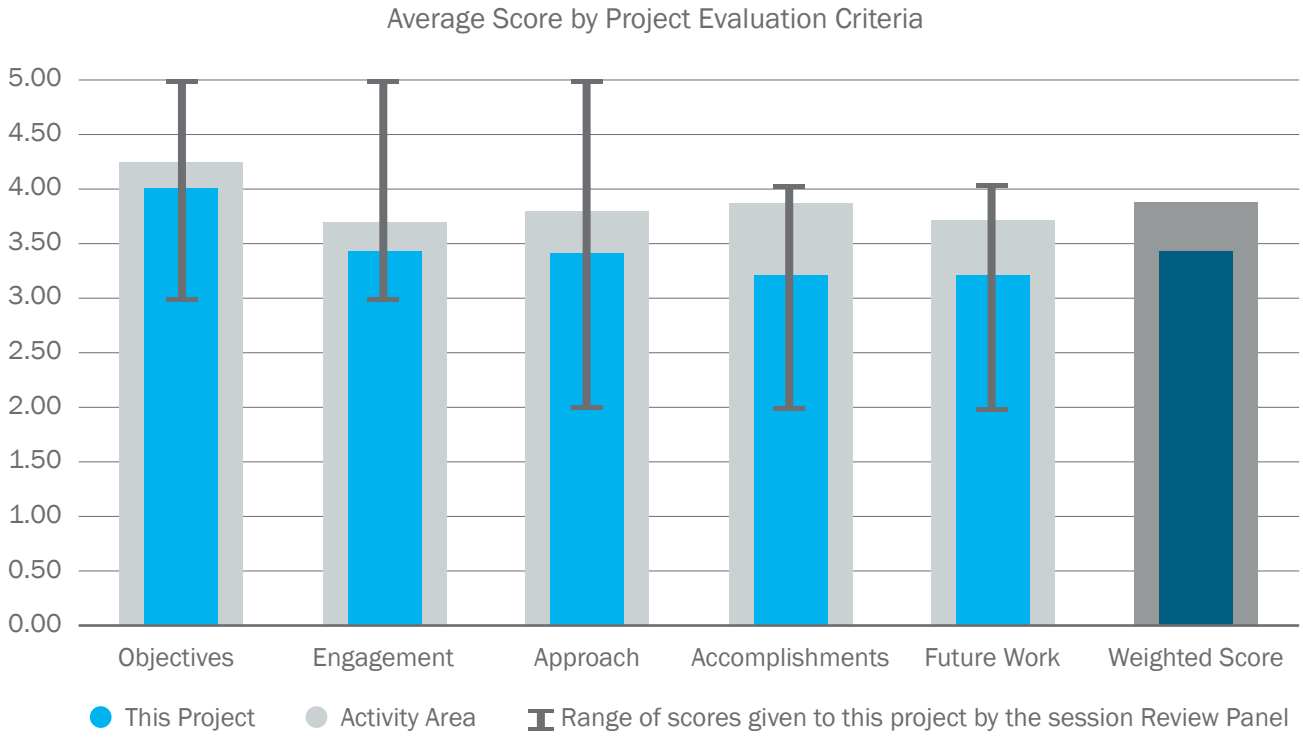
Recipient:	Columbia Power Technologies, Inc.
Principal Investigator:	Michael Ondusko
Project Type:	FOA 1310: Next-Generation Marine Energy Systems—Durability and Survivability
Project Category:	Ongoing Projects
Total Authorized:	$13,488K
Total Costed:	$1,658K

Project Description

C·Power is developing a WEC—StingRAY H2—that converts ocean waves into megawatt-scale electric power. The project goal is to demonstrate the techno-economic viability of the StingRAY H2 WEC by: (1) establishing IO&M costs based on operational and research data; (2) implementing and testing innovative IO&M-centric design improvements; (3) demonstrating the StingRAY H2 WEC in 12-month grid-connected, open-ocean test; and (4) identifying specific cost reduction pathways for future implementation.

Weighted Project Score: 3.4

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The general impression of this project is that they are progressing toward fielding their system but that the efforts really are about fielding the equipment rather than the stated goal in the project title of "Reduction of System

Cost Characteristics through Innovative Solutions to Installation, Operations, and Maintenance." This impression is not that surprising as the planned deployment is not a repeat of previously deployed equipment with changes to address cost, as other development projects in this area have done.

Project Objectives, Impacts, and Alignment with the Program Strategy

This criterion received the highest scores for this project. The reviewers generally agreed that this project is well aligned with WPTO's R&D toward utility-scale development. Despite the high scores, multiple reviewers hinted at concerns about this project. For example, one reviewer thought some of the improvements, such as the ballasting system and umbilical location, were not really innovative but more like corrections to recognized flaws. Another review noted that the PI described risk mitigation strategies that were not honestly or sufficiently addressed, and potential corrosion to components was identified as the only insufficiently mitigated high risk. One reviewer recommended that, while this project fits well with the WPTO program strategy, it should undergo a full review to show there is confidence from DOE that there is a clear trajectory to an attractive LCOE for both utility and niche markets.

End User Engagement and Dissemination Strategy

Reviewers voiced concerns that the project team rationalized the lack of end user engagement by the fact that this project is focused on a specific device development and therefore concentrated on making the device work correctly. Some reviewers noted the project strategy follows industry norms for market exploration and engagement and that it was not fully clear that the project team engaged effectively with potential end users in both utility and niche markets.

However, some reviewers did note that the objectives and impacts of this project as scoped with WPTO would support the office's technology-specific validation objectives. The items the PI list as foundational are valid and useful, though still quite specific to this design. Many of the "nine innovative technical and design opportunities" appear to be reasonable refinements of the H1 design. These refinements are the type of improvements that ultimately make any new engineering design successful and are an important part of this sort of development.

Management and Technical Approach

This section received an average score of 3.4 with a broad range of scores from 2 to 5. The comments and conclusions in this section were hard to summarize due to their breadth. Concerns and strengths of both the management and technical approaches were expressed by the reviewers.

Technical Accomplishments and Progress

Reviewers had diverse opinions regarding the project's technical accomplishments and progress. On the positive side, reviewers recognized that this project is headed for deployment in Hawaii in the near future. A widely expressed concern is that while the PI presented a detailed table of cost reductions, the basis for these encouraging numbers is unclear, as they were compared against a device that was never built or tested. Specifically, one reviewer noted that although there is a very detailed table of the cost reductions and performance improvements, it was not clear how they have been achieved, what the benchmarks were, and whether the cost reductions and performance improvements have been validated.

Future Work

Reviewers offered a range of scares and opinions on the scope of future work. They recognized that the upcoming testing at WETS is the future task that has significant importance. One reviewer indicated concern for this project and the prospects of the upcoming deployment based on performance in earlier phases of the project. Reviewers were generally unsure whether the upcoming deployment will advance the state of the art.

DEMONSTRATION OF AN ADVANCED MULTI-MODE POINT ABSORBER FOR WAVE ENERGY CONVERSION

(WBS #: EE0007819)

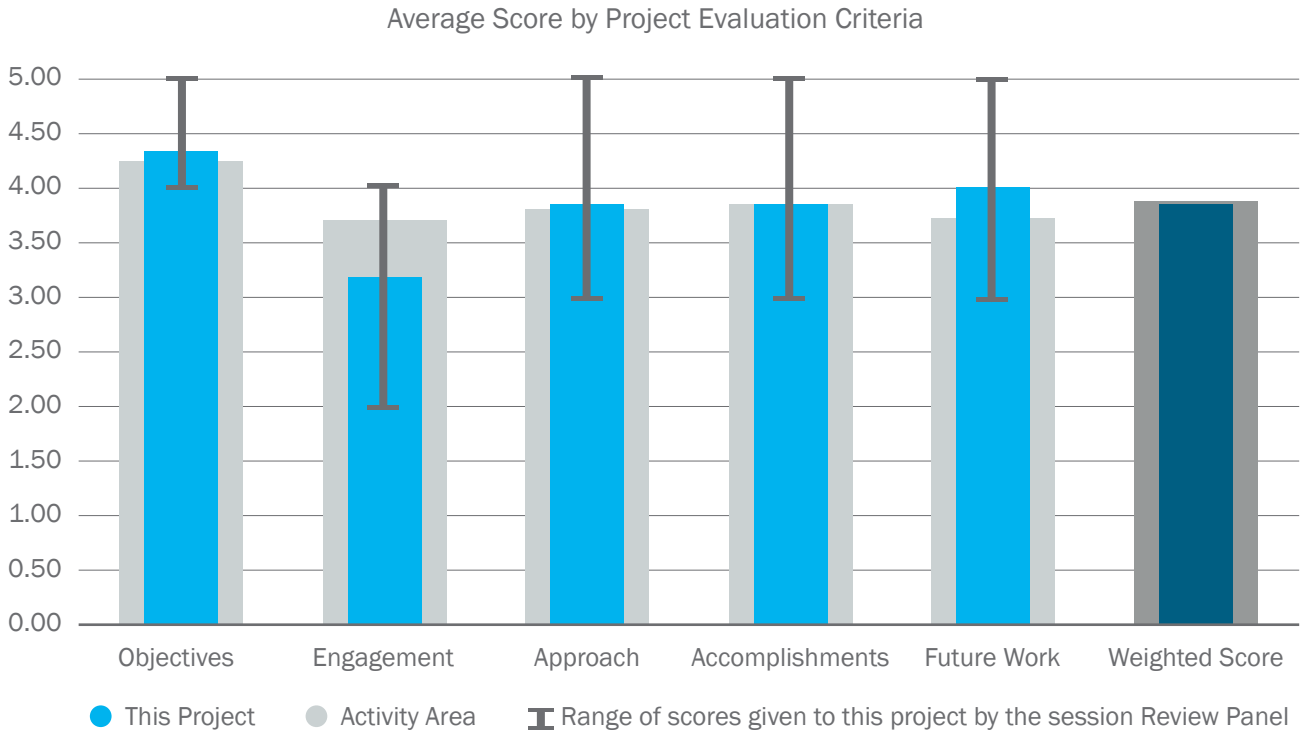
Recipient:	Oscilla Power
Principal Investigator:	Tim Mundon
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Ad-vancement
Project Category:	Ongoing Projects
Total Authorized:	$9,990K
Total Costed:	$2,382K

Project Description

The purpose of this project is to design, construct, deploy, and prove performance of the Triton C community-scale wave energy system. The Triton C is a 100-kW rated power system based on Oscilla Power Inc.'s (OPI's)Triton two-body, multi-mode architecture. At its basic level, the Triton architecture comprises a ring-shaped reaction structure that hangs below a surface float via three tendons. Wave action on the float generates relative motion between these two bodies, which can then be converted to electrical power by the drivetrains. The Triton C is intended to provide power to remote and isolated communities that currently have exceptionally high energy costs and uncertain energy security. The intent is that the Triton C will be able to provide these communities with resilient, independent, and self-sufficient energy. The Triton C has been developed specifically for this application through a long travel rotary drivetrain, allowing a smaller system to operate in fully energetic waves, as well as an improved self-deploying installation approach that allows the system to be deployed quickly and simply with low-cost vessels.

Weighted Project Score: 3.8

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

Scaling down the OPI WEC from a utility scale to supply power to niche markets, and be deployable from smaller, low-cost vessels should be a key consideration of this project because it will increase its utility to the greater community. It would be valuable to provide more detail about scaling down considerations already given to the Triton C. Reviewers wondered if there is an estimate for a timeline required to do so, or funding level required to successfully provide a small scale version, also questioning what scales are tenable. During the review, the reviewer received more information from OPI pertinent to the downscaling opportunities for this device. OPI has clearly considered applying this knowledge to several different markets at different scales. There was good detail provided in presentation on manufacturing and design layout to help reviewers understand the project.

Concerns:

- Reviewers are interested in what the LCOE is for the device for remote communities; for example, is it low enough to displace incumbent technology (diesel/electric)?
- Has a drive sub-system test been carried out to characterize the drivetrain efficiency over the wave spectra in the chosen site?
- Reviewers felt they needed more details on the drivetrain topology. Most developers to date are caught in a trade space of PTOs relative to techno economics, survivability, and efficiency, as well as O&M. This critical stage gate impacts schedule and future funding unless the developer can show a path to high technology readiness level (TRL), as well as high TPL.
- There was a design review by DNV-GL. Is the deliverable a certification of the prototype or conformity statement?
- The budget is in its third year, and having spent $2,382K of $9,990K implies the project is under spent but behind schedule. What needs to be done, and what are the risks?
- The performers mention that they have found their numerical models to be relatively accurate for predicting performance. They join a number of other developers in gaining this important insight. How do they plan to use this ability?
- I would think that the performers evaluated the option of doing the tendon replacement test in harbor for safety sake. Can they share the result of that evaluation?
- The performer does not mention any effort to use historical sea state conditions from the target site to perform simulations prior to deployment.

Recommendations:

- Recommendation to include discussion on cost-share achievements that won't risk the project deployment/installation at WETS.
- Recommendation to complete a detailed techno-economic assessment completed on the project to determine if OPI has a credible pathway to competitive LCOE.
- Recommendation to perform a full-scale experimental tow test that does not focus only on tension loading during the tow but incorporates the actual hydrodynamics of the towed body. Making progress at 3 knots in the ocean may mean not making progress at all. Towing 3 knots through an inlet may have the same results. Some testing is recommended in speeds in excess of 5 knots.

Project Objectives, Impacts, and Alignment with the Program Strategy

This project has contributed to the development of an innovative long travel rotary drivetrain that allows Triton C, and potentially other smaller WEC technologies, to be suitable in fully energetic ocean environments, and it aligns with PBE goals. The Triton C is intended to provide power to remote and isolated communities that currently have exceptionally high energy costs and uncertain energy security. This program has a specific target of powering isolated communities. The intent is that the Triton C will be able to provide these communities with resilient, independent, and self-sufficient energy. The mission statement clearly identified providing power to isolated coastal communities. Discussions around the techno economics of incumbent technology such as diesel generators and cost-benefit of trident system are not discussed/disclosed. Reviewers would have liked to see a cost waterfall with non-recurring engineering vs. Component cost reduction to see where investment in components and sub systems could drive the bill of material cost down or O&M. Reviewers also wanted to know what the baseline COE is and how it compares to diesel. Additionally, reviewers wanted to know what other ancillary markets the Trident could serve in the blue economy. Reviewers noted that project alignment to PBE strategy needs more treatment, as does the impact this topology has in moving the state of the art forward.

The project demonstrated further alignment with data sharing and analysis and provided clear discussion of the project objectives and impacts that address an increase in annual electricity production (AEP) and decreases in OPEX/CAPEX. This project makes contributions in both the "Foundational R&D" area and the "Technology-specific" areas. Fundamentally, DOE funding is allowing this company to field and test their specific design, but that design includes the interested long-travel tendon arrangement that could find application in smaller WEC devices as noted. This technology is almost certainly challenging to perfect. At a high level, there is a clear fit with the program. Although the installation approach appears cost effective, this device's impact toward the significant cost reduction and performance improvement that is required in the ocean energy sector overall is not clear.

Design and validation through in-water testing are well aligned with program strategies. The performers mention that they have found their numerical models to be relatively accurate for predicting performance. They join a growing group of developers in this class. The reviewers find that OPI references vague improvements to efficiency, without details on baseline and objectives. OPI mentions the broad application of aspects of the R&D effort, which clearly aligns with program objectives.

The intent of this WEC to provide power to remote and isolated communities is clearly stated. Technology innovation is explained by the contribution of the long travel rotary drivetrain. Cost-enhancing deployment advances are described through mating the hull and reaction ring for transport and deployment of the drivetrains to deploy the ring at operation depth on sight. The validation of linear numerical models to sufficiently predict power, motion, and loads even when nonlinearities begin to manifest themselves in larger wave environments makes a meaningful impact to the rest of the community. The PI provided evidence that technology progress had been made with the long travel rotary drivetrain, and he identified the research and characterization of the tendons as a potential point of failure/risk. Eventual deployment of the Triton C at WETS and data collection will inform and validate performance and reliability.

End User Engagement and Dissemination Strategy

The OPI WEC is intended to provide power to remote and isolated communities where the cost of energy is exceptionally high. OPI has considered and described the use/applications of their expected products and outputs. The longer-term objective is that the Triton C will be able to (ultimately, in subsequent commercial versions) produce power at competitive rates. When installed in these communities, the Triton C will provide

resilient, independent, and self-sufficient energy. The Triton could be a valuable tool as an engineering test bed. Reviewers would like to know what the process of identifying promising cost improvements and testing them on this platform in situ to improve efficiency is for AEP as well as O&M. They also asked about ancillary markets (such as desalination).

Further, OPI's partners, some with little experience in the WEC area, are gaining important experience and exposure to wave energy, which will benefit the industry as a whole. At a specific innovation level, technology elements being developed as part of the Triton C may have application in other WEC components. These include elements such as the drivetrain, tendons, installation strategy, etc.

Reviewers would like to know what kind of market research and customer uptake have been done to date. Where would the first deployment likely be, and how does the cost-benefit compare to incumbent technology (diesel generator). This section was less expanded upon in terms of end user engagement. It is therefore recommended that a strategy is put in place for how they will engage with potential remote small-scale communities and where. Some reviewers felt OPI does have clear impact in terms of dissemination strategies, including discussion of their intellectual property.

As a commercial technology development and test project, the end users aren't immediately identifiable, and there isn't a big motivation for technology dissemination beyond high-level descriptions. There appears to be an adequate dissemination and engagement process in place. The summary clearly lays out the target for this project as reduced-scale remote customers. The strategy follows industry norms for market exploration and engagement.

Dissemination is in line with the usual efforts to disseminate information.

OPI mentioned a presentation at the ICOE conference and possible journal publication. Much more could be done to engage potential stakeholders. The mention of a down-scaled version of the device could be significant to niche market users like national security, ocean observing, and aquaculture farmers. A rather vague statement was made about how the industry as a whole will benefit from these substantial innovations without providing sufficient examples for how this will be done. Reviewers suggested that OPI develop an engagement plan with specific examples and targets.

Management and Technical Approach

The project performers have implemented technically sound R&D approaches and have demonstrated/validated the results needed to meet their targets. It is known that advances in (active) controls can significantly improve the power output of WECs; however, there is limited to no data about how these strategies perform in a real-world environment. The Triton C drivetrain has been designed to allow different advanced control algorithms to be tested to advance the state of the art and maximize the performance of the system. Having the ability to test the impact of different control strategies and tune the device is valuable. Reviewers would like to know how much has been done with SNL and Re Vision to test the efficacy of those control strategies.

The project performers have identified a project management plan that includes well-defined milestones and adequate methods for addressing potential risks. Another area of investigation is the reliability of the tendons. While OPI has put considerable effort into designing maximum longevity into the tendon, the type of loading and bending that the tendon experiences is unlike any other application, and data does not exist that will allow accurate predictions of lifetime. OPI has used conservative best practices and laboratory testing to develop estimates, but these will be validated through operational data.

Reviewers would like to know what kind of lab testing has been completed to date. How does one test corner points and characterize the duty cycle for low cycle fatigue and high cycle fatigue of the tendons?

The project performers clearly described critical success factors, which will define technical viability, and they explained and understand the challenges they must overcome to achieve success.

Reviewers felt the management approach has solid project team partners that have vast experience in renewable energy. Reviewers would caution that this is predominately wind turbine and not marine based, with the exception of Glosten. Reviewers would have liked to see more treatment with an FMEA and key metric milestones relative to baseline metrics. One reviewer asked what the commercial goal posts for this device were.

Reviewers felt that more detail on the management approach is warranted. OPI discussed how they control their plan, and it is clear in the technical approach how they systematically address each objective and resulting milestone. Additionally, in the future work, they outline the remaining tasks and milestones.

One reviewer remarked that OPI has an excellent technical approach narrative and that it gives confidence in the projected impact of the project. The management approach of this team appears to be appropriate to a project of this size/scale, and they have incorporated appropriate outside expertise.

The primary risk in this design appears to be the tendon design; OPI indicated that they have done extensive testing of this component, and this is a critical detail to get correct. The report includes high-level logistical steps associated with getting the Triton C deployed and recovered from WETS. OPI demonstrated experience with instrumentation and communication of monitoring and control. Objectives of testing included active control; however, there should be a carefully planned campaign that moves from theory to simulation and tank testing to make ocean testing safe and effective.

The project management and technical approach was well presented by the project developers, with specifics of numerical modeling for ocean conditions presented. Reviewers felt that there was a lack of testing in actual ocean conditions—even for the small-scale Triton C prototypes presented. Reviewers stressed that nothing is as good as actual deployment experience and testing in an ocean environment. Reviewers expressed interest in whether there were best practices or lessons learned from previous testing experience to inform transport, deployment, maintenance, and removal strategies. Post deployment strategies for component fatigue and structural assessment have been well considered.

Technical Accomplishments and Progress

The project performers have made progress in reaching their objectives based on their project management plan. However, utilizing $2,382K of $9,990K implies the project is under spent but behind schedule. Reviewers are concerned whether a drivetrain sub-system test had been carried out to characterize the drivetrain efficiency over the wave spectra in the chosen site. Most developers that the reviewers have seen are caught in a trade space of PTOs relative to techno economics, survivability, efficiency, and O&M. This critical stage gate impacts schedule and future funding unless the developer can show a path to high TRL, as well as TPL. Reviewers felt that the project team provided good details on the drivetrain and system top-level topology lacking from other developers. One reviewer questioned their consideration of a gearbox/generator versus a fixed displacement pump where one can dissipate energy via a keel cooler versus a brake. Another asked about the design trades that led to this topology and its relative advantage from an O&M and controls standpoint.

OPI has described its most important accomplishments in achieving milestones, reaching technical targets, and overcoming technical barriers. Using Triton C test data obtained from physical model testing, this project has

demonstrated that time-domain models based on linearized potential flow hydrodynamics can produce fairly accurate predictions of power, motions, and loads (to within approximately 10%), even in large wave conditions where nonlinearities begin to occur. This provides important validation to the numerical modeling approach used and provides increased confidence in the loads used to design the Triton C system.

Through this project, a full-scale prototype (100 kW, 10m x 7m) Triton C WEC has been designed and is currently under construction, with deployment expected in 2020.

Reviewers have found that in some areas, the suggested safety factors are conservative (this implies increased cost of electricity), while they are perhaps marginal in others. Reviewers would be interested in what subsystem sequential de-risking can be done prior to integration and deployment.

Composite hull construction would be less than 50% of the cost of a steel unit and around 70% of the mass. Buoyancy is always a challenge in a fixed displacement system. Composite should be considered in case the system comes in overweight

Reviewers found there to be a strong narrative on the progress of the project milestones achieved and impact of the results, with a clear description of the progress since the last review period. Reviewers noted that the developer provided detailed design completion results. The consideration of composite construction to reduce cost was well considered, but the project team could have provided more details on the specific composites they're considering. Corrosion and biofouling considerations were notably absent from the technical discussion. Tendon testing for fatigue provided valuable information. One reviewer estimated that with a 10-s wave, the tendons would see approximately 3+million cycles over a year. The 4 million cycles tested seemed sufficient, especially with sporadic monitoring during the deployment period.

Future Work

The project performers have outlined adequate plans for future work, including key milestones and go/no-go decision points. The project team should demonstrate that the first commercial units of the Triton C can achieve a system CAPEX of <$1M/Unit with an AEP of >127MWh/yr. Whitehill performed extensive testing to evaluate the fatigue lifetime of the tendons, demonstrating >4M cycles duty cycle. Reviewers have concerns that a bend restrictor or J tube has not been discussed for the power export; they also expressed fatigue concerns around this.

Reviewers wondered how the remainder of cost-share will be met outside of the $1 million matching grant from the State of Washington Department of Commerce through the Clean Energy Fund, further questioning if this would throttle WETS deployment or construction.

Reviewers felt there was a clear outline/summary of the plans for future work and milestones, but they were not able to locate go/no-go decision points in their schedule. Reviewers also expressed concern on the amount of funding OPI has to get the WEC in the water, noting that a cost share of $4.6 million is not insignificant.

The future work is the deployment and test of the device. This appears to be dependent on a BP2/BP3 go/no-go decision. There is not sufficient detail in this summary to advise that decision, and go/no-go decision points are not clearly identified. Some field exercises that consider transport to WETS, deployment, maintenance, and removal should be incorporated into future work. Planned system wear tests after the device returns to Seattle will provide valuable assessment tools.

ADVANCED TIDGEN POWER SYSTEM

(WBS #: EE0007820)

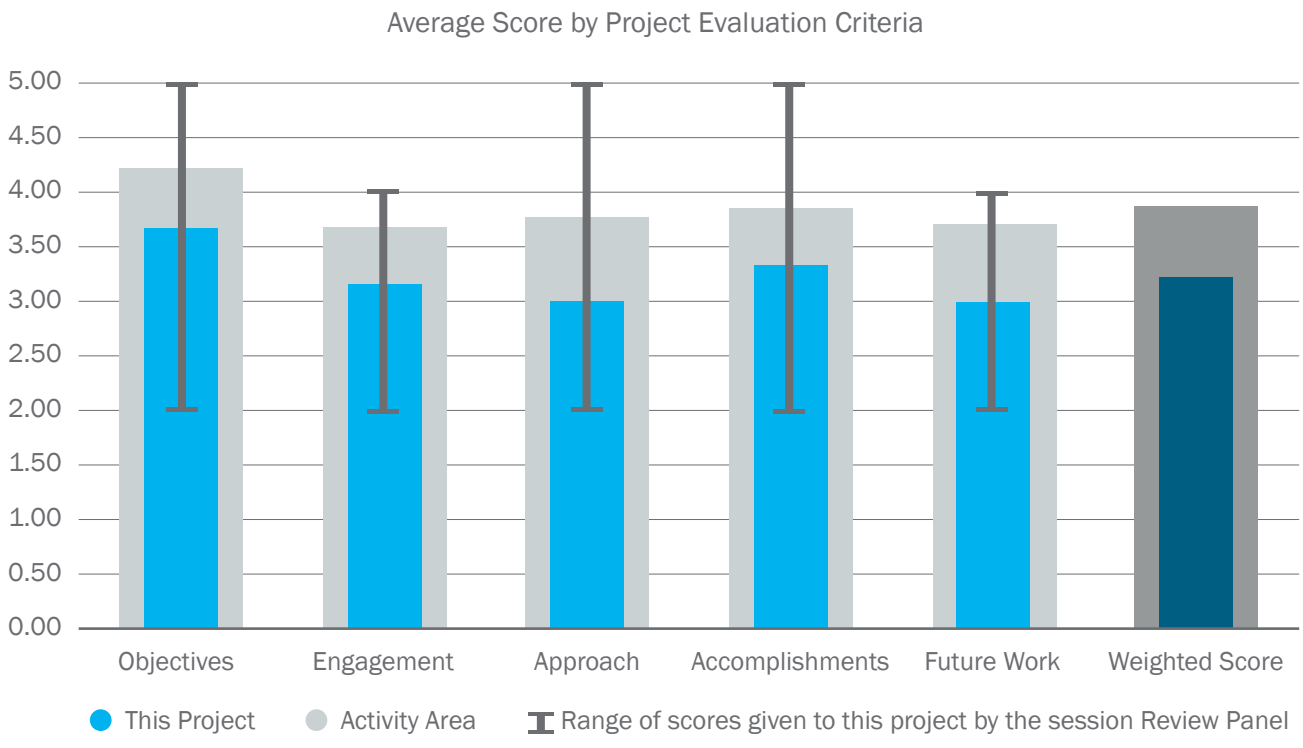
Recipient:	ORPC Maine
Principal Investigator:	Jarlath McEntee
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conver-sion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$11,602K
Total Costed:	$2,248K

Project Description

ORPC Maine, a wholly owned subsidiary of Ocean Renewable Power Company, Inc. (ORPC), will design and demonstrate a commercially viable tidal power system, integrating technologies through a program focused on cost of energy, risk reduction, and component life. ORPC will design; construct, test, and verify subsystems; perform system integration; verify system performance; and validate system reliability and availability by a continuous 12-month deployment in Western Passage, Maine. The integrated design will demonstrate significantly decreased LCOE by improving turbine performance and reliability and by decreasing IO&M costs.

Weighted Project Score: 3.2

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The proposers learned during execution that there are issues with the gravity base anchors' size, cost, and handling. They also identified an issue with deployment detachability. From a certain perspective, this does align with program goals if the industry learns from it. Reviewers would like the project team to share clear and concise details regarding these issues.

The reviewers found it hard to see this project overcoming the anchoring problem, which raises the question of how this approach that involves so much vertical lift in the anchoring came about. The project presentation acknowledges this problem and the project team is advertising a delay of 2 years to address this. Reviewers noted that with the project entering a go/no-go decision at the end of Budget Period 2, WPTO needs to carefully consider the prospects for this project. Reviewers thought the design approach pursued appeared poorly developed (as the reliance on unrealistically large anchors indicates). Additionally, it seems there are tidal energy plans being deployed in Europe that are at a significantly advanced state of maturity. This raises the question of why WPTO would spend a lot of money to invent a competing technology before that technology is proven or disproven as effective.

