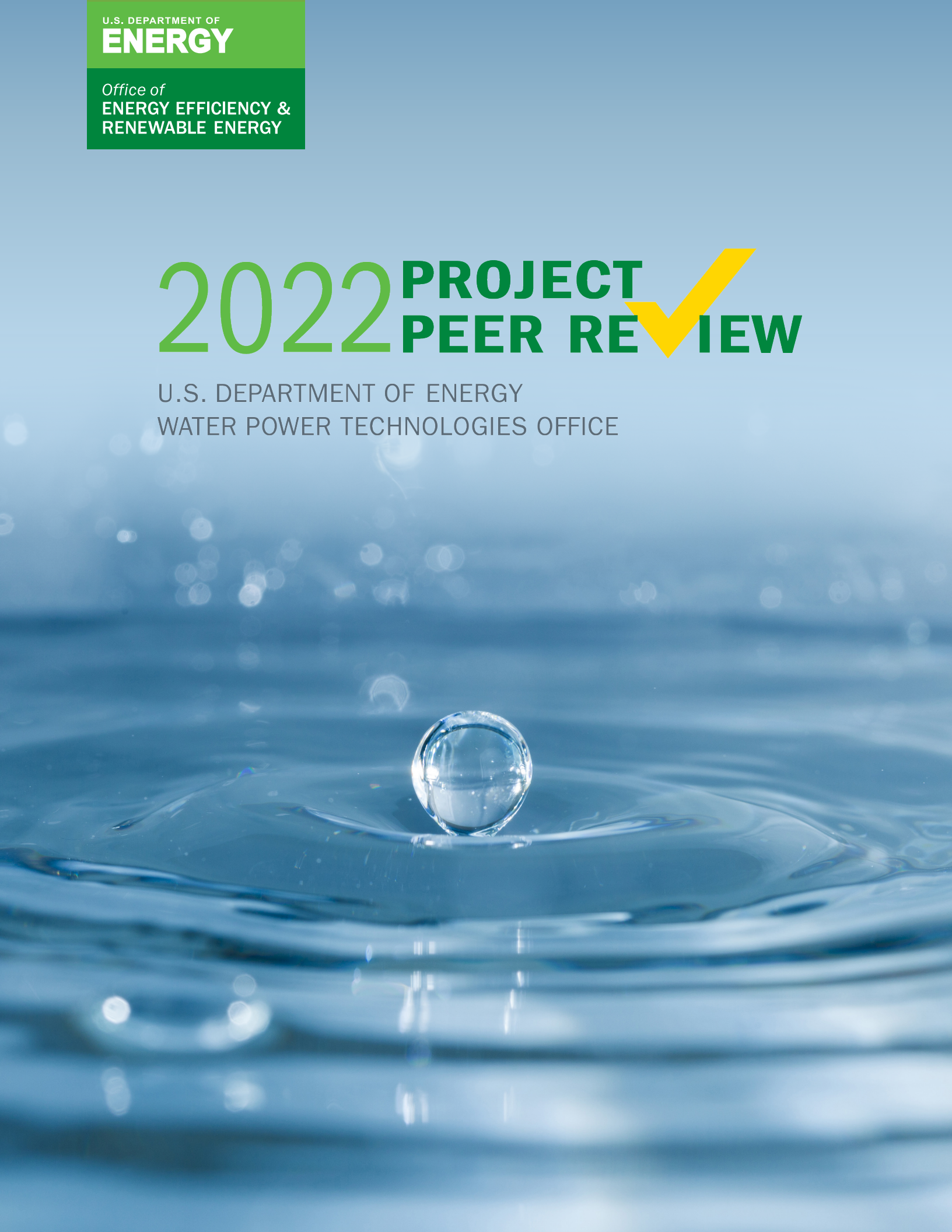
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

2022 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WATER POWER TECHNOLOGIES OFFICE



Disclaimer

Letter From The Director

Dear Colleagues:

On behalf of the U.S. Department of Energy's Water Power Technologies Office (WPTO), I am pleased to share the report from our 2022 Peer Review. Peer review is an opportunity for us to gain invaluable, expert input from external stakeholders on the direction and strategy of WPTO's Hydropower and Marine Energy programs. Their input helps inform our decision making, enhance our project management, and identify how we should consider modifying or expanding existing projects.

We hosted the 2022 Peer Review in July, and notably, this was our first peer review since fall 2019. We held this peer review virtually due to the COVID-19 pandemic, but this approach had the benefit of increasing participation from our stakeholders internationally. This was also our first peer review since we released our Multi-Year Program Plan (MYPP) in March 2022. This strategy outlines our research priorities and plans, and it served as an important resource for reviewers in contextualizing and evaluating our current portfolio of projects against our near- and long-term goals.

I am grateful to our reviewers for their thoughtful and constructive feedback, including on what we are doing well as an office and where there are opportunities for growth and issues to address. Overall, they found our projects to be well-managed and aligned with the MYPP, and that they are helping to advance the hydropower and marine energy sectors. I was especially gratified, though not surprised, to see feedback across both programs on the strength, talent, and professionalism of our WPTO staff.

Reviewers also recommended opportunities for us to ensure stronger connections to industry by developing or advancing commercialization strategies, diversifying communication approaches, and improving information sharing. These recommendations align directly with my priorities as director, and our team is already working to implement them where appropriate. For example, we have been growing our network of stakeholders, who can help guide and inform our work, while allowing us to better connect our projects to potential end users. Discussions with our stakeholders have led us to explore different funding mechanisms—such as prizes and technical assistance—to open doors for more potential applicants to our funding opportunities. We are actively working to incorporate a process to evaluate commercialization and outreach strategies on a by-solicitation basis prior to the release of any funding opportunity, which will solidify this strategy to ensure each solicitation we release matches industry's and academia's needs.

Importantly, we also recognize that we are not alone in our efforts to advance the hydropower and marine energy sectors. This was one of the key findings of this peer review: we need to strengthen our connections to the broader international and domestic communities in both marine energy and hydropower. We will continue to work with our partners in the United States and in government and industry around the world who are enhancing and pioneering marine energy and hydropower technologies, and we will look for opportunities to form other partnerships to collectively achieve our clean energy goals.

I would like to thank everyone who contributed to WPTO's 2022 Peer Review, including those who attended for showing interest in our programs, our project leads for sharing their work, and our team behind the scenes for coordinating logistics and creating a smooth and comprehensive virtual event. And finally, thank you to our reviewers, who so generously offered their time, expertise, and actionable feedback. All of us at WPTO were honored to work with you, and we appreciate your input. I commit to taking your recommendations and feedback to strengthen our portfolio of work over the years to come.

Sincerely,

Jennifer Garson
Director, Water Power Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Executive Summary

Introduction

The Water Power Technologies Office (WPTO), part of the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE), held a virtual peer review on July 18–29, 2022. The purpose of peer review is to evaluate DOE-funded projects for their contributions to the mission and goals of the office, progress made against stated objectives, and the office's overall management and performance. The peer review process enables external stakeholders to provide feedback on the most impactful use of taxpayer funding and develop recommendations for the most efficient and effective ways to accelerate industry development in water power technologies. This report includes the results of WPTO's 2022 Peer Review.

Review Process

A total of 31 external subject-matter experts from industry, academia, nonprofit organizations, and government agencies evaluated more than 100 projects active in WPTO's research and development (R&D) portfolio in fiscal years (FY) 2019–2021. During the peer review, principal investigators (PIs) presented on their projects, and WPTO staff presented on their program and activity area strategies and progress on stated goals and objectives. See Table ES-1 for a list of the programs, activity areas, and number of projects reviewed in each.

Table ES-1. Number of Projects Reviewed by Program and Activity Area

Program	Activity Area	Number of Projects
Hydropower*	Innovations for Low-Impact Hydropower Growth	16
	Grid Reliability, Resilience, and Integration (HydroWIRES)	25
	Fleet Modernization, Maintenance, and Cybersecurity	6
	Environmental and Hydrologic Systems Science	8
Marine Energy	Foundational R&D	13
	Technology-Specific System Design and Validation	22
	Reducing Barriers to Testing	9
	Data Access, Analytics, and Workforce Development	4

*Projects from the Hydropower Data Access, Analytics, and Workforce Development Activity Area were folded into other relevant activity areas.

The peer review was separated by program, starting with the Marine Energy Program and ending with the Hydropower Program. The first four days of each program's review week were dedicated to public presentations from PIs and feedback from the reviewers, and the last day was dedicated to a closed-door review session where reviewers had the opportunity to discuss their initial thoughts with WPTO staff. Each program was separated into four review sessions that roughly corresponded to individual activity areas. Each review session was structured with an activity area overview that linked the projects to the activity area's challenges and the strategy for measuring progress and managing deliverables toward outcomes. The agenda in Appendix A provides a detailed breakdown of the projects presented within each activity area.

Strategic Direction Underpinning WPTO's 2022 Peer Review

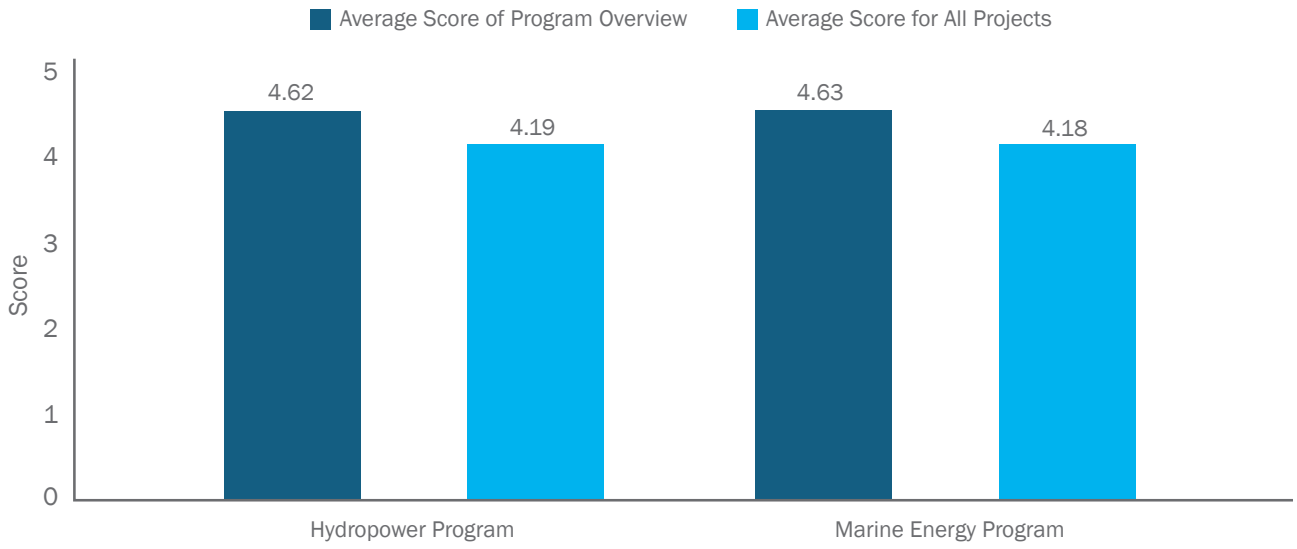
WPTO staff and management considered the 2022 Peer Review a significant milestone and opportunity given that this was the first comprehensive evaluation of WPTO since publishing its Multi-Year Program Plan (MYPP). The MYPP is a comprehensive report that details the office's future research, development, demonstration, and commercial activities across both hydropower and marine energy and describes how these efforts can help meet the nation's energy and sustainability goals. The report outlines key performance goals for each of WPTO's activity areas through 2025 and includes long-term, follow-on objectives through 2030. This report serves as a strategic vision and operational guide to help WPTO manage and coordinate its activities and communicate its mission, goals, and plans.

The MYPP was an integral part of the peer review, providing reviewers insight and guidance on the office's strategy to which WPTO-funded projects must align. For more information about the office's structure, strategy, and R&D portfolio implementation, please refer to the MYPP or the corresponding office, program, or activity area overview slide decks presented during the review.

Summary of Findings

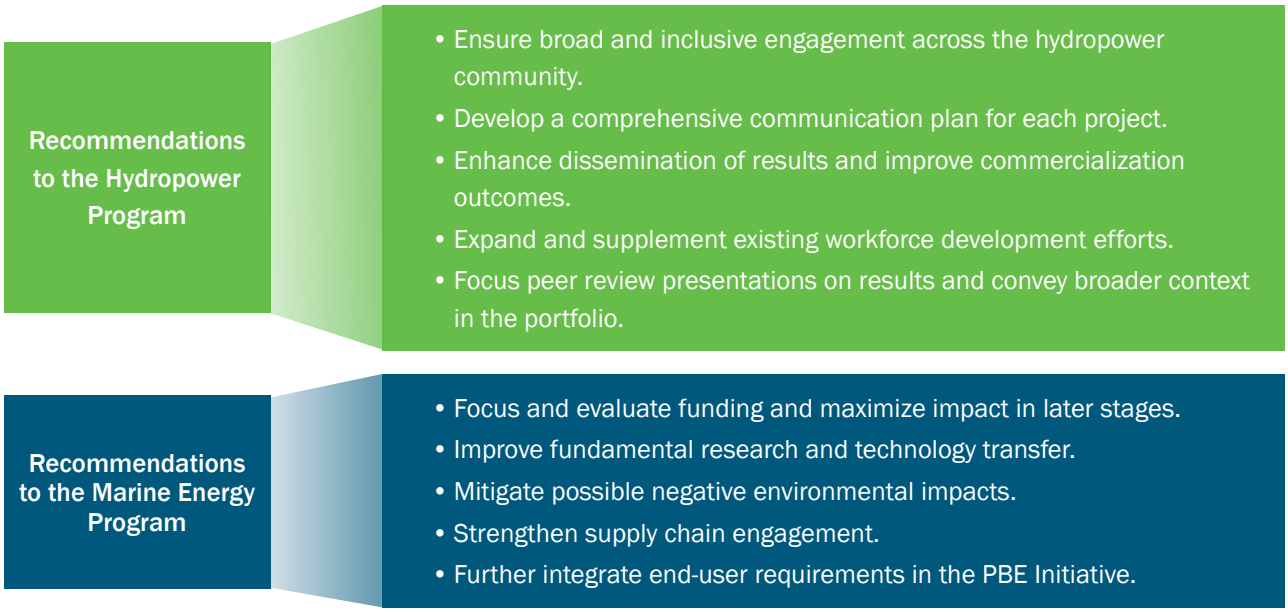
Reviewers rated each program's strategy and implementation higher than the average score for all individual projects. This indicated that current program objectives, which were updated after some of the earliest projects were initiated, align well with evolving industry needs. Figure ES-1 summarizes reviewers' quantitative assessments of how WPTO's programs are performing overall, including the weighted average score of each program and the average score of all projects reviewed per program.

Figure ES-1. Average Score Per Program.



Overall, reviewers agreed that each program has a defined strategy, as outlined in the MYPP, that considers challenges facing industry and other stakeholders and leverages appropriate funding mechanisms to achieve intended outcomes. Reviewers were impressed with the depth and breadth of each of the programs and noted that the variety of funding mechanisms used across the office was a significant strength. Across both programs, reviewers noted the importance of meaningful, early, and frequent stakeholder engagement and impactful dissemination of results. Reviewers also recommended opportunities for WPTO to ensure stronger connections to industry by developing or advancing commercialization strategies, diversifying communication approaches, and improving information sharing. These recommendations are summarized in Figure ES-2.

Figure ES-2. Summary of Reviewer Recommendations to WPTO's Programs.



Key Actions and Next Steps

WPTO takes the peer review process seriously and developed a preliminary set of actions it will take to incorporate feedback and strengthen its body of work over the coming years. Below are high-level, office-wide actions and areas of improvement that WPTO will work toward before its next peer review. Further, each program and activity area section in this report contains additional actions based on reviewer recommendations and feedback.

Ensure Relevance and Connections to Industry and Academia

A key theme that emerged from reviewers during both the hydropower and marine energy reviews was the need to ensure continuous industry feedback, input, relevance, and adoption of work WPTO supports. In recent years, the office has begun to strengthen industry connections and will continue these efforts, while recognizing the private sector's adoption of WPTO-developed solutions will ultimately ensure success. The office is also considering actions that will strengthen connections to industry, including academia, during strategy and solicitation development, project development and implementation, and post-project evaluation and support for commercialization.

In the development of its MYPP, WPTO issued requests for information, met with stakeholders, and considered ongoing stakeholder interactions. As the office updates its MYPP and develops other strategies to inform investments, the office will build on and enhance this engagement. Additionally, WPTO strives to be as collaborative and open as possible in shaping solicitations, prizes, and lab work to be as impactful to industry as possible. WPTO looks forward to hearing more feedback from its partners on how to enhance industry relevance in its projects.

WPTO recently took steps to ensure project outcomes are vetted and analysis has industry relevance. This has included forming technical advisory committees on research, which has led to collaboration during publication of that research and involving industry and academia in design reviews. However, the office recognizes the need to publish information on projects even before their conclusion and engage a broader set of stakeholders in both hydropower and marine energy, including environmental and community-based organizations.

Support Technology Transfer and Strengthen Commercialization

Reviewers noted that for the office to be successful, industry adoption of solutions is critical, and commercialization of WPTO-funded solutions is crucial to ensuring that adoption. Commercialization has become an increasing focus and will be at the center of both the hydropower and marine energy programs, both within projects and through activities being pursued across WPTO. This includes focusing on projects' and programs' follow-on investment potential, strengthening connections to investors in the private sector, requiring serious commercialization strategies from performers, and supporting the broader innovation ecosystem engine through incubators and accelerators.

To support commercialization and adoption of solutions, WPTO will provide the support technologies need to translate from laboratories into their relevant markets. WPTO is currently developing materials for awardees on commercialization processes and options for intellectual property. The office also works closely with national laboratory commercialization offices to understand the options for technology transfer of WPTO-funded tools and technologies. WPTO will publish more public information about intellectual property that could potentially be commercialized and organizations supported by the office that can assist with commercialization, as well as case studies on how the office's support has helped advance technologies in both industries to provide further transparency.

Ensure Impact of Investments and Fit for Financing Mechanisms and Impact

While reviewers noted that WPTO has employed a variety of financing mechanism (e.g., prize, technical assistance, cooperative agreement), the office needs to ensure those mechanisms are the right fit to maximize investment and ensure projects can ultimately achieve success. In recognition that either projects did not align with overall program strategy or a funding mechanism did not fit the purpose of the original technical intent, WPTO is launching a new internal effort to develop a rigorous solicitation selection and evaluation process. The office will implement a process early in solicitation development to determine the correct mechanism for the desired purpose; determine the target audiences and applicants and design a solicitation and complementary outreach plan to engage them; leverage each solicitation to reach new audiences and expand the diversity of research partners; and determine the appropriate budget and sequencing of funding opportunities.

Efforts to ensure solicitations maximize investment need to be coupled with an effort focused on revisiting the metrics that communicate the success or lack thereof in a project. Given the interrelated nature of water power technologies with water quality, environmental performance, community impacts, and greenhouse gas avoidance, the success of WPTO's portfolio is not as easily captured by traditional technology metrics such as levelized cost of energy or other types of cost reduction. New metrics for modeling efficacy and uptake, for example, could be developed, especially as the current portfolio of projects continues to progress. WPTO will work across DOE and with partners to hone and define these metrics. This will include building metrics collection in at the solicitation development stage to better communicate to performers the expectations for the metrics they will need to report on as part of their awards.

Increase International Collaboration and Information Exchange

Lastly, reviewers provided feedback across WPTO's portfolio to look outside the United States for opportunities for collaboration, best practices, research advancements, and technologies. The office has been actively engaged with the International Energy Agency in both hydropower and marine energy, and WPTO plans to continue that engagement and look for additional opportunities for international partnerships. WPTO will also continue to approve international subcontract arrangements on its industry and lab projects and engage the international community to serve as independent reviewers for proposal evaluations and public peer reviews.

In the future, WPTO will look at new ways to exchange information with international counterparts, ensure due diligence by encouraging researchers to conduct literature reviews using relevant international publications, and strengthen relationships with countries and organizations seeking to advance water power technologies abroad.

WPTO again thanks its reviewers for their time, effort, and attention. This report has additional details on actions at the program and activity area levels to address both the opportunities and weaknesses elucidated by reviewers. WPTO commits to providing progress on this work during its public updates, through its annual accomplishment reports, and at semiannual public webinars.