Concerns:

- What are the range of efficiencies expected for this device in low and high current environments? Expected increases in efficiency of 30% are described, but what are the expected ranges for the device?
- More specific details on composites being utilized through the partnership with USACE's Construction Engineering Research Laboratory might benefit other developers through describing lessons learned.
- Are there site-specific anchoring considerations that could be made? For example, if there are boulders at the deployment locations, could existing boulders be ensnared by some sort of netting, and then lines tensioned from the net to the device to secure the device in place? That seems like a cheaper, less comprehensive strategy when compared to screw anchors, and the heavy equipment needed for drilling into stone.
- What is the plan of attack for the anchor selection and deployment window? Is there enough budget to cover this?
- Demonstration of risk (FMECA) analysis should be incorporated and reviewed with WPTO not annually but quarterly if not after design studies have been completed.

Reviewers recommended ORPC undertake a detailed techno-economic assessment to determine if they can achieve a credible pathway to LCOE. DOE should review grid-scale market for TECs in the United States; will it be large enough, and will the current designs be credible with a competitive LCOE?

Project Objectives, Impacts, and Alignment with the Program Strategy

ORPC, will design and demonstrate a commercially viable tidal power system, integrating technologies through a program focused on cost of energy, risk reduction, and component life. ORPC will design; construct, test, and verify subsystems; perform system integration; verify system performance; and validate system reliability and availability by a continuous 12-month deployment in Western Passage, Maine. ORPC plans to significantly decrease LCOE by improving turbine performance and reliability, as well as by decreasing IO&M costs.

Reviewers noted that the project team had clear objectives but needed to mention threshold requirements for reliability, maintainability, and availability, O&M, AEP, and COE. The project team needs to quantify what the expected decrease will be and what the expected baseline performance is for theoretical versus experimental. Reviewers would like to see a comparison of key performance indicators versus milestones to show progress toward achieving 15 cents/kwh.

Strengths

- Strong narrative on alignment with MHK program. Key outcomes and social acceptance from past projects in Igiugig Village are still relevant.
- This is a high-impact project for the program, as it intends to bring a tidal generator close to being a viable, tested, commercially available device to use in different settings.
- This will validate device performance in low and high velocity current environments, thus determining an LCOE that includes deployment, short-term maintenance, and recovery of the system.
- A 12-month test will both prove the viability of this technology and demonstrate areas for improvement. The practical path for achieving 15 cents/kWh is impressive. Several advances in the PTO, control, and mooring are described.

Weaknesses

- Community engagement is discussed, but not specific regarding use cases synergy with adjacent industries (aqua culture) or displacement of incumbent technology (diesel electric).
- Advancements on the state of the art are mentioned relative to advanced controls and generator. Meaningful impacts are not provided in terms of LCOE or % improvement.
- Commercial applications outside of prime power grid applications are not mentioned.
- More treatment on impact and glidepath to LCOE and latest lessons on cost-efficient anchoring systems (i.e., SEPLA?) need to be considered. What is the trade space on this?
- This project obviously addresses the desire for free-standing tidal generation, but it's hard to see that this development is going to compete with the existing technology in Europe that is at a much more advanced state of maturity.
- On a high level, this project clearly fits with the program strategy. What is not clear and is a question for DOE is how important the tidal sector is to their overall MHK strategy.

End User Engagement and Dissemination Strategy

Reviewers felt they needed more information on community benefit. The 15 cents/kwh roadmap is instructive, but the reviewers would like to see a cost waterfall that gives separate cost buckets for discrete improvements in LCOE relative to NRE, BOM cost, and O&M benefits that do not rely on economies of scale. An FMEA should also be included in these reviews. Stakeholder requirements are not mentioned nor are requirements for commercial uptake. Reviewers questioned what traction ORPC has had on a power purchase agreement. There are multiple references to Eastport Community, West passage site, and stakeholders, but reviewers would like more emphasis on peer reviewed papers for journal publication. This is critical to demonstrate the successful innovations discussed that will be implemented in the next device. The project seems to have engaged users through the permitting process, but it's hard to see how this project will be cost effective before the anchoring problem (and perhaps other issues) is addressed. Although it was clear what ORPC's engagement with regulators has been, it was not displayed how they have engaged with their stakeholders to assess the need for this

technology with end users/customers. The performers have demonstrated successful stakeholder engagement with the public and with regulators at the test sites, which has resulted in permission to test. This is a substantial accomplishment. Engagement with city managers, fisherman, and aquaculture facilities is mentioned. DOE engagement through reporting of results is also planned. Participation in industry conferences is mentioned, and specific examples would be useful.

Management and Technical Approach

The results of this project to date have demonstrated a successful management and technical approach to commercialization. Several specific examples of ongoing collaborations that serve the project were presented, and detailed milestones were given.

The challenges with anchoring systems were described, and solutions being considered were addressed. One reviewer thought earlier discussions with the supply chain back in 2017/2018 would have revealed the costly challenges. It appears this design change could also impact the structural loads on the turbines as they are placed in more appropriate flow conditions. Demonstration of a robust risk management system should be described on mitigating the moorings/gravity base anchors and or rock anchors. Rock anchors will require further geotechnical surveys, which are expensive.

Installation of the system is expected to be delayed by at least one year while ORPC resolves the anchoring issue. Over a year delay has been incurred by construction costs, and reviewers suggested engaging with outside consults steeped in mooring design and at sea deployment (e.g., PCCI, InterMoor, etc.). This poses significant risk to the working capital position of the company with engineering rework for deployment that perhaps came too late in the design spiral. O&M and deployment will drive a lot of the design decisions depending on the scale of the array as they are major cost drivers in the COE model. One reviewer asked about the current plan of attack for the anchors to not stall the program.

The fact that the design progressed so far without a viable anchoring strategy is a worrisome reflection upon the management approach. Technically, the presentation and summary don't explain what the benefits of this approach are and why it's worth it to design a system with such major installation costs.

Some additional reviewer comments included the following:

- It is not clear what the overall benefit of the particular technology is compared to more conventional tidal turbines.
- It's not clear how the risk involved with the gravity base anchors was missed.
- This is not a new technology.

Technical Accomplishments and Progress

ORPC has a structured program along the lines of a DOD design practice. As a critical design review has already been concluded, one can surmise the deployment and anchoring is still an outstanding issue and is pacing the program, causing a year or more delay.

Turbine Design

While there was good detail in how the program is structured with milestones and details on the design, the reviewers would like to see more in the way of subsystem testing and FMEA tracking. They did not get a sense that there is a solid basis for load case development. Tidal turbines historically have high turbulence intensity, with ~25% variable load, impacting endurance of the turbine. This impact should be captured on a Goodman

diagram using saturated test coupons. The reviewers recognize ORPC went through the effort of saturating the coupons as fatigue lives tend to drop 50% in sea water relative to air. A Campbell diagram should be considered to determine if there are any resonant frequencies getting excited by generator, blade passing frequency, or upstream flow perturbance to make sure there is no high cycle fatigue excitation through the added mass to drop frequencies, which is usually critically damped.

The turbine manufacturer performed a joint test. The test specimen was completed, and the project team will perform testing and complete a test report that outlines the methodology and results. These results will be used to validate Finite Element Analysis to ensure the overall turbine design will meet design requirements. Reviewers are wondering how the load cases have been captured: Was there an active flow measurement plan to capture flow gradient and turbulence intensity? What designs are allowed, and how will the test coupons loop back into the life calculations of the turbine and impact the design? What is the cavitation margin relative to superposition of sea states, depth, and turbulence intensity?

Reviewers also believe that the project team should introduce flow measurements to capture gradient (ADCPs) and turbulence intensity (ADVs) to capture seasonal variability and load cases for design.

Anchoring and Deployment

Reviewers questioned what the project's major cost drivers that impacted cost efficacy of the design were, also wondering if the project team contemplated a solution path in the cost waterfall and FMEA. Additionally, the reviewers wanted to know what contractor designed the anchor, and they wanted details about their experience (is it mostly with Oil & Gas or naval installations?). Mooring is a critical design element that is crosscutting and impacts all developers in the MHK space. The project team should consider specialty ships of opportunity for MHK deployment, just as testing berths are required as this impacts design. The reviewers scored the outcomes as marginal due to the delay in mooring/foundation design. One reviewer thought the technical accomplishments were hard to score well when ORPC is facing a two-year delay to address the anchoring system. While the project team learned during execution that there are issues with the size, cost, and handling of the gravity base anchor, the reviewers agreed this work does align with program objectives.

Takeaways

While the reviewers recognize there are some good technical achievements, what is not clear is how credible the plan is to achieve the target LCOE of $0.15 will be achieved.

Clear and concise details regarding the issues encountered should be shared. This project has made significant progress and has identified the anchoring system as the main challenge to attaining the LCOE project goal. The project is clearly described in detail, with specific milestones provided.

Future Work

This anchor trade study is still a high-risk factor both from a working capital and technical risk perspective, as it flows back into the design spiral, which impacts the TRL and TPL significantly. This portion of the program needs to be carefully monitored, with ORPC engaging with consultants steeped in deployment, as it is the most cost-intensive part of the program, and other developers have lost their business through a failed deployment or an infant mortality failure (or rather, an early failure resulting in poor performance). The project's highest priorities should be closing out the mooring anchor risk, as well as load cases for turbine design based on measurements that need treatment.

Future work has been described, but the plans are not fully detailed from a risk management perspective. Reviewers recommended that the project performers complete a techno-economic assessment on current design, including the new GBAs to determine if there is a credible path to competitive LCOE. While the future work is obviously aimed at addressing the anchoring issues, at the level of detail presented, it's hard to see why this design has advantages over simpler-to-install devices, some of which appear to be in significantly advanced stages of development in Europe.

The summary identifies the challenge of anchoring the system as a key hurdle, but there is no discussion of what is at risk if a cost-effective solution is not found. Questions from reviewers include the following: How will this project deal with upcoming anchoring decisions? Are there go/no-go decisions to be made here, or does this challenge just change the LCOE?

WAVE PREDICTION LEVERAGING MULTIPLE MEASUREMENT SOURCES – A SENSOR FUSION APPROACH

(WBS #: EE0008099)

Recipient:	Re Vision Consulting
Principal Investigator:	Mirko Previsic
Project Type:	FOA 1663: Marine and Hydrokinetic Technology Development and Advance-ment
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$1,192K
Total Costed:	$625K

Project Description

The purpose of the present effort is to combine wave radar and buoy measurement sources to leverage their unique advantages. Wave radar provides a broad spatial representation of the free surface with limited accuracy, while measurement buoys provide highly accurate measurements at a single point in space. Using sensor-fusion algorithms, the advantages of both measurement sources can be maximized. The core objectives are to: (1) improve the prediction accuracy, and (2) move the TRL from 4 to 6, leading to a technology building block that can be readily employed by WEC system developers in pilot WEC deployments.

Weighted Project Score: 3.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.

Summary of all Reviewers' Comments

Overall Impressions

There was very little overall consensus on several areas of this project among reviewers. Some thought this was a terrific project and thought the at-sea effort was quite valuable. Others found that the technology was not novel, and they felt like several of the statements the project team made were either vague, not supported with examples/details, or a stretch.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were not in consensus on this project, providing scores that ranged from 2 to 5.

Some of the positive comments from reviewers are as follows:

- "No one has been able to implement MPC on a WEC device at sea, due to the fact that phase-resolved wave-prediction is not a capability that has been sufficiently developed to date."
- "This is important work that has an opportunity to benefit all scales of wave energy converters. Excellent fit with the program to ensure performance improvement and the survival of wave energy devices."

There were two reviewers that did not agree that this project was impactful. One reviewer noted that some of the advances in commercial applications presented appear to be a bit of a stretch, including "reducing motion sickness at sea, extending operational windows in marine construction" with a 30-second forecast capability. The project has discussed the potential for the project to advance MPC and noted application with three WEC developers; however, none provided or demonstrated impact on their design, and on the contrary MPC was not applicable or viable for commercial success. The investment in X-band radar development does not seem novel, several developers have made wave measurements with X-band radar in the past. Why develop this technology when off-the-shelf technology like wave rider buoys can provide a more robust at-sea, 30-second forecast with a radio link?

End User Engagement and Dissemination Strategy

Reviewers found little consensus with rankings that ranged from 2–5.

Favorable comments about engagement strategies and collaborations included:

- Good engagement with the Navy to leverage expertise, accelerate scheduling, and reduce cost.
- The performer references strong end user engagement and efforts to maintain their relationships. Engagement with the Navy on the existing data sets is a plus.
- Engagement with WEC developers has provided lessons learned into the development of MPC. However, no demonstration of the use of the X-Band Radar approach was undertaken.
- Good listing of publications, but it is disappointing that the white paper for DOE has not been published yet.
- The dissemination of their work seems weak, and the summary and presentation do not present enough information to evaluate their progress.
- A solid peer-reviewed publication showing the techniques and results is important for this work to have a broad effect on the field.

Management and Technical Approach

The reviewers provided slightly more positive reviews for the management and technical approach of this project, yet there still wasn't full consensus.

For example, some positive review statements provided included the following:

- "An excellent, logical and well-planned technical approach"
- "Leveraging existing data sets is a sound R&D approach. Validating and improving numerical models on such data is of course the thing to do, but they are doing it."

Additional reviewer comments included the following:

- For foundational R&D, one would think the university lab model provides the incentive to publish their work, which may be a better approach.
- Including marine x-band radar for wave prediction has many challenges, and previous projects undertaking marine radar also proved limited industry uptake. There are more demonstrated technical achievements utilizing wave buoys.
- While the report demonstrated that performers have successfully met development goals, there aren't many specifics provided about the technical approach. For example, no details were provided about the buoy types, communication methods, or proximity to the experiment site. I'm guessing these are Waverider buoys that are part of the the Coastal Data Information Program network with Hydropower Foundation telemetry, but was not communicated.
- Several times, co-located measurement devices were mentioned without any detail provided.
- Mention is made of benchmarking the prediction accuracy, but none is quantified in the report. Specifically, what improvements were made in establishing X-band radar accuracy in providing 30-second predictive capabilities to wave phase?

Technical Accomplishments and Progress

There was more consensus in terms of technical accomplishments, with less favorable reviews provided for the developer in technical accomplishments and progress. Most of the critical comments were related to improvement claims made by the developers, without sufficient detail provided. There were few examples of metrics that quantitatively demonstrated improvement.

Specific comments include:

- "It is not possible to evaluate the technical accomplishments and progress from the information presented in the summary and presentation. The companies need to keep their methods proprietary is understandable but some performance graphs that clearly show the success of the method would seem to be possible without compromising the company."
- There is no discussion of how much of a gain in net improvement is made. Based on the milestones table the project appears to have accomplished the goals stated in the project management plan. However, the project summary did not provide specific metrics for improvement on the X-band wave prediction method. I will seek them in the list of publications, but it would be nice to have summarized them in the report. The progress isn't clearly stated, nor is it quantified. What are the improvements in predictive accuracy made by using the proximal buoys? In the illustration on the left, what is the curve? What are the units?"
- "The technical accomplishments and progress lack specific details and are not quantified. It appears there was testing done, but to what end? What improvements were made to the system?"

One reviewer provided a favorable review of this project's technical accomplishments, saying the Re Vision team had made excellent technical progress, but that it was not clear how this will be made available to developers. This reviewer urged DOE to ensure this is open source.

A HERMETICALLY SEALED MAGNETICALLY GEARED MARINE HYDROKINETIC GENERATOR

(WBS #: EE0008100)

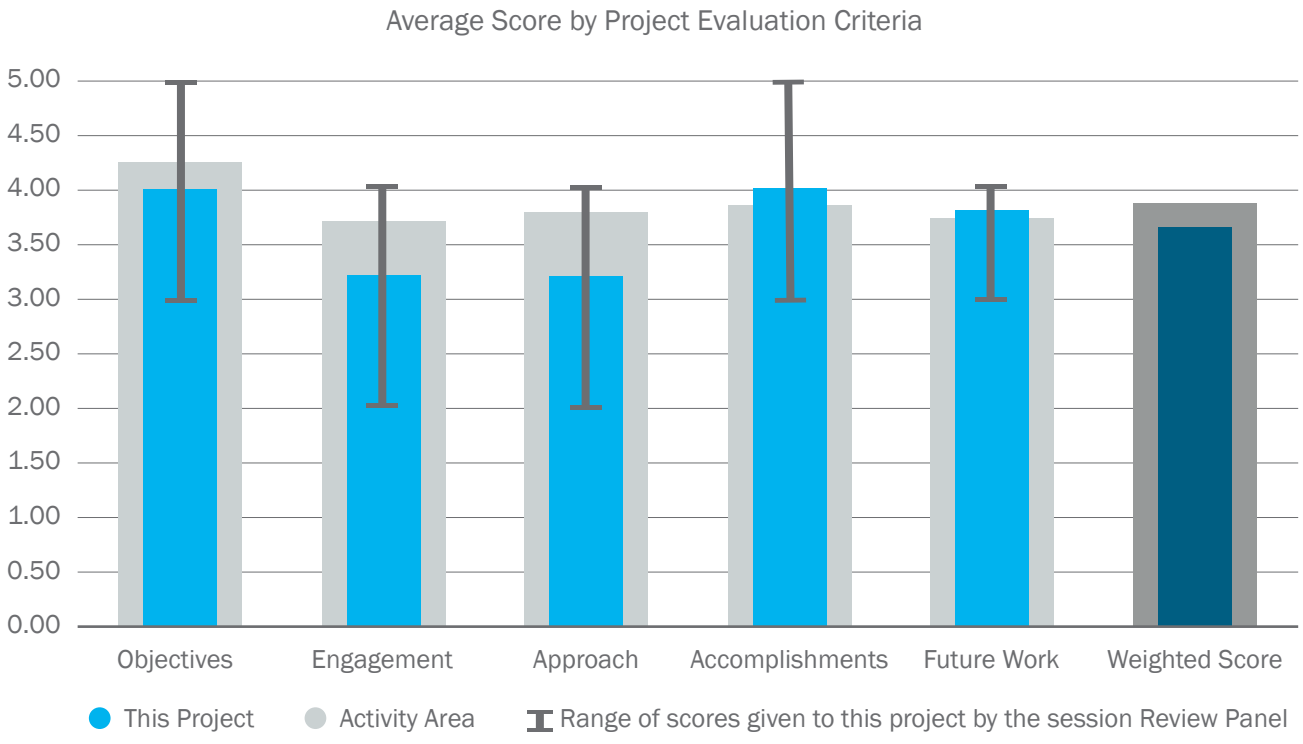
Recipient:	Portland State
University	Mirko Previsic
Principal Investigator:	Jonathan Bird
Project Type:	FOA 1663: Marine and Hydrokinetic Technology Development and Advancement
Project Category:	Ongoing Projects
Total Authorized:	$889K
Total Costed:	$490K

Project Description

The primary objective of this project is to design, fabricate, and test a hermetically sealed 50-kW multistage magnetically geared generator (MGG). To reduce risk, a sub-scale 5-kW multistage MGG was first built. At the end of this project, the team will have (1) experimentally demonstrated a 59:1 gear ratio multistage MGG with a torque density that has at least 3X higher torque density than prior-art baseline published designs, and (2) utilized water tank testing to demonstrate that the efficiency of the hermetically sealed multistage MGG is competitive with existing technology.

Weighted Project Score: 3.6

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

Most reviewers scored the project favorably, with the exception of one who assigned noticeably lower scores. There was general agreement that this is a foundational technology that has the potential to be applicable to high-torque/low-speed issue of wave-energy conversion. This point of view is supported by comments such as *"Important and impactful project that is crosscutting for MHK developers whether tidal or wave energy. Unique attributes can also provide needed opportunities to implement controls."* and *"This is an interesting project that if successful has the ability to address a critical challenge with wave-energy devices."* The project appeared to the reviewers to be well-managed and moving along according to schedule. The upcoming 50-kW device build and test was recognized as a key event. Negative commentary centered on the lack of a direct connection between this project and the impacts of OPEX and the lack of explanation of why a one-year, no-cost extension is required.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers generally agreed the project aligned well with the program strategy as a foundational research project that has the potential to provide a needed reliable and high-density gearing capability useful for MHK energy conversion. Several comments supported this point of view, and most reviewers commented specifically that this project is a good fit for the program. The use/application of this technology development is envisioned, but immature at this point, as the work is a proof-of-concept project. One reviewer found insufficient relevancy was presented as characterized by the following comment. *"Limited discussion on the use/application of their expected products and results."*

End User Engagement and Dissemination Strategy

The reviewers' scores were moderate in this category, with one reviewer scoring significantly lower, which was explained by a concern that the performers could have done a better job relating their work to expected reductions OPEX compared to existing technologies. Regarding end users, one reviewer commented that no key stakeholders were mentioned. On the other hand, several reviewers commented that the existence of a start-up company alongside this project provided a vehicle for commercialization should this technology development be successful. There was some concern in the reviewers' comments that it's not entirely clear how engaged these researchers are in the MHK sector, as there are other applications for this technology outside of the MHK application space that are perhaps being pursued in parallel. To this end, one reviewer recommended that a technology roadmap should be developed for a magnetic generator, so MHK developers can consider this topology in their product roadmap.

Management and Technical Approach

There was general agreement that the performers have implemented a technically sound R&D project. There was some dissatisfaction with the issues of milestones and risk mitigation, and one reviewer stated the team could have provided a more detailed execution plan, including a FMEA risk mitigation plan and sequential de-risking plan of attack. One reviewer scored lower than others due a concern over the reason for the requested one-year extension. In that comment the reviewer limited the criticism to the "management approach" but thought the technical approach was better.

Technical Accomplishments and Progress

This criterion was scored highest by the reviewers. There was broad agreement that the technical work and development of the 5-kW system was well done and has generated information that has been incorporated into the 50-kW design. Reviewers thought the team was making positive technical accomplishments and progress with a rigorous testing plan in place. The reviewers would have preferred the final device benchmarked against mechanical work, as this should be compared to mechanical alternatives.

Future Work

In general, the reviewers find the future work compelling and adequately described. There was broad agreement that the results of the 50-kW device will be instrumental in evaluating the potential of this work. These results naturally will feed into future go/no-go decision points. Concerns were expressed about remaining issues related to the packaging of magnets, hermetically sealing the device, and the impacts on heat dissipation.

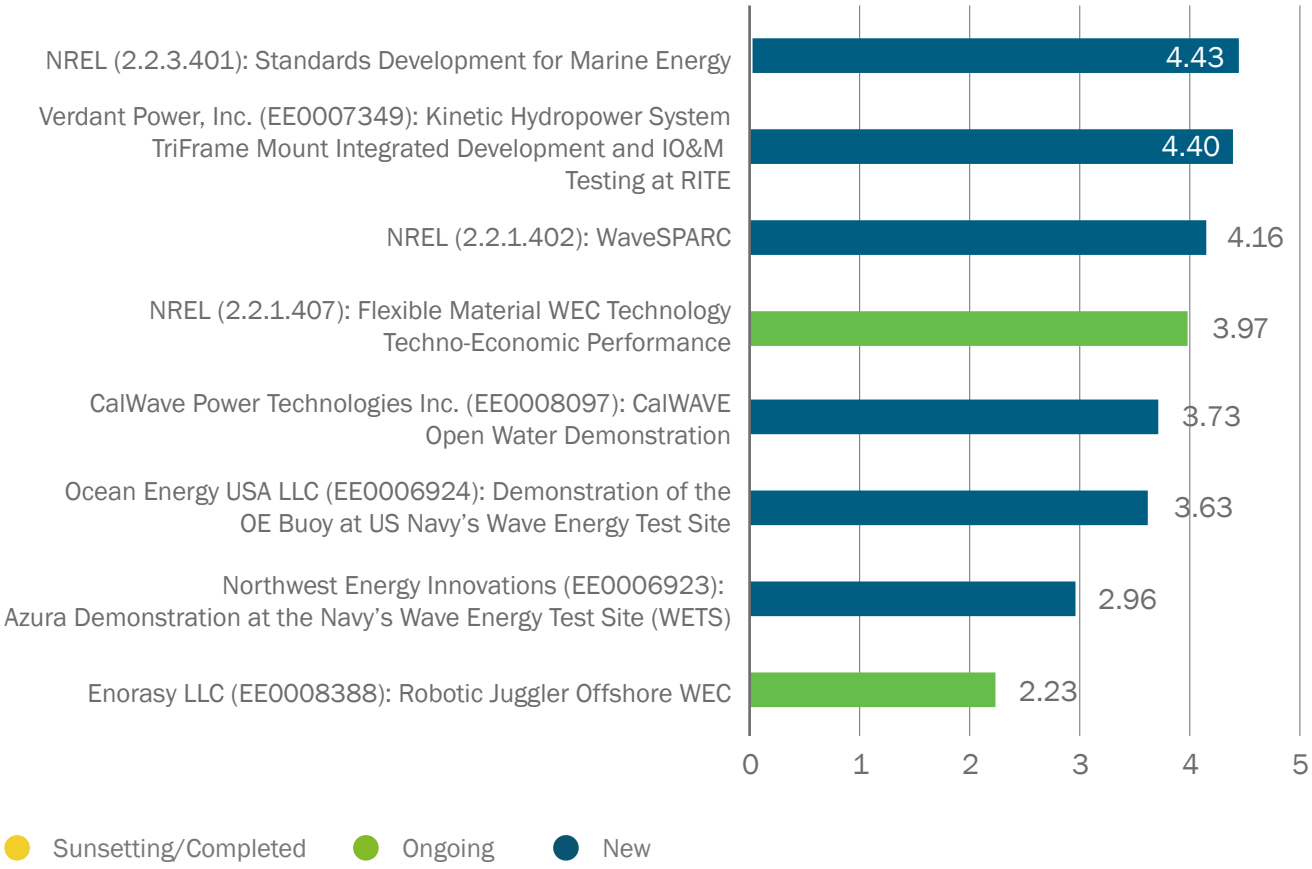
Technology-Specific Design and Validation

This section provides an overview of the scoring for all projects within the Technology-Specific Design and Validation activity area (see Figure 24); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

Activity Area Score Results

Name	Average Weighted Score of All Projects
Technology-Specific Design and Validation	3.68

Figure 24. Technology-Specific Design and Validation activity area—average weighted score by project



Activity Area Summary Report

Prepared by the Review Panel Lead

Feedback from the Review Panel to WPTO

The Technology Specific Design and Validation activity area incorporated device-specific and lab-specific developments, device testing (tank/in-sea), standards development, and techno-economic assessment tool development. Several projects in this activity area had challenges addressing two activity area objectives. Those objectives focused on improvements in methods for safe and cost-efficient installation, grid integration,

operations, monitoring, maintenance, and decommissioning, including the evaluation of potential IO&M infrastructure needs and approaches to bridge gaps that significantly impact the MHK sector.

Device-specific design and validation projects should provide more information on the actual design geometry. The reviewers were unanimous in stating that they would like to see more details and examples demonstrated during the peer reviews. They recommended that WPTO require developers to provide at least a topographical representation or description of the device under investigation (point absorber, attenuator, or oscillating wave surge converter, for example).

WPTO should undertake techno-economic assessments (such as through WaveSPARC) and, at minimum, quarterly detailed design reviews as part of the technology-specific design and validation activities with the developers. Lab integration of tools at early stages with developers is vital for success to the MHK sector. These recommendations are also iterated in the Foundational and Crosscutting R&D activity area.

The panel recommends integration of testing to the standards for developers at technology readiness level (TRL) 7–8. Incorporation of testing to standards and feedback to WG360 will improve the performance and applicability of the standards. The future projects in the MHK program, such as PacWave and TEAMER, should support this effort with developers. It is a vital activity for the medium/long term (reduction of risks and improving investor confidence) for the Technology Specific Design and Validation activity area.

Summary of all Reviewers' Comments

Overall Impressions

The Technology Specific Design and Validation activity area covered two wave developers that the reviewers considered at concept to TRL 4, one wave developer at TRL 5–6, and one wave and tidal developer at TRL 7–8. The reviewers agreed that most projects aligned well with the program strategy and objectives, as stated in the presentations. The developers at concept to TRL 4 have yet to conduct in-water tests (in-sea tests), and thus project teams validate performance models during tank testing.

There was a significant difference between the wave developers at earlier TRL levels. One was well organized and appropriately demonstrated test planning, including a description of results with high confidence by reviewers that they are on a successful path toward a competitive LCOE, even without seeing the actual design geometry. The reviewers had less favorable comments on the second developer's technology development pathway, with a recommendation for WPTO to provide a techno-economic assessment of the concept.

The wave developer seeking to improve and validate the number of design iterations at TRL 5-6, had reviewer comments that questioned the design and recommended that WPTO undertake a techno-economic assessment of the device. "This project is one of four utility-scale wave-energy devices headed for at-sea tests. This project is not as far along… having recently completed a preliminary design go/no-go. The reviewers find it difficult to see a path to economic utility-scale power, and there is insufficient detail in the summary and presentation to make an accurate judgment."

The tidal and wave developer at TRL 7–8 had different reviews overall. There is significant agreement among the reviewers that the tidal device presented "is one of the more well-developed MHK projects in the DOE portfolio."

Whereas the wave device presented gave way to comments that are concerned about the size versus the power rating. “The MHK sector experience to date has displayed that you can develop/build/commission large construction projects only to have failures in poor generation results.” These results further erode investor confidence, and reviewers recommended that WPTO provide a detailed techno-economic assessment of the device.

The panel agrees that where the labs are well integrated and supporting the developers, the impact on project performance results is vital to the success of the program.

The other three projects described are focused on standards development, the development of a techno-economic assessment tool, and validation of an innovative material, which could be a paradigm shift in structural device designs. All are led by the labs and were recognized for their experience and innovation. Most reviewers responded favorably and supported these projects as part of the activity area and MHK program.