List of Acronyms

Argonne	Argonne National Laboratory
C-Power	Columbia Power Technologies, Inc
CAISO	California Independent System Operator
CEC	current energy converter
CEM	capacity expansion model
DEEC-Tec	distributed embedded energy converter technologies
DEI	diversity, equity, and inclusion
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EMEC	European Marine Energy Centre
EPRI	Electric Power Research Institute
FAST	Furthering Advancements to Shorten Time Commissioning for PSH
FERC	Federal Energy Regulatory Commission
FOA	funding opportunity announcement
FOSWEC	floating oscillating surge wave energy converter
FY	fiscal year
GHG	greenhouse gas
GIS	geographic information system
HAWSEC	Hawaii Wave Surge Energy Converter
HFI	Hydropower Fleet Intelligence
HydroWIRES	Hydropower and Water Innovation for a Resilient Electricity System
I AM Hydro	Innovations in Advanced Manufacturing for Hydropower
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IHA	International Hydropower Association
INL	Idaho National Laboratory
IO&M	installation, operations, and maintenance
ISO	independent system operators
kW	kilowatt
LCOE	levelized cost of energy
MECC	Marine Energy Collegiate Competition
MHK	marine and hydrokinetic
MHKiT	Marine and Hydrokinetic Toolkit
MISO	Midcontinent Independent System Operator
MW	megawatt
MYPP	Multi-Year Program Plan
NERC	North American Electric Reliability Corporation
NHA	National Hydropower Association
NMRECs	National Marine Renewable Energy Centers
NPD	non-powered dam

NREL	National Renewable Energy Laboratory
NOAA	National Oceanic and Atmospheric Administration
NYISO	New York Independent System Operator
O&M	operations and maintenance
OES	Ocean Energy Systems
ORNL	Oak Ridge National Laboratory
ORPC	Ocean Renewable Power Company
OWC	Oscillating Water Column
PBE	Powering the Blue Economy™
PI	principal investigator
PNNL	Pacific Northwest National Laboratory
PRIMRE	Portal and Repository for Information on Marine Renewable Energy
PSH	pumped storage hydropower
PTO	power take-off
PUMPSS	Predicting Unique Market Pumped Storage Significance
R&D	research and development
RoR	run of river
Sandia	Sandia National Laboratories
SBIR	Small Business Innovation Research
SEAT	Spatial Environmental Assessment Toolkit
SMH	standard modular hydropower
SR-WEC	surface riding wave energy converter
STEM	science, technology, engineering, and mathematics
TEAMER	Testing Expertise and Access for Marine Energy Research program
TPL	technology performance level
TRL	technology readiness level
UMERC	University Marine Energy Research Community
USACE	U.S. Army Corps of Engineers
VGOSWEC	variable-geometry, oscillating surge wave energy converter
VGWEC	variable-geometry wave energy converter
WBS	Work Breakdown Structure
WEC	wave energy converter
WEC-Sim	Wave Energy Converter SIMulator
WECC	Western Electricity Coordinating Council
WETS	Wave Energy Test Site
WPTO	Water Power Technologies Office
ZAO	Zero Ascend Omnispecies

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Introduction

Peer Review Overview

Purpose of Peer Review

A peer review is a standard best practice for assessing highly technical, complex projects and programs and is widely used by industry, government, and academia. Peer reviews elicit objective reviews and advice from independent experts to provide DOE managers, staff, and researchers with a powerful and effective tool for informing the management, relevance, and productivity of government-funded projects. The 2020 EERE Peer Review Guidance defines a peer review as:

> **A rigorous, formal, and documented evaluation process using objective criteria and qualified and independent reviewers to make a judgement of the technical/scientific/business merit, the actual or anticipated results, and the productivity and management effectiveness of programs and/or projects.**

This definition distinguishes in-progress peer review from other types of reviews, such as merit reviews, which are used to evaluate technical proposals for competitive solicitations; "stage gate" or "go/no-go" reviews, which determine whether a project is ready to move to the next phase of development; and other review activities such as quarterly milestone or budget reviews.

A peer review is based on the premise that enlisting third-party experts to objectively evaluate the progress and impact of a technical project and/or program adds a valuable layer to technical program and project management. Peer reviews are essential in providing robust, documented feedback to EERE leadership to inform program planning. They also provide management with independent validation of the effectiveness and impact of funded projects and program scopes. Knowledge about the quality and effectiveness of current projects and programs is essential in directing (or redirecting) new and existing efforts.

WPTO 2022 Peer Review

The Water Power Technologies Office's (WPTO) 2022 Peer Review was held on July 18–29, 2022. Due to the lasting COVID-19 pandemic, the office decided to hold the event virtually on WebEx, a web conferencing platform. A total of 31 external subject-matter experts from industry, academia, nonprofit organizations, and government agencies evaluated more than 100 projects active in WPTO's fiscal years (FY) 2019–2021 research and development (R&D) portfolio. During the event, PIs presented on their projects, and WPTO staff presented on their program and activity area strategies and progress on stated goals and objectives.

The 2022 Peer Review was split between the programs—the Hydropower Program and projects were reviewed July 18–22, 2022, and the Marine Energy Program and its projects were reviewed July 25–29, 2022. These week-long reviews were split into tracks set by the Marine Energy and Hydropower programs' activity areas (see Table 1).

Results of the 2022 Peer Review will be used to help inform programmatic decision making, modify existing projects, guide future funding opportunities, and support other planning objectives. WPTO released its first Multi-Year Program Plan (MYPP) in March 2022, so this was the first peer review that allowed external reviewers to compare funded projects and initiatives to the MYPP. Due to the time between peer reviews because of COVID-19, reviewers, in some cases, were asked to review projects that no longer matched WPTO's overall strategy. However, it was still useful for the office to receive feedback that compared these sunsetting or completed projects to the

current strategy as outlined in the MYPP. For more information about the office's structure, strategy, and R&D portfolio implementation, please refer to the MYPP or the corresponding office, program, or activity area overview slide decks presented during the review.

Table 1. WPTO's Programs and Activity Areas

Hydropower Program	Marine Energy Program*
• Innovations for Low-Impact Hydropower Growth • Grid Reliability, Resilience, and Integration (HydroWIRES) • Fleet Modernization, Maintenance, and Cybersecurity • Environmental and Hydrologic Systems Science • Data Access, Analytics, and Workforce Development	• Foundational R&D • Technology-Specific System Design and Validation • Reducing Barriers to Testing • Data Access, Analytics, and Workforce Development

*Powering the Blue Economy was also reviewed as an initiative.

Reviewer Roles and Responsibilities

Review panels consisted of four to six external experts who were selected based on their technical expertise and high-level qualifications in their designated technology area. WPTO made efforts to ensure a balance within each review panel by including a mix of reviewers from industry, academia, nongovernmental organizations, and federal agencies with a range of expertise. Reviewers were required to sign legal agreements stipulating an absence of a conflict of interest with the projects they reviewed. A program review chair, as well as a review panel lead, who in most cases had experience as a reviewer, guided each set of reviewers. Table 2 lists the members and affiliations of the program review chairs and review panel leads. Members of each review panel are listed within each individual program section.

Reviewers were responsible for utilizing their subject-matter expertise to evaluate WPTO-funded projects and evaluate WPTO's program and activity area strategies and progress toward goals per panel assignment. They were also expected to provide feedback on the peer review process and to participate in facilitated, reviewer-only discussions during the review and the post-review debrief with WPTO staff and reviewers. Panel leads were responsible for facilitating the reviewer-only discussions on the portfolio of projects and assigned activity area(s) before final comments and scores were submitted, leading the post-review debrief between WPTO staff and the review panel, and drafting a short summary of the activity area reviews for the final peer review report. Program chairs were responsible for participating in reviewer-only activity area discussions, leading the post-review debrief with WPTO staff and all reviewers on the final day, drafting a short summary of the program reviews for the peer review report, and reviewing key parts of the final peer review report.

Table 2. Program Review Chairs and Panel Leads

	Name	Role	Review Panel	Affiliation
Hydropower Program	Shannon Ames	Review Chair and Panel Lead	Environmental and Hydrologic Systems Science	Low-Impact Hydropower Institute
	David Sinclair	Panel Lead	Innovations for Low-Impact Hydropower Growth	Advanced Hydro Solutions
	Tom Acker	Panel Lead	HydroWIRES	Northern Arizona University
	Cathy Campbell	Panel Lead	Fleet Modernization, Maintenance, and Cybersecurity	U.S. Army Corps of Engineers
Marine Energy Program	Henry Jeffrey	Review Chair and Panel Lead	Technology-Specific System Design and Validation	University of Edinburgh
	David Ingram	Panel Lead	Foundational R&D	University of Edinburgh
	Sue Barr	Panel Lead	Reducing Barriers to Testing	Cambrian Offshore
	Michael Atkinson	Panel Lead	Data Access, Analytics, and Workforce Development	North Carolina A&T State University

Evaluation Criteria

Reviewers were asked to evaluate WPTO's R&D programs, initiatives, and activity areas at a strategic level, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each program and activity area based on strategy and implementation and progress. Reviewers provided scores on a scale of 1 ("unsatisfactory") to 5 ("superior") for each criterion, which are outlined in Appendix B. The weighting of the evaluation criteria is summarized in Table 3.

Table 3. Program and Activity Area Criteria Weighting

Evaluation Criteria	Program	Activity Area/Initiative
Objectives	50%	60%
End-User Engagement and Dissemination	50%	40%

Reviewers were also asked to evaluate a set of WPTO's projects and prizes, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each project on the following specific criteria: project/prize objectives, end-user engagement and dissemination, and performance. Reviewers provided scores on a scale of 1 ("unsatisfactory") to 5 ("superior") for each criterion, which are outlined in Appendix B. The weighting of the evaluation criteria is summarized in Table 4.

Table 4. Project and Prize Criteria Weighting

Evaluation Criteria	Project	Prize
Objectives	25%	35%
End-User Engagement and Dissemination	25%	35%
Performance	50%	30%

Format of the Report

The quantitative and qualitative results are summarized at the program, activity area, and project levels. Information in this section has been compiled based on the following sources and is organized as follows, with the Hydropower Program first in each volume followed by the Marine Energy Program:

Volume I (Section 1: Hydropower; Section 2: Marine Energy)

- **Program Overview**: A brief overview of the program and scope of the review.
- **Program Evaluation Summary**: A summary of all 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 in consultation with each review panel lead and all hydropower reviewers. Consensus among the reviewers was not required, and the review chair was asked to include differences of opinion and dissenting views within the report.
- **Program Response**: The WPTO program managers' official response to the recommendations provided in the review chair's program evaluation summary.
- **Program and Activity Area Results**: The results of the reviewers' quantitative scores on the programs and activity areas. This section also includes the activity area evaluation summaries and activity area responses.

Volume II (Section 1: Hydropower; Section 2: Marine Energy)

- **Program and Activity Area Evaluations**: The complete results of the peer review, including the quantitative scores on the programs and activity areas and aggregated anonymous feedback.
- **Project and Prize Evaluations**: Individual project and prize reports that that detail the quantitative scores on each project or prize and aggregated anonymous feedback.
- **Appendices**: Includes the agendas and evaluation criteria.

SECTION 1

Hydropower Program

Innovations for Low-Impact Hydropower Growth

HydroWIRES Initiative

Fleet Modernization, Maintenance, and Cybersecurity

Environmental and Hydrologic Systems Science

Hydropower Data Access, Analytics, and Workforce Development

Hydropower Program Peer Review

Hydropower Program Overview

The Hydropower Program at WPTO aims to conduct research, development, demonstration, and commercial activities to advance transformative, cost-effective, reliable, and environmentally sustainable hydropower and pumped storage technologies; better understand and capitalize upon opportunities for these technologies to support the nation's rapidly evolving grid; and improve energy-water infrastructure and security. In doing so, the program works in five major areas: Innovations for Low-Impact Hydropower Growth; Grid Reliability, Resilience, and Integration (Hydropower and Water Innovation for a Resilient Electricity System (HydroWIRES) Initiative); Fleet Modernization, Maintenance, and Cybersecurity; Environmental and Hydrologic Systems Science; and Data Access, Analytics, and Workforce Development.

Through these five activity areas, the Hydropower Program is working to enable a 100% clean energy future by leveraging hydropower's inherent flexibility and pumped storage's proven use as a cost-effective, long-duration storage asset. The program is looking to expand the value of sustainable hydropower by funding research, development, demonstration, and commercial activities that focus on retrofitting and rehabilitating dams, combining hydropower with water distribution, supply, and treatment systems in an energy-water nexus, and developing testing capabilities and facilities to commercialize technologies that can leverage these systems while preserving and enhancing stream functionality.

The program recognizes that hydropower can play a critical role in decarbonizing the electric grid to mitigate climate change but will also experience negative impacts due to climate change. Therefore, WPTO is advancing climate and hydrologic science, while also working to enhance environmental sustainability and, ultimately, build socioeconomic resilience in communities challenged by climate change.

Finally, WPTO realizes the challenges that can come from being the oldest source of renewable energy in the nation. As the hydropower fleet ages, maintaining efficient and cost-effective operations and ensuring the security of critical infrastructure becomes increasingly challenging. Modernization of the existing hydropower fleet through asset management, environmental mitigation, and relicensing reflects a significant opportunity to restore reliability and performance and add new, cutting-edge technologies.

Organization of Tracks and Review Panels

The Hydropower Program, activity areas, and individual projects were reviewed and scored during WPTO's 2022 Peer Review. Program and activity area overview presentations detailed the goals and objectives outlined in the MYPP. For information about the structure, strategy, and implementation of the program and its relation to WPTO's overall mission, please refer to the corresponding program overview presentation slide deck presented during the review.

Four panels of reviewers reviewed program elements, as well as individual projects across all the Hydropower Program's activity areas. There were also three reviewers dedicated to reviewing the Hydropower Program's prizes and one reviewer dedicated to reviewing the crosscutting Science, Technology, Engineering, and Mathematics (STEM) and Workforce Development project. Finally, both the Innovations for Low-Impact Hydropower Growth and Environmental and Hydrologic Systems Science review panels reviewed the Data Access, Analytics, and Workforce Development Activity Area's strategy and implementation. The accompanying portfolio of projects was incorporated into the session most closely tied with the subject matter and with the relevant reviewer expertise. Figure 1 depicts the total number of hydropower presentations each panel reviewed.

Figure 1. Number of Hydropower Projects Reviewed by Review Panel

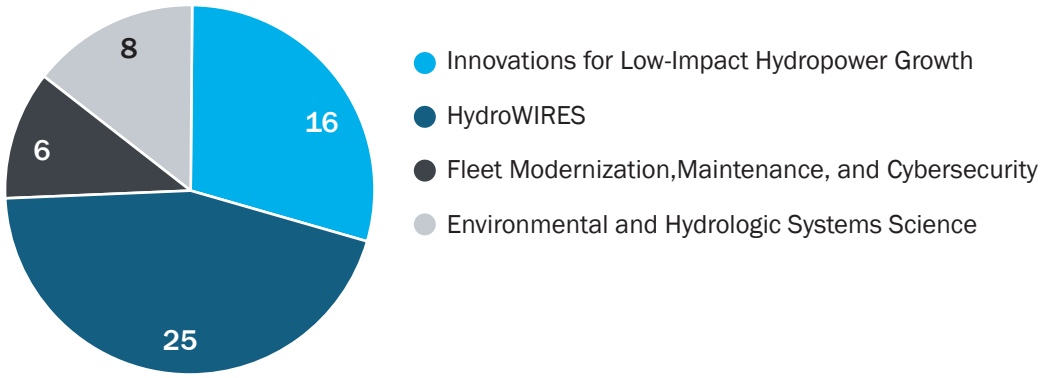


Table 5 summarizes the role, review panel, and affiliation of the external experts who served as reviewers for the Hydropower Program during WPTO's 2022 Peer Review.

Table 5. Hydropower Program Reviewers

HYDROPOWER PROGRAM			
Name	**Role**	**Review Panel**	**Affiliation**
Shannon Ames	Review Chair and Panel Lead	Environmental and Hydrologic Systems Science	Low-Impact Hydropower Institute
David Sinclair	Panel Lead	Innovations for Low-Impact Hydropower Growth	Advanced Hydro Solutions
Doug Spaulding*	Reviewer	Innovations for Low-Impact Hydropower Growth	Nelson Energy
Michael Kerr	Reviewer	Innovations for Low-Impact Hydropower Growth	New England Hydropower Company LLC
Tom Acker	Panel Lead	HydroWIRES	Northern Arizona University
Bente Brunes	Reviewer	HydroWIRES	Rainpower
Debbie Mursch	Reviewer	HydroWIRES	GE Renewable Energy
Cathy Campbell*	Panel Lead	Fleet Modernization, Maintenance, and Cybersecurity	U.S. Army Corps of Engineers
Craig Bourassa	Reviewer	Fleet Modernization, Maintenance, and Cybersecurity	Avista Utilities
Twyla Cheatwood*	Reviewer	Environmental and Hydrologic Systems Science	National Oceanic and Atmospheric Administration
Wendy Bley	Reviewer	Environmental and Hydrologic Systems Science	Kleinschmidt Associates

HYDROPOWER PROGRAM			
Name	**Role**	**Review Panel**	**Affiliation**
John Bakken	Reviewer	Fleet Modernization, Maintenance, and Cybersecurity	McMillian Jacobs Associates
Ram Veeraraghavan	Reviewer	Fleet Modernization, Maintenance, and Cybersecurity	Tacoma Power
Donna Vincent Roa	Prize Reviewer	Prizes	USAID's Partnerships Incubator, The Kaizen Company
Sally Gutierrez	Prize Reviewer	Prizes	Environmental Protection Agency
Craig Connelly	Prize Reviewer	Prizes	New York State Energy Research and Development Authority
Linda Silverman	Reviewer	STEM/Workforce	Potential Energy DC

*Selected to also review the crosscutting Hydropower STEM and Workforce project.

Hydropower Program Scores

Reviewers were asked to evaluate WPTO's R&D programs at a strategic level, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each program on the following equally weighted criteria: strategy and implementation and progress. Figure 2 summarizes reviewers' quantitative assessments of how the Hydropower Program is performing overall. Since the Data Access, Analytics, and Workforce Development portfolio crosscuts the Hydropower Program, the Innovations for Low-Impact Hydropower and Environmental and Hydrologic System Science review panels evaluated the activity area's strategy and implementation, which is summarized in Figure 3. Figure 4 shows average weighted scores for each of the Hydropower Program's activity areas (excluding Data Access, Analytics, and Workforce Development), with reference lines indicating the average project score and program score. The aggregated reviewer comments justifying these quantitative scores can be found in Volume II.

Figure 2. Hydropower Program Average Weighted Score by Evaluation Criterion

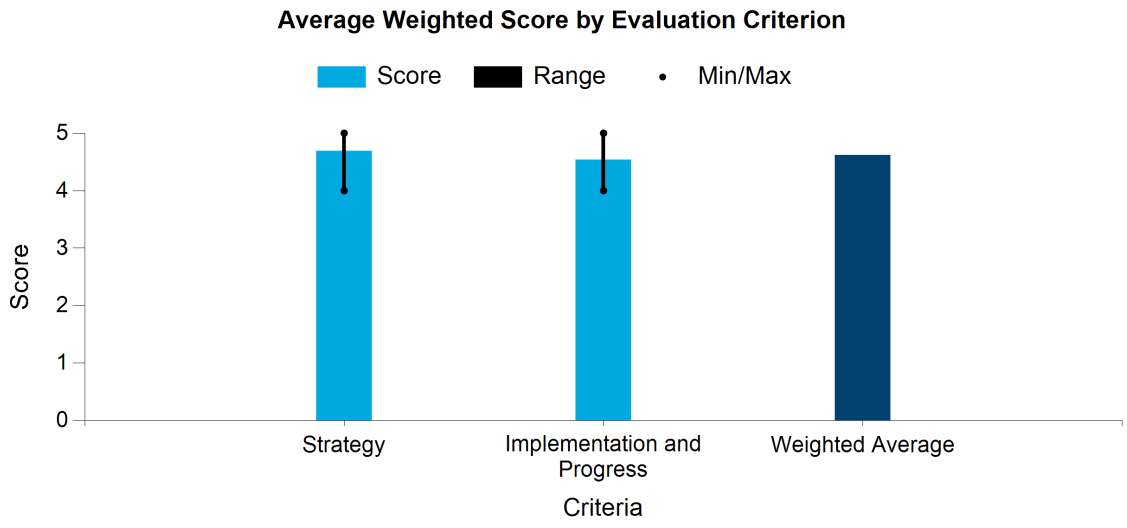


Figure 3. Hydropower Data Access, Analytics, and Workforce Development Activity Area Average Weighted Score by Evaluation Criterion

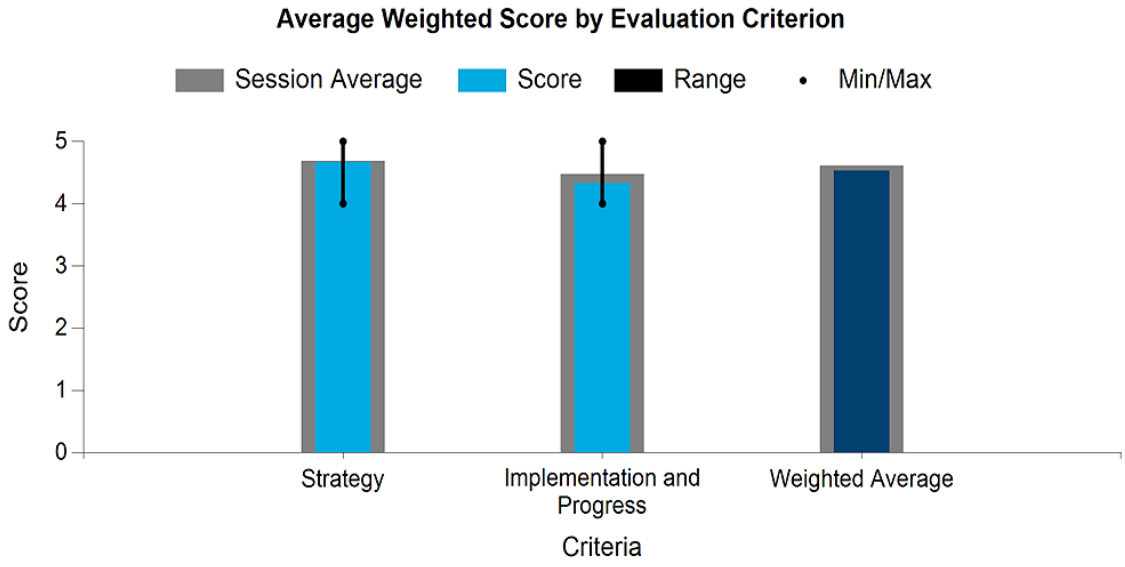
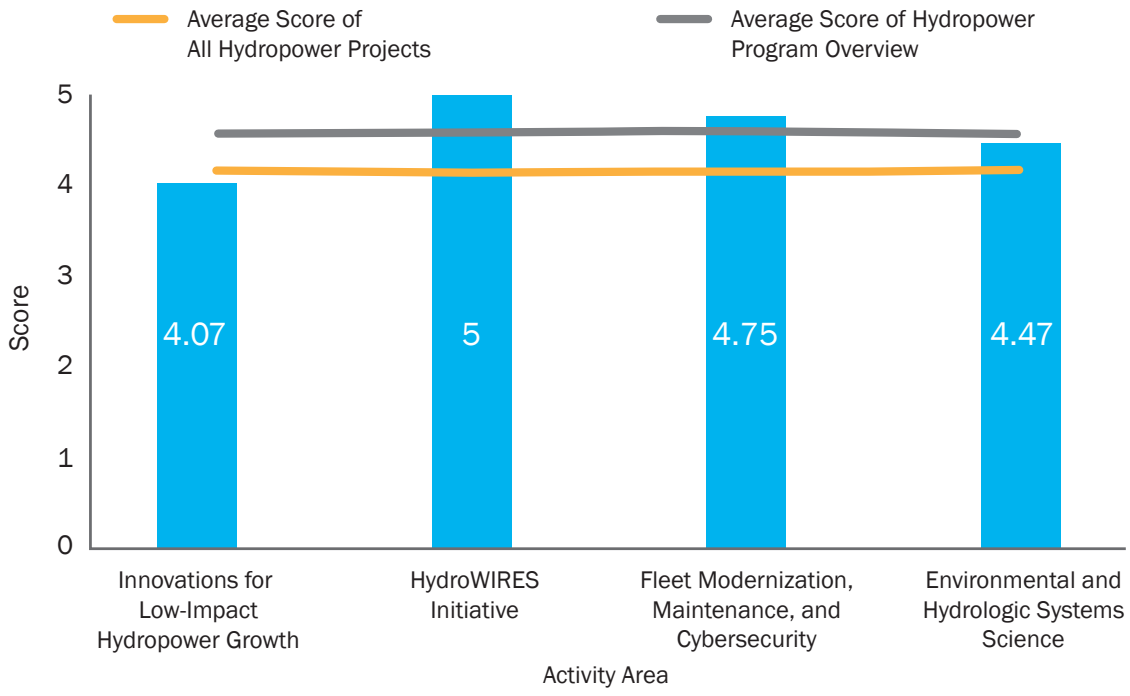


Figure 4. Average Weighted Score by Hydropower Program Activity Area



Organization of the Results

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

- **Hydropower 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 in consultation with each review panel lead and all hydropower reviewers. Consensus among the reviewers was not required, and the review chair was asked to include differences of opinion and dissenting views within the report.
- **Hydropower Program Response**: The WPTO program manager's official response to the recommendations provided in the review chair's program evaluation summary.
- **Hydropower Program Activity Area Results**: The results of the reviewers' quantitative scores on the program and activity areas. Activity area results follow the program results and begin with a summary chart that depicts the average score for each project in each activity area. Each activity area subsection includes the following components:
  - *Activity Area Evaluation Summary*: This consists of a summary of the review panel's comments that provides insight into each 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 the review panel leads were asked to include differences of opinion and dissenting views within the report.
  - *Activity Area Response*: The WPTO activity area lead's official response to the recommendations provided in the review panel lead's activity area evaluation summary.

Hydropower Program Evaluation Summary

Submitted by Shannon Ames, Chair

Key Takeaways

WPTO organized a well-planned, effective peer review that provided sufficient information for reviewers to assess the projects and program overall. Reviewers find the projects to be well-managed and designed and in line with the MYPP. They are led by impressive and effective project leads. With few exceptions, the projects provide opportunities to make significant impacts on hydropower's ability to blossom in the years to come, particularly in the broad area of sustainability. The projects' diversity covers all aspects of developing and operating hydropower facilities. Clearly, the program implemented key recommendations from the last peer review, in particular the suggestions around project management. The staff displays a wide array of expertise and is knowledgeable, professional, and connected to the hydropower community, open to feedback, and interested in engaging. WPTO is doing an exceptional job leading appropriate research and managing and investing taxpayer dollars.

Feedback from the Review Chair to WPTO

Virtually all projects presented are perceived as high value and each demonstrated a concerted effort to involve stakeholders.

WPTO has funded research in areas that would assist in new stream-reach development. The results of these projects will have positive impacts on hydropower's development but not on new stream-reach development, given regulatory and stakeholder reluctance to permit such projects. WPTO has already recognized this and is moving away from new stream reach specifically. The reviewers look forward to seeing the innovative projects implemented at non-powered dams (NPDs) and related to existing site improvements.

While progress has been made in terms of early and lasting involvement of hydropower stakeholders, two consistent themes emerged from this peer review. First, project leads referred to the hydropower community, but the list of stakeholders engaged in each project was inconsistently inclusive. Some projects did a great job identifying and involving stakeholders from all viewpoints—owners, operators, and developers, as well as conservation groups, resource agencies, and academics. This broad and inclusive approach needs to be embraced on all projects such that feedback is received from all viewpoints. The broader the outreach, the better the outcome.

Second, reviewers would like to see a comprehensive communication plan for each project. Reviewers consistently asked about the methods and frequency of communication efforts, and some would have liked to see examples of communication materials. Since stakeholder involvement is more important than ever, WPTO should consider including more comprehensive information on communication plans in the peer review.

The last broad recommendation is to incorporate additional resources related to end use and commercialization. The projects showed impressive progress and results (although some projects did a better job than others at presenting specific information about the results to date as well as stakeholder reception), but only a handful had a solid plan for commercialization, including whether the project would be cost effective in use, how it would be disseminated, who would be using it, etc. Reviewers recommend considering how the projects will be brought to end users' attention and ensuring an organized, easy means of access. Results should be broadly disseminated—bring the results to end users and do not wait for them to find the results themselves. Reviewers also recommend considering how the projects will benefit end users and clearly communicating that at all opportunities. In essence, make sure the project's end is not the end of the project. End-user implementation will be an essential mark of success.

Summary of Reviewer Feedback on the Program

Overall Impressions

The projects presented in all panels were well managed and aligned with the MYPP and represented good uses of taxpayer funds. The staff is impressive and knowledgeable and presented the key information well. The projects vary in their life cycles with some being closer to completion than others. Several of the projects presented important data that is needed before a broader objective could be met. Generally, the reviewers feel it would be important at the next peer review to clearly place the projects within the broader plan to achieve a particular objective. While all reviewers are impressive and knowledgeable of hydropower, some panels include a narrower set of perspectives. Reviewers would like to see more information about projects' end use and commercialization.

Program Strategy

Each activity area has a well-defined strategy, performance goals, and objectives. Project leads clearly articulated how the projects fit within the MYPP, and those goals are all still relevant and useful. Reviewers would like to see how the projects not only fit within the overall strategy, but how they connect and work together to meet the MYPP's goals and objectives.

The funding mechanisms are appropriate and varied. The prizes received the most discussion around whether they are attracting the broadest range of applicants possible, and reviewers note that only a few industry standards receive the bulk of the awards. In addition, reviewers wonder about the ideas not awarded and whether there are opportunities to push any alternative, but promising, ideas forward. Some reviewers specifically cite the lack of academic interest.

The portfolio is broad, addressing all key challenges for hydropower, including aging infrastructure, cyberthreats, lack of data, grid demand, funding constraints, and environmental impacts (especially fish passage). Some reviewers would like to understand the projects not funded to help them understand if these were the most relevant projects to fund. The project on reservoir methane emissions illustrated a good example of a project that successfully incorporates the needs of multiple viewpoints within the broad hydropower community. This approach should be maintained but articulated clearly and often. Reviewers would like to see a specific strategy focused on end use and commercialization with some suggesting a "pull" strategy to encourage stakeholders to embrace and owners to adopt technologies, rather than relying solely on hydropower owners to invest in new technologies they would then have to convince stakeholders to embrace.

Overall, the program is well organized. The activity areas are clearly articulated and rational in their categorization and approach. The projects fit clearly within the overall strategy.

Implementation and Progress

The projects are well managed, on budget, carefully designed, and aligned with the MYPP goals and objectives. The program is open, willing to engage with all stakeholders, and transparent. Their outreach efforts are impressive, even if many reviewers request they do more. All reviewers feel the projects are well managed and the program carefully stewards taxpayer funds.

Overall, reviewers feel the projects are relevant and meet the MYPP's objectives. Some reviewers question any continuing efforts to develop new stream-reach technologies, but WPTO is already moving away from this focus area. Another exception is the reservoir emission research. One reviewer is unconvinced it is an important area of study. However, other reviewers feel strongly that it is a critical area of study, filling a gap in existing science, and that the program is uniquely qualified to provide impartial data. Some reviewers question whether they could determine if the projects are the most relevant without comparing them to projects that were not funded.

Dissemination and commercialization were key topics of discussion and questioning in all activity areas. Multiple reviewers requested specific plans for implementation of project end results. It is premature for many projects to have fully articulated commercialization plans; however, it would be useful for commercialization and end-user implementation to have clear goals for successful implementation. Such implementation plans would consider cost effectiveness, ease of access, updates to data over time, and clear use cases.

Reviewers recommend sharing the comprehensive communication plan for not only each project, but the program as a whole—who stakeholders are, how they are being reached and involved, and what mechanisms or materials are being used in communications. Reviewers recommend considering a specific panel with reviewers with expertise in hydropower communications to review the plan, which would be consistent with the importance of involving the whole hydropower community in all stages of projects.

Hydropower Program Response

Submitted by Corey Vezina, Acting Program Manager

Response to the Review Chair's Key Takeaways

The Hydropower Program would like to thank the reviewers for the significant time and effort they spent evaluating the program's strategy and R&D portfolio, sharing their expertise, and providing constructive and robust feedback. The program will continue to benefit from feedback from the hydropower community regarding the program strategy and investment of taxpayer funds. The program thanks reviewers for acknowledging that the diverse portfolio of projects is well managed and aligned with the MYPP. The program also appreciates reviewers' recognition of its staff as "knowledgeable, professional, and connected to the hydropower community, open to feedback, and interested in engaging." The program also appreciates reviewers' acknowledgment of progress since the last peer review and implementation of reviewer recommendations, especially around project management.

Overall, reviewers outlined several areas for improvement to: (1) ensure broad and inclusive engagement across the hydropower community, (2) develop a comprehensive communication plan for each project, (3) enhance dissemination of results and improve commercialization outcomes, (4) expand and supplement existing workforce development efforts, and (5) focus peer review presentations on results and convey broader context in the portfolio. The following sections outline the program's official response to the recommendations provided in the review chair's program evaluation summary, as well as responses to specific recommendations noted across the review panels.

Recommendation 1: Ensure Broad and Inclusive Engagement Across the Hydropower Community

Reviewers recommended the program focus on broad, inclusive engagement of owners, operators, and developers, as well as conservation groups, resource agencies, and academia. The reviewers recognized some projects successfully engaged a broad swath of the hydropower community, while other projects fell short. WPTO agrees representatives from across all sectors of the hydropower community must be engaged to better understand the many complex and diverse issues affecting hydropower technologies and operational improvements. Stakeholders may include, but are not limited to, representatives from tribal nations, hydropower developers, owners/operators of hydropower facilities, research institutions, hydropower industry representatives, nongovernmental organizations, nonprofit organizations, and resource agencies.

WPTO will ensure broad and inclusive engagement across the hydropower community through several existing efforts, such as continuing dialogue with the hydropower community as the program develops short- and long-term goals through the Hydropower Vision Roadmap update. WPTO will also continue to engage the broader hydropower community through participation in national hydropower trade shows, conference panels and discussions, and regional meetings, as well as through industry and federal agency workshops designed specifically to identify high priority hydropower R&D needs. Since the last peer review, WPTO has convened several technical advisory groups that include diverse hydropower representatives and will continue to leverage the expertise of and expand its use of advisory groups. WPTO is also working to recruit diverse subject-matter experts to review research funding applications and the current water power portfolio.

Two funding opportunities announced in fall 2022 support efforts to diversify and expand applicant pools and support stakeholder engagement. WPTO issued an approximately $4 million funding opportunity to support the efforts of diverse hydropower stakeholders to discuss and find paths forward on topics that include U.S. hydropower fleet modernization, hydropower system sustainability, and hydropower facilities' environmental impact. Many of the issues intended to be addressed through this funding opportunity are "hot-button" issues from which stakeholders often back away. This opportunity intends to help engage stakeholders, using the services of a trained facilitator,

and bring these complex conversations to the forefront to drive real action. These efforts will enhance and inform current and future R&D needs for hydropower technologies and environmental mitigation efforts at DOE and in industry.

In addition, WPTO released a $14.5 million funding opportunity to further the sustainable development of hydropower and pumped storage hydropower (PSH), with a topic area focused on hydropower R&D by emerging organizations. Both funding opportunities and any related activities will seek to encourage meaningful engagement and participation of workforce organizations, including labor unions, as well as underserved communities and underrepresented groups, including consultation with tribal nations. These new funding opportunities are also designed to help meet the goal that 40% of the benefits of the administration's investments in clean energy and climate solutions be delivered to disadvantaged communities.

Recommendation 2: Develop a Comprehensive Communication Plan for Each Project

Reviewers recommended WPTO consider developing a comprehensive communication plan for each project and share the program's communication plan as a whole, including details on who stakeholders are, how they are being reached and involved, and what mechanisms or materials are being used in communications. The program agrees with reviewer feedback that there is room to improve communication and results dissemination. WPTO will continue to use various communications tactics, such as newsletters and webinars, to increase awareness of funding opportunities and effectively disseminate projects' results and tools. Just last year, WPTO began including communications plans as a requirement in all lab projects to better identify target end users and plan how results will reach the appropriate stakeholders. WPTO will also evaluate using this same process for projects funded under other funding opportunities.

Reviewers also recommended considering a specific panel with reviewers with expertise in hydropower communications to review both program and project-level communications plans to ensure the hydropower community is broadly and inclusively engaged in all stages of projects. WPTO will consider incorporating communications subject-matter experts into future peer review panels. WPTO will also work to include additional communications requirements in future peer review presentations and materials, such as including a specific communications criterion for evaluation.

Recommendation 3: Enhance Dissemination of Results and Improve Commercialization Outcomes

Reviewers noted that for some projects, the results or lessons learned were not clear in the presentation and/or some key R&D findings may not reach interested and relevant stakeholders. In the past few years, WPTO has developed a variety of tools to better share project findings and lessons learned, such as its R&D Deep Dive Webinar series (announced in WPTO's Water Wire and Hydro Headlines newsletters), a comprehensive map of all projects (updated annually with links to project deliverables and a summary of the work), and Annual Accomplishments Report (to highlight project success stories and their results). Internally, WPTO also requires projects to develop logic models to define their target end users, outputs produced, and how activities relate to program-level outcomes. This a recent effort WPTO is considering expanding across the office and will help track progress on goals and objectives.

In addition, reviewers stated that only a few projects had a comprehensive commercialization plan. The program fully agrees with reviewers that every project should have a clear plan for commercialization that identifies how results will be disseminated and the end users who will benefit. WPTO is taking a comprehensive approach toward technology commercialization, which includes making robust investments in the Small Business Innovation Research (SBIR) program (targeted toward R&D of commercially relevant technologies in the private sector), providing lab vouchers for winning prize teams to enable commercialization of promising technology innovations, incorporating end-user-focused commercialization activities in funding opportunities and cooperative agreements, and building an innovation ecosystem network through incubators and accelerators to bring promising technology innovations to market.

WPTO will continue to develop outreach materials to tell the story of where the office is and has been, what does and does not work, and the ultimate vision for its R&D and a society that uses it. WPTO will continue to identify methods to make information and results from projects more accessible, such as with search engine optimization on the office's website and by tagging or labeling to bring this information up in internet searches. Finally, WPTO will identify stakeholders for which project information is relevant but who are not currently engaged and determine ways to target dissemination of project results for such audiences. WPTO will also continue to improve how it shares key results and lessons learned from projects.

Recommendation 4: Expand and Supplement Existing Workforce Development Efforts

The reviewers expressed high praise for WPTO's hydropower workforce development and STEM outreach activities, stating the relatively new portfolio has been well designed, stakeholder engagement has been well prioritized, and future work plans are strategic. Reviewers commented that this work is "vital" to the hydropower industry and recommended WPTO build on this foundation by increasing the budget and resources dedicated to workforce development, supporting additional programs, coordinating with more federal agencies and broader workforce initiatives, and expanding reach to more students and potential hydropower workforce entrants. At the same time, reviewers emphasized that industry partners need to remain central to this work, and some future activities should be owned by industry directly. Additionally, reviewers suggested WPTO try to provide more granularity in future workforce analyses to help the industry better understand how to address retirement and recruitment challenges and target students in specific majors.

WPTO appreciates the reviewers' praise for its workforce development portfolio, which is still a relatively new but growing area of emphasis for the Hydropower Program. The program is not surprised by the reviewers' recommendations to expand this portfolio as industry outreach has indicated that hydropower employers are even more concerned about recruitment, retainment, and skills development than they were in 2018 when WPTO, the National Renewable Energy Laboratory (NREL), and the Hydropower Foundation first initiated the water power workforce project. The program knows this sense of urgency is partially due to the COVID-19 pandemic's impacts on the energy sector generally, but the hydropower sector is facing a wave of retirements at the very moment when new workers and skillsets are needed to realize the historic opportunities presented by the Bipartisan Infrastructure Law and the Inflation Reduction Act. The program is actively engaging the National Hydropower Association (NHA) staff and hydropower employers in discussions about how to better align and scale efforts to recruit new workers to the sector, recognizing opportunities to have a larger impact by working together and leveraging different perspectives, platforms, and convening powers. The program is proud of the foundation it has built with new programs like the Hydropower Collegiate Competition and wants to inspire a larger and more diverse audience to consider a career in hydropower. The program looks forward to working with NHA, the Hydropower Foundation, and hydropower employers to realize this goal together.

Recommendation 5: Focus Peer Review Presentations on Results and Convey Broader Context in the Portfolio

Many reviewers stated they would like to better understand a project's findings or results, which may not have been clearly conveyed in the peer review presentations. As reviewers understand, time was limited, and project presenters had to be concise. However, the program agrees conveying results should be a priority in future peer review presentations. WPTO will work to modify the presentation template to put greater emphasis on project results and develop additional guidance for the presenters that outlines best practices and shares a good example presentation.

In addition, reviewers wanted a better understanding of how projects fit together within the overall portfolio and connect and work together to meet the goals and objectives outlined in the MYPP. The program agrees it is critically important for reviewers to understand how projects and activity areas fit together and contribute toward the office's goals. The program also agrees with the suggestion to provide a presentation at the end of each session (after the projects have been presented) that summarizes the activity area strategy to show how the projects fit together and the program strategy to show how the activity areas fit together.