Program Strategy and Objectives

All reviewers agreed that there is a split between developers in the activity area that demonstrate good value and performance, as well as provide confidence toward a competitive LCOE. The reviewers agreed that the program supports efforts to validate device designs, but the most significant impact of this support is when the labs integrated within developer projects. A developer “demonstrated good synergy with Sandia. The impact is clearly described in terms of results: used to verify the system identification principles/approaches published by Sandia.”

The reviewers are not sure of how well the activity area supports the program objective of ensuring long-term sustainability of the MHK sector. The reviewers agree that less performing developers are not providing a clear demonstration of device design performance. The panel agrees that further assessment is required by WPTO to manage stakeholder expectations and confidently utilize taxpayer funds. It will ensure the long-term sustainability of the program, while continually testing and validating new innovations as introduced in the sector.

What is not clear to the reviewers is the link between the activity area approach (technology specific design and validation) and projects presented to the challenge of installing and operating reliable systems. There were device-specific presentations in the Foundational Crosscutting R&D portfolio that would have fit better in this activity area (e.g., the HAT integrated into the OE Buoy, or the Columbia Power Technologies device). Although each developer has aligned across the activity areas, can the two approaches now be incorporated? Opportunities for shared lessons learned during installing and operating activities, as well as innovations in components and materials should help accelerate the sector.

Program Portfolio

Reviewers did comment that there is a split between device designs and how they are addressing the critical challenge of installing and operating reliable systems. Only one device design presented convincingly on the installation and operating challenges. One reviewer commented that the developer should, after in-water tests, incorporate lessons learned quickly and effectively in design upgrades. The portfolio provided less evidence that installation and operating reliability challenges are addressed.

The reviewers consider all other aspects of the portfolio, including contribution to program strategy and objectives, the rationale for funding and approach taken, balance of research priorities, resource allocation, and WPTO's role, to be appropriate.

Program Management Approach

All reviewers agreed that the WPTO program team is highly competent and energetic in the delivery of the program. The team is focused on creating the most significant impact on advancing the sector. It is evident that the WPTO staff effectively engage and influence the developer projects to bring them closer to successful outcomes. The program team has demonstrated strong professional and technical capabilities, including active portfolio management.

Stakeholder Engagement, Outreach, and Dissemination

The reviewers agree that the outreach achieved in the standards projects and demonstrated by a couple of the developers and how they are incorporating, applying, and critically evaluating the standards is of great value to the sector.

The reviewers are unanimous that developers should provide more detail in their concept description or design representation. The MHK program strategy states, "the WPTO program is committed to sharing and disseminating the results of government-supported R&D while respecting the intellectual property rights of industry partners to ensure public investment in MHK technologies advance the state of the entire industry." During the peer review, this was a hot topic of discussion during the Q&A session. The panel and audience do not necessarily agree that there is consistent transparency. The panel expects WPTO to give clear guidance on how it is managed for future peer reviews.

As mentioned in the summary of the Foundational and Crosscutting R&D activity area, the peer review process in and of itself is an excellent example of communicating how WPTO funds are being utilized and providing evaluations (reviews) on the success and impacts of the projects as a whole.

Project Evaluations

WAVESPARC

(WBS #: 2.2.1.402)

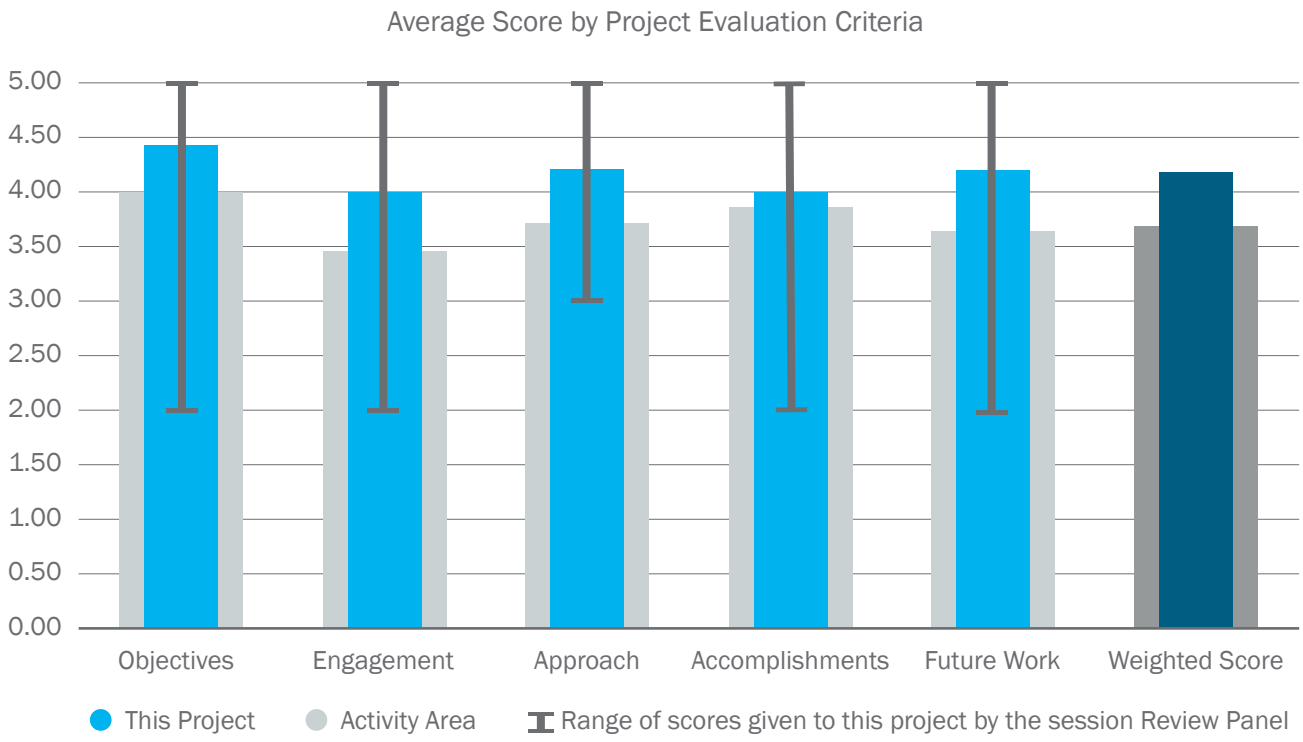
Recipient:	NREL
Principal Investigator:	Jochem Weber
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$4,866K
Total Costed:	$3,378K

Project Description

The core objective of Wave-SPARC is empowering the marine energy community with the tools necessary to achieve a significant improvement in techno-economic performance of wave-generated grid power. A detailed systems-engineering approach simultaneously balances around 100 cost and performance drivers (functional requirements and capabilities) for WEC devices. This holistic approach is crucial for unlocking the vast wave energy opportunity. This project has delivered publicly accessible technology innovation and assessment methods and tools (new to the wave energy sector), which are used to identify potential novel, high-promise WEC concepts for further exploration, development, and commercialization. Leveraging these tools, WEC techno-economic performance increases can be realized by implementing the technology development trajectories with the lowest possible cost, schedule, and risk mitigation at the earliest stages of development. Future efforts will expand Wave-SPARC capability to the various PBE maritime markets (e.g., ocean observation, autonomous underwater vehicle recharge, desalination).

Weighted Project Score: 4.2

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

Reviewers thought this was a great project and demonstrated perseverance in the midst of protests from developers. The tool is informative as to what projects are worth pursuing with a high TPL level, as well as "structure innovation" to new paradigms in MHK topology development, with a glidepath to commercial LCOE potentially.

Project Objectives, Impacts, and Alignment with the Program Strategy

Project performers have demonstrated alignment with program strategies by continuing to drive device design innovation, through component controls and early stage R&D. The project builds collaboration between users and provides a valuable tool for developers. This project, if successful, has the potential to set the program strategy in the future.

End User Engagement and Dissemination Strategy

The project performers have identified who will benefit from this project and how the success of the project will advance the industry or meet the needs of specific stakeholder/end user groups.

Many stakeholders have already benefitted, and will further benefit, from the successful outcomes of the project to date and in the future. It provides an important structure for nascent wave energy developers to cover all the ilities in a holistic design sense. The project performers have not fully explained whether specific industry members or end users were engaged/are planning to engage and at which points in the project.

Management and Technical Approach

Although the objective of the project was clear, the management and structured innovative process applied was not clear for the down-select approach used in this project.

Technical Accomplishments and Progress

The 500 use cases and 100 technologies appear very impressive. What would be useful to see is the impact the tool is having for its users.

Future Work

The future work to build the user-friendly interface in practice is a welcome plan for this tool. The future work is well organized, divided into project branches with individual details.

FLEXIBLE MATERIAL WEC TECHNOLOGY TECHNO-ECONOMIC PERFORMANCE

(WBS #: 2.2.1.407)

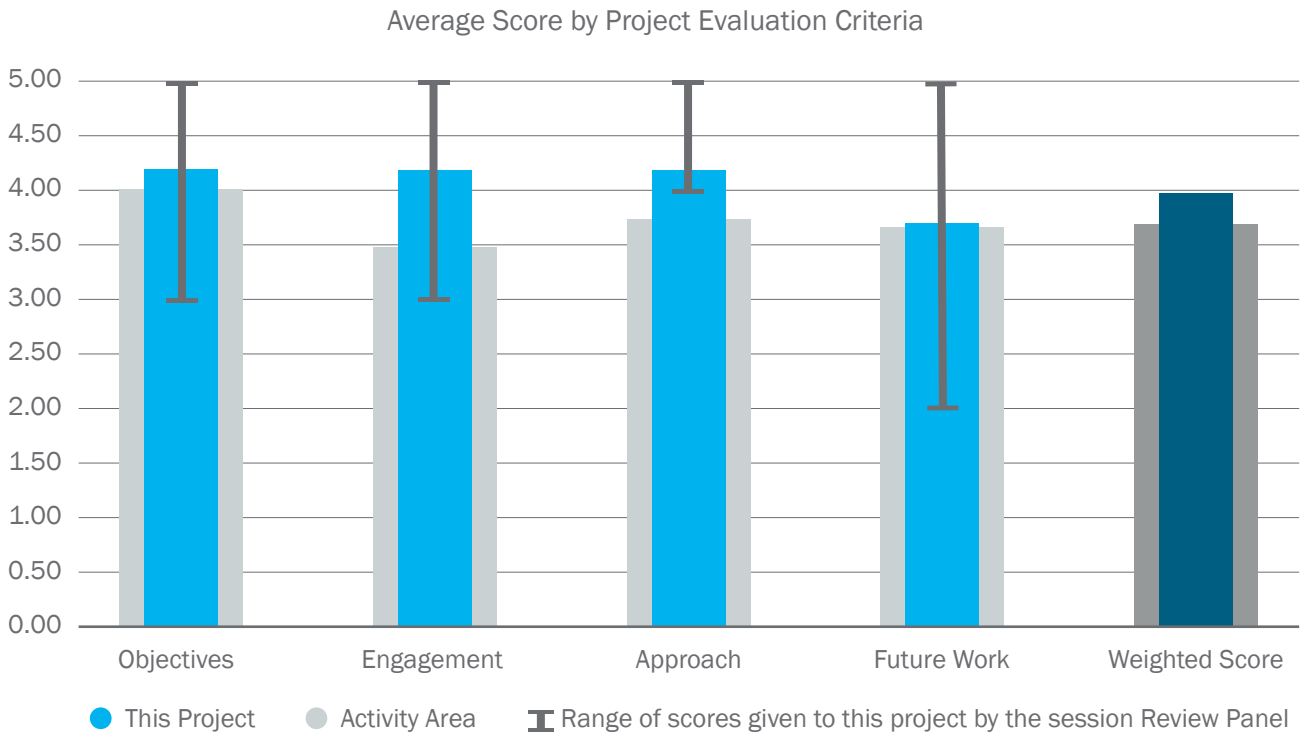
Recipient:	NREL
Principal Investigator:	Jochem Weber
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	$426K
Total Costed:	$51K

Project Description

WECs using flexible materials with distributed PTO systems (FMDP-WECs) have attractive features: (1) broad-banded wave energy absorption; (2) redundant PTO systems; (3) low material costs; (4) ease of deployment and survival mechanisms; (5) reduced maintenance schedules; and (6) near-continuous structural control. Accordingly, this project's objective is to identify, understand, and evaluate foundational characteristics of FMDP-WECs for their general techno-economic assessment. Therefore, the project team will provide descriptions of archetype FMDP-WEC technology with corresponding appropriate assessment criteria, achieve numerical modeling techniques and outreach programs, and identify future innovation pathways.

Weighted Project Score: 4.0

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.



Summary of all Reviewers' Comments

Overall Impressions

Reviewers generally agreed that this is a successful project with the potential to provide disruptive new technology for PTO systems in WECs. One reviewer stated that this is an exciting project that could unlock the economic potential of MHK devices more than other presented concepts, as long as material can meet LCOE goals. This is an important effort. Given how difficult it has been to realize cost-effective WECs using existing and mature technology (hydraulics and generators), an innovation in material science will likely be necessary to make wave energy cost effective.

Project Objectives, Impacts, and Alignment with the Program Strategy

Reviewers found positive consensus that this is a valuable project with significant potential impacts, although a fairly new technology. One reviewer wasn't sure that this was in alignment with the program strategy, perhaps because it is so different from previous WEC tracts funded, but agreed that it was a good project if in alignment.

This project represents a paradigm shift in thinking in the MHK ecosystem, with distinct advantages over current rigid structure Gen-1 approaches in terms of load shedding and efficient use of structure. Reviewers thought this project was very innovative and had positive feedback on the following project activities:

- Research into the embedment of distributed PTO systems within relatively inexpensive and easily manufactured structurally flexible materials (e.g., synthetic plastics and/or natural rubbers)
- Use of inexpensive and easily manufactured materials for novel PTO systems that are effective and efficient (e.g., stretchable elastic capacitors, miniature electrolytic generator cells, static electricity nano-generators, and/or magnetostrictive fibers)
- Use of distributed PTO systems—hundreds or thousands of PTOs being embedded throughout a WEC structure
- Ability to respond to inherent PTO redundancy—if a few PTOs fail, the FMDP-WEC is, overall, unscathed
- Semi-infinite control of the FMDP-WEC structure—the distributed embedded PTO system is a means of control for an FMDP-WEC structure, thereby enabling greater structure-ocean-wave-resonance
- Use of advanced manufacturing and/or novel new material-manufacturing synergy techniques.

Numerical modeling of this technology is novel as well, and the development of numerical models for this technology will also provide valuable new tools to the community. Although this project is in the very early stages, reviewers suggested considering implications for at-sea deployment, maintenance, and recovery strategies as early as possible by considering a specific example of this technology; the report refers to the SBM Offshore S2 WEC.

End User Engagement and Dissemination Strategy

The reviewers' scores ranged from average to good in this category. Examples of very favorable reviews of the project strategy include:

- The project performers have clearly described the rationale for the stakeholder/end user engagement strategy and how project results and information have been/will be disseminated.
- The project interacts directly with a private developer and SBM Offshore, and it has plans to disseminate project outcomes through technical reports, journals, and presentations.

- They provide a good working foundation for addressing specific issues and promoting new discoveries.
- It would be valuable for the team to identify additional developers that could also benefit from this effort.
- There is at least one other project funded by DOD that could leverage this effort. Pliant Energy Systems (PES) should be engaged in this effort early as a collaborator as well, and other similar developers should be sought.

Less favorable comments include:

- It is not clear what the dissemination strategy is for this project.
- The summary and presentation don't really describe much beyond the standard "technical publications and conference presentations."

Management and Technical Approach

Reviewers agreed that this project demonstrated a sound management and technical approach. While reviews were generally favorable, noting that the project performers provided an overall excellent description of the critical success factors to investigate, which will define overall success of FMDP-WEC viability, they shared several suggestions for this early stage project:

- Involve PBE requirements (aquaculture), as this could be a step change for both sectors.
- Integrate power into product (FMDP material into aquaculture cages), which would be similar to integrating solar into roof tiles.
- Research, distill, describe, and model those archetypical characteristics defining FMDP-WECs.
- Identify those cost-performance drivers predominantly associated with FMDP-WECs technologies
- Assess the potential for FMDP-WECs to be game-changing, paradigm-shifting forms of WEC technology.

Performers describe the challenge to modeling their particular type of WEC and clearly understand some of the challenges. It would help the review to have an example description of the existing SBM Offshore S3 technology with diagrams/pictures for consideration. In addition, if it isn't too soon to consider LCOE, it shouldn't be too early to consider practical considerations for deployment, maintenance, and recovery strategies that will be essential to accurately estimate LCOE. "Offshore engineering and marine operations" are mentioned in the management approach without further detail.

Technical Accomplishments and Progress

It was apparent to the reviewers that this project is at too early a stage to have high expectations for technical accomplishments and progress. However, there were recommendations made for the project as it progresses, and some questions posed.

The tasks and work done to date have high potential impact for the industry, and the reviewers hope the knowledge (including the promising elements of design) makes the intended impact once transferred to and applied by WEC developers. One concern expressed was that the PI did not mention any validation attempts or baseline metrics that the team is considering for this technology.

Future Work

Reviewers lacked consensus in this category, with scores ranging from 2–5. One reviewer felt that information provided on the plan for future work was a bit vague and not entirely focused on the most important aspects of the project's scope. A project website and journal articles related to project approach are not going to have a big impact without the successful identification and evaluation of materials that could be useful, as well as a concept design showing how these materials would be used with a quantifiable benefit over existing technologies. Reviewers would have liked more details about next steps, and they noted that details about integration with other sectors (semiconductor, textiles, etc.) would have been appreciated. Finally, reviewers recommended the project team seek and engage developers of similar technologies early to share in this study.

STANDARDS DEVELOPMENT FOR MARINE ENERGY

(WBS #: 2.2.3.401)

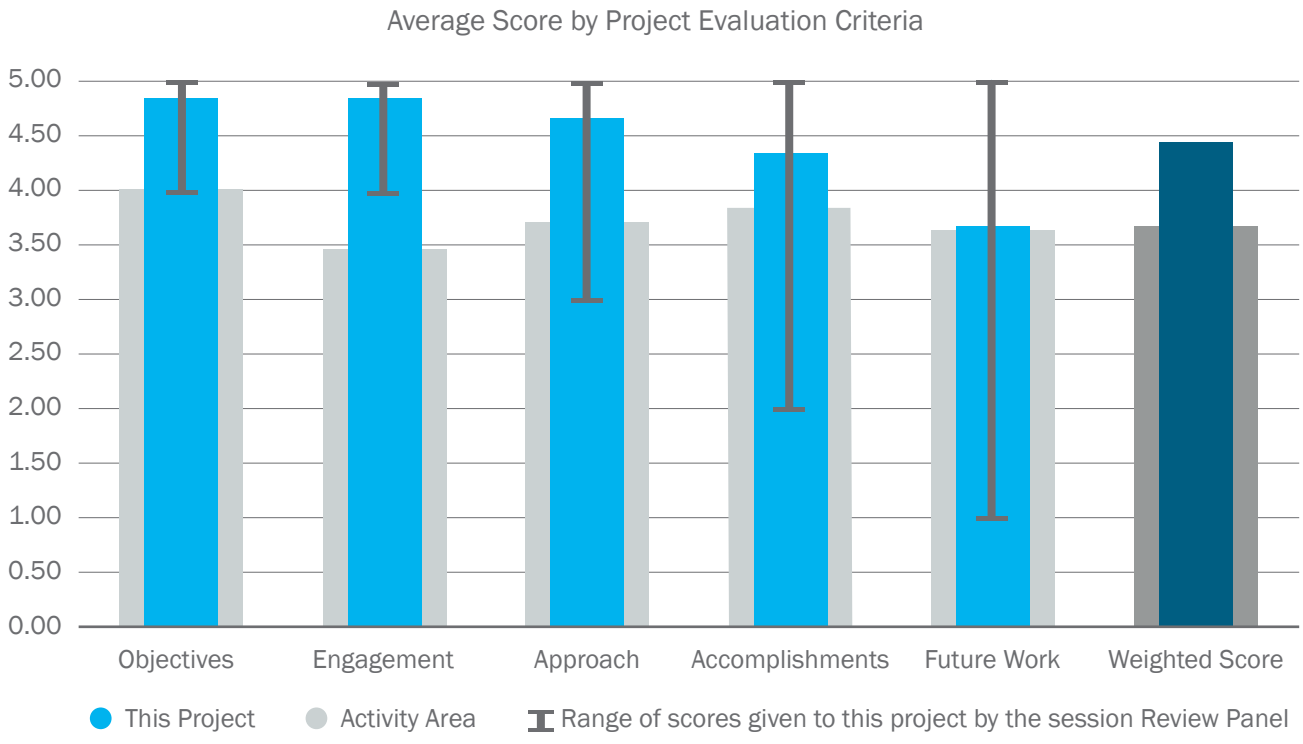
Recipient:	NREL
Principal Investigator:	Walt Musial
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$1,934K
Total Costed:	$1,536K

Project Description

The project comprises two primary activities: (1) standards development and conformity assessment by the IEC TC 114 Marine Energy and IEC System relating to renewable energy applications (IECRE), and (2) U.S. representation on the IEA-OES Executive Committee. Consensus-based, internationally recognized standards and conformity assessment are vital to the industry to ensure safety, reduce market barriers, and increase confidence in the technology. DOE's support of IEC and IEA-OES is the only formal international project connecting the Program with the global industry and is necessary to construct a well-informed, targeted Program. These activities will help accelerate the development of ocean energy devices in the United States by providing critical information on international ocean energy research activities, such as standards working groups, workshops, and technology benchmarking tasks.

Weighted Project Score: 4.4

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers recognize NREL's experience in wind and solar standards development as a strength for the overall leadership of this project and MHK standards. The contributions made by the coordinated activities of NREL to the U.S. Technical Advisory Group and internationally at IEA-OES and IECRE are exemplary. The reviewers caution, though, that the success of the project may have overtaken the U.S. MHK device development progress. The reviewers recommended a performing baseline assessment of standards through test site application and testing the applicability of standards, including the provision of improvement feedback to the IEC TC 114.

The reviewers want to commend NREL and WPTO on the vision and focus of this critical project, as well as the initiative of contributing to the international standards community. The reviewers want to ensure that standards development and conformity assessment are integral initiatives into future projects such as PacWave, TEAMER, and lab support to developer projects.

Project Objectives, Impacts, and Alignment with the Program Strategy

The NREL-led project demonstrates a key project aim in the U.S. coordinated activities supporting the IEC, IEA-OES, and IECRE development of marine energy standards and conformity assessment.

This project provides formal U.S. representation at the international level. Without DOE funding of these activities, the MHK sector would struggle to reduce technology risks and gain investor confidence, thereby limiting overall sector progression to commercialization.

The reviewers agreed that the project objectives aligned directly with the MHK program approach for technology-specific system design and validation that address the challenges of installing and operating reliable MHK systems.

The reviewers agreed the project demonstrates how the outcomes of its activities will eventually impact the following in the near, mid, and long term MHK technology development:

Near term:

- Increase access to critical data and provide growth opportunities with international collaboration.
- Enable DOE to construct a well-informed and targeted ocean energy research program.
- Provide feedback to the U.S. sector on international activities.

Midterm:

- Help regulators manage public safety by reducing failures.
- Reduce technical risks.

Long term:

- Gain investor community confidence for project financing.
- Accelerate the commercialization of marine energy technology.

Reviewers clearly understood the importance of the NREL project as this work is supporting vital standards development. The technical accomplishments include international collaboration activities benchmarking WEC simulation models and LCOE; representation at IEC TC 114, IEA-OES, and IECRE; and outputs from

engagements such as the annual reports to DOE. The reviewers thought the project was clearly achieving near-term goals and recommend WPTO project managers focus on future activities that address the mid-term and long-term objectives, such as building conformity assessment into PacWave accreditation strategy, thereby achieving Renewable Energy Testing Laboratory status.

The project demonstrated significant outputs from its activities, including publications, U.S. representation, and subject matter experts recruited to U.S. Technical Advisory Group, IEC TC 114, and IEC ME-OMC groups. The nomination and support of young professionals in the standards program is vital to the sustainability of U.S. standards engagement, as are the newly launched U.S. Technical Advisory Group website and the successful ongoing international commitment through meetings and workshops.

End User Engagement and Dissemination Strategy

The project demonstrated who the end users are and how they will interact and benefit from the standards development activities. Most immediately notable end users are the developers, researchers, and WPTO. A few developers, through the peer review presentations, are addressing the implementation of specific standards. The annual report to DOE supports evidence that the project delivers critical information on international progress and activities back to WPTO.

The presentation did not describe how the project engaged with other end users. The regulators, certification bodies, and test centers do not seem to be taking up the requirements for standardized test reports and conformity statements as quickly as needed for the advancement of the industry. The challenge back to NREL is how can they influence and lead in best practices to improve international acceptance.

Dissemination activities described by the lead project performer are outstanding. DOE support of NREL to manage this activity, especially the management of 25 subject matter experts and participation in international meetings and workshops, is vital to the success of the MHK program.

Management and Technical Approach

The reviewers agreed that the strength of the project lies in NREL experience and management of standards development. There is a detailed management plan with milestones. However, a reviewer noted that without an end milestone that has a defined goal post for baseline standards documentation, the developer is at risk to be in an infinite loop trying to certify their program with an evolving certification process.

Reviewers identified another risk, stating that the development of standards has overtaken MHK device development progress. Stating that if the project team accelerates the technical approach (as demonstrated by the support activities to the IEC TC 114) without follow-on implementation back into the U.S. developer community could slow down the successful installation and operation of a reliable MHK device.

Reviewers recommended that NREL and the 25 subject matter experts develop a report on best practices in standards implementation to disseminate into the U.S. developer sector.

The reviewers also noted that the project technical approach lacks a description of critical success factors.

The reviewers questioned several potential critical success factors. What are the technical barriers? What are the gaps in the certification process that should be addressed? What tools are required to enable the implementation of standards and methods for safe, cost-efficient installations? What is the pathway to certification? The answers to these questions are critical success factors and should be emphasized and described in the technical approach.

Technical Accomplishments and Progress

As noted above, the technical accomplishments are the results of activities that are addressed for the near-term objectives:

- Increase access to critical data and provide growth opportunities with international collaboration.
- Enable DOE to construct a well informed and targeted ocean energy research program.
- Provide feedback to the U.S. sector on international activities.

The challenge will be for NREL to demonstrate at the next peer review how they have achieved progress toward the mid and long-term objectives:

- Help regulators manage public safety by reducing failures.
- Reduce technical risks.
- Gain investor community confidence for project financing.
- Accelerate the commercialization of marine energy technology.

The proof will be dependent on a viable industry that is developing at the same pace as the standards development.

Future Work

Reviewers thought the future work, as described, needed more vision and detail.

The reviewers recognized the importance of the continued participation and contributions at IEC, IEA-OES, and IECRE, as well as the international collaboration undertaken through the benchmarking activities. However, the focus on standards for cable laying and grid connection will outpace the development of fit-for-purpose cable and connector designs for MHK devices.

Reviewers recommended that the project team provide more detail in the next budget period phase of this project, especially addressing PBE and integration into standards development. Will PBE make the pace of MHK standards development more apparent and potentially irrelevant?

AZURA DEMONSTRATION AT THE NAVY'S WAVE ENERGY TEST SITE (WETS)

(WBS #: EE0006923)

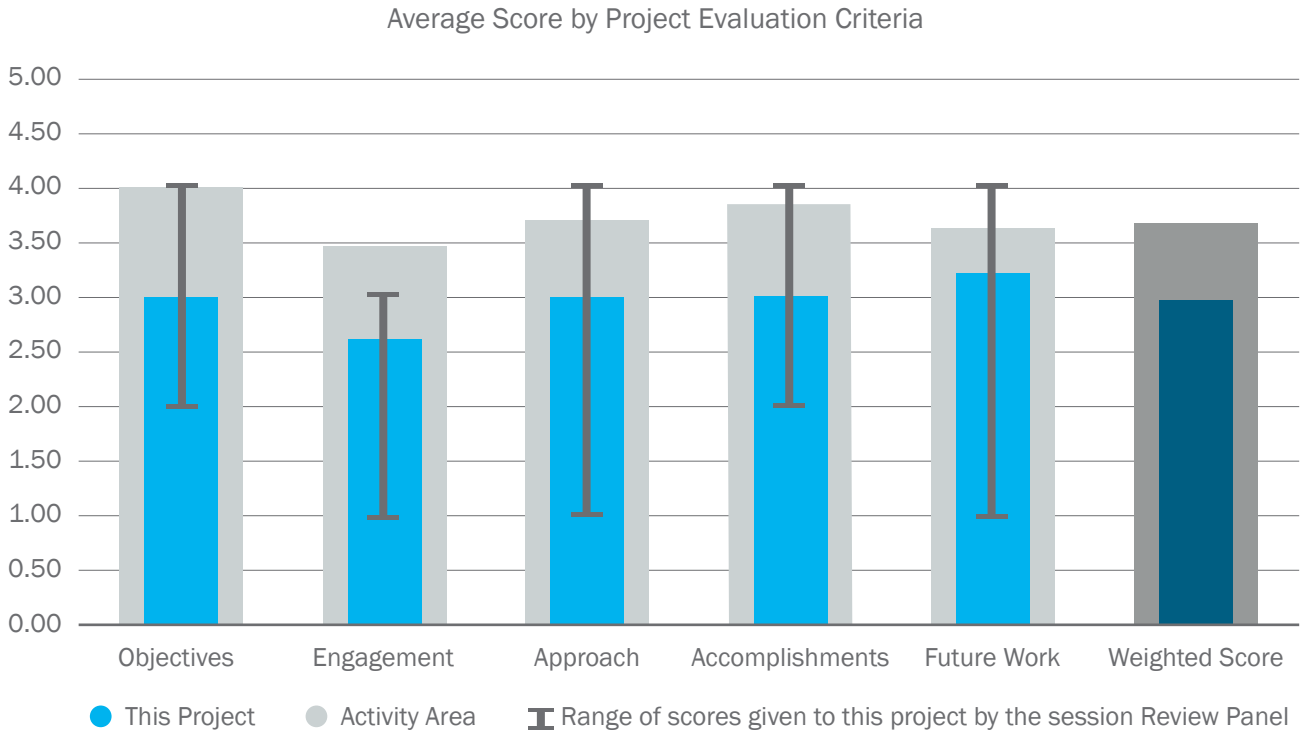
Recipient:	Northwest Energy Innovations
Principal Investigator:	Steven Kopf
Project Type:	FOA 1081: Marine and Hydrokinetic Demonstrations at the Navy's Wave Energy Test Site (WETS)
Project Category:	Ongoing Projects
Total Authorized:	$9,623K
Total Costed:	$1,476K

Project Description

The objective of the project is to design, fabricate, deploy, and test a full-scale 250-kW Azura wave energy device appropriately sized for the Hawaii wave climate with an LCOE reduction over previous WECs, demonstrating a pathway to commercialization. Northwest Energy Innovations (NWEI) plans to test the Azura device at the Navy's WETS located at the Marine Corps Base Hawaii for comparison of performance, reliability, and LCOE. The preliminary design of the 250-kW Azura device has been completed; predicted performance has been verified with 1/15th scale wave tank testing; and detailed design tasks are currently underway.

Weighted Project Score: 3.0

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

Reviewers recommended that the new methodology as described in the WEC design optimization program be evaluated for the Azura design and that it undergoes detailed techno-economic assessment to determine if there is a credible pathway to competitive LCOE. This project is one of four utility-scale wave-energy devices headed for at-sea tests. This project is not as far along as C-power and Ocean Energy, having recently completed a preliminary design go/no-go. The reviewers found it difficult to see a path for Azura to achieve economical utility-scale power, and there is insufficient detail in the summary and presentation to make an accurate judgement. Performance aside, the presentation did indicate a reasonably scoped project, and they highlighted that a key factor for success is the development of a cost-effective, robust, and reliable structure. As they are earlier in the process than the Ocean Energy and C-Power designs, the reviewers think that the performer or perhaps DOE should make a comparison of the techno-economic viability of this project compared to the others. The underlying issues of the two-year delay need to be understood. The reviewers felt that funding should be directed to MHK developers that are making progress toward deployment; therefore, it is important that progress is made and a viable pathway to cost-competitive LCOE is understood for NWEI.

Project Objectives, Impacts, and Alignment with the Program Strategy

The objective of the project is to design, fabricate, deploy, and test a full-scale 250-kW Azura wave energy device appropriately sized for the Hawaii wave climate, with an LCOE reduction over previous WECs, demonstrating a pathway to commercialization. The project performers presented the relevancy of this project and how successful completion of the project will advance the state-of-the-art technology, meaningful impacts, and/or the viability of any commercial applications through the following:

1. Advance understanding of innovative MHK technologies in the ocean environment
2. Demonstrate system durability in a highly energetic ocean environment
3. Validate numerical models to allow commercial-scale design validation.

Strengths

- Reviewers agree the Azura project does align well with WPTO's priorities to conduct in-water tests of industry-designed prototypes at multiple relevant scales.
- Based on the project's objectives, the reviewers thought this work also aligned well with the MHK Program's objective to advance System Integration R&D and Testing of Prototype Devices.

Weaknesses

- The target LCOE of the prototype is $500/MWh. At 50 cents/kwh, this is not going to be cost competitive with the exception of isolated coastal communities reliant on diesel generators. The reviewers suggest NWEI consider aligning better with the PBE strategy and consider potential Blue Economy markets.
- The project team's description of the performance of the device and its rated capacity were insufficient in detail.
- The validation of the performance was during tank testing and not in-sea tests. It is also noted that device power rating was reduced from 500 kW to 250 kW due to the electrical infrastructure at WETS. It is not apparent if the first prototype to go in was rated at 500 kW and then it was found that it could not be grid integrated due to the WETS electrical infrastructure.

- It is doubtful that a 12-month test will demonstrate useful data for device design life.
- The potential impacts described were generalized and would have been better if they were more specific to the NWEI device.

The goal of this project is clearly aimed at cost-effective, utility-scale power, which fits into the stated goals of the program. However, there is a big question as to whether or not this is possible, which the summary and presentation seemed to acknowledge.

End User Engagement and Dissemination Strategy

The statements of end user engagement are practical in that they recognize that the utilities are the end users, and successful dissemination will require a reliable and robust device. They also deserve credit for their plan to upload their test data to the Marine and Hydrokinetic Data Repository (MHKDR) after the 5-year moratorium expires. Although some conference presentations have been delivered, there is not a clear formal dissemination and engagement strategy in place. The reviewers felt like there were only nominal efforts at dissemination and end user engagement for a WEC developer. Data dissemination is discussed with data uploaded to the MHKDR and the 1/15th scale experimental data disseminated at conferences.

Reviewers felt the project lacks engagement from the broader MHK community. What results were shared on the wave tank tests with SNL or NREL? Reviewers did acknowledge efforts to disseminate data through numerous relevant conference venues.

Reviewers were confused by NWEI stating the aim was to achieve LCOE and provide confidence to utilities, while also stating that they have ongoing discussions with utilities but no "formal stakeholder engagement planned." The primary objective of engaging utilities and energy investors is to validate that the project provides confidence to secure the ongoing private investment required to advance the technology. The reviewers recommended the presenter be clearer in this messaging in the future.

Management and Technical Approach

The reviewers found it difficult to discern whether the LCOE metric is achievable based on the data provided. It appeared that the team carried out some good wave tank testing at 1/15th scale, but the results were effusive with the exception variable versus baseline hydraulic control. The second budget period will consist of detailed design activities. This will include developing structural load estimates; developing a detailed structural design; finalizing the PTO design, grid interface designs, and a mooring design; and developing an O&M plan. NWEI will also develop a commercialization plan and update the LCOE and AEP analysis of the design. Once the detailed design is completed, the next major project milestone is the Critical Design review #2.

Concerns:

- How does the tank test translate to full-scale results?
- The project has been stalled out for two years, and there doesn't appear to be any traction with full-scale design development.
- The reviewers do not see any progress toward the second budget period deliverables, seeing cogent milestones but no progress toward them. The project seems stalled out due to budget shortfalls, a critical flaw to the technological approach, or a combination of the two. Risks are not identified, nor mitigated.

- Although project partner roles are clearly documented, there does not appear to be a clear management structure in place for this project.
- There was no discussion of risk for the full-scale PTO design/build, and it seems there would be a significant number of risks there.

The project performers described the project management approach through a work breakdown structure. Interface with other projects funded by WPTO was also described. The PI also covered the high-level project schedule with go/no-go dates and assumed milestones, with the Installation Readiness Review in 2021. NWEI described a project strength as the utilization of expertise at NREL, whereby NWEI is working with NREL to determine structural loads (WEC-SIM) that will impact the design of the full-scale Azura.

Based on the review of the SNL WEC Design Optimization project led by Ryan Coe, it should be decided whether Azura should be engaged to utilize this tool prior to final design. Reviewers recommended that the new methodology as described in the WEC design optimization program be evaluated for the Azura design.

The program mentions effective use of scaled testing to reduce risk and aid design as scales increased. The summary gives details for significant studies that will be leveraged to de-risk and improve the prototype design.

Technical Accomplishments and Progress

A 1/15th scale model was constructed for testing at the University of Maine. A test campaign was performed to validate the numerical WEC-Sim model of the Azura used to estimate power production, verify the predicted performance of the Azura in irregular sea states, and perform preliminary survivability tests. The hydraulic PTO dynamics were included in the wave tank testing via a hardware-in-the-loop scheme. The performers shared some specific, clearly described metrics regarding their program during the presentation

Concerns:

- Outside of the 1/15th wave tank tests, this program has not shown consistent execution.
- The outputs and accomplishments were explained, but there are still some concerns on budget period one's budget overrun and no decision for budget period two or three yet.
- The fact Azura is still in the design phase (preliminary) is concerning. This is a 7-year project (2015 to 2022), and so far, the preliminary design phase has taken 4 years.
- Downsizing from 500 kW to 250 kW is not a technical accomplishment.
- NWEI is making progress with the technical aspects of the program and have completed modeling and scale wave tank testing. They show some results, which indicate close agreement between modeling and testing. Unfortunately, there aren't results presented that demonstrate a path to cost-effective power beyond the statement of expecting specific LCOE. The assumptions and modeling that go into that estimate are critically important.
- It is too early to assess the overall technical achievements. It is not clear whether there is a clear strategy to achieve an attractive LCOE. Reviewers suggest this is investigated prior to the go/no-go review.
- There is no mention of baseline metrics from their test campaign. They do offer an opinion that testing was good enough to provide confidence.

There is some good execution from the PI on the wave tank test that the reviewers would like to see translated to the rest of the program. Reviewers acknowledged good work modeling the hydraulic PTO response.

Future Work

The reviewers expressed the following about the project's future work:

- What is the progress toward the second budget period objectives?
- The future plans are made unclear by mentioned negotiations. The presentation elaborated on some future work, including pressure distribution for finite element analysis.
- The summary provides high-level details for schedule and milestones.
- The reviewers feel this program should be seriously scrutinized and reviewed.
- The next budget period's work involves detailed design. As NWEI plans to "refine" the LCOE, WPTO oversight should probably pay close attention to this refinement to ensure this project is headed toward a successful outcome if built.

DEMONSTRATION OF THE OE BUOY AT US NAVY'S WAVE ENERGY TEST SITE

(WBS #: EE0006924)

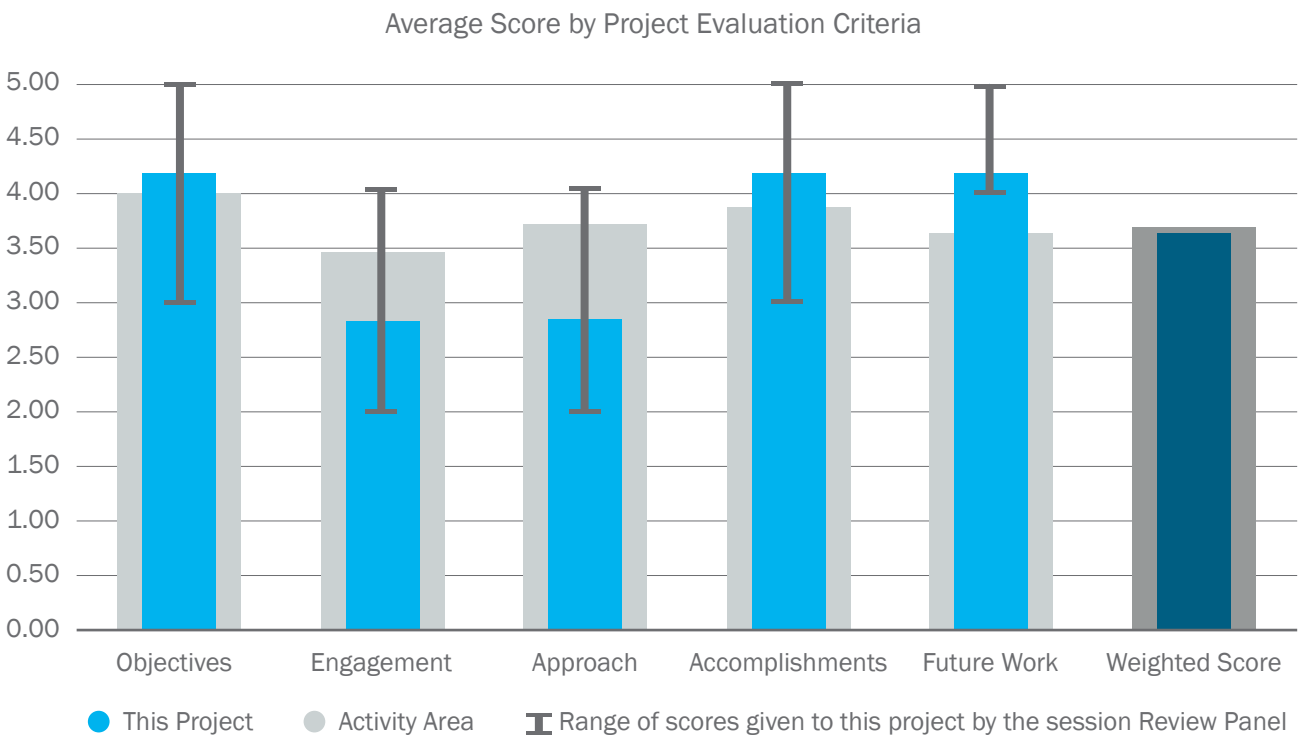
Recipient:	Ocean Energy USA LLC.
Principal Investigator:	Tony Lewis
Project Type:	FOA 1081: Marine and Hydrokinetic Demonstrations at the Navy's Wave Energy Test Site
Project Category:	Ongoing Projects
Total Authorized:	$11,650K
Total Costed:	$8,589K

Project Description

The OE Buoy is based on the floating oscillating water column concept, which uses variability in wave height to move air through an air turbine that rotates in a single direction. The device isolates the power conversion system from seawater and provides a high-speed air flow to the turbine to generate electricity. The OE Buoy has been tested at quarter scale in real sea conditions for over 3 years, resulting in a TRL level of 6. The OE Buoy will be demonstrated for 12 months at large scale, with a prototype machine rated at 500 kW at the U.S. Navy's WETS in Hawaii.

Weighted Project Score: 3.6

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The MHK sector experience to date has displayed that you can develop/build/commission large construction projects only to have failures in poor generation results. The funding that goes into demonstration projects with lower-than-expected results contributes to a watered-down success story for the entire MHK sector. It is strongly recommended that OE/HydroAir turbine integration undergo detailed techno-economic analysis to determine if there is a credible path to a competitive LCOE.

Project Objectives, Impacts, and Alignment with the Program Strategy

The main project objective is to make a full-scale demonstration of Oscillating Water Column energy production for an extended length deployment. This is a very ambitious undertaking requiring a sizable investment that would produce a meaningful result of the WPTO program. What is not clear is how the economics of this device are viable; it is a large structure for a modest amount of electricity. It would seem a system failure or an under-performance of the energy production during this test would be a significant failure and setback for wave energy.

End User Engagement and Dissemination Strategy

There have been conference presentations and DOE engagement, but it is not clear what the dissemination strategy is for this project. The reviewers would have appreciated more of a discussion on who will benefit from this project and how project performers planned to meet the needs of their key stakeholders or end user groups.

Management and Technical Approach

The reviewers did not feel like they received sufficient information to be certain the project teams implemented clear management and technical practices to manage the project partners effectively. The project principals did not perform the project presentations, so it was harder to get insight into how this is being executed from a management point of view. The associated turbine project did express concerns about the lack of a common integrator of the two components, and it sounds like WPTO brought in support from NREL to help the teams complete this project.

Technical Accomplishments and Progress

The teams involved have worked hard to overcome the usual problems that come up in any large effort. The result is that this system is completed and on its way to the test site, so the team should be commended for all of this. Overall, there appears to be good technical progress. It would be good to see the commercial progress of this device.

Future Work

Future work has a brief timeline but no inclusion of operational reviews. This would be important to include for showing lessons learned after each phase/step in the deployment/installation activities are critically assessed and verified.

KINETIC HYDROPOWER SYSTEM TRIFRAME MOUNT INTEGRATED DEVELOPMENT AND IO&M TESTING AT RITE

(WBS #: EE0007349)

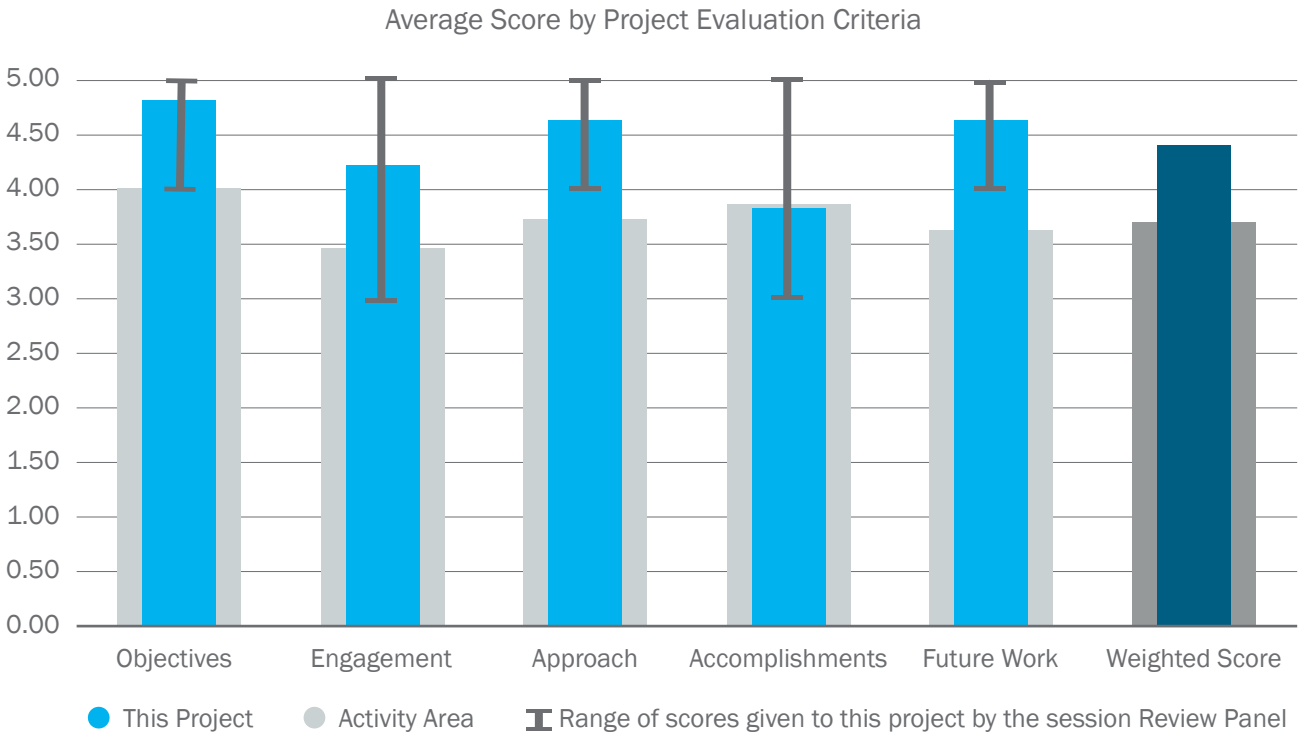
Recipient:	Verdant Power, Inc.
Principal Investigator:	Dean Corren
Project Type:	FOA 1310: Next-Generation Marine Energy Systems—Durability and Survivability
Project Category:	Ongoing Projects
Total Authorized:	$7,999K
Total Costed:	$2,310K

Project Description

This full-scale, open-water project will develop, build, operate, and maintain a TriFrame™ mount with three Verdant Power Gen5 Kinetic Hydropower System axial-flow turbines. Deployment is at Verdant's FERC-licensed RITE Project in New York. Goals include advancing the TriFrame from TRL 3 to 8 and optimizing the TriFrame for both CAPEX and OPEX. Metrics include the time and cost of on-water operations for installation and maintenance, while meeting all requirements and providing a path for scale-up. A key aspect to this project is the Integrated Design Process, closely and iteratively linking mechanical design with operational procedures to reduce the combined contributions of CAPEX and OPEX to LCOE.

Weighted Project Score: 4.4

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

This project was favorably reviewed and received high scores from the reviewers. Two reviewers noted that the upcoming deployment is a proof of concept for the cost-saving approach of relying on accurate site bathymetry and found that the results from this will be interesting and worth following. Reviewers also had some technical concerns about cavitation and turbulence intensity, and they were pleased to see the upcoming review by NREL. Finally, one reviewer was interested to learn more about other markets and locations outside of the test site. One comment suggested that this is one of the more well-developed MHK projects in the DOE portfolio.

Project Objectives, Impacts, and Alignment with the Program Strategy

This category was scored very highly by the reviewers. The comments reflect the high quality of the presentation and explanations of what the upcoming deployment aims to achieve.

Representative comments include:

- "The project performers have presented the relevance of this project and how successful completion of the project will advance the state of technology, meaningful impacts, and/or the viability of any commercial applications."
- "This new foundation structure for the Verdant turbines aligns with the program's strategy in both crosscutting R&D as a new design meant to minimize CAPEX and OPEX."

End User Engagement and Dissemination Strategy

The reviewers scored Verdant well on this criterion, though a few comments show some concern that a description of end users outside of the grid operators were neglected in the presentation. This is explained somewhat by the fact that Verdant is setting up to be both a technology developer and operator, so they are their own end user. Several reviewers commended the high degree of engagement Verdant has regarding standards development, and they recognize this is a significant dissemination of their efforts. For instance, "Verdant has done an industry leading job on standards development, pushed regulatory approval and adopted a failure mode and effects analysis in concert with National Lab oversight."

Management and Technical Approach

In this category, the reviewers scored very highly. Again, the high quality of the presentation was reflected in the comments, and all reviewers felt this group has performed well in both their management and technical approach. One reviewer noted that Verdant was the only developer in the peer review that provided detailed cost metrics and goal posts. The project performers have clearly described critical success factors, which will define technical viability and have explained and understand the challenges they must overcome to achieve success. The emphasis this company appears to have on the management and technical process was also noted by reviewers. The reviewers were intrigued by the technical approach of using detailed bathymetry to simplify the design of the device and allow three turbines to be deployed/recovered simultaneously.

Technical Accomplishments and Progress

The reviewers scored this section slightly lower than the rest. This was possibly due to the fact that the deployment phase and proof of concept of this project is still upcoming.

The lowest scores were supported with comments such as the following:

- "Light on details here. I would have liked to have seen more on I am still concerned about tip cavitation with superposition of loads since this is at a fixed depth. Tides, Wave orbitals and turbulence intensity can have a periodic cavitation issue one a once per a rev. Where is the cavitation bucket margin?"
- "Detail was missing on the achievement of the competitive LCOE, which will be essential for the commercialization of this technology."

Positive scores were supported with comments about the project's demonstrated ability to perform in-water tests and "incorporate lessons learned quickly and effectively in design upgrades."

Future Work

This section was scored favorably by the reviewers. The reviewers expressed an interest in the results of the upcoming test and the 120-day results. Other noteworthy reviewer comments include:

- "Good detail in the future work section. Interested in the activity with the Magnetic Gearbox group."
- "The project performers have communicated key planned milestones and addressed how they plan to deal with upcoming decision points and any remaining issues."
- "Future work focuses on testing of Gen5 plastic blades and assessing post-deployment performance of upgrades made, as it should. Consideration for the expiring FERC license in 2021 and whether the program will be continued or retired in the East River [should be] a focus."
- "Suggest significant consideration for broadening future markets, and testing/deploying at other sites should be paramount."

CALWAVE OPEN WATER DEMONSTRATION

(WBS #: EE0008097)

Recipient:	CalWave Power Technologies Inc.
Principal Investigator:	Thomas Boerner
Project Type:	FOA 1663: Marine and Hydrokinetic Technology Development and Advancement
Project Category:	Ongoing Projects
Total Authorized:	$5,517K
Total Costed:	$2,566K

Project Description

The main project objective is to advance the TRL of the WEC developed by CalWave Power Technologies Inc. (CalWave) through advanced numerical simulations, hardware/tank testing, and ultimately scaled open water demonstration, while continuing to exceed DOE's target ACE (Average Climate Capture Width / Characteristic Capital Expenditure) threshold of 3 meters/M$. Budget Period 1 concluded in June 2019, with detailed design of the scaled demonstration unit and bench testing of the critical hardware components. Key outcomes in Budget Period 2 will be installation and operation of the demonstration unit in open water in close proximity to the Scripps Institution of Oceanography. Performance and load measurements will be used to validate the high techno-economic performance of the concept.

Weighted Project Score: 3.7

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.

Summary of all Reviewers' Comments

Overall Impressions

The reviewers recognize CalWave as a well-organized team that has incorporated the industry best practices of utilizing state-of-the-art controls from SNL and tools to guide load shedding approaches. The reviewers consider CalWave a promising MHK wave energy topology, with a better chance of reaching commercial LCOE; however, the reviewers felt unable to give a full assessment due to the lack of top-level system drawings and metrics. The reviewers would like to see greater dissemination of the actual design geometry and review of deployment area in terms of operational device performance loads expected. The reviewers considered CalWave an interesting project in that this team is pursuing a different approach to wave energy compared to what developers have done previously. In particular, the choice to keep the entire device submerged could significantly benefit the survivability of the device, which is a large cost driver in most wave-energy systems. The reviewers felt CalWave did not give a sufficient overview of the device in the review materials, making it difficult to make a judgement on the device itself. Perhaps because there are so few details, it's enticing to imagine that there is a novel design here that could change the economics and viability of wave energy compared to the surface piercing devices that have not fared very well. CalWave readily admitted that their reluctance to share details publicly is a company choice made for strategic reasons and not a lack of knowledge about their device. This team seems very competent and well organized. Even without providing details, they are able to answer questions about the device and their approach that inspires confidence. Presumably, the DOE team had access to considerably more detail about the device in the recent DOE go/no-go process and found a compelling story as the project is still funded. The next budget phase includes an at-sea demonstration, and CalWave appears well along in those preparations. The results from that test will be very interesting and should dictate the appropriateness of future funding.

The reviewers unanimously agreed that they would have liked to see more details and examples of this WEC technology. There are many significant claims made about the novel abilities and applicability of this WEC for several applications without providing examples of end users, diagrams, quantified outputs from the WEC modeling, etc. The reviewers believe that the close collaboration with the labs corroborates some of these claims, but would still like to see more evidence.

Project Objectives, Impacts, and Alignment with the Program Strategy

The CalWave project performers have described how the project contributes to the program's strategy/approaches with Wave Prize ACE metric threshold of 3 meters/M$. Project objectives embraced the work developed by the labs to advance TRL/TPL. CalWave demonstrated good synergy with SNL. The reviewers would have liked to see where CalWave is relative to wave prize requirements analytically and demonstrated through wave tank test.

The project performers have considered and described the use/applications of their expected products and outputs.

- Budget Period 1 concluded in June 2019, with a detailed design of the scaled demonstration unit and bench testing of the critical hardware components.
- CalWave's holistic control approach includes novel means to directly control the energy input into the WEC, such as loads exerted into the physical structure by using novel load management capabilities such as absorber geometry control. Similar to pitch- and yaw control in wind energy, this novel approach has not been implemented in any deployed WEC technologies so far, however, it allows a paradigm shift in designing and operating WEC devices.

The project performers have presented the relevance of this project and how successful completion of the project will advance the state of technology, meaningful impacts, and/or the viability of any commercial applications.

- The WEC's high performance numerical prediction and capability to survive extreme wave events was validated by CalWave during 7 weeks of wave tank testing at 1:25 scale (operational cases) and 1:30 scale (survival cases) at various wave tanks.
- Final objective of the project is to deploy and operate a 1:5 scale device at open water (Scripps, San Diego) for at least 6 months to assess the device performance in realistic environments and to validate the novel holistic control approach, including geometry and depth control.
- Experimental system identification tests for multiple degrees of freedom of the device were conducted that allow the derivation of precise hydrodynamic models for simulation and control. During multiple wave tank test campaigns, the project team conducted experimental system identification. SNL staff attended these campaigns. Results were used to verify the system identification principles that SNL staff released a year prior using a floating point-absorber. Lessons learned fed back into multi-degree-of-freedom system identification work conducted by SNL. Proof of principle of the method was validated again using the CalWave device as an inherently different device archetype.

Strengths

- Reviewers found CalWave's approach that makes the project impactful is that they use a different device topology archetype, which aligns with the creative design approach of NREL (e.g., Dr. Jochem Weber's use of flexible structures).
- Project PI described well how the project contributes to the program strategy and approaches. The impact is clearly described in terms of the results:
  - The project was used to verify the system identification principles/approaches published by SNL.
  - The 7 weeks of tank testing operational cases developed and at 1:30 scale with survival cases.
  - The team is currently critically evaluating the testing -103 standard for wave tank assessments.
- Of all the wave-energy development projects in the WPTO portfolio, this project is the most interesting in that the project team appears to be pursuing a novel approach to wave-energy extraction. The presentation materials align well the WPTO objectives, in this case fundamental R&D and also device specific technology development.
- The project objectives align with program strategies. This project is unique, as it is a WEC design that has been developed with the full assistance of the new modeling tools developed in the labs, and the performers have demonstrated several successful collaborations that utilize these evolving new tools.
- The progressive numerical model validation is well aligned with DOE strategies.

Weaknesses.

- Many reviewers felt it was difficult to judge the fit with the program, as very limited information has been discussed about the actual technology.
- The reviewers were universal in that there was not enough design information given. It was hard to discern the efficacy of the design. For instance, what was the result of these wave tests relative to threshold requirements?
- The load management aspect of this project does provide a straightforward exercise for pursuing such benefits.