Hydropower Program Activity Area Results

Innovations for Low-Impact Hydropower Growth

The Innovations for Low-Impact Hydropower Growth Activity Area aims to develop, test, and validate cost-effective, sustainable technologies for non-conventional hydropower applications in new-stream reaches, NPDs, and conduits. Through this activity area, WPTO is working to:

- Enable new technology development for both existing water infrastructure and new stream-reach applications that incorporate ecological and social objectives.
- Leverage advancements in manufacturing and materials to dramatically lower costs of components and system designs.
- Support testing of new technologies, including development of necessary testing infrastructure.
- Explore new development opportunities in which hydropower is a critical enabler of a larger suite of benefits.

The review panel was impressed by the number and variation of projects contained within this activity area, though there were specific suggestions on how to improve communication of the projects and how they fit into the overarching WPTO strategy as a whole. Figure 5 summarizes reviewers' quantitative assessments of how the activity area is performing overall, and Figure 6 provides an overview of the scoring for all projects within the Innovations for Low-Impact Hydropower Growth Activity Area.

Figure 5. Innovations for Low-Impact Hydropower Growth Activity Area Average Weighted Score by Evaluation Criterion

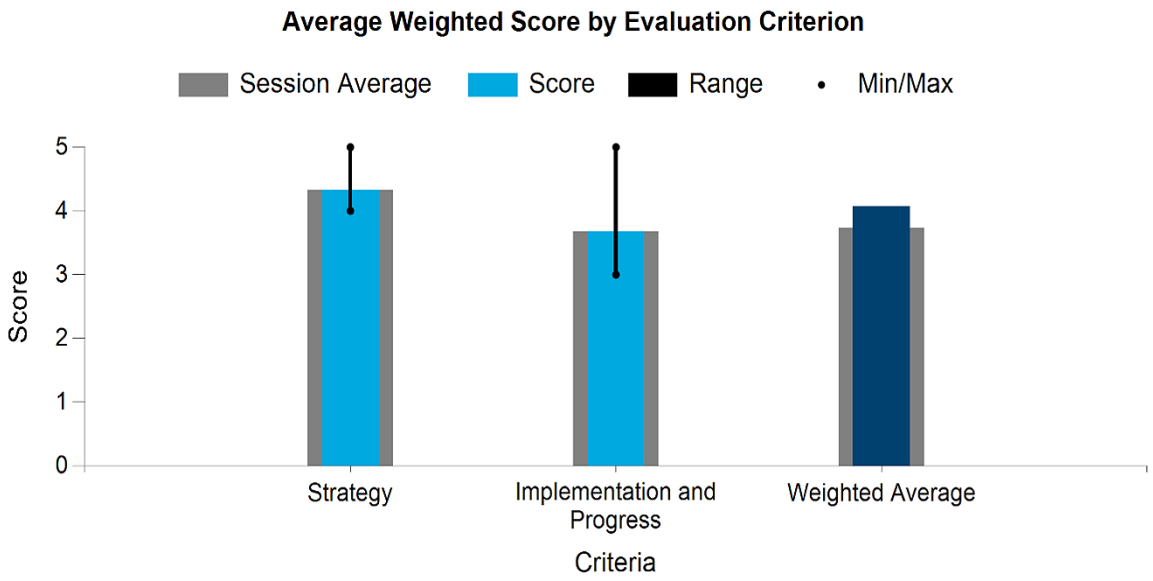
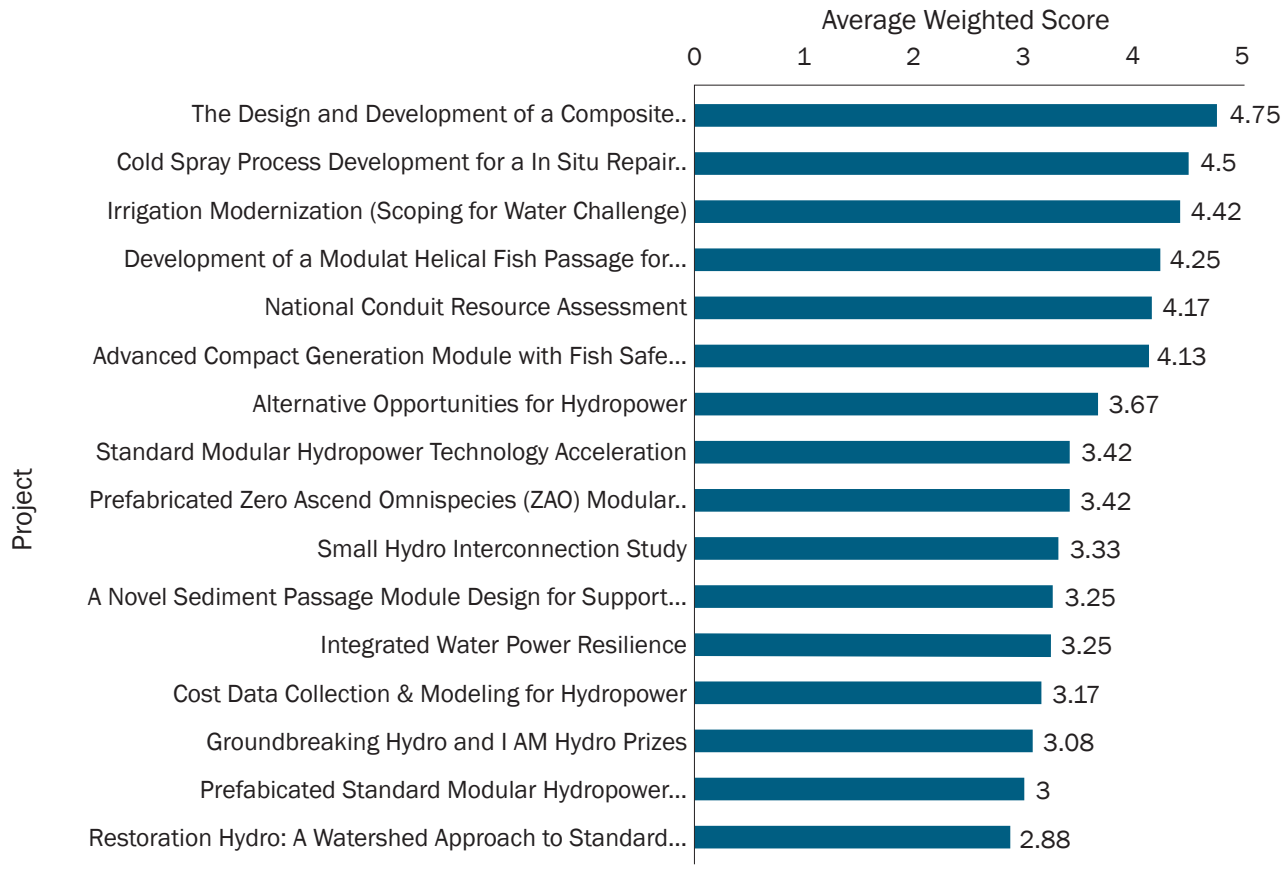


Figure 6. Innovations for Low-Impact Hydropower Growth Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by David C. Sinclair

Feedback from the Review Panel to WPTO

The Hydropower Program has a sound foundation, strategy, and approach for implementing and achieving its goals. The program team did an excellent job ensuring reviewers understood the details about the program and its foundation and outlining and providing the supporting documentation.

The mass of programs and projects must be difficult to track and organize. It is certainly daunting to an outsider to understand all the facets of the program's work. Notable strengths of the program execution include a focus on current needs for environmental sustainability, including improved data collection techniques and technology. Notable weaknesses include an inefficient communication strategy to promote prizes and competitions and to disseminate information.

Overall, the peer review was a resounding success, promoting stronger links between researchers and industry. These linkages are important to maintain and build upon during the interim between these reviews.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

The review panel consists entirely of developers, and as a result, there is consistency in their thoughts and responses to the individual projects. There are two follow-on projects (cold spray and composite runners) that were applauded as truly innovative efforts that will yield major advances in equipment construction and maintenance. Projects supporting the standard modular hydropower (SMH) concept had mixed success with the design of turbine and fish passage packages leading the pack.

Other data-related assessments were found to be less focused on the industry and more on providing high-level datasets for a certain point in time to illustrate specific issues or opportunities.

Activity Area Strategy

The sheer volume of work undertaken and funded by WPTO is laudable and multipronged. While each of the project presenters identified how their project fit into the different facets of the MYPP, one could not see how the projects all work together to fulfill the office's goals as identified.

Reviewers recommend WPTO establish a point of contact for the new technologies arena specifically to guide any inquirer as to which program and funding opportunity would be the best fit for their idea. WPTO should also undertake a gap analysis and create a chart that shows how past, current, and planned projects fit into the MYPP. Further, while competitive bidding on funding opportunities may be required, this results in winners and losers wherein a loser may have had a great idea that was not funded. Thus, the number of winners should not be pre-determined.

It will be challenging to encourage developer interest in other value propositions for hydropower that do not provide additional income for the developer/operator, especially during this era of low wholesale electricity pricing. This suggests the need for a "pull" strategy from agricultural, local government, and environmental stakeholders rather than hydropower being the driver.

There is a consistent pattern of certain national labs and independent firms receiving significant funding every year along with a few small firms securing funds for work that does not result in market-ready solutions. No new entrants appeared in the projects presented, which speaks to insufficient industry appeal to work with WPTO to advance R&D.

The Hydropower Collegiate Competition is a great idea that should be expanded and supplemented with a broader reach for the competition and a supporting scholarship program. The workforce development goal would benefit from both. This would also help expand reach into the academic community and create avenues to connect with more students to present the industry's available opportunities. Only a small budget supports this important program, and the reviewers recommend expanding funding for these important hydropower education and workforce development programs.

The Groundbreaking and Innovations in Advanced Manufacturing for Hydropower (I AM Hydro) prizes were disappointing and clearly did not understand how to attract good, innovative offerings. Whether because of too tight a specification or too low a prize value or both, the reviewers recommend a rethinking of this undertaking.

Reviewers also recommend adding to the process, where relevant, financial metrics or the need for awardees to keep their eye on and test the potential challenges new products face in gaining investor/banking support.

The addition of hydropower to NPDs is the most likely opportunity for new hydropower. In particular, the many U.S. Army Corps of Engineers (USACE) navigation dams are generally similar in configuration and provide an opportunity for modular intake and waterway passages involving siphons or other schemes to avoid coffer dams and significantly reduce construction costs. Additional research in this area could stimulate a large amount of NPD hydropower development.

Implementation and Progress

The reviewers agree that projects tackling real-world problems facing hydropower owners and developers have progressed, albeit slowly, toward meeting their objectives. It is important that ongoing reviews by end users help direct the projects going forward and avoid project myopia.

Reviewers also agree that innovative approaches to small hydro development are having some success in creating packaged solutions for generation and fish passage that should be further funded. However, it would be a mistake to link them solely to SMH and new stream-reach development. New stream-reach development is not going to happen in any significant quantity, which implies that investment in this area should be limited.

Sediment transport is an admirable objective for which cost-effective solutions need to be found. The reviewers agree the design approach currently proposed by the sediment transport module project is ill conceived and would not be practical. Data collection is an interesting academic undertaking but of little value unless creating such information also provides tools for the evaluation and development of specific sites, whether in conduits or new NPD sites.

Activity Area Response

Submitted by Katie Jackson, Technology Manager

The program would like to thank the review panel for their excellent reviews and active engagement throughout the presentations related to the Innovations for Low-Impact Hydropower Growth portfolio. This includes a wide range of work, and reviewers' feedback as members of the industry is valuable. The comments on both individual projects and the portfolio's overall strategic direction are a crucial way for the program to get external feedback and make sure its work is supporting the industry's needs.

The program was very excited to see positive feedback on much of its work in the advanced manufacturing for hydropower space. For example, the cold spray project is currently considering next steps for better enabling in-situ repair and looking forward to potential partnerships with external groups, which is in line with the review panel's feedback. Additionally, the program is developing an advanced manufacturing strategy for hydropower to encourage the hydropower and advanced manufacturing industries to work together to consider the opportunity space.

The program also appreciates the recommendations provided to help guide and improve the value of the portfolio's R&D efforts. The program recognizes the challenges in encouraging developer interest in some of the alternative opportunities for hydropower and will continue to engage with hydropower developers, as well as agricultural, local government, and environmental stakeholders. The program is considering a deeper dive into understanding the value proposition for each opportunity, partnerships with external stakeholders, and potential technical assistance opportunities.

Reviewers expressed serious concern with the sediment transport project under the SMH project. The program understands and has heard similar feedback about feasibility from other external reviewers. However, the cost modeling tasks are worth pursuing to investigate cost effectiveness and feasibility. Additionally, this is a unique project on sediment passage for the portfolio, and like the reviewers, the program believes this is an area of research in which to consider investing. Lessons learned from this project will inform future efforts related to sediment passage at dams.

Overall, reviewers outlined several recommendations to (1) focus efforts on the largest potential for new hydropower: powering NPDs; (2) engage new partners on projects, including through different mechanisms; and (3) ensure industry can leverage the work supported by WPTO. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Focus Efforts on the Largest Potential for New Hydropower: Powering NPDs

The program agrees with this recommendation and recognizes this is feedback also received in the last peer review. The program currently has national laboratory projects and external funding opportunities (either ongoing or new) focused on NPDs. The SMH project was focused on a concept that standardization and modularity could help reduce costs and enable new low-impact hydropower. While the SMH project initially focused on new stream-reach development, more recent efforts led to the development of the NPDamCAT and NPD Explorer tools on which the reviewers provided positive feedback. The current SMH project is nearing completion, and the national lab team will finish technical support related to advanced manufacturing and modeling to the external awardees connected to the project in FY 2023.

Moving forward, the program will take lessons learned from SMH and apply those to NPDs as appropriate. Additionally, the program has several new efforts related to powering NPDs:

- The program issued a funding opportunity related to innovative approaches to powering NPDs. The goal is to address current challenges with NPDs including, but not limited to, high development costs, permitting challenges, grid connection, and utilization of the full range of flow and head fluctuations that occur for dams that were built for purposes other than power generation.
- The program plans to update the NPD resource assessment in FY 2023 and FY 2024 to include better available data and evolving interests since the last assessment was published in 2012.
- Two new SBIR awardees will work to address the costs associated with the water conveyance systems at NPD projects.
- The program recently selected six new national lab projects as "seedlings" to explore early-stage concepts for improving the value of or reducing the costs associated with powering NPDs. This seedlings approach involves relatively low budgets and short timelines to explore innovative ideas before down-selecting those that may be more promising.

Recommendation 2: Engage New Partners on Projects, Including Through Different Mechanisms

The program agrees with reviewer feedback that there is room to improve communication and results dissemination. Within the Innovations for Low-Impact Hydropower Growth portfolio, the program will continue efforts to better match the technical need with the appropriate solver audience and funding mechanism. The program appreciates the feedback related to the I AM Hydro and Groundbreaking Hydro prizes and recognizes there may not have been a perfect pairing of the technical challenge and intended prize applicants. The program will continue to use prizes to engage new communities beyond the hydropower industry, while also considering lab calls, SBIR, and other funding opportunities when the challenge problem is better suited for these mechanisms.

As reviewers are very aware, the hydropower industry is relatively small, but the program also recognizes the need to expand applicant pools to new parties, including students and early-career innovators. In future hydropower innovation funding opportunities, the program plans to encourage a more diverse set of applications and topics as done in a recent funding opportunity (Innovative Technologies to Enable Low-Impact Hydropower and PSH Growth, Topic 3: Hydropower R&D by Emerging Organizations). The program appreciates the positive interest in the Hydropower Collegiate Competition and looks forward to how that may also impact interest in funding opportunities.

Lastly, reviewers noted to continue to look outside the United States for additional best practices and technologies. The program has been actively engaged in the International Energy Agency (IEA) Hydropower Task 16, which is focused on "hidden hydropower," and leads the task on NPDs. The program plans to continue that engagement and look for further opportunities for international partnerships.

Recommendation 3: Ensure Industry Can Leverage the Work Supported by WPTO

The program appreciates the positive feedback related to the efforts to identify and characterize NPD opportunities. The program recognizes that some of the portfolio's efforts are more academic in nature but will make a greater effort to ensure those efforts feed into information and tools that are useable by the industry. The program has planned efforts related to technical assistance and looks forward to those as a method to ensure industry adoption of technical work. Moving forward, the program will also put an emphasis on market transformation plans in funding opportunities like that in the Innovative Technologies to Enable Low-Impact Hydropower and PSH Growth opportunity.

Additionally, the program will prioritize efforts to ensure it utilizes the correct metrics for targeting adoption. The feedback related to cost modeling efforts and industry engagement will be considered in next steps to ensure reasonable representation of the development potential. Industry consultants have been actively engaged through subcontracts for the cost modeling projects.

The program was also excited to see comments related to a need for a test facility and agrees a test facility would be of great interest to and use for the industry. At congressional direction, the program conducted a scoping study through Oak Ridge National Laboratory (ORNL) regarding existing and emerging hydropower testing needs, existing capabilities, and gaps between the two that could be filled with federal investment. This scoping study included a request for information that aimed to incorporate valuable feedback from industry and federal labs/agencies. The study proposed two initiatives that are currently being evaluated for implementation. The first includes a hydropower testing network that better connects innovators to available testing capabilities across national, federal, academic, and private labs, particularly for early-stage innovations. The second is a full-scale, flow-through, federal hydropower test facility that is constructed at existing federal infrastructure, like an NPD or hydropower plant. This facility would aim to target first adoption challenges for late-stage innovations. WPTO will continue to support this effort and leverage feedback from the reviewers. Additionally, the program sees the availability of in-situ testing as a big need to validate new technologies developed by the labs and industry to support industry adoption.

The interest in the Interconnection Study was positive, and the program understands reviewers' request for further work on understanding how to help developers and planners improve the process. Next steps for the ongoing project are being considered and will incorporate reviewer feedback to ensure production of useful tools. The program anticipates the guidebook and best practices for hydropower interconnection, expected in FY 2023, will be of interest to the industry.

Grid Reliability, Resilience, and Integration (HydroWIRES)

The HydroWIRES Initiative aims to understand, enable, and improve hydropower's and PSH's contributions to reliability, resilience, and integration in a rapidly evolving electricity system. Through this activity area, WPTO is working to:

- Understand the needs of the rapidly evolving grid and how they create opportunities for hydropower and pumped storage.
- Investigate hydropower's full range of capabilities to provide grid services, accounting for the machine, hydrologic, and institutional constraints to fully utilizing those capabilities.
- Optimize hydropower operations and planning—alongside other resources—to best utilize hydropower's capabilities to provide grid services.
- Develop innovative technologies, including new pumped storage system designs, which improve hydropower capabilities to provide grid services.

The review panel was impressed with the way that the initiative had grown since last reviewed in 2019 and found its projects to be an excellent representation of the presented strategy. However, the panel suggested there could be better focus on communicating this work to the larger industry, especially once a project concludes. Figure 7 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 8 provides an overview of the scoring of all projects within the HydroWIRES Initiative.

Figure 7. HydroWIRES Initiative Average Weighted Score by Evaluation Criterion

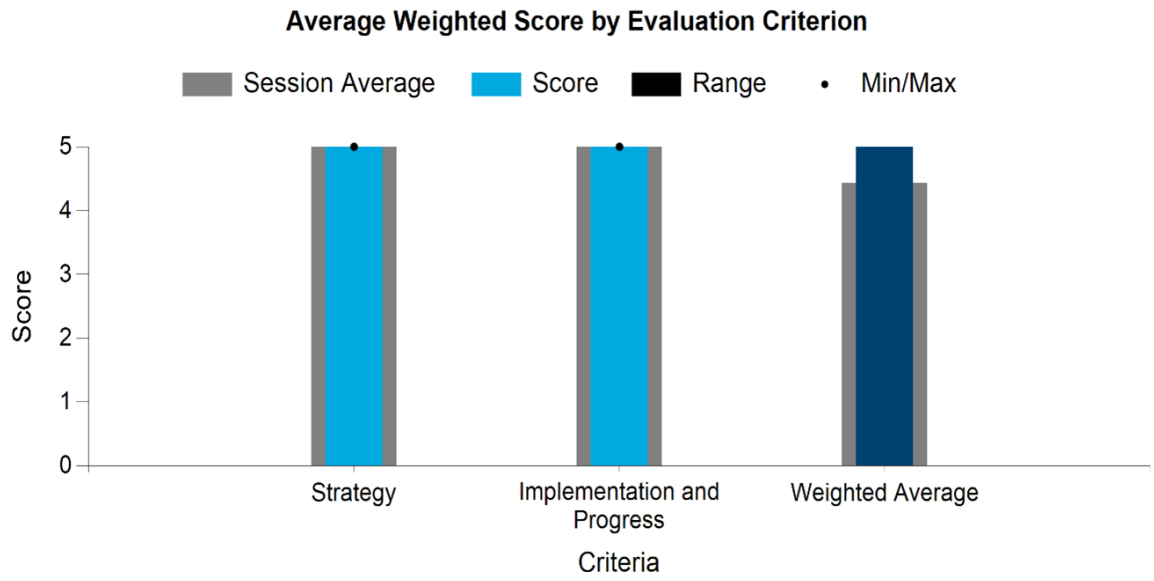


Figure 8. HydroWIRES Initiative Weighted Average Score by Project

The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Dr. Tom Acker

Feedback from the Review Panel to WPTO

The review panel finds the HydroWIRES Initiative to be well defined, led, and executed. Reviewers recommend increased dissemination and outreach to relevant communities (e.g., hydropower professionals, utility planners, environmental organizations, and interested citizens) and other stakeholders. While project leads generally did a good job engaging with relevant stakeholders, these interactions go away after a project's end. It is important to continue communicating projects' results until it is clear the outcomes are impacting the industry and society.