End User Engagement and Dissemination Strategy

During their detailed design, CalWave has advanced the state of the art of existing numerical tools. In one example, fundamental improvements to the WEC-Sim framework have been developed in collaboration with NREL and Evergreen Innovations to properly simulate the multi-degree-of-freedom device. CalWave showed good use of national lab resources, leveraging their expertise as a force multiplier and garnering state of the art control work to drive PTO design.

The project performers have clearly described the rationale for the stakeholder/end user engagement strategy and how project results and information have been/are planned to be disseminated. SNL work on high-fidelity CFD modeling for extreme wave response yielded improvements to the WEC Device Response Toolbox Extreme Sea State Contour tools. Coupling CFD modeling tools with other software environments to simulate staged failure modes of the device in extreme seas led to a scientific paper being presented at the 2019 European Wave and Tidal Energy Conference potential first market-ready WEC product, addressing the maritime markets identified by DOE's *Powering the Blue Economy* report.

CalWave has engaged many potential customers, ranging from defense to ocean science and observation to marine aquaculture, who have expressed interest in a low-power, rapidly deployable WEC. Feedback from all customers has been collected and synthesized into guidance for a potential revision and market introduction of the WEC developed in this project. A lot of good work has been carried out by CalWave, but the topology remains a mystery to reviewers, which impacts the scoring assessment.

Strengths

- Excellent demonstration of dissemination back into tools WEC-SIM and MHK lessons learned (10 reports).
- They have listed who they have spoken to in state agencies, local agencies, and the oceanographic research community.
- Within the limitations of their relatively secretive approach to their technology, the project team describes appropriate interactions with stakeholders in the state government and broader community. For instance, they have done some public education work with both politicians and the Exploratorium in San Francisco. Additionally, they appear to have involved SNL in their design work.
- The project summary describes efforts and plans for WEC developers in the area of dissemination, as well as end user engagement.
- The performers identify engagement primarily through the development of a novel WEC device, and they suggest that the multiple degrees of freedom of the device have pushed model advances at the labs.
- They identify utility in the PBE initiative by "addressing the maritime markets identified by the DOE's Powering the Blue Economy report."

Weaknesses

- There is very limited information provided about end user/customer engagement and dissemination of this project.
- While promising, it is difficult for the reviewers to identify actual engagement without specific examples.
- End users are unclear. There is mention of maritime markets in PBE, but because we can't see the device, it is not clear who those customers could be.

- There is no clear plan explained on how the project team will continue engagement or on their rationale for stakeholder/end user engagement strategy.
- Little detail or examples of specific customers within this sector are identified.

Management and Technical Approach

CalWave's approach considers the entire chain of conversion steps as a single process with intrinsically connected requirements, revealing optimization potential for WEC performance improvement and cost-efficient device design via synergies at the subsystem interfaces. This involves Co-optimized WEC hulls, PTOs, and electrical export frameworks, which must be considered holistically. The reviewers see CalWave as a well-managed team, with independent validation via the Wave Energy Prize. Reviewers' main concern is the PTO down-select and characterization that many teams suffer from that prevents the design from moving forward and achieving a cost-competitive LCOE.

Strengths:

- The device topology is derived from a kinematic modal optimization, allowing for true extraction of multiple degrees of freedom (Surge, Sway, Heave, Pitch, and Roll) with inherent load management capabilities.
- The project takes a "holistic design" approach. CalWave has advanced a submerged pressure differential type WEC since first developed in 2014. The single body device is oscillating, submerged, positively buoyant, and taut moored to the sea floor. A completely submerged device avoids many of the pitfalls of a surface presence device subjected to extreme loads and 100-year storm events.
- Customers in the blue economy, especially DOD applications, would prefer an approach without a signature or surface presence.
- Capturing multiple degrees of freedom in energy extraction is unique relative to others
- A wave load control mechanism via adjustable absorber geometry was integrated from the beginning of the project. This is analogous to the pitch/yaw control of wind turbines.
- Interesting approach to shed load that the author should have disclosed to access efficacy or independent validation; the concern would be active versus passive load shedding.
- No need for active measurement devices to improve power output through feedback loop is a plus.
- The project allows for control of five degrees of freedom separately (heave and yaw resemble a coupled mode), further optimizing operations in different bandwidth limited wave states.
- Kinematic control of the device follows cable driven parallel robot approaches, which are well understood.
- This team seems very competent and well organized; even without device details, they present a compelling storyline of integrated development involving all aspects of the problem in the design (controls, structural, operational costs, etc.). The project is organized into milestones, and the team size is appropriate to the tasks.

Weaknesses

- Reviewers are skeptical of the approach using undersea winches, as they have a litany of issues and will pose an O&M issue if it is actively used or intermittent as a means of power optimization or load shedding.
- Is there a design requirements and best practices report? Or is there a conformity statement?

- Use of techno-economic metrics for performance monitoring of the project, including technical/commercial viability, to dictate the development targets is a best practice and should be incorporated into other project/technical approaches. WPTO should use this best practice.
- The technical approach is hard to evaluate from the materials presented, but it does appear that this group has been thoughtful about pursuing a design that addresses one of the prime challenges of wave energy (storm loading) by keeping with a submerged device.
- There was very limited information provided about the project's management and technical approach.

CalWave included the management of the project in LCOE considerations, which was unique for most of the presentations. The collaborations with the labs appear to be mutually beneficial. It is difficult to completely evaluate the management and technical approach without more details and examples. Why are there not more details, pictures, schematics, etc. available? All of the outcomes of this project sound appealing, but the lack of concrete examples concerned the reviewers.

Technical Accomplishments and Progress

CalWave has fully designed a 1:5th scale novel submerged pressure differential WEC.

Over 200 project and technical risks have been identified in collaboration with national lab and industry partners, and mitigation strategies were successfully derived. The reviewers would be interested in seeing this FMEA and how issues were mitigated through analysis, inspection, or test. System identification via experimental tank testing was used to derive hydrodynamic models for numerical simulation and controls development. Models were successfully implemented and used for performance optimization, load assessment, and hardware-in-the-loop PTO bench testing.

Concerns:

- Reviewers wonder how accurate the numerical simulation and hydrodynamic model prediction was relative to wave tank tests. Is it accurate enough to predict full-scale performance and used as a design tool? What are the limitations?
- Validation of the device's high energy absorption capability was carried out via extensive experimental wave tank testing. Results yielded a two-fold performance improvement, reaching up to 60%–70% capture width ratio in common wave states. This was a great result and a reason to do more experimental wave tank testing in a controlled environment versus open water tests to iterate quickly in a controlled and cost-efficient setting
- An efficient PTO drivetrain was developed, which is capable to support the submergence depth change of the device, while enabling execution of advanced PTO control strategies to maximize absorption efficiency. Absorption efficiency was increased by up to 40% compared to a passively controlled device. The reviewers would like to know what the baseline performance was relative to key COE metrics and ACE system requirements. While a 40% improvement is impressive, it has to be in the context of acceptable baseline performance.
- A PTO test stand and single PTO unit were developed. PTO characteristics were derived from experimental system identification. A hardware-in-the-loop approach using the validated numerical simulation was used to experimentally assess the PTO's behavior in all conceivable wave states. PTO performance characteristics were found to be well in the bounds of numerically derived values. Reviewers would like to know if a PTO topology been down selected or if the trade space still open.

- For the CWR Performance results in Case IWS5 significant: what sea state was this in? Was the load reduction also by factor of 2?
- The reviewers agreed that while all of the performer's claims were tantalizing, they were not provided quantifiable examples. What is the current expected LCOE of this device, and the path for lowering it? The reviewers don't have much more information to evaluate the technical prowess of this project than the successful collaborations with the labs and the claims of the performers.

The project provided an excellent review of the FMEA analysis in approach to risks associated with IO&M planning. The co-design approach is well demonstrated in this project. Additionally, the incorporation of the third-party reviews demonstrated to validate the performance of project were excellent. They have completed the design and tank test, but no specifics have been presented. They are moving to an at-sea deployment and appear to be on schedule and budget. There appears to be a good technical process. It would be good to see the commercial process.

Future Work

Future plans include further project development contributing to the holistic control design for the open water demonstration. The second is a FOA to co-design a PTO with controls. Improved understanding of device behavior gained from the open water demonstration project will feed into this PTO design project. CalWave was awarded tank testing from the MaRINET2 fund, which enabled tank testing to be conducted without accruing cost to the project

The upcoming Budget Period 2 of the project includes the manufacturing, build-out, deployment, operation for at least 6 months, and decommissioning of a 1:5th scale WEC. This demonstration device will include all novel features to manage loads directly in the wave-structure conversion step. Geometry control, as well as submergence depth control, of the device will be integrated into a holistic control framework with the PTO controls. Target deployment site is Scripps, San Diego, which has a well-suited wave climate to assess relevant operation of the WEC.

Concerns

- Reviewers would like to see a free-body diagram layout of the system to understand it better. Reviewers were concerned about buoyancy control versus an active ballast system or winch system to control depth. Reviewers needed to see more detail on the design, as others have provided to give a proper assessment.
- The future plans for testing and evaluating the WEC at Scripps are sound. Reviewers would like to know the scalability of this novel WEC system. Deployment is planned for Scripps because this wave climate is well suited for the WEC. Are other climates wells suited for getting power from this WEC? The developers claim there is interest in PBE applications, so does future work include scaling the WEC to provide power in lower-energy wave climates?
- The reviewers would like to know how CalWave envisions that survivability in large sea states will be demonstrated at SCRIPPS pier.

The 2020 deployment will be the big test for this project, and the project performers outlined appropriate planning and an understanding of what they hope to achieve from the testing.

ROBOTIC JUGGLER OFFSHORE WEC

(WBS #: EE0008388)

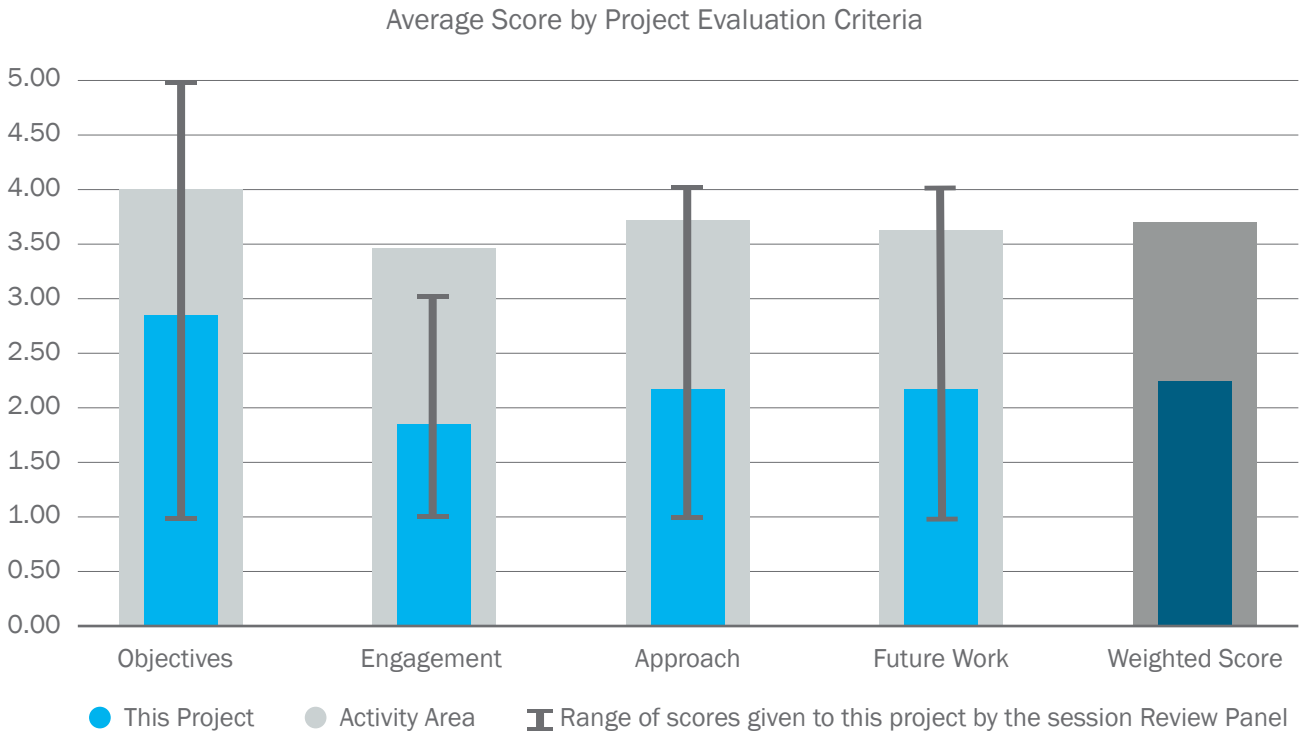
Recipient:	Enorasy LLC
Principal Investigator:	Vassilios Vamvas
Project Type:	FOA 1663: Marine and Hydrokinetic Technology Development and Advancement
Project Category:	New Projects
Total Authorized:	$942K
Total Costed:	$93K

Project Description

The Robotic Juggler device is an innovative, offshore floating WEC that utilizes a rotating eccentric mass. The eccentric mass rotates about a vertical shaft and provides rotation to a permanent magnet generator. The device's PTO is entirely enclosed within the WEC's hull. The project objectives are to numerically model the performance of the Robotic Juggler, validate the device's average climate capture width/characteristic capital expenditure metric, and then test a scaled prototype with an incorporated control algorithm.

Weighted Project Score: 2.2

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.



Summary of all Reviewers' Comments

Overall Impressions

Many reviewers thought the very early stage aspect of this project explained some of its shortcomings. All reviewers expressed concern that the performer was perhaps not taking the project as seriously as he should. There was some agreement among reviewers that the project should undergo a techno-economic review as part of upcoming go/no-go decisions.

Project Objectives, Impacts, and Alignment with the Program Strategy

A number of the reviewers agreed that the project aligned well with the WPTO strategy for cross-cutting R&D. In particular, the sealed PTO provides an attractive area of focus for the industry. However, a lack of detail on performance measurements and the inability to model the system were a concern. There were a number of comments indicating the reviewers used the very early stage aspect of this project to explain some of its shortcomings.

End User Engagement and Dissemination Strategy

Reviewers agreed that the details on end user engagement were lacking or vague. Dissemination strategies were nominal for a developer.

Management and Technical Approach

A number of the reviewers noted the absence of a clear management plan. A few of the reviewers recognized the value of the scaled testing program that was discussed and presented. This is accepted as a good technical approach; however, the reviewers also expressed some concern on the technical strength of the team given the admitted struggles with modeling a fairly simple topology.

Technical Accomplishments and Progress

This was not scored due to the early stage of the project. Concern again was mentioned regarding technical ability due to the modeling struggles.

Future Work

The reviewers noted that a discussion of milestones was missing from the presentation but recognized the upcoming go/no-go decision point. There were a couple of reviewers that expressed a fair bit of skepticism regarding the viability of the project given the summary and presentation content.

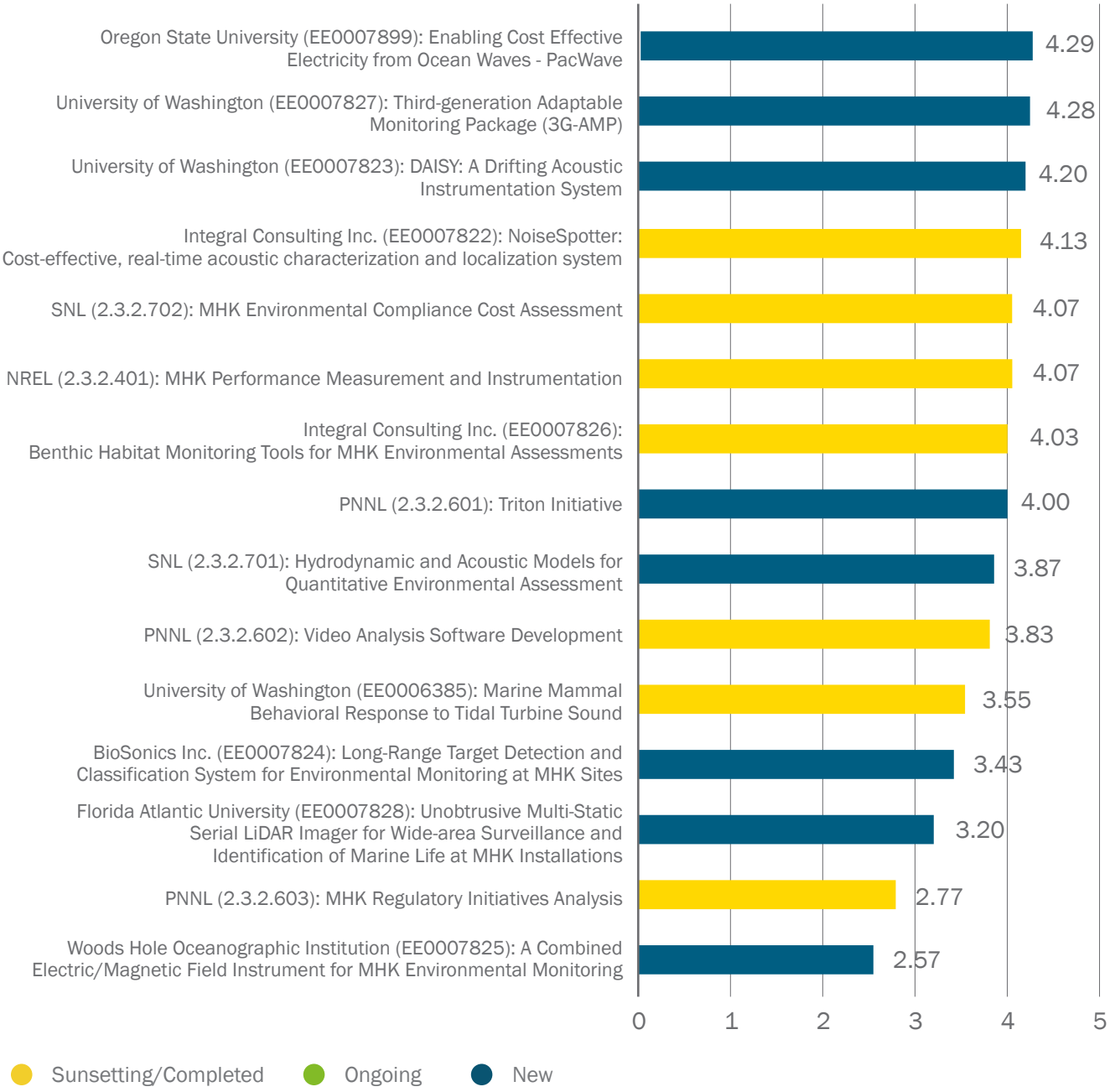
Reducing Barriers to Testing

This section provides an overview of the scoring for all projects within the Reducing Barriers to Testing activity area (see Figure 25); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

Activity Area Score Results

Name	Average Weighted Score of All Projects
Reducing Barriers to Testing	3.78

Figure 25. Reducing Barriers to Testing activity area—average weighted score by project



Activity Area Summary Report

Prepared by the Review Panel Lead

Feedback from the Review Panel to WPTO

The projects presented within the Reducing Barriers to Testing track deal broadly with issues of environmental monitoring and regulatory concerns. The investments in technological development appear to be driven by environmental concerns identified in previous MHK projects and reflect a programmatic vision to be well-prepared to address the same issues should they be raised in future projects. This forward-looking objective contrasts with the discussions related to regulatory concerns, which appear to be primarily driven by experience. New information, if any exists, that can guide projects and investments should be collected from relevant stakeholders and further refined and communicated to project participants supported by WPTO. The most efficient way to achieve these goals is not at the level of individual projects.

A regular discussion point among reviewers was end user engagement and how engagement strategies informed project objectives and broader program goals. For these projects, the end users are generally regulatory agencies and developers. When available, project performers should work to better convey how information obtained from these conversations was used as opposed to stating that the discussions took place.

Reviewers agreed that, at a program level, now is a good time for WPTO to engage in conversations with the regulatory community to better understand their needs and what technology gaps remain for addressing these issues (i.e., are most of the necessary tools now available to address key concerns?). When engaging in conversations with regulators, it is important to follow up and ensure that the conclusions drawn by the program or project participants adequately reflect the concerns and priorities of these agencies and individuals. An outcome of these conversations should be a conclusion as to whether WPTO should continue to invest at comparable levels in these areas or whether technological developments allow the program to scale back the levels of investment. It was not clear during the review process what up-to-date information is available on this subject and how that is informing program strategies. However, due to investments in this area, the program is likely well-positioned to leverage work funded in this track to address high priority issues.

The technology development for environmental monitoring in this track appears to be going well, with projects generally making progress toward field deployments at WETS. While WETS demonstrations will demonstrate key technological advances, it is not clear how these deployments will successfully achieve WPTO strategies of reducing risks. It would be highly beneficial to industry if similar targeted deployments of these technologies were accompanied by specific efforts to identify and/or reduce risks associated with device deployments.

Given the level of investment in environmental monitoring technologies, WPTO should identify pathways for providing funding for environmental monitoring using technologies developed through this program at future device deployments. Any technologies chosen for such deployments should have previously demonstrated the capacity to directly address a concern raised by a regulatory agency. This points to the benefit of upcoming deployments at WETS, even if the deployments are not successful in working toward the reduction of risk. One potential approach to ensuring investments in environmental monitoring technologies are leveraged in the future would be a structure like TEAMER, which would allow flexibility in timing that is more difficult to manage with a traditional FOA.

Some projects within the portfolio may ultimately be unable to play a future role in field efforts to reduce risks around MHK devices, and upcoming deployments will identify the effectiveness of applicability of the projects. Regardless, progress on these projects suggests that the technological developments will be useful in other contexts. For example, several projects are already scheduled to be used in non-MHK studies or have resulted in peer-reviewed publications.

Several reviewers commented that, when possible, WPTO should encourage project participants to publish results in peer-reviewed publications as opposed to technical reports. Some projects appear to be progressing toward peer-reviewed publications, but others seemed to be entirely focused on technical reports and documents addressing internal resources and goals. Although technical reports are still of value, particularly when they provide a level of detail that cannot otherwise be conveyed, peer-reviewed publications are likely to have a wider audience and a broader impact.

Large projects like Triton are difficult to evaluate in this context. Numerous reviewers recommended that each Triton task be subject to an independent review or that the project be broken up given that they are not necessarily related. Given the available time and information, a thorough review of Triton Tasks 2 (fish mesocosm) and Task 3 (Triton Field Trials) was not possible. As a significant project within the portfolio, this, and others with comparably large scopes, should be given additional time and space in written reports. Triton Task 1 seemed to be extremely successful, with the PIs of all projects interacting with Triton speaking highly of the interactions and the benefits to their projects. This collaborative work could also be emphasized when there is overlap between other existing projects (e.g., projects emphasizing compliance costs and regulatory initiatives).

Quantifying the return on investment (ROI) made by this program is difficult and made more challenging by the shortage of opportunities to test these technologies and address existing risks. Nonetheless, WPTO should identify ways to quantify the impacts of these projects and ask project performers to provide meaningful metrics, when possible, to the program.

Many reviewers commented on and had strong feelings about the widely used "risk retirement" narrative employed by many project participants. This framing inadequately captures the nuances of the regulatory processes and concerns of regulators, while failing to recognize that no two projects are subject to identical concerns or pressures. As such, a risk cannot be retired, but it can be reduced or minimized. Stating that risk has been "retired" undermines the value judgements of those tasked with making key regulatory decisions. Relative levels of risk should instead be presented with appropriate context. Reframing the "risk retirement" discussing acknowledges that identifying and appropriately managing regulatory concerns requires dialogue between diverse stakeholders and cannot be simply reduced to binary statements.

The most significant strengths present in the portfolio were the advances that should facilitate environmental risk studies in future deployments of MHK devices. Perhaps the most significant weakness was a general lack of understanding of how these projects align with regulatory concerns.

Summary of all Reviewers' Comments

Overall Impressions

Projects within the Reducing Barrier to Testing track are diverse and represent different challenges facing the MRE industry. The projects that are focused on instrumentation or methods to address existing environmental concerns apply a broad range of technologies, some of which are likely to be applied in future projects. In some cases, there were concerns that the technologies themselves would be a source of concern. These

projects are making progress, but the impact of these investments can't be measured without devices in the water analysis to quantify impacts of devices. Regulatory and compliance initiatives might benefit from synergies with offshore wind regulatory processes and analyses that directly compare compliance costs of MHK with that of other maritime industries. Multiple reviewers expressed concerns for multiple projects, stating that technological developments being pursued with WPTO funding were similar to developments that had other agencies had previously funded. Identifying pathways for ensuring these efforts better leverage other work would be beneficial.

Program Strategy and Objectives

The program's long-term strategic approaches and future direction were not clearly conveyed during the peer review. This is less of a concern if WPTO plans to maintain the status quo with respect to this research track. Many of the presented projects are completed or nearing completion. Additional information about how recent investments will be leveraged to reduce risk in the future would have been helpful. The program understands important barriers to testing and development based on previous experience, and these can logically be extended to the near and long term given that little has happened in recent years that would fundamentally change existing challenges. Although not included in this review, WPTO has invested more recently in better understanding the current challenges in this area.

The Reducing Barriers to Testing research portfolio invests in a variety of early-stage research projects that aim to support studies and ensure long-term sustainability and environmental impacts are understood. In addition to technologies to measure these impacts at the scale of individual devices, program funding supports modeling efforts to expand these results to larger scales to address larger-scale development scenarios.

Investment returns for projects in this track are difficult to measure given the state of the industry. However, should ongoing projects perform successfully in future deployments—thereby demonstrating their future role in environmental monitoring and risk mitigation—the investments will provide meaningful returns for the MRE industry, with many applications to other industries.

Program Portfolio

Projects within the Reducing Barrier to Testing track contribute to program strategies by supporting scientific research to mitigate environmental risks and reduce the costs of environmental monitoring. Funded projects within this track aligned well with program strategic approaches. These projects address a range of potential environmental impacts, including collisions with devices, avoidance, radiated noise, and physical effects on the environment. Additional program-level information regarding the selection of the different projects would have helped reviewers understand whether their existing redundancies in the portfolio were strategic. For example, there were two projects aimed at quantifying radiated noise, two projects whose technology would be focused on the detection and quantification of animals in the near-field of devices, and two regulation-oriented projects. This redundancy is not inherently problematic, and to an expert, the benefits may be clear, but such funding decisions could be better conveyed.

Apart from the significant initiatives with larger budgets, funds were well distributed between the projects aimed at technological development and those working to research the costs of compliance and the regulatory environment. The broad range of projects is appropriate for WPTO's role as a public R&D organization.

Program Management Approach

The program team appears to effectively manage and direct program activities to meet program objectives. For the benefit of reviewers, WPTO could provide brief summary of procedures for the development of

project milestones, statements of project objectives, and steps taken to ensure project alignment and progress during quarterly reporting. Additional information could also be provided to help reviewers better understand internal processes at WPTO that are used to manage the existing portfolio.

Within the context of the Reducing Barrier to Testing activity area, research priorities were not explicitly identified; however, the program portfolio effectively communicates an interest in a range of environmental effects research and instrumentation needs to accomplish these goals. These projects represent areas of research that have been identified as high priority based in part on past experiences. Any additional motivating factors informing portfolio investments should be more clearly communicated to reviewers.

Program team members have many of the professional and technical capabilities to guide the portfolio. There were, however, a couple of cases in which program investments overlapped with niche technologies from other industries. With additional expertise from the technology, oceanographic, and defense sectors, different paths toward more efficient technological development could have been identified. WPTO could explore the possibility of open communication with experts from these other agencies to identify areas of overlap.

Stakeholder Engagement, Outreach, and Dissemination

WPTO effectively communicates how investments are distributed to address priority research areas. Identifying methods for evaluating project impacts would help to better communicate the results of program investments. For projects within this track, such metrics could include (but are not limited to) estimates in the reduction of costs associated with the use of technologies developed with program funds and metrics on relevant publications with an emphasis on peer-reviewed publications.

WPTO funding in this area should be directly driven by the issues that are of highest concern to stakeholders. While project performers can individually reach out to these stakeholders, multiple reviewers raised concerns about stakeholder fatigue. By addressing stakeholder issues at a program level, as opposed to having project performers guide this outreach, program managers could reduce the burden on individual stakeholders, while gaining a better understanding of how individual projects address their concerns. When the stakeholders are regulatory agencies, the program should seek to leverage activities in other industries (e.g., offshore wind) to identify overlapping issues and solutions relevant to both sectors.

WPTO-funded projects are active participants in industry conferences and document project achievements through technical reports and other documents to DOE. Not all potentially interested parties have the bandwidth to attend these conferences or will be aware of technical reports. When relevant, projects should seek to publish results in areas with broader readership and in places where reviewers may have deeper subject matter expertise (i.e., a renewable energy journal is not always the most appropriate place to present environmental monitoring results even if the application is MRE). Another option identified by a reviewer was to create a consolidated database populated with known environmental concerns, as well as with information about existing capabilities to address the issue, and to publish results demonstrating the types of observations that could be expected.

Through its other efforts, WPTO provides access to information and data with the goal of informing decision makers and accelerating industry development. As discussed, with respect to the Data Sharing and Analysis activity area, it may be possible to streamline these resources to ensure that the best available information is better emphasized.