Many projects have been funded through the HydroWIRES Initiative, and by the very nature of this type of work, it is often difficult to make the results readily accessible to potential users. It would be beneficial for the program to find an organized way to simply access all key project outputs (such as reports, articles, tools, and software). Reviewers recommend continuing to support and develop online tools.

The HydroWIRES Initiative has 15 technical objectives. It would be good to map projects back to HydroWIRES' logic model and/or its Research Roadmap to assess the projects' comprehensiveness in addressing these objectives and the underlying challenges. For example, the HydroWIRES roadmap includes "examples of current and prospective work" under each technical objective, and a condensed version of this could be created to show the actual projects and prizes that were funded.

Several R&D projects developed comprehensive datasets for their own modeling. Some of these sets can probably be used for future research with other objectives, both individually and combined. This increases the value of the datasets but may require a more aligned approach in how researchers name and tag the same data points, variables, parameters, etc. Reviewers recommend WPTO explore the possibilities for unified nomenclature for datasets.

Research for a flexible, reliable, and resilient grid can also enable hybrid power plants that use hydropower as the main source to enable and increase generation with any other renewable energy source. The HydroWIRES Initiative already funds several activities needed to achieve this, and it may be interesting to explore and identify R&D areas that may benefit from more funding to enable a hybrid plant.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

Reviewers' overall impression is that the HydroWIRES Initiative has evolved very well since its inception and initial review in 2019. The program is now very useful and well defined and run. The staff is professional, experienced, knowledgeable, and well connected to the hydropower community and stakeholders. It is a good and appropriate use of taxpayer dollars, and the program is effective and efficient in using those funds.

Activity Area Strategy

Reviewers unanimously agree the HydroWIRES Initiative has a defined strategy as presented in the MYPP and the HydroWIRES Initiative Research Roadmap. Activities have been devised based on near- and long-term challenges identified by industry and relevant stakeholders. The HydroWIRES Initiative considers industry and stakeholder needs in defining its strategic objectives and research areas via the Hydropower Vision report and many interactions with industry and stakeholders. The projects build upon past work.

As presented in its logic model and as detailed in the HydroWIRES Initiative Research Roadmap, a solid rationale is presented that defines activity areas and research priorities. To execute its program, the HydroWIRES Initiative leverages appropriate funding mechanisms, such as financial assistance, prizes and competitions, national lab-led R&D, and others.

Implementation and Progress

Reviewers evaluated 25 projects under the HydroWIRES Initiative. These projects are diverse and appear to have addressed all 15 of the technical objectives described in the HydroWIRES Initiative Research Roadmap. Understanding that with its finite, albeit substantial, budget, it is impossible to fund all of the most relevant technologies, tools, and studies, those receiving funding certainly are relevant and important. Based upon the well-defined goals and objectives of the HydroWIRES Initiative and the project presentations, it is clear the program will very likely meet all of the performance goals and objectives set forth in the MYPP.

Activity Area Response

Submitted by Sam Bockenhauer, HydroWIRES Initiative Lead

The program would like to thank reviewers for their excellent evaluations and active participation throughout the HydroWIRES presentations. The comments on both individual projects and the HydroWIRES Initiative's overall strategic direction are a crucial way for the program to get focused external feedback and make sure its work is technically sound and getting into the hands of external users.

The program is pleased by reviewers' comments that the HydroWIRES program is well defined in its strategy and making strong technical progress. All reviewers awarded HydroWIRES perfect overall scores for both the activity area's strategy and implementation and progress. Reviewers noted that HydroWIRES is well defined, led, and executed, and the team is professional, experienced, knowledgeable and well connected to the hydropower community and stakeholders. In addition, the reviewers noted that it was "effective and efficient" at using taxpayer dollars for public benefit. The program is particularly pleased the review panel noted significant progress since the previous review in 2019 when HydroWIRES had just been launched. The panel was unanimous in its feedback that the strategic direction and technical focus were fully clarified, and projects reviewed were very strong. The program would also like to emphasize that HydroWIRES is a team effort, and the team of technical leads at DOE, as well as project leads at the national labs and industry, share the credit for this successful progress.

Overall, reviewers outlined several recommendations to (1) increase dissemination of results and tools for potential users, (2) develop performance metrics at the initiative level, (3) sharpen focus on technical work in hybrids and data sharing, and (4) continue international engagement to gain insight for U.S. research. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Increase Dissemination of Results and Tools for Potential Users

Reviewers noted that projects across HydroWIRES are valuable and address important questions, but further focus on end-user engagement would be helpful. For instance, several projects address hydropower and PSH valuation in different ways, but tools developed in these projects are not housed in a single centralized location. The idea of a "developer's corner" on NHA's website or a similar industry-oriented portal was raised, and the program agrees this could be very useful.

Reviewers also remarked that engagement with industry in the projects themselves is often present, but some projects last only a few years, after which time the collaboration may end abruptly. The program agrees with this concern but sees a need to balance open-ended stakeholder engagement goals with well-defined project milestones to be achieved in a set amount of time. With lab projects, there are fewer limitations, as successful projects can be continued with additional merit review and/or new projects can be started based on successful relationships developed with industry partners. With funding opportunity awards, however, significantly extending the duration is less straightforward and would generally require a new award. The program will continue to explore new options that can support long-term industry relationships while maintaining rigor in project management. A new technical assistance opportunity, released in November 2022, may meet some of these requirements.

To better increase the likelihood of dissemination and outreach for HydroWIRES, the program has preliminary plans including:

- Continue to prioritize end-user engagement in project selection, scoping, review, management, and communication. While HydroWIRES has made strong efforts in these areas, continued focus is critical, especially given the highly technical nature of many of the HydroWIRES projects.
- Engage with NHA and other industry groups on how to create a one-stop shop for HydroWIRES tools for developers and other users. Key needs include a place to reference tools for PSH developers, such as the PSH Valuation Tool, but a broader "developer's corner" across hydropower could be valuable.
- Consider mechanisms to support research for longer-term industry engagement beyond typical one-to-three-year lab projects and funding opportunity awards. This would enable continued relationships for sharing data among labs and industry partners, such as utilities, which is especially important in HydroWIRES modeling projects but could also be applied across hydropower.
- Develop new technical assistance processes that lower the barrier to industry participation and enhance national laboratory engagement. Streamlining requirements for data sharing are especially important for HydroWIRES modeling projects but are also generally applicable.

Recommendation 2: Develop Performance Metrics at the Initiative Level

Reviewers noted a need for performance metrics and visuals for strategic plans across the hydropower program. In HydroWIRES, this could be particularly useful due to the large budget and number of projects, as well as the projects' complexity and interrelationships. Project- and portfolio-level success in HydroWIRES is not easily captured by traditional technology metrics such as levelized cost of energy (LCOE) or other types of cost reduction. New metrics for modeling efficacy and uptake, for example, could be developed, especially as the current portfolio of projects continues to progress. Visuals for the strategic plans in HydroWIRES could also be enhanced to more clearly show where various projects fit. Reviewers also suggested a "tying together" presentation at the end of the peer review to reiterate the strategy once reviewers have seen project presentations, and this idea would be easy to implement.

In future peer reviews, and in other outreach before the new peer review, the program will develop visuals for future peer reviews to better categorize projects within each activity area and highlight remaining research gaps. Due to the number of projects in HydroWIRES, these visuals can help reviewers better understand the initiative's scope and goals. Additionally, there are preliminary plans to begin a more comprehensive study of programmatic performance metrics, informed by other DOE efforts.

Recommendation 3: Sharpen Focus on Technical Work in Hybrids and Data Sharing

In addition to broader strategic feedback, reviewers identified several specific research areas that may deserve even greater focus in HydroWIRES. One example was hydropower hybrids, which reviewers noted as a strong area of interest in industry and internationally. The program agrees with this sentiment and has new and planned future work to explore hydropower hybrid use cases in greater depth than the current cohort of projects. While preliminary, the program will build on existing work in hydropower hybrids to consider broader use cases related to multi-resource hybrids, environmental and machine benefits, and enhanced market participation. While this hybrids work is specific to HydroWIRES, results from other activity areas will be incorporated.

Another cross-cutting idea reviewers proposed was more uniform warehousing and tagging of datasets generated by HydroWIRES projects. While many projects create this data, it was not immediately obvious to reviewers how other researchers (in the national labs or outside) would be able to use it for additional studies. The program agrees this is an important need; currently datasets are shared on an ad-hoc basis. A centralized repository on DOE or national lab websites would be a helpful first step. The program will examine processes for organizing and sharing data—including data tagging, consistent descriptions, and sharing protocols—generated in HydroWIRES projects for use across the national labs and interested external partners.

Recommendation 4: Continue International Engagement to Gain Insight for U.S. Research

Across multiple activity areas, reviewers highlighted the value of international collaboration, noting that new hydropower technology and large-scale projects are, in many cases, led by other countries. The program fully agrees the international perspective is valuable, and insights from international partners (e.g., Norway) can be applicable in the United States. In HydroWIRES and across the hydropower program, WPTO leads or contributes to various international initiatives and expects to continue to expand these mutually beneficial relationships.

The program will continue (for HydroWIRES and other activity areas) strong collaboration with Norway and other countries where hydropower is highly advanced. This has provided value to U.S. efforts. Additionally, the program will promote research collaboration through the IEA Technology Cooperation Programme on Hydropower chairmanship and other international venues and develop new ways to streamline collaboration between countries.

Fleet Modernization, Maintenance, and Cybersecurity

The Fleet Modernization, Maintenance, and Cybersecurity Activity Area aims to develop digitalization, maintenance, and cybersecurity tools and capabilities to enable data-driven decision making, improve system reliability and reduce costs, and enhance infrastructure security. Through this activity area, WPTO is working to:

- Create mechanisms to classify diverse hydropower plants by mechanical and cyber-physical systems and identify exemplary facilities and best practices.
- Research advanced technologies and data evaluation approaches to improve equipment longevity and condition-based repair.
- Develop cross-cutting digitalization systems and advanced sensor suites to empower data-driven decisions on operations and maintenance (O&M) and asset management.
- Create cybersecurity tools and studies to articulate the cybersecurity target, risk, and recovery landscape in order to enhance the security of critical dam infrastructure.

The review panel found that the activity area's strategy was in line with the strategy outlined in the MYPP but did note they would have liked to see some additional focus on and work done in the maintenance part of the portfolio. Figure 9 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 10 provides an overview of the scoring of all projects within the Fleet Modernization, Maintenance, and Cybersecurity Activity Area.

Figure 9. Fleet Modernization, Maintenance, and Cybersecurity Activity Area Average Weighted Score by Evaluation Criterion

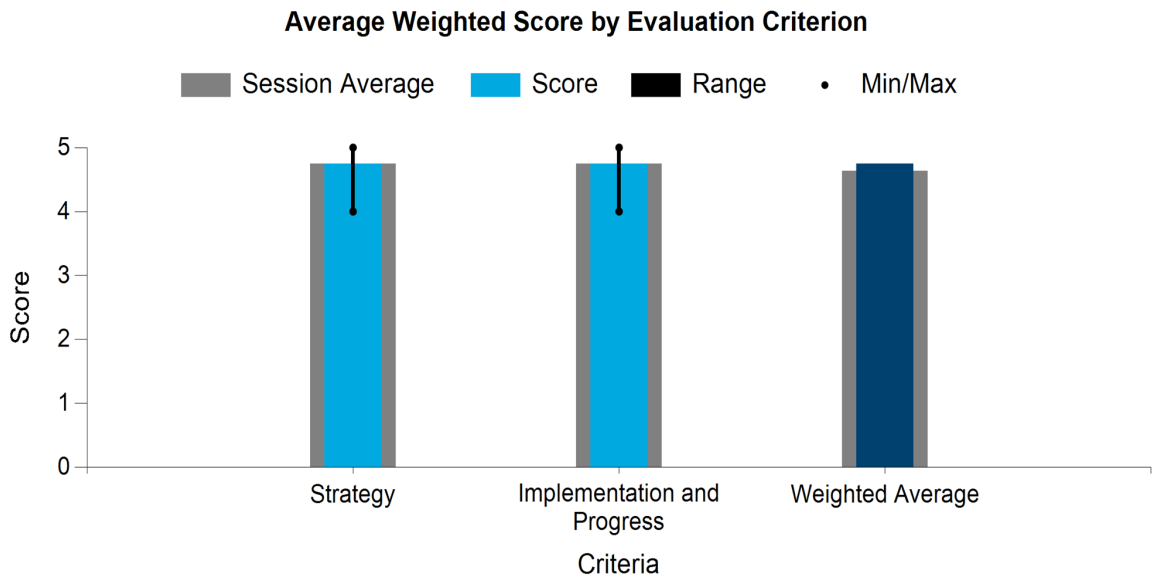
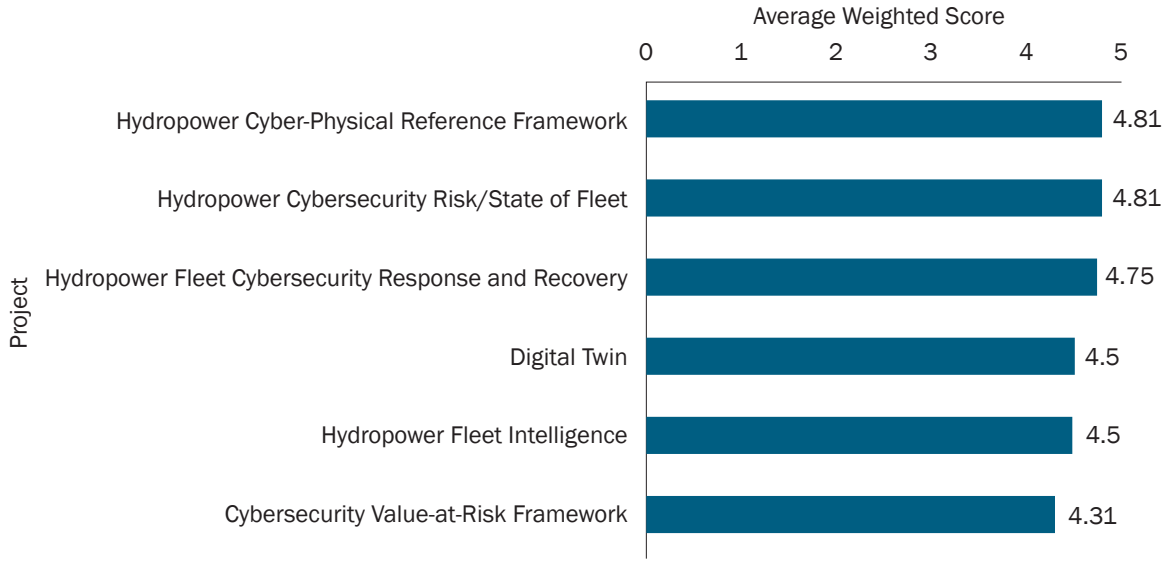


Figure 10. Fleet Modernization, Maintenance, and Cybersecurity Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Catherine Campbell

Feedback from the Review Panel to WPTO

WPTO demonstrates a clear understanding of the nation's hydropower owner-operator needs and concerns, chooses relevant R&D projects in alignment with the MYPP and the Hydropower Vision report, and organizes activity areas such that the projects complement each other. Reviewers agree the Hydropower Program has a sound foundation, strategy, and approach for implementation.

Most of this panel's reviewers were from hydropower owner-operators. The reviewers requested more details regarding the program's stakeholder outreach process, the overall landscape of hydropower R&D, and how the chosen projects compare to other projects that would also have been in alignment with the MYPP. Some areas of interest might be considered too far along to require the R&D investments, some might be premature, and some might have not been proposed. It would be informative to see how the chosen work ranks with other areas of interest. The reviewers understand there are communication plans in place to reach stakeholders, but they were not provided to reviewers, which left some gaps in their understanding of how progress and results were disseminated as well as how projects originate.

The introductory presentations on the program and the activity area are important and were very well done. The level of detail regarding the strategies, how the activity areas fit together within the program, and how the projects fit together within the activity area was at the right level. This information bears repeating after the individual project presentations when it will have more meaning for the reviewers. With few exceptions, the individual projects did not describe how they fit with each other or within the activity area's strategy. Reviewers recommend each project include a slide depicting their place within the activity area and which other projects complement theirs and how. After the projects have been presented, consider another brief presentation of the activity area strategy to show how the projects fit together and of the program strategy to show how the activity areas fit together.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

Reviewers would have liked to hear about selected, rejected, and deferred projects and how they ranked with each other. However, the reviewers acknowledge this may be outside the scope of the review.

The reviewers noted there are several cybersecurity projects, which is in line with the MYPP. The cybersecurity projects themselves seem to be cost effective, were selected to avoid redundancy, and work well together strategically. In future, it would be desirable to include more maintenance projects. Hydropower Fleet Intelligence (HFI) is a great project, but there is still room in the activity area for more maintenance-centered efforts (such as around baselining maintenance costs, benchmarking plant outage causes, or quantifying common failure modes and frequencies for typical systems) while maintaining diversity among projects.

The development of wear-and-fatigue models is starting and seeks to cover critical hydropower components while avoiding one-off models that do not translate across the industry. This is an exciting but challenging task for complex hydropower components that have a great deal of variation, especially in details relevant to wear and fatigue. If models can be accurate without having to be unique, that would represent a major step forward for predictive/smart maintenance.

Modernization projects like the digital twin can be seen by end users as requiring significant initial investment of time and funds with potentially tremendous returns someday. According to the activity area presentation, "value sensitivity and articulation" will be critical to success. For outreach and results dissemination on digitalization projects, reviewers recommend explicitly pointing out that an all-or-nothing approach is not necessary, and benefits can be gained with a gradual approach to installation of machine condition monitoring, for example. In general, reviewers would like to see more details about how owner-operators could use project outputs and the business case to invest in the results given competing needs in hydropower to keep costs low, maintain fleet readiness and resilience, and remain in compliance with environmental, safety, and other requirements.

Activity Area Strategy

Reviewers find this activity area has a well-defined strategy in alignment with the MYPP with clear goals and objectives. Reviewers agree this activity area's strategy shows an understanding of the industry's challenges, such as aging infrastructure, cyberthreats, lack of data, grid demand, and funding constraints. It would be desirable to have more focus on short-term benefits to end users in addition to long-term benefits such as the lure of a fantastic digital twin model after many years of input and calibration.

It appears the cybersecurity R&D activities build on work completed during the last two to three years. However, in the fleet modernization and maintenance areas, it is not clear to what extent future activity builds on past work, except that the digital twin project description indicates a feasibility study was completed in FY 2021.

The activity area presentation did a great job outlining the strategy. For this activity area, there might be an opportunity to use a case study to demonstrate how each of the projects can provide benefits, and how those benefits integrate to accomplish the activity area's goals. Such a case study could serve as proof-of-concept for the activity area.

It appears all funding comes from government. It is not clear if industry and academia or prizes/competitions are part of any of the funding. Also, funding is explained for the development of wear-and-fatigue models and cybersecurity research, but it is not clear to reviewers how the maintenance and digitalization areas are funded.

Implementation and Progress

The digital twin, wear-fatigue lab call, and HFI projects are complementary to each other. Cybersecurity projects were not intuitively complementary to these other projects; cybersecurity is just necessary. The cybersecurity projects are diverse in nature, and reviewers believe they complement each other and cover different needs for WPTO and the industry.

The activity area is funding relevant tools and studies. Without seeing the unfunded studies, it is not possible for reviewers to determine whether these are the most relevant. According to the MYPP, maintenance research priorities include the development of first-generation condition sensors, but this does not appear to be included this year. The activity area looks likely to fulfill all the 2021–2025 key results and performance goals defined in the MYPP.

Activity Area Response

Submitted by Kyle DeSomber

The program would like to extend its thanks to reviewers for their participation in the review of the Fleet Modernization, Maintenance, and Cybersecurity Activity Area. Their participation and specific hydropower experience helps to ensure the products the program is developing and studies it is undertaking are both useful and valuable to the industry. The program understands time is a limited resource, and these efforts required reviewers to go above and beyond their daily duties. Their participation, through review comments and discussions, helps to create the collective future.

An observation from reviewers' general comments was to continue to utilize industry groups for feedback and communication of project outcomes. This is an important reminder to WPTO that industry groups represent the larger industry. WPTO is an active member in many of these groups and will continue to rely on the expertise of these groups to form and guide projects and research with the national laboratories. To address reviewers' recommendations, it will be important for WPTO to coordinate efforts with industry groups seeking feedback to align work products with ongoing efforts occurring through the industry groups.

Reviewers also commented that the MYPP discusses the development of first-generation condition sensors, but none of the projects appeared to include the development of sensors. WPTO agrees with this observation. The current portfolio includes projects developing strategies and observations, not physical devices. The portfolio is working to diversify its approach through a new round of lab funding for wear-and-fatigue models and cybersecurity projects, as well as a recently released SBIR topic on cybersecurity. It is clear that funding mechanisms, such as small business grant programs, are better suited for development of physical devices than those that lead to lab studies. This observation will also be shared with the selection teams, so they can be mindful of the goal when selecting the next projects to undertake.

Overall, reviewers outlined several recommendations to (1) incorporate project implementation and financial considerations for end users, (2) include more maintenance projects in the portfolio, and (3) share project perspectives with how they fit in the larger portfolio strategy. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Incorporate Project Implementation and Financial Considerations for End Users

A common, multi-layered theme emerged from reviewers' feedback and was interpreted as follows:

- Project dissemination does not have to be all or nothing; the industry may realize benefits through the presentation of project progress.
- Project presentations and projects as a whole need to include business cases and implementation strategies for end users to evaluate the necessity and benefits of implementation against competing interests, notably environmental, safety, and North American Electric Reliability Corporation (NERC) requirements.

This is great feedback that is not necessarily stated within project objectives individually but is important to consider as these projects and this program continue to evolve. This also ties to the overall theme of continued coordination between WPTO and industry groups. As a first action, WPTO will examine annual operating plans within the Fleet Modernization, Maintenance, and Cybersecurity portfolio and look for opportunities to assess value and share project deliverables throughout the year. Further, the program invites suggestions from industry groups with ongoing work that may benefit from collaboration. A recent example of this collaboration was meeting with the start/stop working group at the Centre for Energy Advancement through Technological Innovation's hydropower conference to discuss ORNL's HFI project. This recommendation is valid and will be incorporated into plans for FY 2023.

Recommendation 2: Include More Maintenance Projects in the Portfolio

The projects presented are maintenance related and may lead to best practices in the future, but reviewers noted they do not necessarily address maintenance as it currently occurs. This comment is well received, as one value proposition of the HFI and Digital Twin projects is to enable predictive maintenance activities that reduce outages and maintenance costs. These projects approach predictive maintenance from different angles: HFI uses data-driven analysis that benefits well-monitored and recorded sensor systems, while Digital Twin uses a parallel, model-driven approach to simulate systems. Work to date has addressed several challenges related to data collection (cleaning, assimilation, sufficiency) and the construction of models. In FY 2023, both projects will develop concrete case studies to demonstrate the value of their approach related to current maintenance practices.

Additionally, WPTO funded two wear-and-fatigue projects this fiscal year that will select critical components and create user-friendly models to assess remaining useful life. These projects will complement the HFI and Digital Twin projects with more specificity to individual components. However, WPTO recognizes the need to develop and communicate the value proposition of predictive maintenance activities, and this need is reflected in revised project scopes. Further, the program will coordinate with industry groups to examine opportunities or pain points where WPTO and the national labs can assist hydropower owners and operators through applications of the existing portfolio (case studies), new funding opportunities, and dissemination of results. Engagement with plant operators will be beneficial in assessing existing data and gaps, allowing these software-centric projects to scale quickly.

Recommendation 3: Share Project Perspectives with How They Fit in the Larger Portfolio Strategy

Reviewers recommended a larger strategy beyond the MYPP be shared for cybersecurity and noted it would be worthwhile for individual projects to reiterate how they fit within the larger portfolio and WPTO strategies. The current cybersecurity strategy is based on Pacific Northwest National Laboratory's (PNNL) Cybersecurity in Hydropower Landscape Assessment and Roadmap. This document has not yet been made public but was used internally to ensure the recent FY 2023 cybersecurity project selections did not overlap and addressed all the perceived gaps. The program is working to publish this report publicly, while simultaneously incorporating it into a WPTO-led strategic plan for the Fleet Modernization, Maintenance, and Cybersecurity portfolio. This strategic plan will better tell the story of WPTO goals and investments and how they relate to each other and within the larger energy and cyber communities. In particular, the cybersecurity strategy will be overlayed with the fleet modernization and maintenance strategies to show the holistic picture as reviewers recommended.

Environmental and Hydrologic Systems Science

The Environmental and Hydrologic Systems Science Activity Area aims to research and develop new technologies to better characterize river systems and evaluate potential impacts; avoid, minimize, or mitigate environmental impacts; and improve understanding of various hydrologic risks and uncertainty. Through this activity area, WPTO aims to:

- Develop better monitoring technologies to study river systems and evaluate environmental impacts.
- Develop technologies and strategies to avoid, minimize, or mitigate environmental impacts.
- Support development of metrics to better evaluate environmental sustainability for new hydropower developments.
- Assess potential impacts of long-term climate and hydrologic changes to hydropower.
- Improve abilities to assess risk of potential methane emissions from water bodies.

The review panel thought the strategy presented was in line with the MYPP, and the projects were all representative of the overall strategy, though they did recommend a greater focus on communicating results and commercialization. Figure 11 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 12 provides an overview of the scoring of all projects within the Environmental and Hydrologic Systems Science Activity Area.

Figure 11. Environmental and Hydrologic Systems Science Activity Area Average Weighted Score by Evaluation Criterion

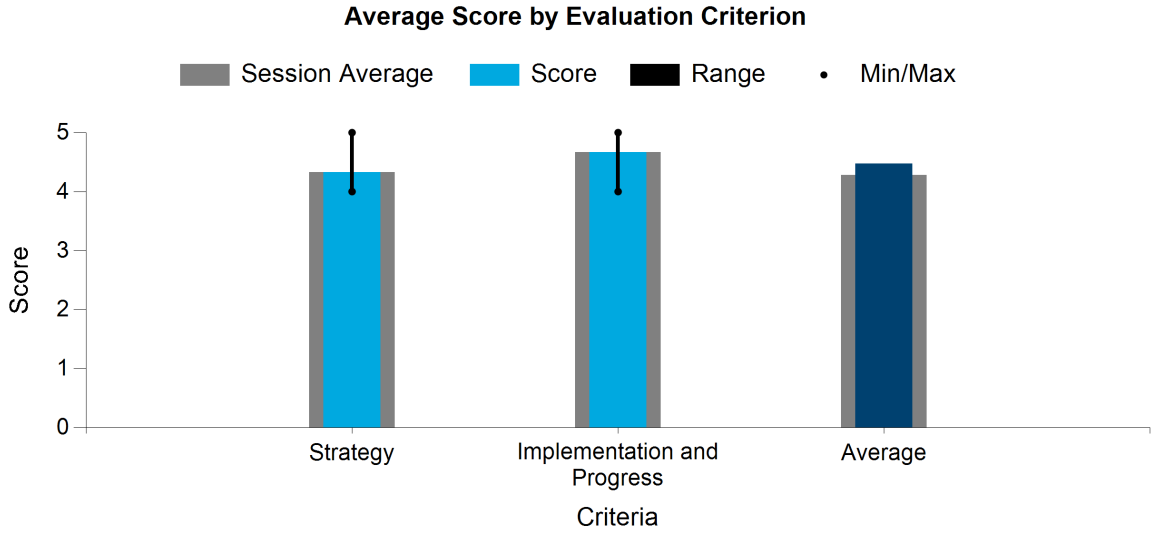
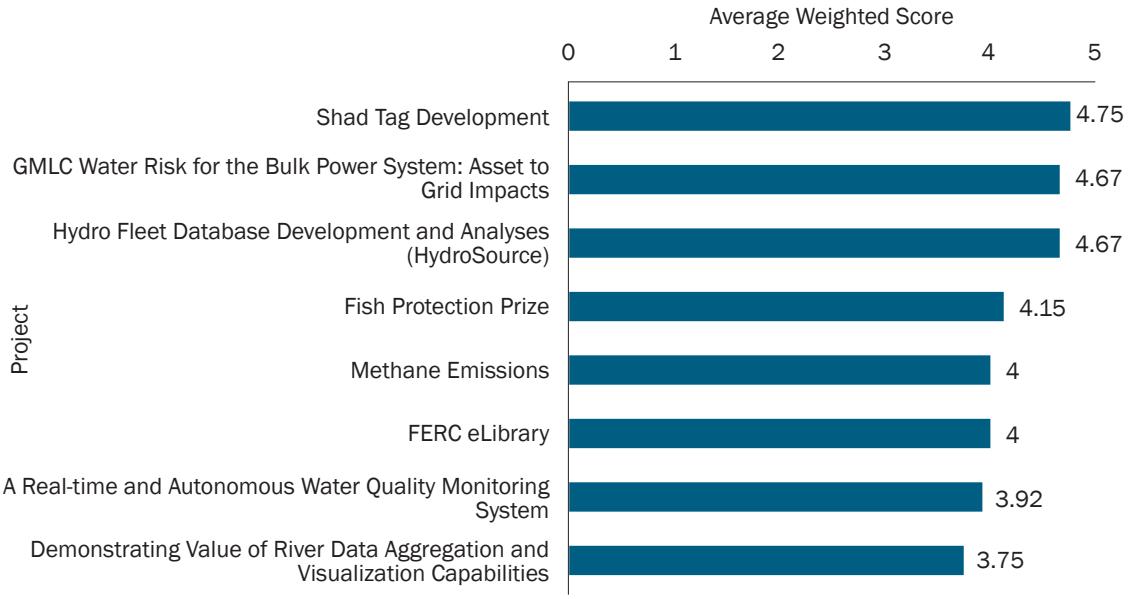


Figure 12. Environmental and Hydrologic Systems Science Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Shannon Ames

Feedback from the Review Panel to WPTO

The projects in this activity area are valuable, worthwhile, and strategically aligned with the MYPP. The reviewers agree the projects have made significant progress against their original project plans. There is no question the projects are being managed carefully, thoughtfully, and responsibly.

All reviewers, however, would have appreciated more detail on the results of or lessons learned from the projects to date. Each project, and the activity area as a whole, has thoughtfully considered communications and stakeholder outreach. Reviewers agree, though, that the effectiveness of outreach differed by project. The notion of "hydropower industry community" needs to be clearly defined and must include a broad array of those who interface with hydropower—owners and operators, agencies, river conservation organizations, universities, etc.—and tailored to the specific project. The dissemination of this work must result in the average person's ability to quickly access research results. The success of these projects will be determined by their ability to get through the next stage, be it dissemination and adoption, commercialization, or additional research.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

Reviewers agree the summary of the activity area was effective in placing the projects within the overall strategy of the MYPP. The reviewers would like to see more comprehensive and frequent outreach and incorporation of feedback from the hydropower community to ensure projects and their strategy align in this quickly changing landscape. In addition, reviewers would like to see a clearly articulated strategy for commercialization.

Commercialization, in this case, would incorporate both how to get products to market, as well as deployment of research, so stakeholders can incorporate it as quickly and effectively as possible.

Activity Area Strategy

Reviewers agree the activity area has a well-defined strategy that is outlined in the MYPP. There are clear performance goals, objectives, and research priorities associated with the strategy.

It is clear to reviewers that the strategy reflects an understanding of the short- and long-term challenges facing the industry. The strategy incorporates the challenges facing industry and, to a lesser extent, the broader hydropower stakeholder community. Some reviewers think the strategy should be more focused on meeting the needs of the hydropower industry, while other reviewers believe the strategy should reflect a better balance between hydropower development and broader stakeholder community interests. Maintaining a balance in research priorities to address the needs of the hydropower industry and broader stakeholder community should remain a top focus for the program.

The activity area's activities build on past work and address real needs within the industry. Shad tagging is a good example of this attempt to fill a data gap with new technologies applicable to multiple species and watersheds. While the reviewers are not united on whether the reservoir emissions research is valuable to the industry, it is addressing a key need for hydropower stakeholders at large and the ongoing need to understand hydropower's role in a carbon-free future. This is a clear case where additional details on the results of past and current work would help to demonstrate the value and relevance of the research to the hydropower community.

The shad tag and methane projects are good examples of the slight variation in communication effectiveness. The findings of the shad tag work have been presented to appropriate audiences, which are excited to commercialize and use the technology. The methane research has been published, but information has been presented to select audiences without clearly articulating to the industry why this work is important.

The activity area primarily leverages national labs and prizes for the sub-activity areas. These mechanisms appear to be appropriate for the projects reviewed, but reviewers would like to see more involvement of academia.

Implementation and Progress

The projects within the Environmental and Hydrologic Systems Science Activity Area are closely tied to the program's strategic direction. The projects are diverse—they incorporate product development (e.g., shad tags and robots for water quality monitoring), data dissemination (via HydroWIRES, HydroSource, and Federal Energy Regulatory Commission (FERC) eLibrary search capabilities), and new research in a nascent field (e.g., reservoir emissions). However, the projects all address the central need to provide scientific information, in coordination with stakeholders, to allow hydropower generation to continue to grow responsibly with improved environmental outcomes at hydropower facilities and to contribute to the clean energy future through modeling, design, and analysis of environmental effects and stakeholder involvement. These areas are all relevant. The data access tools will be important but depend on effective dissemination. The mechanical tools are demonstrably in demand but will depend on affordable commercialization.

Provided these projects are either effectively commercialized or funded in future years so the full scope of research can be completed, they all do or will meet performance goals and objectives.

Activity Area Response

Submitted by Dana McCoskey, Technology Manager

WPTO would like to express its sincere thanks to reviewers for their critical feedback, active engagement, and thoughtful recommendations on the Hydropower Program's Environmental and Hydrologic Systems Science portfolio. The program also expresses additional thanks to the panel chair for leading the group and facilitating conversations to create a productive environment where all reviewers' thoughts could be respectfully voiced. While this review is only a snapshot of the types of projects WPTO has funded in this activity area, the range of comments, impressions, questions, and dialogue from reviewers help WPTO to better understand how to further develop projects for greater benefits and provide valuable insights into the overall strategy. This input will support future investments in technically sound and relevant R&D, help to deliver commercial products and key research findings to diverse stakeholders, and assist in improving outreach and engagement.

Overall, reviewers outlined several recommendations to (1) develop mechanisms and metrics to evaluate the effectiveness of outreach and engagement at the project level, (2) develop and clearly articulate strategies for commercialization, and (3) maintain a balance in research priorities to address hydropower industry and broader stakeholder community needs. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Develop Mechanisms and Metrics to Evaluate the Effectiveness of Outreach and Engagement at the Project Level

Reviewers recommended WPTO evaluate whether outreach is working. Reviewers also commented on examples of projects where they believed communications varied in effectiveness by pointing out the differences between the Shad Tag and Methane Emissions from Reservoirs projects. Some of these differences could be attributed to the fact that the shad tag project is related to multiple past WPTO-funded projects that aimed to deliver different fish-tracking tags to the hydropower industry, resulting in a mature existing network of interested researchers and practitioners. It may also be attributed to the principal investigator's (PI) participation in formal training (DOE's Energy I-Corps) on commercialization.

Meanwhile, the Methane Emissions from Reservoirs project is relatively new to WPTO and the laboratory, so networks with industry and other hydropower stakeholders are in the process of being developed. However, the methane emissions team has engaged the hydropower community by presenting its findings to the Uncommon Dialogue, which is an established group with diverse viewpoints on emissions from reservoirs. In addition, WPTO developed a webpage highlighting the results of the Methane Emissions from Reservoirs project and will continue to provide transparent and objective information related to this topic.

But there are ways that the program will strengthen both the methods and evaluation of mechanisms to engage with the industry and environmental industry. This includes the following – which is inclusive of the activity area but also broadly applicable to the WPTO portfolio:

- Support PIs' development through peer mentoring and trainings, prioritizing new staff for professional development.
- Support PIs in sharing best practices for outreach from successful projects with the WPTO laboratory research community.
- Add more emphasis on outreach and engagement, including stakeholder identification, for all new laboratory projects early in the project work plan with funding to support efforts.

WPTO will continue to utilize existing outreach and engagement tactics and pilot new efforts.

Recommendation 2: Develop and Clearly Articulate Strategies for Commercialization

WPTO appreciates this feedback and agrees that such planning is helpful for internal, longer-term planning and engagement with potential external partners. WPTO is currently developing materials for awardees on commercialization processes and options for intellectual property. WPTO also works closely with national laboratory commercialization offices to understand the options for technology transfer of WPTO-funded tools and technologies. In this activity area, national laboratories frequently use a licensing pathway for both hardware and software, although some software is open source. WPTO will develop methods to make this information clearer and to evaluate plans to progress.

Recommendation 3: Maintain a Balance in Research Priorities to Address Hydropower Industry and Broader Stakeholder Community Needs

The program appreciates the feedback that there are a variety of stakeholders that have research needs related to hydropower and the recommendation that there should be a balance between industry needs and those of other stakeholders. WPTO's Hydropower Program has strategically focused resources on projects that have a hydropower nexus, assisted projects in developing partnerships with industry for testing and demonstrations, and often prioritized R&D in this activity area that benefits stakeholders from multiple hydropower sectors. WPTO will critically review projects in terms of primary stakeholders and categorize projects to assess gaps and evaluate R&D services by sectors. WPTO strives to maintain such balance and will intentionally review priorities with this in mind.

SECTION 2

Marine Energy Program

Foundational R&D

Technology-Specific System Design and Validation

Reducing Barriers to Testing

Marine Energy Data Access, Analytics, and Workforce Development

Marine Energy Program Peer Review

Marine Energy Program Overview

To help realize the Marine Energy Program's vision, WPTO conducts research, development, demonstration, and commercial activities that advance the development of reliable, cost-competitive marine energy technologies and reduce barriers to deployment. This work is concentrated in four activity areas and one initiative: Foundational R&D; Technology-Specific System Design and Validation; Reducing Barriers to Testing; Data Access, Analytics, and Workforce Development; and the Powering the Blue Economy™ (PBE) Initiative.

As defined in the Energy Act of 2020 (Title 3, Subtitle A, Sec. 3001) the term "marine energy" means energy from:

- Waves, tides, and currents in oceans, estuaries, and tidal areas.
- Free-flowing water in rivers, lakes, streams, and man-made channels.
- Differentials in salinity and pressure gradients.
- Differentials in water temperature, including ocean thermal energy conversion.

Utility-scale marine energy technologies are at an early stage of development compared to other renewable energy technologies due to the fundamental challenges of generating power from dynamic, low-velocity, and high-density waves and currents, while surviving in corrosive marine environments. These challenges are intensified by high costs and lengthy permitting processes associated with in-water testing. Addressing these challenges is a key part of WPTO's portfolio.

These challenges are worth overcoming as marine energy has the potential to contribute to an electric grid primarily powered by renewable energy while also addressing the need for climate change mitigation. The program is working to ensure this potential is unlocked while avoiding an undue burden on the environment surrounding deployed marine energy technologies. Current research shows that marine energy's potential environmental impacts are low compared to other energy sources, particularly fossil fuels, with minimal drilling-associated noise pollution and low to non-existing risks of oil spills leading to ecosystem damage, and WPTO is dedicated to ensuring these technologies are developed in a way that keeps this statement true.

In addition to marine energy's potential contribution to the grid, WPTO also sees the value this resource could have in advancing many of the United Nations Sustainable Development Goals by providing power at sea for activities from ocean observation to aquaculture. With all these areas of use, WPTO is working to accelerate the maturity of marine energy technologies according to international standards and specifications, ultimately leading to system accreditation. The program also recognizes marine energy's potential to enhance resilience and power electric microgrids in coastal, remote, and islanded communities. Marine energy technologies can, importantly, help make these communities more resilient in the face of extreme events such as tsunamis, hurricanes, floods, or droughts.