Project Evaluations

MHK PERFORMANCE MEASUREMENT AND INSTRUMENTATION

(WBS #: 2.3.2.401)

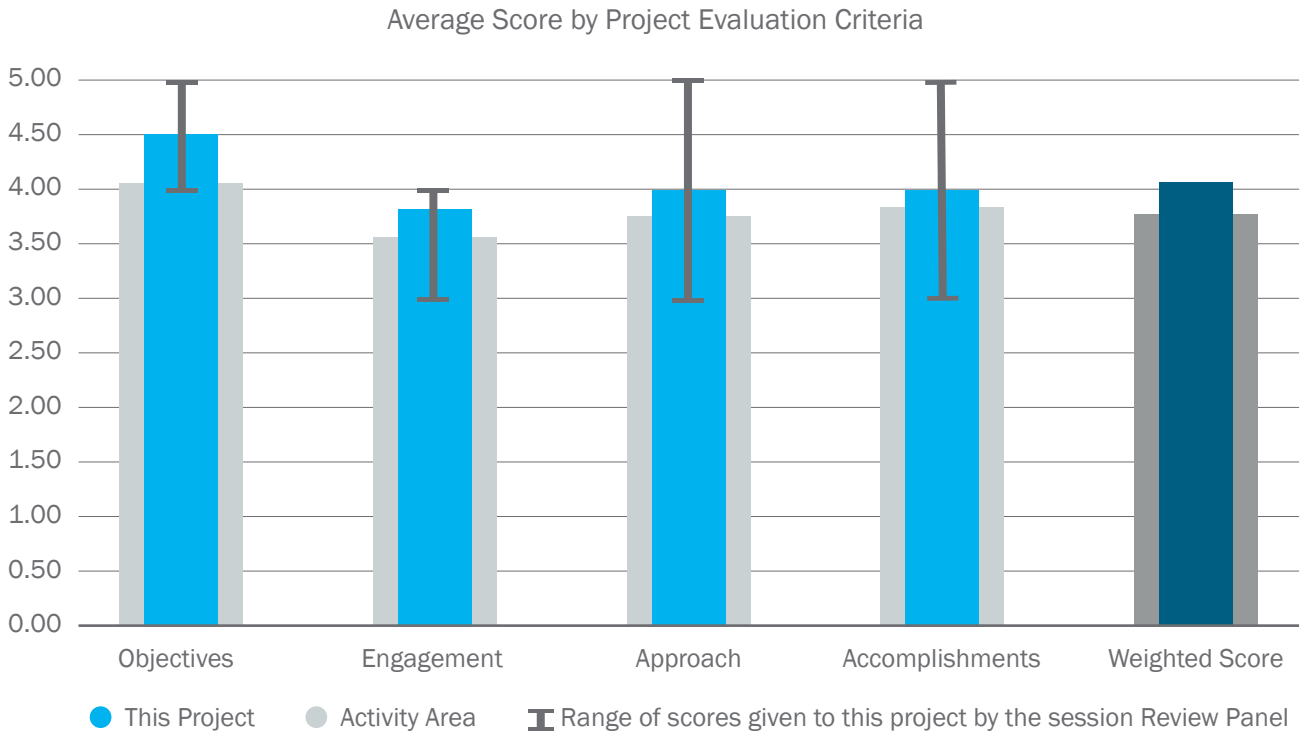
Recipient:	NREL
Principal Investigator:	Rick Driscoll
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$195K
Total Costed:	$195K

Project Description

The project identified gaps, characterized impacts, and prioritized solution pathways for measurement and data processing for the marine energy community. Along with years of engagement with and activity in the marine energy and other offshore industries informing this effort, a third MHK Instrumentation Workshop was held at Florida Atlantic University's Sea Tech Campus from February 28 to March 1, 2017. In addition, a comprehensive assessment and literature review was performed for gaps in MRE measurement and testing technology. The focus was marine-grade instrumentation systems used for site characterization, structural testing, certification testing, system verification, commissioning, operational monitoring, and controlled testing in a laboratory environment for wave and current systems. Findings were published as a technical report and disseminated through mechanisms such as conferences and on Tethys (tethys.pnnl.gov).

Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers were positive about this project, and three of the reviewers explicitly stated that the workshop the project team organized should happen again at regular intervals, as there seemed to be good value generated. Two of the reviewers commented that they were not sure how the results of the workshop fed into WPTO priorities, and that it might be worth strengthening this connection when communicating about this project. One reviewer also commented that there was good representation by national labs and universities at the workshop but not from the MHK industry and that it would be good to increase industry participation.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the project performers described how the project contributes to the program's strategy/approaches, the use/applications of their products/outputs, and the relevance of the project. One reviewer pointed out that the outcomes won't directly lead to impacts but that the implementation of the recommendations from the workshops will.

End User Engagement and Dissemination Strategy

The review team felt that there was appropriate end user engagement and dissemination. Particular strengths were good use of pre and post workshop surveys, as well as good theme generation and identification of limited knowledge transfers. One reviewer seemed to question if an invite-only approach was the right one to take, and another noted that they would have liked to have the workshop generate a more detailed technical report.

Management and Technical Approach

The review team agreed that the management and technical approach was good for this project. The breakout sessions, which identified gaps and ranked potential solutions, were a workshop strength.

Technical Accomplishments and Progress

All of the reviewers felt that the project performers had reached their objectives of conducting the workshop, identifying gaps, and reporting on this. The report and recommendations have since been used by DOE and have led to other national lab collaborations. These are all project strengths.

TRITON INITIATIVE

(WBS #: 2.3.2.601)

Recipient:	PNNL
Principal Investigator:	Genevra Harker-Kilmes
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$8,365K
Total Costed:	$4,746K

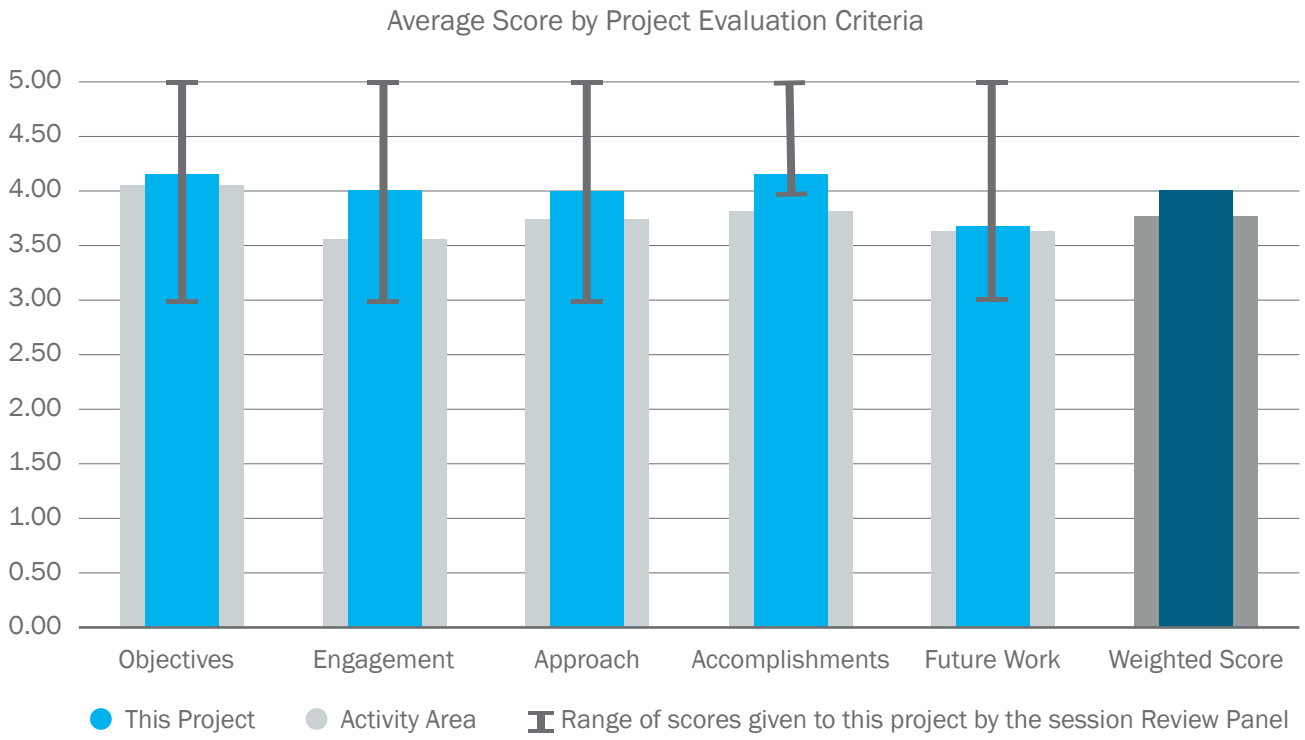
Project Description

The Triton Initiative, led by PNNL, aligns with the DOE objective to improve the efficiency and effectiveness of environmental monitoring. The initiative supports DOE-funded projects that advance environmental monitoring technologies, including sensor and software development for use in MHK energy projects (and potentially offshore wind where appropriate). Development of monitoring techniques and platforms associated with MHK deployments will reduce costs and timescales for permitting to enable widespread deployment of energy devices. Triton is composed of three tasks:

1. The continuation of the FY 2016 FOA support (FOA Support): PNNL provides technical expertise (engineers, oceanographers, data scientists, scientific divers, fisheries experts), research vessels, and permitted in-water testing sites available for use by instrumentation developers.
2. Fish Mesocosm Study: PNNL includes fundamental research focused on providing new data related to fish collision, avoidance, and evasion in response to interaction with a tidal turbine (developed by UW-APL for the navy).
3. Triton Field Trials: PNNL will produce criteria for standardized environmental measurements by developing guideline methodologies to inform environmental data collection and analysis, which will increase the robustness and comparability of datasets across the industry.

Weighted Project Score: 4.0

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The Triton Initiative is a project with a large scope and budget, with three distinct tasks. Reviewers agreed that there was not enough information given in the project summary or presentation time allocated to adequately evaluate each of the three tasks. The first task, FOA support for WPTO awardees, received outstanding reviews from these awardees and additional detail on the Triton initiative could be gleaned from collaborators' presentations. Several reviewers strongly suggested that the Triton Initiative be separated into its three components, even if only for peer review purposes. The reviewers made two pages of additional "Recommendations" on this project and suggested that WPTO carefully reviews them.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that this project aligns very well with the overall WPTO program and significantly contributes to its strategic goals. One of the project's goals (or products) is to provide support to existing MHK FOA projects engaged in environmental monitoring instrumentation development under WPTO's Reducing Barriers to Testing activity area, as well as provide access to in-water testing. This makes the project relevant, as it had and will have a meaningful impact on other projects. The reviewers' impression from other presentations under the Reducing Barriers to Testing activity area was that the FOA support of the Triton initiative was viewed very positively by the various collaborators.

In addition to the FOA Support task (Task 1), the Triton Initiative includes the Fish Mesocosm Study (Task 2) and a task to develop best practices for environmental monitoring (Triton Field Trials, Task 3). Two of the five

reviewers commented that the three tasks appeared to be unrelated or distinct projects, which made it difficult to evaluate each task and the overall project.

End User Engagement and Dissemination Strategy

Reviewers agreed that the project clearly identified who will benefit from Task 1, FOA Support, and how it will help advance the MHK industry by facilitating field tests for various (environmental) instrumentation. Similarly, it was clear which end users were engaged under this task, and how they benefitted. Feedback from FOA collaborators (engaged as "end users") was very positive regarding responsiveness and project support.

Three of the five reviewers commented that the end user or stakeholder engagement strategy for the FMS (Task 2) was not clear. One reviewer commented that the end user engagement strategy for Task 3 lacked information about how conversations with subject matter experts will be translated into best practices.

The dissemination strategy mainly discussed Triton Field Trials (Task 3), with Task 1 being disseminated through website features and, presumably, through the FOA awardees being supported by this initiative. As Task 2 is still in its early stages, plans to disseminate the results were not specific.

Management and Technical Approach

All reviewers agreed that the FOA Support (Task 1) was well organized and managed. The technical approach to this task was sound and well received by collaborating FOA recipients.

Two reviewers thought that management and technical approach for the Triton Field Trials were good or appropriate, while two reviewers thought they were less clear and would have benefitted from additional specificity.

All reviewers expressed some form of concern for the Fish Mesocosm Study. Concerns ranged from requesting more specificity/clarity on management and technical approach, to the metrics of success and goals of this study, to questions about the (deepwater) fish species and the (shallow) test site in Sequim Bay. It was noted that the fish study was delayed since the installation of a tidal turbine was delayed. There is a lack of data on fish interaction with MHK turbines. It was noted in reviewer discussions that it is ironic that permitting is the cause of the delay for this task.

Technical Accomplishments and Progress

The reviewers agreed that the project has made excellent progress toward achieving the objectives of Task 1. Several field tests were supported, and reviewers generally found the context provided by the collaborators in later presentations very helpful for understanding the full scope of this part of the Triton project.

For the FMS, 100 sable fish were tagged with acoustic tags Juvenile Salmon Acoustic Telemetry System, and fish tracking was demonstrated in Sequim Bay.

Initial progress on Task 3 was reported. Two reviewers expressed concerns about the Triton Field Trials goals, as well as what level of detail "best practices" recommendations for environmental monitoring can be made at this stage of the still divergent MHK industry.

Future Work

Some goals for future work were listed in the project summary. No milestone schedule and go/no-go decision points were given.

Reviewers agreed that more details about future work, broader objectives, specific project goals, methodologies for the FMS, technical issues and challenges, etc., would have been helpful for assessing plans for future work.

VIDEO ANALYSIS SOFTWARE DEVELOPMENT

(WBS #: 2.3.2.602)

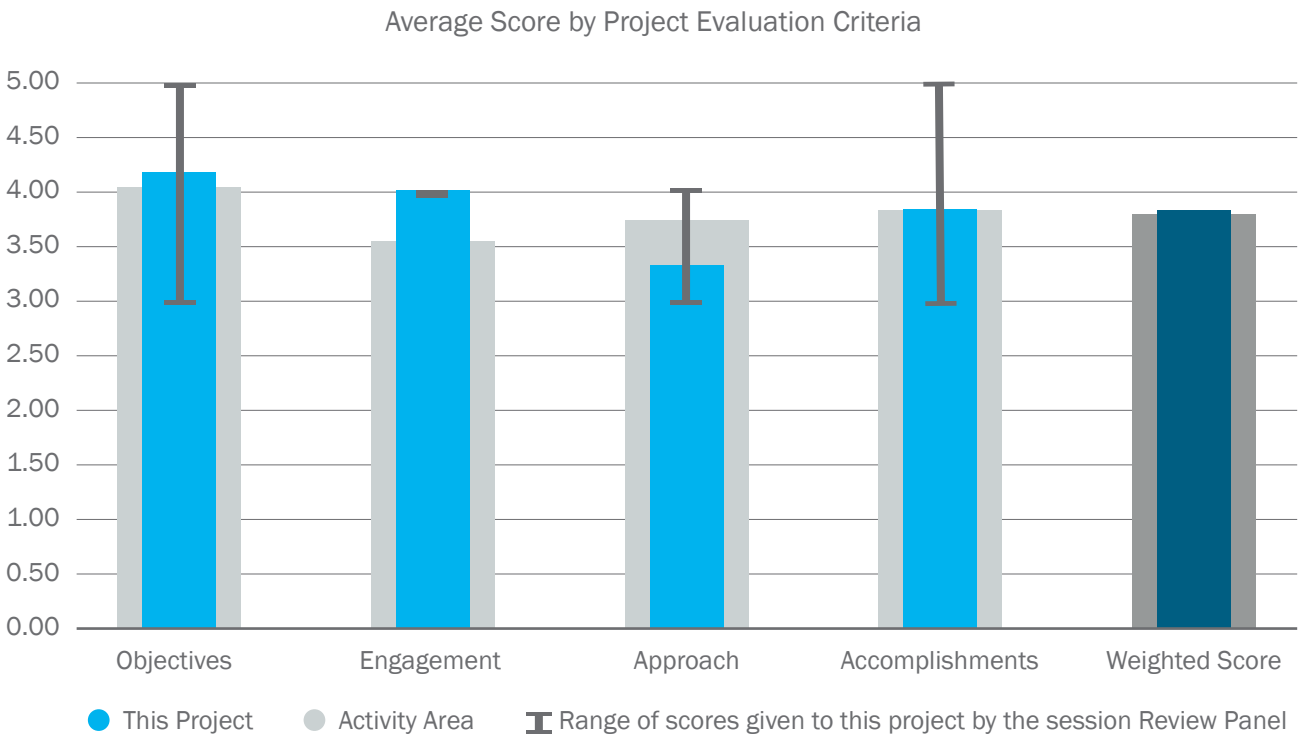
Recipient:	PNNL
Principal Investigator:	Shari Matzner
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$300K
Total Costed:	$300K

Project Description

The aim of this project was to develop software to expedite underwater video analysis. Underwater video camera systems are effective for recording fish and wildlife activity around MHK devices. But the process of reviewing and quantifying the information in underwater video is time consuming and costly due to the labor-intensive nature of the analysis. There is a need for automation to reduce labor costs. The EyeSea software was developed as a framework for the underwater video analysis workflow to make manual analysis more efficient by incorporating automated detection of the presence of wildlife.

Weighted Project Score: 3.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

This project summary was well written and addressed all of the topics in a concise manner. With the high false-positive rate, the most significant challenge remains the application to broader video datasets. This will require additional work/supervision and development investment. To avoid further reinvention in automated image processing approaches, there are lessons from other fields of study (such as fluid dynamics) that the project team could apply to capitalize on existing research investment. The project should also have an objective on how the tool will be implemented beyond automated detection. One recommendation is to work with NOAA and NMFS to come up with metrics and analysis approached to address monitoring questions.

Project Objectives, Impacts, and Alignment with the Program Strategy

The project performers have described how the project contributes to the program's strategy/approaches. The reviewers agreed that the project aligns with the overall program strategy. There is a significant observer burden to review the data, and a tool like this is necessary if MHK is going to use video to detect fish. The major contribution of this project is an automation routine to detect fish in video data. The project performers have considered and described the use/applications of their expected products and outputs. This project is focused on detection for human assisted review of video data. Project objectives are well-defined in terms of in-situ application and technical goals (e.g., true positive and false-positive detection rates). Other than reducing workload to find segments with fish, it was not clear yet how it would be implemented to review data with specific monitoring objectives. The project will demonstrate relevancy as the open source software will be used by ORPC with the RivGen turbine deployment.

End User Engagement and Dissemination Strategy

The project performers have identified who will benefit from this project and how the success of the project will advance the industry or meet the needs of specific stakeholder/end user groups. The end users seem to be largely PNNL, contractor support, industry, and regulators. Stakeholders from relevant agencies such as NOAA, EPRI, and the U.S. Environmental Protection Agency were engaged via webinar and a follow-on survey, but the participation rate was too low to provide useful data. Planned software updates will be made available to the MHK community. There was a concern of whether there was planned future interaction with user groups to receive feedback for continued maintenance and feature development. The reviewers noted that a great project feature was the annotated video data sets that are publicly available for future development. The questions regulators want to answer with the monitoring data need to be identified to successfully develop the application of the software.

Management and Technical Approach

The roles and experiences of project contributors, all located at PNNL, were clearly described. Quarterly milestones were well defined for the one-year project. The project was initially conceived as one to simply develop algorithms for the application, but the project performers felt that the project would benefit from an expanded approach to emphasize the development of not only algorithms but an open source software application to allow for flexibility, outside development, and future integration with new algorithms in the field. This framework allows for users to automatically process video data to detect targets and then manually review data by removing false positives and annotating relevant targets. These data are written to a database for further post-processing. The primary noted challenges related to the lack of datasets from training algorithms and the low quality often associated with such data streams. To address these issues, the goal was to obtain at least four unique data sets for annotation, analysis, and algorithm verification. The

issue of low-quality data was to be addressed by verifying that the developed algorithms worked in these circumstances.

Three reviewers had some concerns about the technical approach. First, the datasets were not annotated in a systematic way. From the presentations and questions, it seemed that the subset of data that were annotated in each data set were done ad hoc. This raises concerns about bias that may have entered into the validations of the auto detector because of this ad hoc approach. The creation of annotated datasets is well established in a number of fields. The literature should have been used to find appropriate systematic ways of annotating these data to minimize potential biases. Second, it is worrying that the deep learning algorithm did not seem to work consistently, even within the same data set. This inconsistency may be related to biases introduced by the ad hoc annotation.

Technical Accomplishments and Progress

The most significant technical achievements were the generation of datasets (i.e., annotated video appropriate for algorithm development), the creation of the open source software, and the successful application of deep learning techniques for the automatic detection of fish. In this process, six datasets (including two from MHK sites) were collected and analyzed. In addition to their use in the project, these annotated data have been made publicly available, and the project team has received multiple requests for access to the data. As a web-based system, the open source application is suitable for any operating system. In addition to text file outputs for database and statistical analysis, data summaries include heat maps for the location of the detections. False detection rate was higher than desired, and detection capability of fish was limited to those that were available in the training datasets. The goal of reaching the 30% false-positive rate was not reached, and algorithms trained by two of the datasets did not successfully detect targets when applied to all of the datasets. These false positives were primarily attributed to detection of the RivGen due to its rotation and changing ambient conditions during optical monitoring. This is a significant challenge since the use of artificial light could have an impact of behavior in this context. This challenge highlights the need for careful implementation. The detector also needed to be trained and evaluated on each dataset before use. This could lead to a significant investment of labor initially for each site, but would improve over time. Regardless, improvements in detection statistics will be successful application to a broader range of relevant data.

MHK REGULATORY INITIATIVES ANALYSIS

(WBS #: 2.3.2.603)

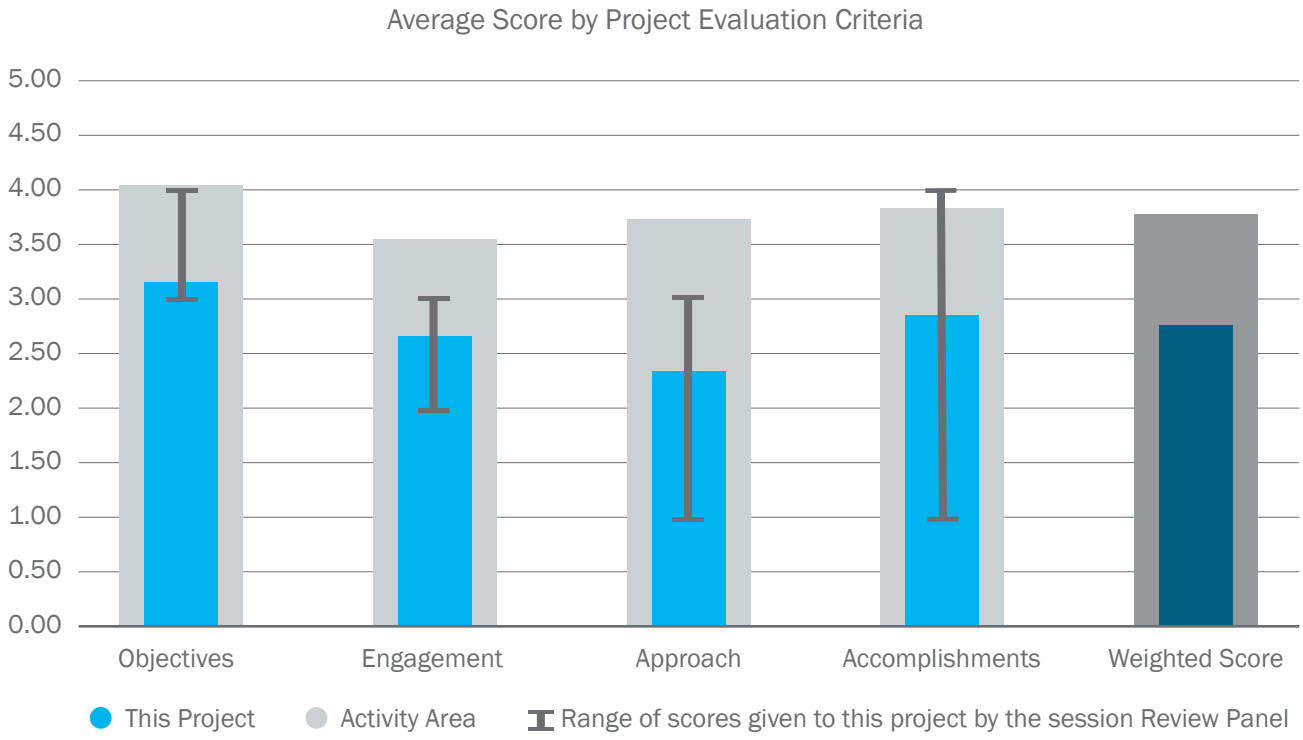
Recipient:	PNNL
Principal Investigator:	Bo Saulsberry
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$222K
Total Costed:	$211K

Project Description

The MHK Regulatory Initiatives Analysis project was created to review current regulatory conditions for MHK development, identify opportunities for greater regulatory success, and provide a set of recommendations for potential R&D that DOE might undertake in the near term to reduce the cost and time of regulatory activities. The project resulted in two laboratory publications—a formal literature review and a report detailing over 35 forward-looking regulatory research topics and potential actions—as well as an update to an existing compendium of state and federal regulations governing MHK projects, the *2019 Handbook of Hydrokinetic Regulatory Processes* (Publication Number DOE-EE1793).

Weighted Project Score: 2.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers did not feel that they received sufficient information to review this effort. Some reviewers acknowledged that this was likely a project that should have been exempt from the Peer Review, as the main purpose of the research was to inform internal WPTO decision making. The only external-facing product from this project was the update to the permitting handbook, which reviewers agreed was a valuable product.

The project was focused on using the results of interviews with industry and regulator representatives to inform the PI's programmatic recommendations to WPTO. While this is a good initial approach, the interpretation of the interview data could be subjective. A significant component missing from the presentation was the project's results beyond vague statements about the state of the regulatory environment. The presenter's discussion on technical achievements did not include details on the key findings, which made it difficult for the reviewers to evaluate this project.

The real challenge lies in making recommendations of best investment approaches to address the overarching themes in the matrix. The addition of this task would have made this a more valuable project. The approach would have benefitted from initial end user engagement. Result validation with the regulatory/stakeholder groups would benefit the products, particularly if they will be shared outside of DOE.

Some reviewers thought there may have been some overlap in scope between this project and the "MHK Environmental Compliance Cost Assessment" project.

Project Objectives, Impacts, and Alignment with the Program Strategy

The project aligns with the overall program strategy, and the major contribution to the MHK community is the release of the Handbook. The project performers have considered and described the use/applications of their expected products and outputs. Regarding the report to DOE, the project performer's results were largely focused on DOE as the internal end user. Therefore, the application is purely internal agency guidance that may not be the best strategy in the regulatory view. Further, the interviewees or the regulatory community did not have the opportunity to provide feedback on the product. The resulting recommendation matrix in the synthesis report was underwhelming and did not make any significant recommendations on how to advance the knowledge of the overarching themes presented.

End User Engagement and Dissemination Strategy

The project performers identified and directly interviewed over 30 interviewees with a variety of stakeholder interests, representing a broad range of industry and regulator representatives. The choices made in direct stakeholder engagement were clearly made with the goal of representing a sufficiently diverse group of individuals to identify points of consensus or diverging attitudes about particular regulatory issues. A missed opportunity in this project was the lack of engagement with the regulatory entities to shape the project, which would have enabled buy-in and possibly the actual modification of policy/process. Stakeholders were engaged in the second phase of the project as interviewees; however, communication back to the end users on the results is unclear since the products to date are 'inwardly' facing. Further, there should be end user engagement to achieve the goal of the project. An oversight or advisory group would have improved this project.

Management and Technical Approach

The project performers have implemented technically sound R&D approaches. The whole project was focused on using the results of the interviews to inform the recommendations. While this is a good initial approach, the interpretation of the interview data can be subjective and biased. Reviewers recommended that the project performers have a feedback loop with the interviewees. This would have been a stronger project if there was a steering group, composed of peers and regulators that summarized the interview comments in the final report. The project outcome included two publications to DOE; however, it was not clear to reviewers whether the publications will be used to inform program strategy. It is possible that the Handbook will be reviewed by a significant number of regulators.

Technical Accomplishments and Progress

The project performers have made progress in reaching their objectives based on their project management plan, which included two publications; however, the project timeline was lengthened and shifted due to personnel rotations. While significant research products were described, no substantive information about key findings was presented. The primary results that were reported were quite vague and were mostly limited to broad statements that could have been identified by those familiar with the industry without having gone through the research program described. Likewise, the lack of discussion of the findings in the context of the evolution of the regulatory environment makes it difficult to identify the significant of the contributions from this work. The valuable product of this project is the update to the Handbook.

HYDRODYNAMIC AND ACOUSTIC MODELS FOR QUANTITATIVE ENVIRONMENTAL ASSESSMENT

(WBS #: 2.3.2.701)

Recipient:	SNL
Principal Investigator:	Jesse Roberts
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	$2,321K
Total Costed:	$1,889K

Project Description

The project fulfills an industry need for methodologies and open-source software tools that quantify, a priori, the effects of MHK-device interactions and MHK-generated noise in marine environments. The tools also support MHK-device design and array layouts to minimize environmental effects incurred through altered hydrodynamics and acoustics. The state-of-the-art modeling tools support accurate characterization, screening, and mitigation of environmental risk, while providing for cost-optimized MHK project planning that maintains environmental compliance. Ultimately, quantifying and minimizing uncertainty in regulatory processes increases investor confidence and decreases project risks, thereby improving developer funding and commercialization outlooks.

Weighted Project Score: 3.9

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.

Summary of all Reviewers' Comments

Overall Impressions

The reviewers generally acknowledged the potential utility and complexity of these tools and seem positive about this project and the progress it has made. There are however some concerns about how the tool gets used. Three of the reviewers were concerned about who ultimately uses these tools. One recommendation was that only experienced users who understand the specific models should use them to ensure that erroneous input parameters aren't used and that outputs are properly interpreted. One reviewer raised a concern for how these tools would be supported in the longer term (bug fixes, training, etc.).

Project Objectives, Impacts, and Alignment with the Program Strategy

The review team agreed that the project performers described how the project contributes to the program's strategy; they considered the application of their products, and the project was relevant. Two concerns were raised about how this software is ultimately used. Both focused on the potential misuse of the software by non-expert users.

End User Engagement and Dissemination Strategy

The reviewers generally agreed that there has been outreach to industry and regulators, but were confused about outreach beyond that. There seems confusion in terms of what outreach has happened already and to whom and whether developers or other end users will have the capacity to use this kind of a tool.

Management and Technical Approach

Generally speaking, the reviewer found the project performers have implemented a technically sound research approach and project management plan. One reviewer felt there was not sufficient information to evaluate the management plan. Two reviewers raised concerns about the risk metric. One suggested engaging with the regulator to understand how they might want risk measured. The other asked that the project team provide details of how risk is measured.

Technical Accomplishments and Progress

All reviewers agreed that significant progress had been made in developing these tools, and objectives/milestones have been reached. One reviewer raised concerns about the risk metric and how various risks are combined into a single metric. One reviewer reminded the project team that tool validation will be particularly important before the tools are rolled out, while another reviewer commented that they were happy with the model validation to date.

Future Work

The review team generally agreed that future work was well outlined, with a few comments that more details were needed. One reviewer suggested an a priori decision on how the metric of tool 'uptake' is evaluated to determine success. Another reviewer raised concerns about how the risk metric is developed.

MHK ENVIRONMENTAL COMPLIANCE COST ASSESSMENT

(WBS #: 2.3.2.702)

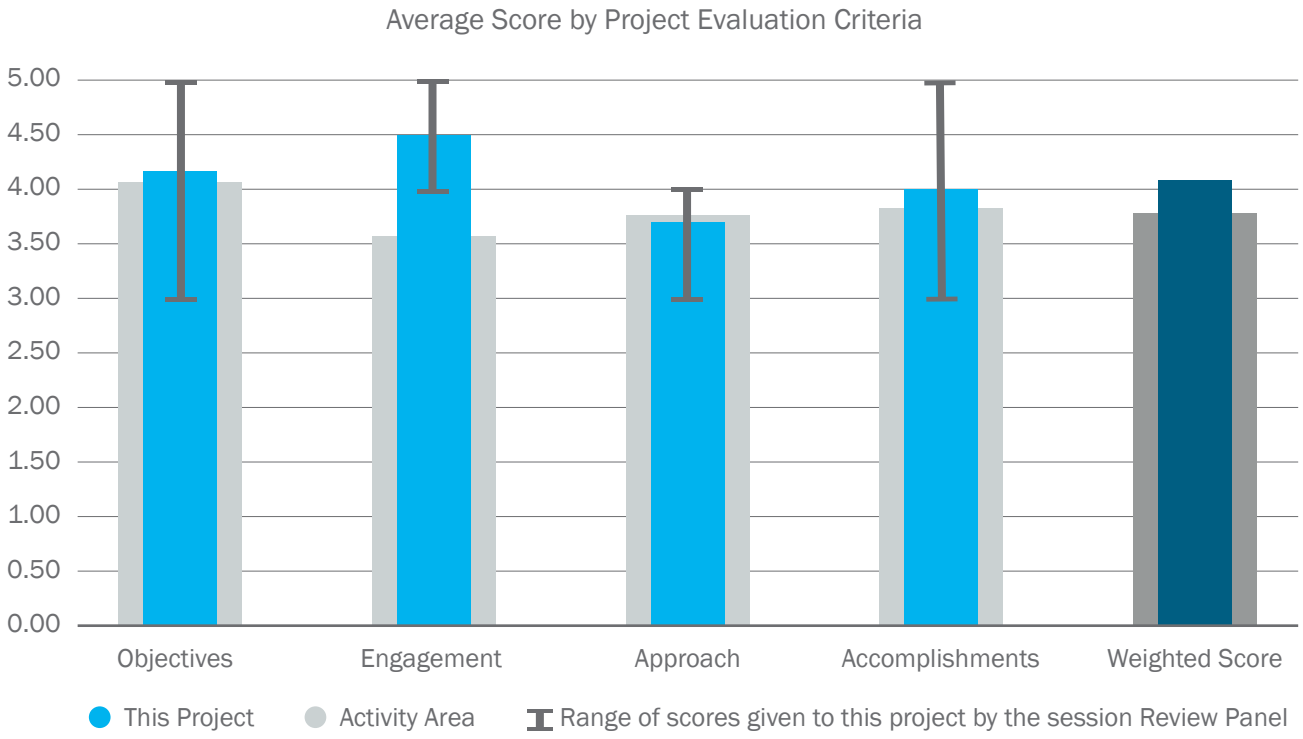
Recipient:	SNL
Principal Investigator:	Jesse Roberts
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$1,637K
Total Costed:	$1,246K

Project Description

This project seeks to reduce time and costs associated with successfully licensing and permitting MHK developments and maintaining environmental compliance throughout its lifecycle. This is accomplished by understanding the regulatory process, key costs, and their environmental uncertainty for licensing/permitting, monitoring, and license implementation. Strategic representatives from the MHK industry and state and federal regulatory agencies are engaged to gather first-hand, detailed data on environmental compliance costs and regulatory concerns, which are central to the development of successful cost reduction strategies, or the identification of improved effectiveness and permitting and compliance. Further, the project team benchmarks permitting and compliance costs with other renewable and marine technologies to understand their costs and how they changed over time with the technologies' advancement, regulatory processes, and project deployment experience.

Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The project was uniquely positioned to inquire in detail about what information would be needed to reduce regulatory burdens and to investigate what the broader impacts of those costs would have been to projects. Each project is, and will continue to be, unique in the sense that different sites have different social and political pressures, as these are complicated issues. It would have been helpful to have more details about what level of information would be acceptable in terms of risk from a management perspective.

Additionally, it would be helpful to come full circle and seek regulatory concurrence on the prioritization and action plan. Two reviewers commented that it may be helpful to investigate synergies with the emerging offshore wind regulatory processes. Additional project cost data from other small MHK deployments could be included to refine the project cost trend lines. The presenter linked the data to an LCOE comparison; however, based on WPTO's interest in discovering alternative metrics to LCOE, future linkages could be made with more complementary data.

Project Objectives, Impacts, and Alignment with the Program Strategy

The purpose of this project is to collect cost estimates associated with permitting, environmental monitoring, and similar issues from previously WPTO-funded projects, then use this information to identify approaches for increasing the effectiveness and efficiency of permitting processes in a quantitative way.

The project performers described how the project contributes to the program's approaches and showed good connection to Tech-Specific Design and Validation via cost estimates of permitting throughout the project's lifecycle. Two specific approaches to reduce barriers to testing include addressing regulatory efficiency and leveraging baseline data to inform future opportunities to reduce costs. Information from other sectors was used to inform strategies in the project. They used data collected to identify cost reduction strategies to improve the process for the industry and regulators. In the end, it was difficult for the reviewers to determine if the objective was fully achieved because of the limited amount of data that could be collected. Explanation of relevance and how the project will advance DOE's direction was very well done. Overall, this project will work across multiple applications.

End User Engagement and Dissemination Strategy

End users were engaged from the beginning of the project. The project performers have identified who will benefit from this project and how the success of the project will advance the industry or meet the needs of specific stakeholder/end user groups. The project team defined the end users and stakeholders, discussing how they are integrated in the overall project to be as transparent and end-user-focused as possible. The project team conducted interviews for 19 projects to get a diverse perspective on costs and challenges that are affecting MHK projects. The project performers have clearly described the rationale for the stakeholder/end user engagement strategy and how project results and information have been/are planned to be disseminated.

Project performers successfully engaged industry to identify their costs, which was a particularly valuable exercise. The project included an iterative process to inform, rank, and prioritize strategies.

Management and Technical Approach

Project performers had a comprehensive approach to determine permitting costs, as well as to identify and develop cost reduction pathways with a good management team. The stakeholder engagement approach was strong. Project responsibilities and division of labor among project participants appears well defined. Critical to the project was the participation of individuals involved with prior projects. To ensure that the results were representative, it was necessary to draw from the experiences of as many stakeholders as possible.

The benchmarking and quantitative economic analysis was less clear in the text. It was unclear how the lack of data affected the process and results.

Technical Accomplishments and Progress

The project is sunsetting, and the project largely accomplished its goals by collecting and analyzing information from a range of different projects. Project performers assessed costs for each category and have begun to make near- and long-term investment strategy to ultimately reduce costs. They demonstrated linkages in strategy, hosted a workshop, and developed an action plan. Project products were summarized, but additional information about key results would have been helpful.

There was limited quantitative information on the comparison of MHK project environmental compliance and permitting costs to other industries (e.g., other renewables or offshore oil and gas) or to other countries. Several reviewers commented that the "interconnectedness" diagram and linkages were not effective but recommended a social network analysis. Additionally, it would have been helpful to see concrete examples of cost savings.

MARINE MAMMAL BEHAVIORAL RESPONSE TO TIDAL TURBINE SOUND

(WBS #: EE0006385)

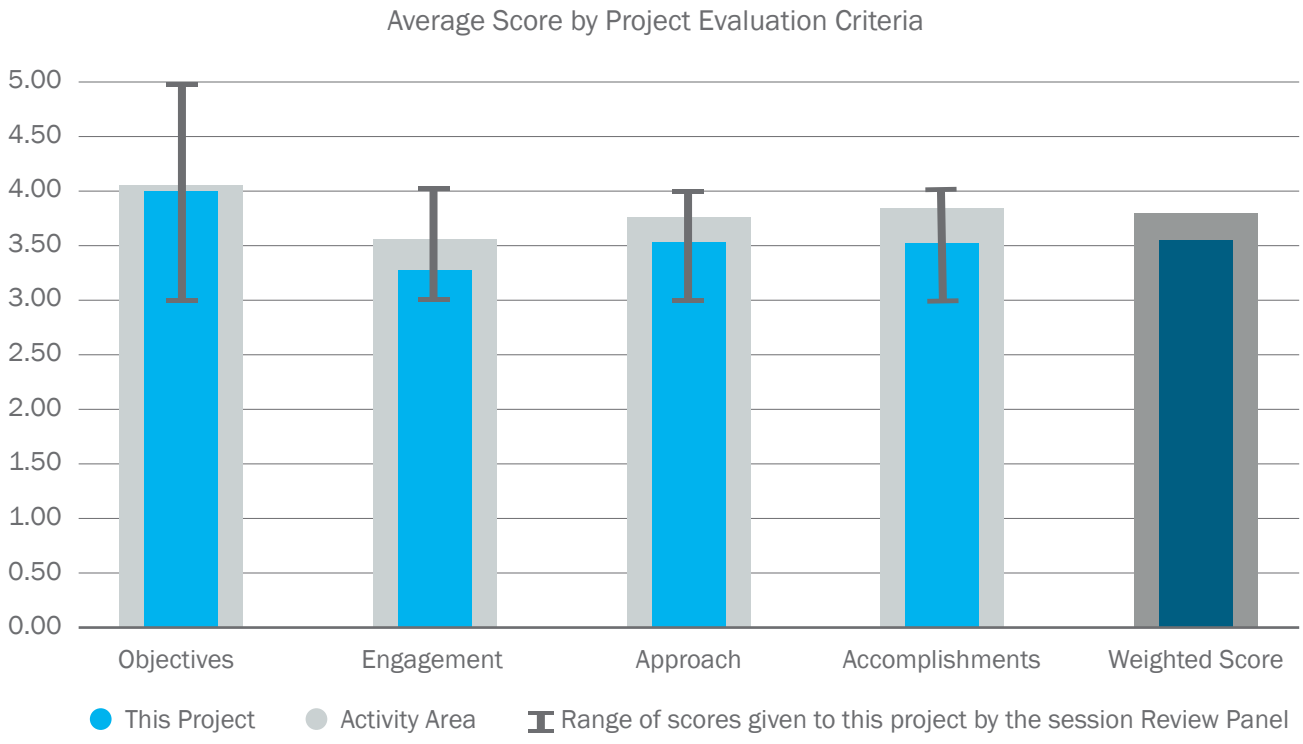
Recipient:	University of Washington
Principal Investigator:	Brian Polagye
Project Type:	FOA 816: Marine and Hydrokinetic Environmental Effects Assessment and Monitoring
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$500K
Total Costed:	$495K

Project Description

Originally conceived as a study of marine mammal behavioral responses to the sound produced by a small array of tidal turbines, the project was re-scoped to evaluate behavioral responses to a playback of turbine sound in Admiralty Inlet, Washington. Results suggest that harbor seals are unlikely to show a measurable response to turbine sound with a broadband source level of 158 dB re 1 µPa (0.030–10 kHz). An avoidance reaction to a range of 300 was observed for harbor porpoises during the initial trial, but this declined during the second trial and was not observable in the third.

Weighted Project Score: 3.6

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The project aligns with the overall program strategy and provides data on behavioral response of harbor porpoise and harbor seals to simulated playback of turbine sounds. There was overall concern about end user and scientific peer review engagement at the beginning and throughout the study. Regulators should be considered end users and should provide feedback on the study design and how the results would be interpreted in making policy decisions. There were sample size concerns, with a limited number of playbacks per seasons, and there were observer bias concerns from the visual presence of the playback boat without any controls. There was no mention of how the responses were scored or how their approach compares to the approaches of other marine mammal behavioral response studies. The results of this study need to be published in a peer reviewed journal to be considered by the regulators. Reviewers recommended an additional field year of data collection and an advancement of the methods to mitigate observer bias from the boat presence.

Project Objectives, Impacts, and Alignment with the Program Strategy

The project performers have described how the project contributes to the program's strategy/approaches. Reviewers generally agreed that the project aligns with the overall program strategy. The major contribution is the assessment of behavioral response of two marine mammals to a simulated MHK signal. The project performers have considered and described the use/applications of their expected products and outputs. Results would be used to inform the regulators and action proponents about the potential behavioral impacts. However, several reviewers expressed concern about regulator engagement and the ability to "retire risk" from one study. The project performers have presented the relevance of this project and how the successful completion of the project will advance the state of technology, provide meaningful impacts, and/or contribute to the viability of any commercial applications.

End User Engagement and Dissemination Strategy

End users were listed as researchers and consultants who implement monitoring requirements. However, there was no mention of outreach to the end user community at the onset of the study to seek feedback. Only one peer review presentation was given in 2017. The project would benefit from presentations at relevant scientific conferences. Reviewers felt that the regulators should be considered an end user, and they should be given the opportunity to comment on the study design and analysis from the beginning. Results need to be published in a peer reviewed journal.

Management and Technical Approach

Despite the project's challenges, it appears to be very well managed. The project was forced to abandon its planned study in Europe due to the financial instability of the project partner, and the project team found a way to move forward in local waters with a turbine sound play-back approach. Observer bias based on presence of playback ship needs to be evaluated. While the PIs made the best of the situation they had, there is a big concern that playing back sounds collected in a River in a Bay system (even amplified) is not appropriate, and the reviewers questioned how relevant the responses observed will be for future applications in that Bay or even in a river situation. Seasonal changes in behavior could explain the change in responses of harbor porpoises. The timeframe for the project was not long enough to tease out these differences. Behavioral response severity scoring (such as in Southall 2007) should be considered in evaluating response data. As such, retiring or even reducing the uncertainty of acoustic production by turbines cannot be discerned with this study. The project duration should be extended to repeat project over different seasons and repeat seasons to have adequate sample size.

Technical Accomplishments and Progress

The project team has completed their stated modified and constrained project objectives. The performers overcame significant challenges in the study design and ultimately reverted to a simulated playback of the turbine. They effectively set up the experiment to conduct three trials within one year. However, this is a limited sample size when considering seasonal variability, breeding state, the effect of boat presence, and observer bias because the observer is not blind to the presence of the stimulus. There was concern from several reviewers if playback, with amplification, was the right approach. The project performers have described their most important accomplishments in achieving milestones, reaching technical targets, and overcoming technical barriers. Much of the focus was on effective source simulation and assessment of transmission loss. Very little data was presented in how the observations were conducted and response scored. There was limited focus on publishing the results, and this should be a main goal of this project. For the results to be utilized, they need to be published in a peer-reviewed journal.

NOISESPOTTER: COST-EFFECTIVE, REAL-TIME ACOUSTICCHARACTERIZATION AND LOCALIZATION SYSTEM

(WBS #: EE0007822)

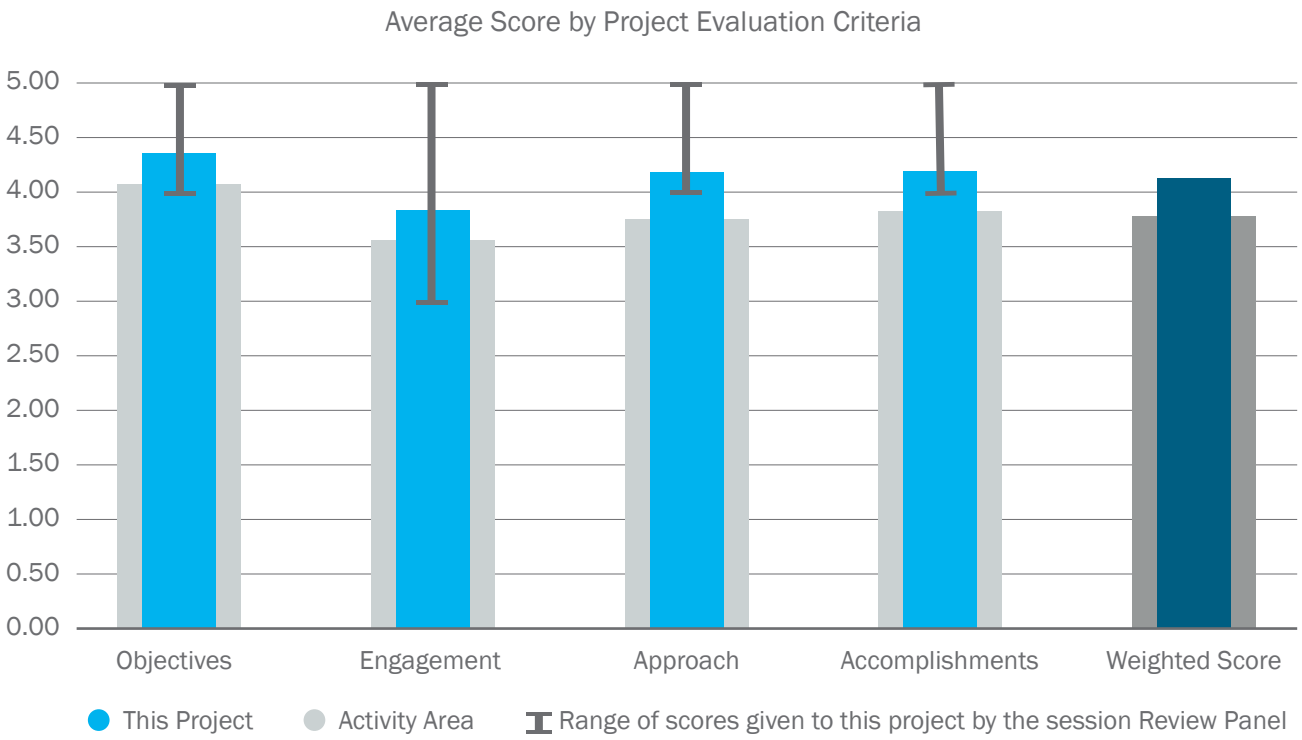
Recipient:	Integral Consulting Inc.
Principal Investigator:	Kaustubha Raghukumar
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$945K
Total Costed:	$710K

Project Description

The primary objective of this project is to develop a cost-effective, fit-for-purpose environmental monitoring system that characterizes, classifies, and provides accurate location information for anthropogenic and natural sounds in real-time. "NoiseSpotter" has been developed to support the evaluation of potential acoustic effects of MHK projects. By utilizing a compact array of three acoustic vector sensors, NoiseSpotter triangulates individual bearings to provide sound source localization, allowing for the ability to discern MHK device sounds relative to other confounding sounds in the environment, while providing location estimates to nearby marine mammals for environmental mitigation purposes.

Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The project team used a technically sound R&D approach to develop a system with a real-time passive acoustics array to characterize noise from MHK devices. All reviewers agreed that this was a well-executed project, which met or exceeded all of its technical goals. The ability of the system to localize sources to within 4 m at a range of 300 m is considered valuable. The NoiseSpotter is viewed as an interesting and promising system to measure noise from MHK devices.

Two general concerns were voiced by the reviewers: (1) that the flow-generated noise of the device was still too high for it to be suitable to characterize MHK devices in tidal energy sites with strong currents, and (2) that the system can only measure up to 3 kHz, while marine mammals' hearing extends to higher frequency, and some MHK devices may generate sound at higher frequencies as well.

Project Objectives, Impacts, and Alignment with the Program Strategy

The accurate measurement of radiated noise from MHK devices remains a significant challenge. The project performers are developing a system, called NoiseSpotter, which uses a real-time, passive acoustics array that can characterize noise from MHK devices at lower cost than comparable systems.

There was consensus among reviewers that the project aligns well with the overall WPTO strategy of reducing barriers to testing and demonstration deployments. The product would allow the MHK industry and regulators to assess acoustic impacts to fish and marine mammals, and thereby address a significant environmental concern. The product could be used both in MHK site characterization and for device noise measurements (i.e., environmental impact assessment). Compared to a single sensor, the vector array allows sound source location, which is necessary to distinguish MHK noise from other sounds.

Most reviewers thought that the successful development of this system will advance the state of the technology and have a meaningful impact in reducing barriers to testing and advancing the MHK industry.

End User Engagement and Dissemination Strategy

Reviewers generally agreed that the project performers identified industry needs and regulatory questions, as well as project beneficiaries.

The project team clearly described how project results have been disseminated to date. The majority of the reviewers were satisfied with the level of end user engagement and surveying of end user needs, although two reviewers questioned whether the dissemination of information about the system at various conferences and workshops allowed for true engagement of relevant stakeholders, as no outcomes of this type of engagement were reported.

The survey of industry and regulator needs was viewed positively, albeit one reviewer noted that it was not included in the milestone table and expressed concern whether sufficient importance was placed on this task.

Management and Technical Approach

The reviewers agreed that the project was well managed and executed by a capable research team. The R&D approach was viewed as technically sound by all reviewers. A strategy for development, testing/validation, and end user feedback was incorporated into the management approach. While one reviewer praised the clear and well laid-out milestone table and schedule, another commented that it was not clear from the milestone

table whether the quantitative metrics to be used for decision making will be developed with input from stakeholders beyond the initial surveys.

A risk that was brought up by all reviewers (which was also extensively commented on under "Technical Accomplishments and Progress") was the issue of flow-generated noise. When compared to drifter hydrophones, e.g. DAISY, the NoiseSpotter has a significantly higher flow noise (between 20 and 40 dB higher). The flow noise reductions that were achieved with the NoiseSpotter make it suitable for wave environments and WECs, but not for energetic tidal sites. Two reviewers recommended establishing a metric to determine performance/utility for environments with strong currents (beyond the technical target table). Another risk that was mentioned was that the frequency response of the system, only goes to 3 kHz, while most of the acoustic energy from MHK devices will be below 3 kHz, marine mammal hearing goes to higher frequencies.

It was viewed very positively by all reviewers that the system has undergone a good amount of field testing already, and will undergo further testing with a deployed WEC at WETS.

Technical Accomplishments and Progress

The reviewers commended the project team on their accomplishments and agreed that the project met or exceeded its technical goals.

The system achieves a 50% cost savings over the baseline system. It can localize noise sources to within 4 m over a 300 m distance. A flow-noise reduction of 10–15 dB was achieved so far, but this is still a 20–40 dB higher flow noise than for the DAISY drifter.

The project performers clearly described their engineering goals and how they overcame technical barriers in a table that compares the current system scores to their target sores.

DAISY: A DRIFTING ACOUSTIC INSTRUMENTATION SYSTEM

(WBS #: EE0007823)

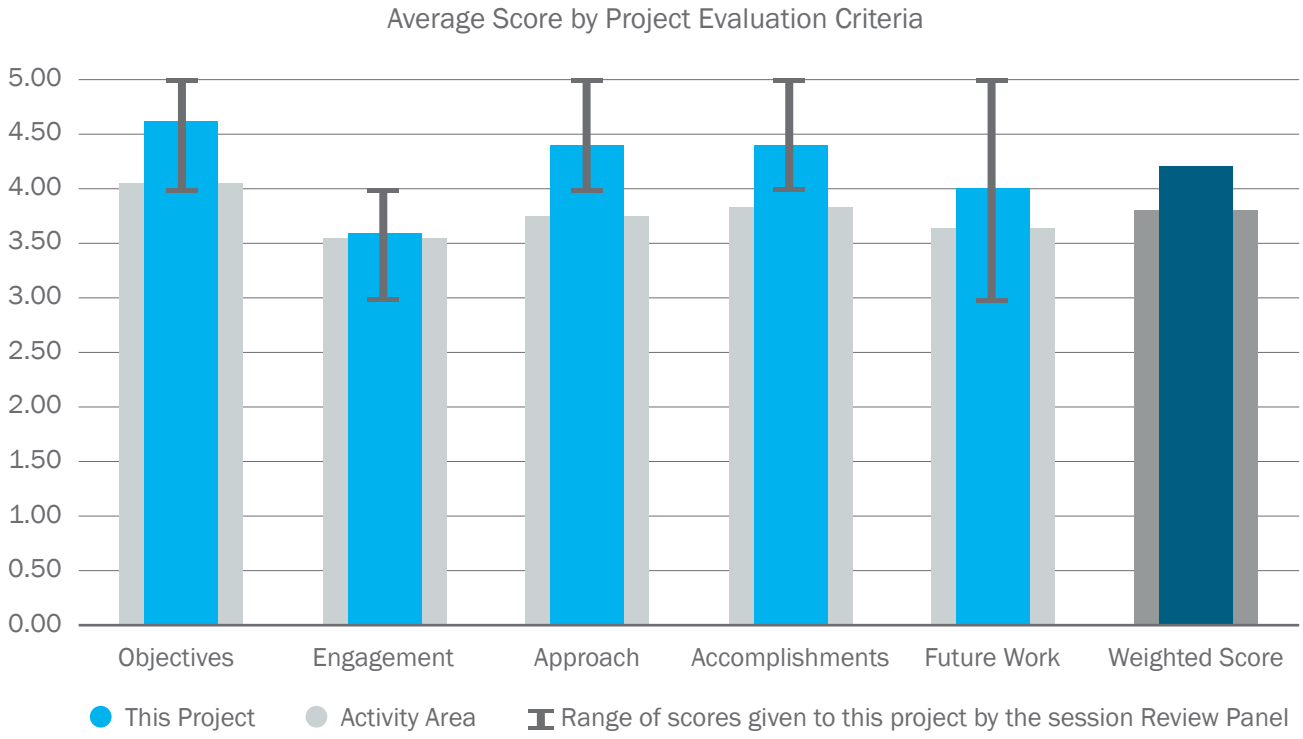
Recipient:	University of Washington
Principal Investigator:	Brian Polagye
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$835K
Total Costed:	$501K

Project Description

The objective of this project is to improve the cost effectiveness of high-fidelity measurements of underwater sounds in marine energy environments. To this end, the project team developed the Drifting Acoustic Instrumentation SYstems (DAISY) modular drifting system that can make accurate acoustic measurements in energetic waves and currents. Using arrays of georeferenced DAISYs, it will be possible to explore spatial variations in acoustic emissions from marine energy converters and localize these emissions to differentiate them from ambient noise. The latter is a critical limitation of existing measurement systems and their ability to retire environmental risks.

Weighted Project Score: 4.2

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The reviewers generally agreed that this project has been well managed and made significant progress. Particular strengths have been benchmarking and comparing to other technologies (e.g. the OSU spar buoy). A weakness that was noted by all of the reviewers was that similar technologies have been developed with support from other agencies and in other fields, and engaging with them could have avoided some duplication of effort and lessons learned.

Project Objectives, Impacts, and Alignment with the Program Strategy

All reviewers felt that this project aligned with the program's objectives (characterizing potential noise impacts) and that end use had been considered (a version for both current and wave devices have been developed).

End User Engagement and Dissemination Strategy

There was general agreement that engagement and dissemination on this project was good. However, one reviewer felt the engagement approach was unclear. Another reviewer felt the engagement was one way (via publications) with not enough feedback from regulators or developers. Two reviewers felt that outreach to related fields/equipment (e.g., sonobuoy) earlier on would have been beneficial. Reviewers felt that there are other interagency users that would be interested in this technology. The team should continue to think about who the end users operating DAISY would be and how they will be made commercially available. Broader, interagency application may foster commercial success.

Management and Technical Approach

All reviewers agreed that the management and technical approach were strong. Strengths that were noted included recovery from a delay due to component availability and benchmarking against the OSU spar buoy.

Technical Accomplishments and Progress

The reviewers agreed that the technical accomplishments and progress on this project have been strong. Two reviewers thought it was beneficial that this project compared the DAISY performance to other assets (e.g., OSU spar buoy, fixed hydrophones). One reviewer noted that some of the same technical challenges have been dealt with during NOAA and Navy projects and that these other projects could have helped inform the DAISY project.