Organization of Tracks and Review Panels

The Marine Energy Program, activity areas, and individual projects were reviewed and scored during WPTO's 2022 Peer Review. Additionally, the reviewers scored and provided specific feedback on the PBE Initiative—an effort that seeks to understand the power requirements of emerging coastal and maritime markets and advance technologies that could integrate marine renewable energy to relieve these power constraints and promote economic growth. Program and activity area overview presentations detailed the goals and objectives, as outlined in the MYPP. For information about the structure, strategy, and implementation of the program and its relation to WPTO's overall mission, please refer to the corresponding program overview and PBE overview slide decks presented during the review.

Four panels of reviewers reviewed these program elements, as well as individual projects across all the Marine Energy Program's activity areas. There were also two reviewers who focused solely on the cross-programmatic prize portfolio and one who did the same for the STEM and workforce work. Figure 13 depicts the total number of marine energy presentations reviewed by program and activity area.

Figure 13. Number of Marine Energy Projects Reviewed by Review Panel

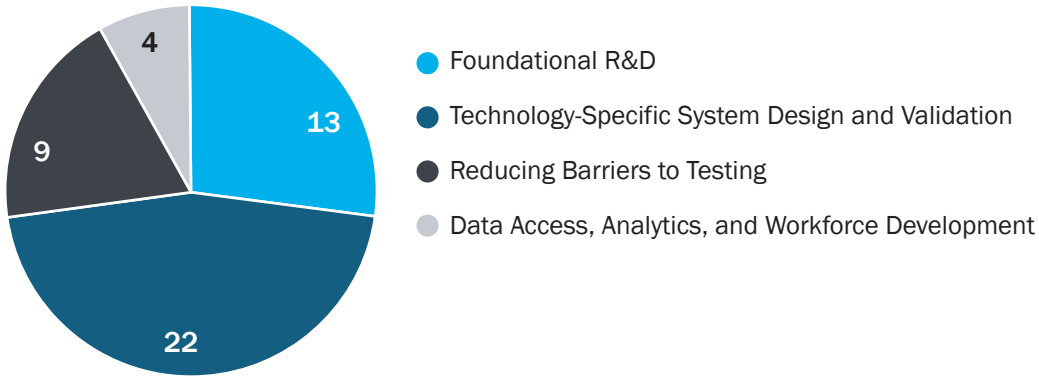


Table 6 summarizes the role, review panel, and affiliation of the external experts who served as reviewers for the Marine Energy Program during WPTO's 2022 Peer Review.

Table 6. Marine Energy Program Reviewers

MARINE ENERGY PROGRAM			
Name	**Role**	**Review Panel**	**Affiliation**
Henry Jeffrey	Review Chair and Panel Lead	Technology-Specific System Design and Validation	University of Edinburgh
David Ingram	Panel Lead	Foundational R&D	University of Edinburgh
Deborah Greaves	Reviewer	Foundational R&D	Supergen Offshore Renewable Energy Hub (University of Plymouth)
Jessie Carman	Reviewer	Foundational R&D	National Oceanic and Atmospheric Administration
Umesh Korde*	Reviewer	Foundational R&D	Johns Hopkins University
Beth Dickens	Reviewer	Technology-Specific System Design and Validation	Quoceant Ltd.
Claudio Bittencourt Ferreira	Reviewer	Technology-Specific System Design and Validation	DNV Renewables
Sue Molloy*	Reviewer	Technology-Specific System Design and Validation	Glas Ocean Electric

MARINE ENERGY PROGRAM			
Name	**Role**	**Review Panel**	**Affiliation**
Sue Barr	Panel Lead	Reducing Barriers to Testing	Cambrian Offshore
Denis Nault	Reviewer	Reducing Barriers to Testing	Maine Department of Marine Resources
Louise McGarry	Reviewer	Reducing Barriers to Testing	Fundy Ocean Research Centre for Energy
Phil Vitale	Reviewer	Reducing Barriers to Testing	Retired (formerly Naval Facilities Engineering Systems Command)
Michael Atkinson	Panel Lead	Data Access, Analytics, and Workforce Development	North Carolina A&T State University
Ana Couto*	Reviewer	Data Access, Analytics, and Workforce Development	European Marine Energy Center
Dan Hasselman*	Reviewer	Data Access, Analytics, and Workforce Development	Fundy Ocean Research Centre for Energy
Linda Silverman*	STEM/Workforce Reviewer	Data Access, Analytics, and Workforce Development	Potential Energy DC
Donna Vincent Roa	Prize Reviewer	Prizes	U.S. Agency for International Development's Partnerships Incubator, The Kaizen Company
Sally Gutierrez	Prize Reviewer	Prizes	Environmental Protection Agency

*Selected to also review the crosscutting Marine Energy STEM and Workforce project.

Marine Energy Program Scores

Reviewers were asked to evaluate WPTO's R&D programs, activity areas, and initiatives at a strategic level, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each program on the following equally weighted criteria: strategy and implementation and progress. Figure 14 summarizes reviewers' quantitative assessment of how the Marine Energy Program is performing overall. While all PBE projects fell into other marine energy activity areas and were scored within those panels, it was critical to solicit reviewer feedback on the overall strategy. Figure 15 shows the quantitative assessment of the PBE Initiative. Figure 16 shows the average weighted score for the Marine Energy Program's activity areas, including PBE, with reference lines indicating the average project score and program score. The aggregated reviewer comments justifying these quantitative scores can be found in Volume II.

Figure 14. Marine Energy Program Average Weighted Score by Evaluation Criterion

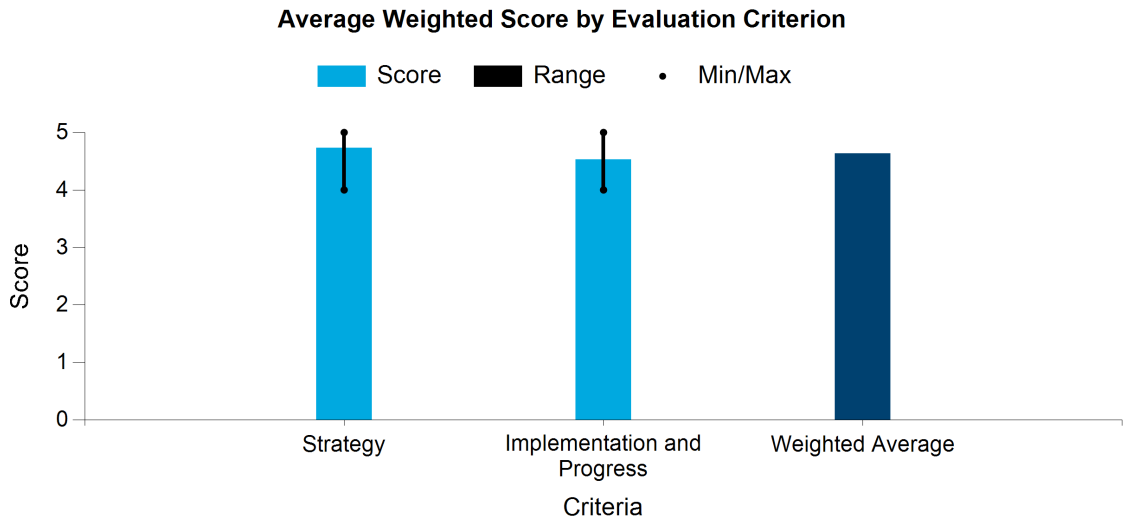


Figure 15. PBE Initiative Average Weighted Score by Evaluation Criterion

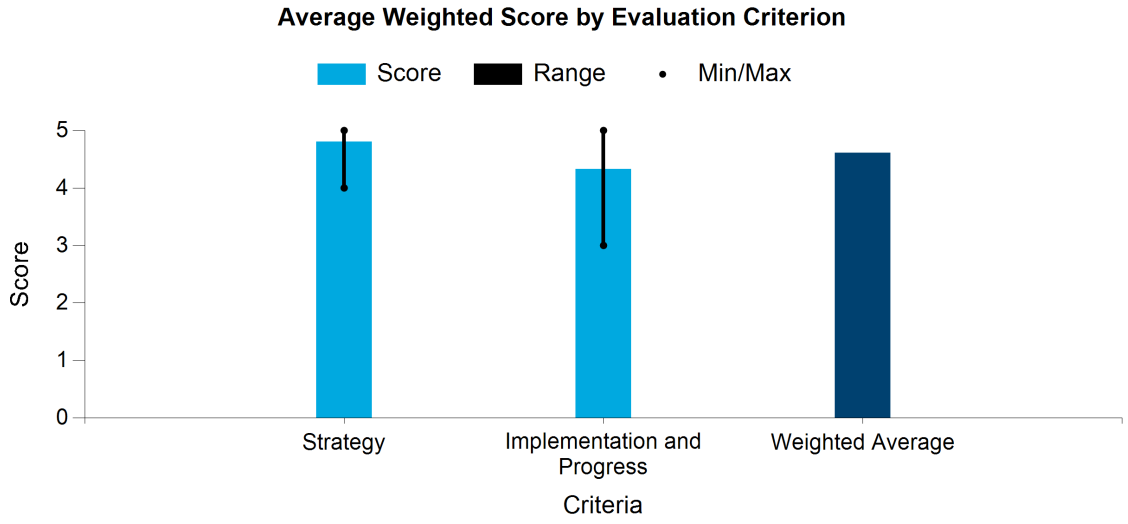
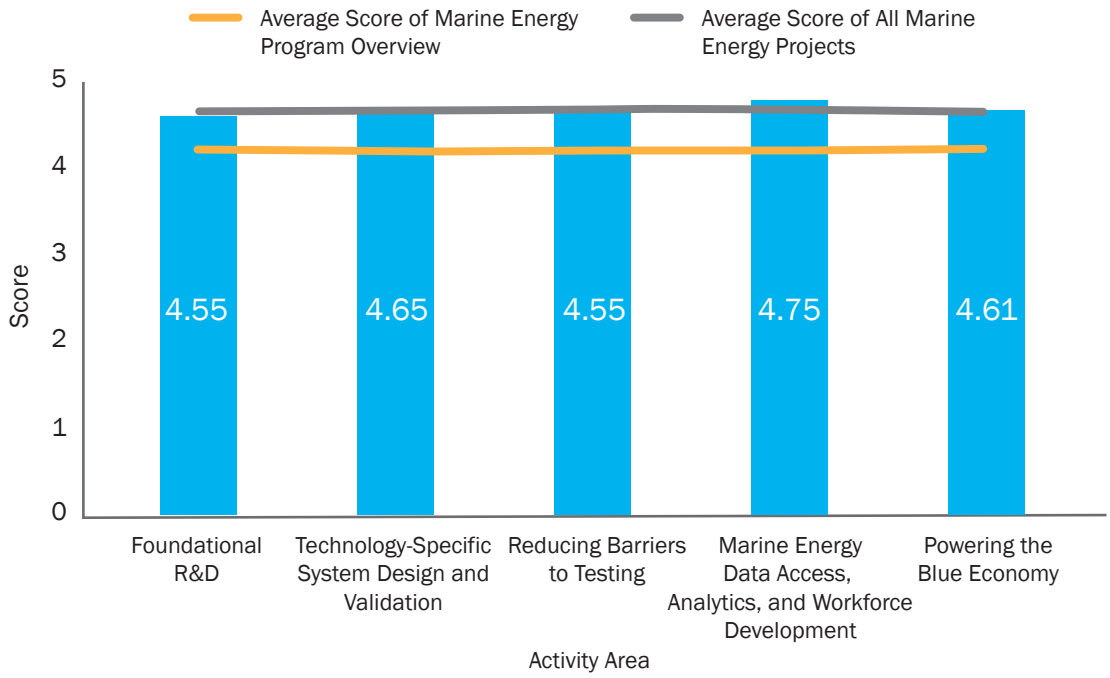


Figure 16. Average Weighted Score by Marine Energy Program Activity Area



Organization of the Results

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

- Marine Energy Program Evaluation Summary: A summary of all marine energy 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 in consultation with each review panel lead and all marine energy reviewers. Consensus among the reviewers was not required, and the review chair was asked to include differences of opinion and dissenting views within the report.
- Marine Energy Program Response: The WPTO program manager's official response to the recommendations provided in the review chair's program evaluation summary.
- Marine Energy Program Activity Area Results: The results of the reviewers' quantitative scores on the program. Activity area results follow the program results and begin with a summary chart that depicts the average score for each project in each activity area. Each activity area subsection includes the following components:
  - *Activity Area Evaluation Summary*: This consists of a summary of the review panel's comments that provides insight into each 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 the review panel leads were asked to include differences of opinion and dissenting views within the report.
  - *Activity Area Response*: The WPTO activity area lead's official response to the recommendations provided in the review panel lead's activity area evaluation summary.

Marine Energy Program Evaluation Summary

Submitted by Henry Jeffrey, Chair

Key Takeaways

WPTO's Marine Energy Program has moved from strength to strength, ensuring the activity areas are well integrated and leading to the marine energy sector's continued progression. The program laid extensive groundwork related to research capabilities and has ensured there is cohesive coordination between industry and national labs, ranging from the development of full-scale devices to the innovation of supporting components and specialist software.

Pending future budgetary constraints, the scaling of technologies in size, and development and deployment costs, it may now be time to focus the many different research strands to maximize the program's potential to deliver returns consistent with the level of support it has provided. This approach will prevent assets, research themes, and future projects from becoming stranded and ensure the program grows in line with its research commitments moving forward.

Over the medium and long terms, it will be important to fully consider how funding and management environments will need to adapt as projects scale and advance through multiple technology readiness levels (TRLs). It is important to question whether WPTO will have the requisite funding for innovation, as well as the staffing levels for continued sector progress and to continue to run an effective, well-coordinated, and adequately staffed program. If the program is going to continue to grow, it will be critical to ensure the necessary support mechanisms are in place.

Value can be added to WPTO's already effective program in a few ways. The most pressing issues include prioritizing effective knowledge transfer, initiating clear processes to ensure projects can learn from previous successes, tracking long-term project awardees' progress, and ensuring WPTO scales accordingly. However, it is important to highlight the Marine Energy Program's and the staff's progress and laude the impact the program has on an organizational level at accelerating the sector's development and helping to shape the much-needed net-zero transition.

Feedback from the Review Chair to WPTO

The program's breadth and depth are impressive, and its expansive nature ensures multiple key research areas are being targeted and their objectives achieved. It is important to question if this will remain sustainable as technologies achieve higher TRLs. Depending on future funding levels, it may be necessary to focus the program's scope to ensure its continued success and impact.

Value could be bolstered with stronger user engagement, ensuring customer needs, whether in a niche or utility market setting, are well understood. DOE could deliver this centrally, removing the onus from technology developers that may not be uniquely equipped to deliver strong end-user engagement.

Program breadth can also be addressed by assessing the progress of technology developers that have enjoyed sustained exposure to the WPTO support system and received numerous project awards. This will safeguard the long-term validity and effectiveness of the program, and the use of IEA Task 12, Stage Gate Metrics may be an effective tool for this process. Projects' abilities to transition to commercial business models following funding from WPTO is also a key concern and an area that should be explored further.

Prizes remain an effective tool to attract innovation in a new project area. However, they need to be analyzed to ensure they remain cost effective and have a traceable pathway to serve the sector's innovation needs. It is also important to capture each prize program's lessons learned regarding program structure and the technological developments they helped to underpin. Prizes should have a clear pathway for successful developers to continue their journey forward to remove the risk of stranding innovation.

The process of technology transfer is important to ensure that, in the case where any individual project might not meet its long-term goals, there is a mechanism to extract specific, successful technological developments or procedural lessons that might be of benefit to the wider sector.

While there is a strong drive to develop sea-ready, full-scale devices such as wave energy converters (WECs), more needs to be invested into projects conducting fundamental research to better characterize realistic ocean conditions. This can be accomplished by increased funding at the university level where publishing fundamental research is key, and peer-reviewed articles add credibility to new technologies. Additionally, in instances where technologies are being developed by other companies or nations, knowledge transfer will help to limit wasteful duplication and replication of research. Where possible, it would also be beneficial to ensure projects are aligned with other funding such as that from the Department of Defense.

The overwhelming consensus from reviewers is that there needs to be an increased effort in recognizing and mitigating possible negative environmental impacts. While this may be a result of many projects being in the early stages of development, funding projects that genuinely explore eco-friendly solutions should be prioritized. Reviewers also recommend foundational technology and component development projects be required to consider the impact of the real ocean environment (i.e., multidirectional waves, wind driven, ocean and tidal currents, and turbulence) as part of a co-design approach. Finally, reviewers advise that a fair approach is taken to compensate for the adverse effects of COVID-19 and its impact on the flexibility and security of supply chains, working conditions, and internal timelines.

Summary of Reviewer Feedback on the Program

Overall Impressions

WPTO needs to be supplied with both the innovation funding and staff resources to ensure the depth and breadth of the program continues to be effectively managed. There may be a need to focus the program to ensure key projects do not become underfunded and investments do not become stranded. Further, a comprehensive cost-benefit analysis of the prize program approach will ensure it continues to be an effective tool and delivers continued innovation.

It is advisable to ensure there are synergies between technologies underpinning both the blue economy and utility-scale devices with common goals and areas of overlapping research expertise highlighted. WPTO should also ensure all strands of the program have full pathways and funding to commercialization, ensuring broader sector uptake. Sector engagement should be delivered centrally as there are instances where certain projects are heavily focused on single devices with limited potential for outreach and dissemination, ultimately limiting their usefulness to the broader sector.

Program Strategy

The program benefits from having a well-defined strategy in full alignment with the MYPP, including clear objectives and defined research priorities. Although the overall program deals well with short- and mid-term challenges, it is less clear how it will evolve to deal with the longer-term challenges of the sector, whether this is at scale or for new and emerging technologies. Without attempts to refine the scope or expand WPTO's resources, it may be difficult to scale up to comprehensively cover all current areas of development and deployment. Scaling should also involve increased levels of international collaboration, drawing on the expertise and testing capabilities of international leaders in the sector.

With respect to industry and stakeholder needs, the overall strategy is well considered. However, this should be monitored in line with the sector's evolution and with consideration to technologies' scales and the expected differences between niche blue economy and utility-scale technologies. It would also be advantageous to ensure projects are not just aimed at specific end users but, where possible, expanded to take into consideration varied industry and stakeholder requirements. Ensuring strong, diversified attempts at stakeholder engagement are made will only benefit a sector that has global appeal and reach.

Currently, there is a good rationale to support the organization of the sub-activity research areas and priorities. However, this might need to be reconsidered if the program chooses to refocus its priorities or as technologies scale to higher TRLs and introduce different challenges. There is a good mixture of funding mechanisms across the program for academia, labs, and industry, supported by a comprehensive range of prizes and competitions. Ensuring complementary and collaborative links between DOE and the Department of Defense will help to foster accelerated technological development and ensure end users in both sectors have the opportunity to fund or engage with complementary projects.

WPTO funding is additive in its ability to raise additional funding to support projects without compromising overall program deliverables.

Implementation and Progress

The current program is in full alignment with WPTO's stated objectives. Reviewers unanimously agree the program is funding the most relevant technologies, tools, and studies. However, in all instances, whether a project has been deemed successful or not, it is important to retrospectively examine milestones and deliverables that will allow WPTO to highlight isolated instances of technological development that can be utilized or lessons that can be learned and applied across the sector. There should be clear processes in place to ensure future projects can learn from previous projects, limiting the scope for duplication and replication of research aims and challenges.

Companies that receive long-term or consecutive project awards should be monitored to ensure they remain on track to deliver strong results throughout the duration of the project lifetime. This should be supplemented by the inclusion of a go/no-go decision at the halfway point of any project. This will help ensure projects in danger of not achieving their milestones do not continue to accept funding that could be allocated to other projects.

Across the program, activity areas include diverse and complementary R&D projects that are closely tied to the program's strategic direction. This can be safeguarded by enacting a robust evaluation process that can determine risk profiles of projects as they progress. Additionally, it is important to fully understand the context and subsequent consequences of not progressing a project, especially in the later stages of development.

The peer review is a robust and transparent process, reinforced by ensuring outcomes are made publicly available to the wider marine energy sector. However, there should be greater sector and public awareness of the process with effective advertisement and dissemination of the process and its outcomes.

Despite the level of collaboration and knowledge exchange that exists within the WPTO community, the panel feels there could be stronger attempts to coordinate additional dissemination and sharing of results with the wider marine energy sector (in addition to the peer review process). At an individual project level, the program could benefit from greater communication between domestic and international bodies, projects, and industry stakeholders.

Additional Comments on the PBE Initiative

Using WPTO's research capabilities to help power the blue economy has the added advantage of providing an additional route to industrial-scale commercialization of devices in the sector. However, the blue economy is a market in its own right, and any funds directed to it need to be examined to ensure they are an appropriate use of public funds that contributes to the net-zero challenge. Funds should not be diluted, subsidizing both the blue economy and low-carbon utilities, especially in instances when technological development will produce devices with end-user qualities that are not designed for use in low-carbon utilities. This reinforces earlier suggestions that efforts should be made to continually focus the program to ensure it remains a good value for money invested and future research interests are aligned.