Future Work

The review team was positive about the future testing of DAISY at WETS. One reviewer noted that dates were not given for this testing. Another reviewer asked how testing on a current energy converter device will be conducted in the future, and another reviewer suggested that it would be good to test DAISY at a current energy converterlocation.

LONG-RANGE TARGET DETECTION AND CLASSIFICATION SYSTEM FOR ENVIRONMENTAL MONITORING AT MHK SITES

(WBS #: EE0007824)

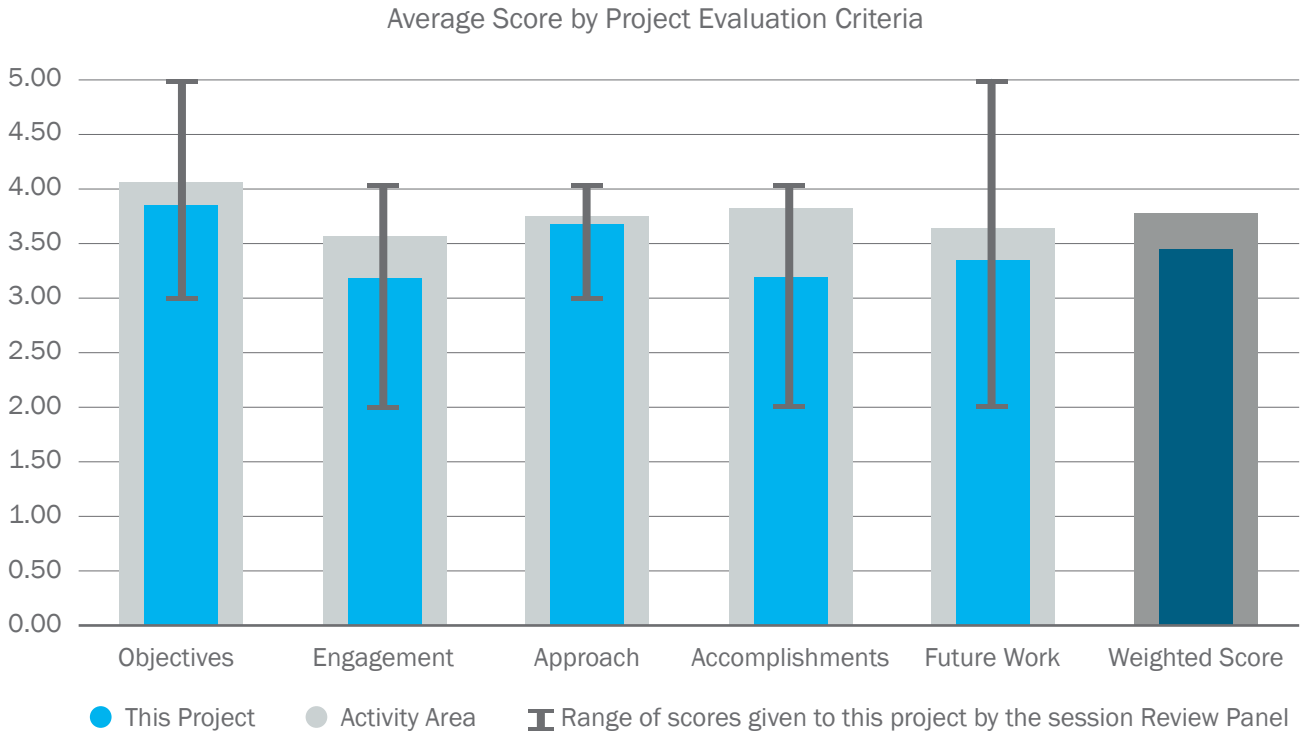
Recipient:	BioSonics, Inc.
Principal Investigator:	James Dawson
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$938K
Total Costed:	$762K

Project Description

BioSonics, Inc. will deliver a practical, robust, and cost-effective, long-range (200–300 m) active acoustic monitoring system, with innovative shaped pulse and Chirp capabilities to suppress off-frequency sound energy within the hearing range of marine mammals and to automatically assess marine life behavior at MHK sites. The one-of-a-kind sonar system successfully integrates a 360-degree perimeter detector to automatically detect and geolocate targets at range and a focused split beam directed classifier to track and classify target types. Initial target type classification is accomplished by analyzing target size, swimming speed, and behavior. Further target classification is accomplished by analyzing the phase coherence from reflected echoes via the split bream technique (i.e., point source versus nonpoint source targets). The system will automatically send low bandwidth, real-time reports on detected targets to project operators.

Weighted Project Score: 3.4

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The greatest strength of this project is the large detection range of large marine animals, which has the potential to improve monitoring around MHK sites. The greatest weakness is that there are still side lobes from the sonar that will be audible to many of these large animals. These side lobes have not been adequately addressed (from a biological perspective), and the use of this technology at WETS needs to be considered before deployment. Reviewers questioned if the system still has the potential to alter behavior of marine mammals and if a permit has been secured for the WETS testing.

Project Objectives, Impacts, and Alignment with the Program Strategy

The review team generally agreed that this project successfully described how it contributes to the program's strategy and approaches. There was less consensus on whether the project performers considered and described the use and applications of their expected product. Three reviewers agreed that this project has considered its use and application, while two reviewers did not specifically address this criterion, and one felt that this project had not sufficiently considered use and application in terms of concerns about the ability of marine animals to detect the side lobes of this sonar technology. There was most concern about the chance of success of this project in advancing the state-of-the-art technology and its impact and/or commercial applications. The concern here was not that a successful project would not have impact but rather that there seemed to be some doubt about the ability of this project to adequately deal with end user concerns (e.g., regulators), and some of this doubt was caused by not enough detail from the project.

End User Engagement and Dissemination Strategy

There seemed to be general agreement that this project has identified its beneficiaries. The reviewers also agreed that MHK developers and technical stakeholders were engaged, but the regulators and biologists (i.e., other stakeholders) were not engaged adequately or in a meaningful way, and the project team needs to address this.

Management and Technical Approach

Reviewers also agreed that the project performers had a sound project management plan and used a technically sound approach. Four of the reviewers raised concerns about the out-of-band noise from this sonar technology. These concerns were largely focused on regulator/biologist buy in and their concerns about audibility of these out-of-band peaks to marine animals and whether it was technically feasible to reduce the out-of-band peaks sufficiently.

Technical Accomplishments and Progress

Reviewers generally agreed that the project has been reaching its milestones and making progress, but there was still general concern about the metrics being used to describe success. One reviewer thought the metrics of success should relate out-of-band noise to marine mammal hearing thresholds.

Future Work

In general, the reviewers were positive about the next steps of testing at WETS. However, half of the reviewers raised questions about how marine mammals will be managed during the WETS testing (i.e., will they need special permits, or will a shutdown be needed for mitigation is unknown). Reviewers were generally interested in more details on this planned testing at WETS.

A COMBINED ELECTRIC/ MAGNETIC FIELD INSTRUMENT FOR MHK ENVIRONMENTAL MONITORING

(WBS #: EE0007825)

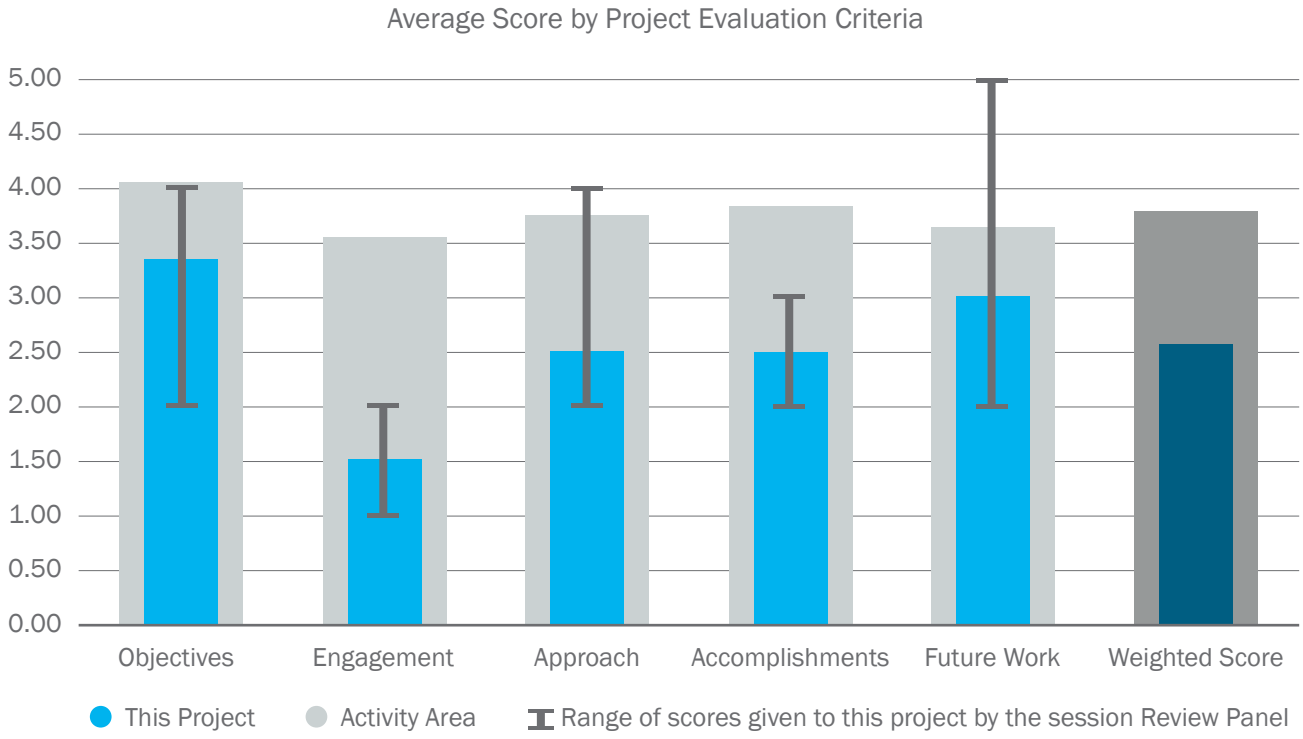
Recipient:	Woods Hole Oceanographic Institution
Principal Investigator:	Alan Chave
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$833K
Total Costed:	$668K

Project Description

The scientific/technical goal is measurement of the direct and indirect effects of MHK systems on the seafloor vector magnetic and electric fields with a resolution of 0.1 nT and 0.1μ V/m, respectively, over the range of 10-4-100 Hz. An instrument design that is a modification of a Technology Readiness Level 9 one designed and built at WHOI was proposed. Four units of the instrument were constructed and tested at PNNL during Budget Periods 1 and 2. In addition, a Geometrics G-882 scalar cesium vapor magnetometer with altimeter was used to measure the magnetic field in the water column.

Weighted Project Score: 2.6

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

The project team demonstrated an insufficient understanding of biological considerations of their work, and the presenter seemed to have a general lack of knowledge of the overall project. A biologist should have been included on the team (mentioned by three reviewers). End user engagement was dismissed, along with the need to consider stakeholders and their needs. Reviewers recommended that the project team set criteria of what they plan to accomplish at WETS based on lessons learned at PNNL before moving forward. This project needs a better developed end user strategy since right now it is solution seeking for a problem that is not well defined. Project performers should work to better demonstrate how their project fits into the WPTO program. Tests should be made on cables at higher power levels (>10 kW). The project team should consider a more integrated approach to the application that would link to risk reduction associated with permitting. Such an approach would require engagement with regulators or biologists who could provide information on animal detection of electromagnetic field. There is a body of literature to consider in this area that the project team did not seem to be familiar with.

Project Objectives, Impacts, and Alignment with the Program Strategy

While some text was provided that linked reducing barriers to testing, particularly the ability to measure electromagnetic field from cables, project implementation did not link tightly to addressing larger program objectives. Two reviewers felt the project generally aligned with the program strategy. The regulatory nexus was not clearly stated, and the tool development did not consider the biological sensitivities that would be used for considering risk to animals. Additionally, reviewers felt that the performers had not considered biological level sensitivities and, as such, questioned if the project was addressing regulatory needs. The commercial viability of the technology was also not discussed.

End User Engagement and Dissemination Strategy

All reviewers were surprised at the lack of end user engagement and what appeared to be the performer's lack of understanding of how information would be used/applied by the MHK community. While regulatory concerns about the electromagnetic field were mentioned, equipment sensitivity or testing was not shaped around that need. The sensitivity of the equipment (uV/m) is well below what animals can detect, (e.g., nV/cm for sharks 9000 W). This needs to be considered/addressed. The threshold of sensitivity for the equipment should be determined with the regulators.

Management and Technical Approach

The management and technical approach included a single academic institution's management with quarterly interaction with WPTO staff for approval for testing. This approach seemed acceptable to most reviewers (3) but several mentioned the lack of a biologist on the team. The tool development and testing seemed appropriate for the academic development of a tool, but applied less to the overall goals of the program.

Metrics and standards for developing the tool should have been better vetted with a group from WPTO and/or regulators. Critical success factors seemed to be related to making something that would work, rather than a tool that is useful to achieve the goals at hand.

Technical Accomplishments and Progress

Progress toward stated objectives was made, and lessons learned were included for instrument simplification. As previously mentioned, reviewers were concerned about equipment sensitivities, as well as whether or not the project team was addressing regulatory needs.

Future Work

The majority of the reviewers noted that the future work plan was brief and did not include milestones. Most reviewers recommended that tests be conducted at sites closer to the home institution, near cables with higher power load.

BENTHIC HABITAT MONITORING TOOLS FOR MHK ENVIRONMENTAL ASSESSMENTS

(WBS #: EE0007826)

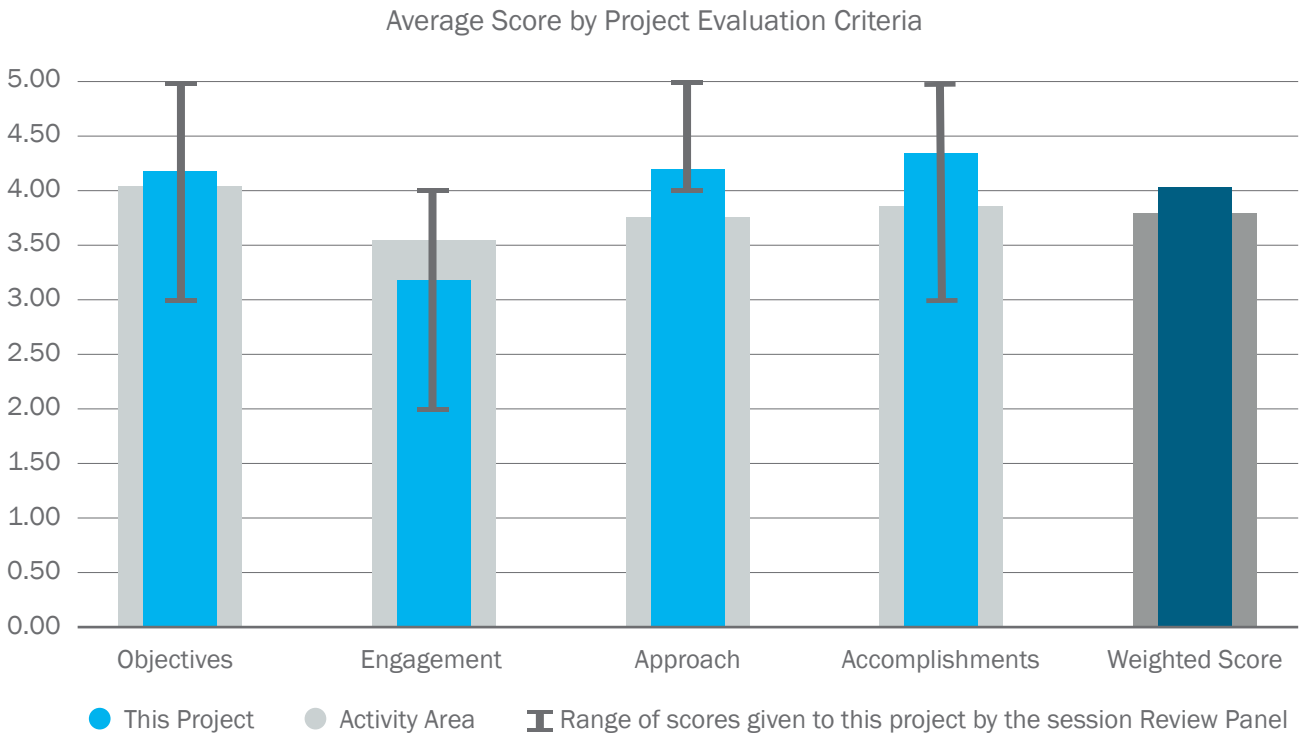
Recipient:	Integral Consulting Inc.
Principal Investigator:	Eugene Revelas
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Completed and Sunsetting Projects
Total Authorized:	$856K
Total Costed:	$632K

Project Description

The goal of this project was to develop a consistent and semi-automated seafloor survey method for generating high-resolution benthic habitat maps, essential for environmental assessments and monitoring of MHK sites. Sediment profile and plan view imaging technology was combined with multibeam bathymetry and acoustic backscatter methods to demonstrate a rapid, cost-effective benthic mapping protocol. A key technical innovation was the development of a computer-automated image processing platform that automatically identifies key features in the sediment profile images. We also designed and tested a prototype power sediment profile imaging camera that is effective in sampling firm substrates.

Weighted Project Score: 4.0

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



Summary of all Reviewers' Comments

Overall Impressions

The project performers described how the project contributes to the program's strategy/approaches, and they noted that the project aligns with the overall program strategy. Overall, the reviewers were impressed with the technical approach, management, and progress of this project. However, it was unclear on the regulators' needs for this tool at the WEC sites. The project team should be clear about the utility of this tool in MHK applications in that it is limited to certain bottom types that are more consistent with WEC device installations than current installations. It was unclear on how this technology will be transitioned to the broader MHK and scientific community beyond the technology developer, Integral Consulting. The reviewers recommended that the project team consider transitioning this MATLAB developed software into a standalone application if the target user group is beyond the development team.

Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers believe this project aligns with the overall program strategy. The major contribution is increased efficiency in processing benthic imagery data. The project performers have considered and described the use and application of their expected products and outputs, which they note are largely internal to the developers. Improvements in imagery automation would advance the utility of this method of benthic mapping. Applying these project techniques would result in more consistent and semi-automated benthic habitat surveys than current techniques. The project team was also able to quantify the project's impact in equipment costs and time savings (2 days without the tool vs. 37 minutes with the tool). Assuming lower costs when compared to traditional benthic habitat surveys, the use of a similar technique in other offshore industries suggests the approach could be more widely adopted. However, the tool is mostly limited to soft sediment. One reviewer felt it was not articulated what the current challenges are with respect to seafloor surveys and what the cost savings would be with the project. The tool itself is currently not available to the broader community as it's developed by a for-profit company. This raises future application concerns. They did not discuss commercial applications.

End User Engagement and Dissemination Strategy

The project performers have identified who will benefit from this project and how the success of the project will advance the industry or meet the needs of specific stakeholder/end user groups. They identified the stakeholders as the technology developers and project proponents, federal and state regulators, environmental groups, and the public. But they did not describe the technical end users of the technology. They plan to engage stakeholders for feedback through a webinar and include a regulatory outreach plan. The intent is to facilitate stakeholder acceptance. The performers also had a good variety of conferences/workshops in different sectors (e.g., dredging association) and had a follow-up questionnaire for regulators who attended the webinar. The reviewers felt the project team was missing further plans to disseminate results beyond the MRE industry. The reviewers felt that the end user was unclear, as the performer seemed to develop a proprietary system. It was unclear how the project fits within existing regulatory needs or guidelines (e.g., BOEM guidelines).

Management and Technical Approach

The project performers have implemented technically sound R&D approaches, and they have demonstrated and validated the results needed to meet their targets. The goal of this project was to design and test a computer-vision system to automatically extract data from sediment profile/plan-view imaging. The project team used an established means of defining criteria from manual methods of evaluating parameters (such

as grain size) and implemented automated routines to find and identify the features. The project performers identified a project management plan that includes well-defined milestones and adequate methods for addressing potential risks. The project performers clearly described critical success factors, which will define technical viability, and they explained and understand the challenges they must overcome to achieve success. The performers validated their tool with several approaches. They did not define success factors in their technical approach, but they listed technical challenges from the previous budget period that they wanted to achieve. A noted remaining challenge is securing funds to commercialize the sediment profile imaging camera used in budget periods 2 and 3 to penetrate firmer substrates.

Technical Accomplishments and Progress

The project performers have made progress in reaching their objectives based on their project management plan. They were able to automate the imagery processing and were able to evaluate the performance. They gave several examples of how well the imagery processing algorithm worked and provided a brief description of how the neural networks used in processing were trained. Everything except the biological features meet the performance criteria. However, specifying that it met performance criteria is not the only indication that should be evaluated. It would have been good to know the limitations of the system (i.e. missed and false classifications). The project performers have clearly described the progress since any last review period. Additionally, the tool has limited benthic habitat applicability (works with sandy bottom only) and will not be suitable for most tidal environments.

THIRD-GENERATION ADAPTABLE MONITORING PACKAGE (3G-AMP)

(WBS #: EE0007827)

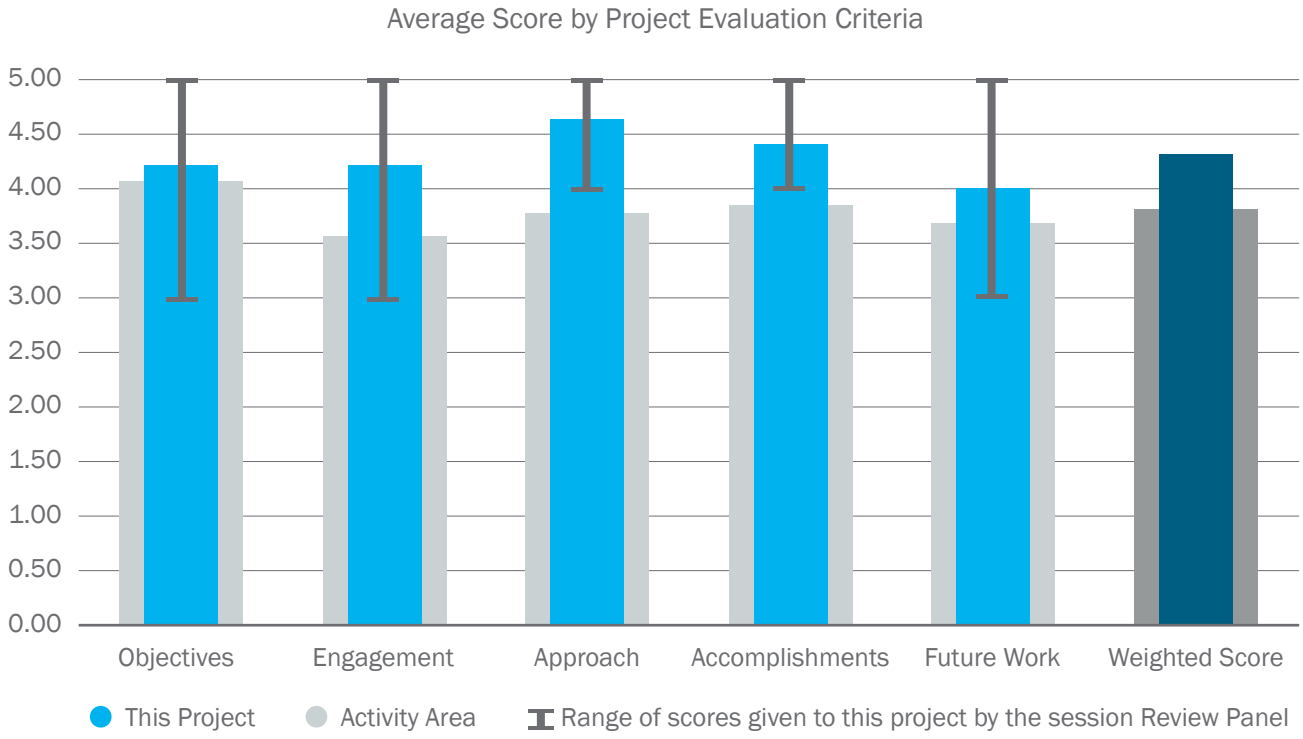
Recipient:	University of Washington
Principal Investigator:	Brian Polagye
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$1,555K
Total Costed:	$1,028K

Project Description

Retiring high-priority environmental risks for marine energy projects (e.g., collision, entanglement) requires environmental monitoring systems that can make observations without biasing animal behavior, capture important information about rare events, and archive only essential data. The third-generation Adaptable Monitoring Package (3G-AMP) achieves these objectives by classifying targets in real time using a modular approach to hardware and software. This has been demonstrated at PNNL's Marine Science Laboratory and will be deployed at WETS in the next phase of the project.

Weighted Project Score: 4.3

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.



Summary of all Reviewers' Comments

Overall Impressions

This project was well managed and leveraged for a good return on investment, despite many challenges. This relatively mature tool seems to be important to present to regulators carefully since there is some question of collecting lots of data, and perhaps that will impress the idea that all the data that can be collected should be without bounding the questions that might be used to help decision making for regulation. Since this is the third generation of the tool, and devices have not been in the water for true testing, the reviewers questioned if the need for the technology is still there, noting that it is important to frame the current regulatory questions for the tool. Progress on sensor integration and triggering, a primary goal in early generations of the tool, have still not been tested. It would have been good to see backbone costs quantified. The tool may be useful in other applications, and WPTO or the project team should consider discussions with other agencies (e.g., the Navy) to evaluate their needs for the tool. Moving to WETS may be good validation data, but may not be useful data collection since the tool's application has been focused on tidal sites.

Project Objectives, Impacts, and Alignment with the Program Strategy

The project is an application of a suite of environmental monitoring tools that could ultimately contribute to MHK site monitoring when devices are deployed. Goals were clearly defined; they were relevant to advance technology for commercial application; and they aligned with WPTO strategy. One way to quantify the impact of the project was presented as a cost reduction in monitoring, but cost reduction was presented relative to scaling the number of tools added to the backbone of the device, rather than overall costs. The true cost of operation and data analysis to provide answers to monitoring questions was unclear. This is a "Swiss army knife" of monitoring, with impressive capabilities, integration, and form factor. The question remains whether the monitoring goals could be attained with a simpler integration of fewer instruments. The technical approach built on previous success, and the reviewers thought it would be good to check in to be sure the utility of the tool is still relevant since its inception.

End User Engagement and Dissemination Strategy

End users are identified as consultants, regulators and, indirectly as developers, as permitting may be streamlined based on this. If the project team cannot quantify how this project streamlines/changes the permitting process, they need to update their impact statement. The developer and researcher communities were engaged at the start of the project to receive feedback prior to development, and the project team intends to for market the device to developers/consultants. Engagement has included discussions with researchers and developers, but not regulators (end user target). Other dissemination strategies include publications and presentations. One reviewer questioned the use of the "responsibly retiring risk" terminology when engaging additional end users to discuss the tool's future use. Several reviewers wondered what questions would be answered with the tool and felt that regulators should be engaged directly to define the questions.

Management and Technical Approach

The project team holds bi-weekly meetings, which reviewers felt was a great management practice. The project has a diverse group of knowledgeable participants building on previous success, and the team does a great job of leveraging additional activities and involving students. Milestones were defined and adequate methods for addressing potential risks to the project were provided.

Technical Accomplishments and Progress

There have been delays, but the project is on track for on time completion. The performers did improve automated detection performance and had a reliable device with 97% uptime, which impressed reviewers. However, target classification is still questionable. Reviewers questioned if regulators would accept the tool's rate of error and misclassification, and they recommended the project team evaluate this. In addition, the difficulty of getting the random forest classifier to work in different locations is worrying since training may be needed in each new location and perhaps even for different seasons (something to consider for all automated detection systems). The performers stated that they hope to demonstrate the ability to retire risk, but evidence that "retiring" any risk was not provided and is unlikely to be able to be provided in the timeframe of this project. As such, these types of statement should be avoided.

Future Work

Two reviewers wondered if the shift to WETS is the right next step. This tool was developed for current energy converters, and several reviewers suggested that the nearfield of a WEC may not be an effective monitoring strategy for a WEC. More details of how sensors will be evaluated there would have been helpful. However, the majority of the reviewers thought the WETS testing would be worthwhile.

UNOBTRUSIVE MULTI-STATIC SERIAL LIDAR IMAGER FOR WIDE-AREA SURVEILLANCE AND IDENTIFICATION OF MARINE LIFE AT MHK INSTALLATIONS

(WBS #: EE0007828)

Recipient:	Florida Atlantic University
Principal Investigator:	Anni Dalgleish
Project Type:	FOA 1418: Marine and Hydrokinetic Energy Conversion and Environmental Monitoring Technology Advancement
Project Category:	Ongoing Projects
Total Authorized:	$944K
Total Costed:	$492K

Project Description

This project will increase the technical performance and cost effectiveness of an optical monitoring system designed and validated for an MHK project lifecycle observation and automated in real-time for the classification of marine animals. This system, called the Unobtrusive Multi-static Serial LiDAR Imager can be deployed to collect pre-installation baseline species observations at a proposed deployment site with minimal manual post-processing overhead, such as feature detection and classification. To satisfy deployed MHK project endangered/threatened species monitoring requirements, the Unobtrusive Multi-static Serial LiDAR Imager provides automated tracking and notification of the presence of managed animals around MHK equipment and provides high-resolution imagery of their behavior through a wide range of conditions.

Weighted Project Score: 3.2

Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.