Marine Energy Program Response

Submitted by Tim Ramsey, Program Manager

Response to the Review Chair's Key Takeaways

The Marine Energy 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 they shared their expertise, and the U.S. marine energy community will benefit for years to come thanks to the reviewers' hard work and dedication. WPTO gained invaluable insights and has already started to incorporate some of the recommendations into the program strategy.

The Marine Energy Program thanks the reviewers for their many positive comments on the quality of WPTO staff. The program is very proud of the team and acknowledges that its success reflects their hard work and professionalism.

Overall, reviewers outlined several areas for improvement to (1) focus and evaluate funding and maximize impact in later stages, (2) improve fundamental research and technology transfer, (3) mitigate possible negative environmental impacts, (4) strengthen supply chain engagement, and (5) further integrate end-user requirements in the PBE Initiative. The following sections outline the program's response to the reviewers' key recommendations.

Recommendation 1: Focus and Evaluate Funding and Maximize Impact in Later Stages

The Marine Energy Program agrees with the reviewers' feedback regarding later-stage technologies and recognizes the challenge ahead. The program has supported a wide breadth of technologies across many resource types and end-use applications, and costs inherently increase as systems advance in TRL. Within current funding levels, the program may be forced to down-select as technologies continue to mature. Selecting the most impactful technologies and projects will be crucial for the industry's advancement. The program will gather as much information as possible to inform these decisions, including feedback on the MYPP and from subject-matter experts across the industry, the National Marine Renewable Energy Centers (NMRECs), and the national labs. The program will also apply IEA-Ocean Energy Systems (OES) Task 12, Stage Gate Metrics, to assist in measuring technology development progress and success. Furthermore, a robust project management plan for later-stage projects will be critical to maximize program funding and support the entire industry's advancement.

The program must also better capture and disseminate information from all projects funded, though particularly for higher-stage and higher-cost projects. It is important to retrospectively examine milestones and deliverables that will allow WPTO to highlight isolated instances of technological development that can be utilized or lessons that can be learned and applied across the sector. The program will strengthen its dissemination plan around the peer review process and look to expand efforts to disseminate and share results with the wider ocean energy sector.

The program will require stronger end-user engagement at the beginning of projects, ensuring customer needs are well understood and projects transition to commercial business models. The program will consider additional mechanisms to foster end-user engagement, including centralizing this effort at WPTO, thereby reducing the onus on technology developers.

In addition to evaluation of the stage of projects being funded, WPTO is actively tracking, evaluating, and monitoring the effectiveness of these programs, including prizes across the portfolio. In addition to the need to fund later stage solutions, the program also views it as critical to continue to invest in new ideas, people, and approaches to ensure a portfolio that has a forward-looking approach and includes reducing risk by investing in new approaches.

WPTO uses a range of financing mechanisms, including prize competitions to spur innovation in new areas and/or from new and under-resourced entrants, SBIR grants to provide non-dilutive grants for commercialization-focused R&D, and larger cooperative agreements for sustained R&D. In addition to financial assistance, WPTO also works with the American-Made Network's Power Connectors and other organizations to provide commercialization support to prize and SBIR awardees, and provides funding to a network of blue economy incubators and accelerators to provide business development support. And the program is committed to tracking and evaluating and disseminating information on the effectiveness of this approach.

Recommendation 2: Improve Fundamental Research and Technology Transfer

The Marine Energy Program appreciates the reviewers' feedback to invest more into projects conducting fundamental research to better characterize realistic ocean conditions. The program has invested heavily in the Foundational R&D Activity Area, notably in controls, modeling, and resource characterization, though more can be done. The program will continue to assess industry's foundational and crosscutting requirements and prioritize those research areas of greatest need and impact. The program also plans to bolster engagement with the NMRECs and affiliated universities to broaden its foundational research impact. The Bipartisan Infrastructure Law included $40 million to support the NMRECs, and the program will leverage this funding to support foundational research. In addition, the recently established University Marine Energy Research Community (UMERC) Program will foster collaboration within the marine energy research community and amplify the impacts of foundational research. The program will look to UMERC to help increase transparency and awareness of marine energy research, inform areas to enhance marine energy research activities, and improve overall research coordination and collaboration.

Recommendation 3: Mitigate Possible Negative Environmental Impacts

The Marine Energy Program thanks the reviewers' feedback regarding environmental impacts. The program will continue to support OES-Environmental (Task 4), led by PNNL, which synthesizes into collaborative reports and documents information and scientific research about marine renewable energy and the environment on a global scale. OES-Environmental hosts workshops and webinars to bring researchers together around environmental effects research and supports environmental effects tracks at international conferences. The program will also continue to engage with regulators and permitters, including the continued use and refinement of the Marine Energy Environmental Toolkit developed by Kearns & West. Additionally, the program agrees with reviewers' recommendation that foundational technology and component development projects should consider the impact of the real ocean environment as part of a co-design approach and will look to strengthen this connection and prioritize projects that genuinely explore eco-friendly solutions.

Recommendation 4: Strengthen Supply Chain Engagement

The Marine Energy Program agrees with reviewers' feedback regarding supply chain engagement. The industry is at a critical stage of development and supply chain engagement is paramount to ensure adoption and commercial success. The program will put more emphasis on the challenges developers face with electrical cables, access to marine vessels, and/or specific device handling and mooring designs, as well as integrate lessons learned from other renewable energy industries, like offshore wind. The program will aim to foster site-specific supply chain development, including at PacWave, to support marine energy developers.

Recommendation 5: Further Integrate End-User Requirements in the PBE Initiative

The PBE Initiative recognizes current challenges in deploying grid-scale marine energy systems, and therefore identifies near-term markets and end users for marine energy to enable technology deployment, prototyping, and testing to accelerate the development and maturity of marine energy technologies. This program is also aimed at commercializing non-grid marine energy systems and applications in the near term.

Because developers are in the concept phase of technology development, PBE recognizes end-user requirements are key to contribute to the concept design, particularly for those non-grid applications. The program will work to engage more with the U.S. Navy, Department of Defense, and the National Oceanic and Atmospheric Administration (NOAA) on system requirements (as they are key end users for the technologies under development) and ensure requirements are considered at the design phase. The Marine Energy Program will facilitate end-user engagement and identification of end-user needs. And as previously mentioned, WPTO is committed to supporting entrepreneurs, industry, and academia connections to end users through mechanisms like the American Made Challenge platform and through other support.

Marine Energy Program Activity Area Results

Foundational R&D

The Foundational R&D Activity Area aims to drive early-stage R&D on components, controls, manufacturing, and materials; develop and validate numerical modeling tools; improve resource assessments and characterizations; and develop quantitative metrics to evaluate devices' potential. Through this activity area, WPTO is working to:

- Drive early-stage R&D on components, controls, manufacturing, and materials.
- Develop and validate numerical modeling tools and methodologies for improved understanding of important fluid-structure interactions.
- Improve marine energy resource assessments and characterizations needed to optimize devices and arrays and understand extreme conditions.
- Develop and apply quantitative metrics to identify and evaluate technologies with high ultimate techno-economic potential.

The review panel was impressed by the focus of the work and the overall deliverables produced but did suggest there be a larger focus on stakeholder engagement to help increase the pool of applicants, recipients, and partners. Figure 17 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 18 provides an overview of the scoring of all projects within the Foundational R&D Activity Area.

Figure 17. Foundational R&D Activity Area Average Weighted Score by Evaluation Criterion

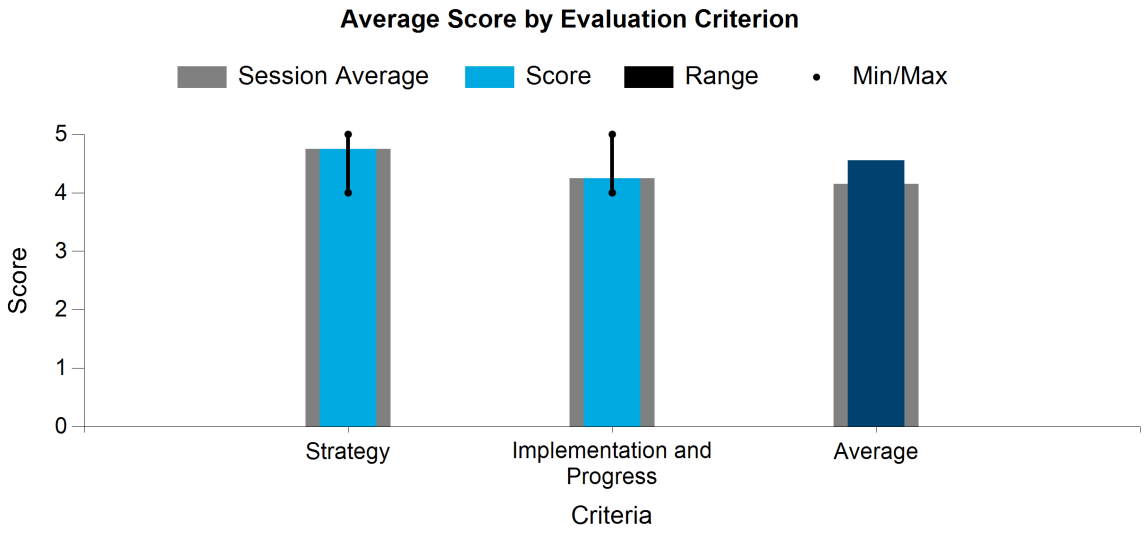
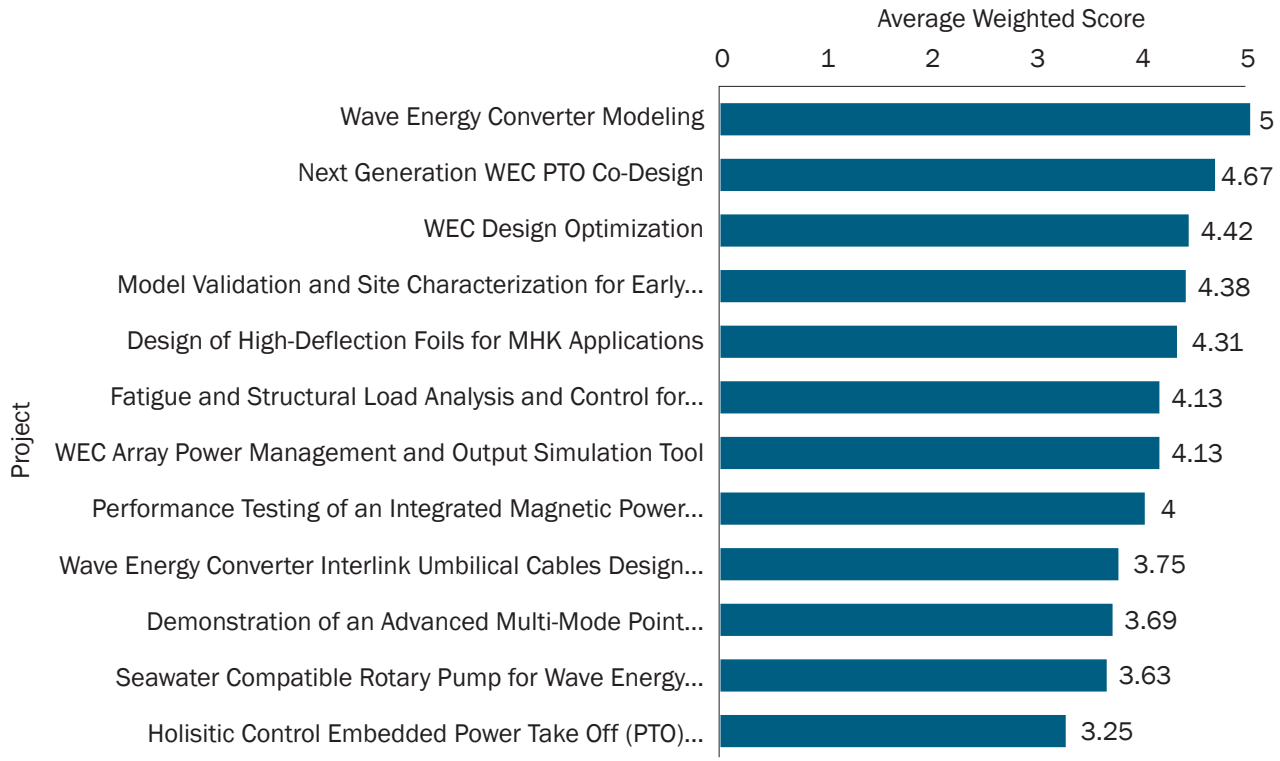


Figure 18. Foundational R&D Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Professor David M Ingram

Feedback from the Review Panel to WPTO

The Foundational R&D portfolio has delivered some very significant work, particularly in the development of software tools, and WPTO and DOE should be proud of this achievement. The activity area is focused and addresses many of the key challenges facing the sector with a strong focus on co-design.

One concern is that only three wave energy companies and one marine and hydrokinetic (MHK) energy company are involved in foundational R&D, and these companies are often the only stakeholders represented in a project. Wider stakeholder engagement is critical, so lessons learned are shared widely, enabling the overall development of the sector. Another concern is that there are clear linkages and synergies between projects with the risk that work is duplicated, or opportunities are missed due to teams working in silos.

Reviewers recommend much broader stakeholder engagement. Project teams should engage with the international community to leverage learning, accelerate development, and consider a broader range of options/decision needs. Linkages to green hydrogen and floating offshore wind activities within other DOE offices should be explored with the potential for projects to be jointly funded and commissioned.

The development, maintenance, and dissemination (including promotion and training) of the open-source software tools should be continued. In particular, the Wave Energy Converter SIMulator (WEC-Sim) is widely used and has a significant global impact. Furthermore, development of the Marine Energy Atlas should continue with the addition of deployment constraints to deliver a multicriteria site selection tool that includes wind and MHK energy resources. Reviewers consider the development of sea state classifications premature.

Foundational technology and component development projects should be required to consider the impact of the real ocean environment (i.e., multidirectional waves, wind driven, ocean and tidal currents, and turbulence) as part of a co-design approach. Testing should be conducted on the bench or in the laboratory wherever possible. A stage-gated approach should be taken to ensure risks are minimized when devices are deployed in the marine environment and to subject them to a set of standard but representative sea conditions. Access to laboratories should continue to be facilitated through an extended portfolio through the Testing Expertise and Access for Marine Energy Research (TEAMER) program that provides access to large-scale international facilities where domestic capabilities (e.g., multidirectional waves or wave and current testing) are not available.

At-sea testing at specific test sites should only be mandated when the test site is ready and fully able to accept devices for test. DOE should work with test sites and local ports and harbor facilities to ensure there are adequate berth and laying down areas available to accommodate devices during test portfolios. DOE should also encourage the development of local supply chains to support developers coming to test.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

The Foundational R&D portfolio has delivered some very significant work. The design of the MYPP is based on a careful and competent analysis of the sector's needs. Strengths include the open-source software tools, the Marine Energy Atlas, and the Seedling and Sapling projects that support the investigation of "blue sky" ideas.

In many cases, stakeholder groups are very limited, and projects would benefit from wider engagement. Some projects are not foundational and have limited outreach and dissemination. These are heavily focused on single devices and do not support the broader sector.

Activity Area Strategy

Reviewers agree the Foundational R&D activity area has a clearly defined strategy outlined in the MYPP, which includes clear performance goals, objectives, and research priorities. The reviewers also agree the activity area's strategy reflects an understanding of the near- and long-term challenges facing industry and other stakeholders. In addition, the activity area's strategy effectively communicates the rationale for and organization of the sub-activity areas and research priorities. Finally, reviewers agree the activity area leverages appropriate funding mechanisms to achieve its intended goals and objectives.

While the strategy considers the needs of industry and wider stakeholders, many of the projects have limited stakeholder representation (often drawing on the same stakeholders). This limits the impact of the work and leads to poor dissemination of results. It would be beneficial to include wider, international stakeholder groups and to share learnings more widely with the community. This is a global grand challenge with so many opportunities that technology developers do not need to worry about competition.

Reviewers are concerned that funding models drive developers to test at the U.S. Navy's Wave Energy Test Site (WETS) when it is not ready. WPTO must ensure WETS and the necessary port facilities are ready to accept developers. Another concern is that funding models drive projects to work with WEC designers when other industrial companies (e.g., cable manufacturers) would be more appropriate.

Finally, projects should bench and laboratory test as much as possible. Tests must consider the forces due to multidirectional waves, turbulence, shear, etc. This is critical to de-risking field deployment and will maximize benefits. Projects should have access to international facilities in cases where domestic capabilities do not exist.

Implementation and Progress

Reviewers agree the activity area has selected diverse and complementary R&D projects that are closely tied to the program's strategic direction. The activity area is funding the most relevant technologies, tools, and studies to achieve the MYPP's stated goals and objectives and is likely to meet performance goals and objectives based on the current portfolio of projects.

Many of the projects are clearly foundational and have broad applicability. The open-source software tools and the Marine Energy Atlas and associated resource data are strengths of which WPTO and DOE should be particularly proud.

The umbilical project has struggled because it is working directly with a WEC developer rather than a cable manufacturer. As with the Marine Energy Atlas, its findings are critical for many other sectors, including floating offshore wind.

In several projects, dissemination and engagement activities are very limited, impacting the portfolio's ability to meet its overall performance goals.

Activity Area Response

Submitted by Bill McShane, Technology Manager

The Foundational R&D Activity Area would like to thank the reviewers for their attention during the peer review and for their diligent comments and insights. The breadth and depth of the Foundational R&D portfolio is significant, and WPTO acknowledges that a complete review of the activity area was no easy task. The Foundational R&D Activity Area will take reviewers' comments and evaluate them thoughtfully. The activity area aims for a high performing and focused cohort of research projects and topics. Reviewers' expert and independent comments will help improve WPTO's strategic direction and program management. To sum up, the activity area thanks reviewers for their engagement, which will help the Foundational R&D Activity Area accelerate R&D, enabling a thriving U.S. marine energy industry.

Overall, reviewers outlined several recommendations to (1) ensure test sites are ready and prepared for at-sea testing, (2) explore linkages to green hydrogen and floating offshore wind R&D, (3) engage with the international community to leverage lessons learned and accelerate development, (4) continue to develop, maintain, and disseminate open-source software tools, and (5) consider real ocean environments in Foundational R&D projects. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Ensure Test Sites Are Ready and Prepared for At-Sea Testing

There were several comments on Oscilla's project deployment at WETS, noting that delays were due to WPTO not having control of the test site. In the simplest sense, the activity area agrees. However, there are several factors to consider. First, the award was made in 2016, and this test birth availability delay could not have been foreseen six years ago. WPTO has great communication with the Navy's WETS team, and the two have been working on this issue together. The U.S. Navy needs to be able to maintain its facility as the need arises. Second, the delay was a function of weather windows affecting both Navy maintenance and Oscilla installation. Weather delays will affect other open ocean test sites like PacWave as well.

To anticipate and mitigate future installation delays, WPTO considers the statistical probabilities of relevant weather windows at different open-water test sites. It will also examine weather window probability trends in El Niño and La Niña years, as well as the transition years in between. WPTO has already begun examining the statistical probabilities and trends for weather windows for WETS with Naval Facilities Engineering Systems Command and Hawai'i Natural Energy Institute, which manage the site. WPTO recognizes the current trend for weather windows is significantly scarcer in the past two years than the average of the past 20 years.

Recommendation 2: Explore Linkages to Green Hydrogen and Floating Offshore Wind R&D

Reviewers commented on the potential benefits of co-locating marine energy with other renewable technologies, specifically offshore wind. The reviewers noted that capital and one-time costs—such as cabling, anchoring, and permitting—can potentially be reduced in a larger project, improving levelized cost of electricity and market competitiveness. The Foundational R&D team agrees this is an interesting area to examine to see if there are savings or advantages with co-location. As such, WPTO selected Tufts University to conduct a wave energy technology assessment for optimal grid integration and blue economy advancement, which will be reviewed in a future peer review.

Recommendation 3: Engage with the International Community to Leverage Lessons Learned and Accelerate Development

There were several thoughtful peer review comments urging international connections to avoid duplication of effort and accelerate knowledge transfer and progress for the marine energy sector. WPTO agrees and will continue to encourage international connection and learning by participating in the IEA's Technology Collaboration Programme on OES, the International Electrotechnical Commission's (IEC) Technical Committee 114 on international standards for marine energy, and conferences like the International Conference on Ocean Energy, European Wave and Tidal Energy Conference, Asian Wave and Tidal Energy Conference, and Pan American Marine Energy Conference. WPTO will also continue to approve international subcontract arrangements on its industry and lab projects and engage the international community to serve as independent reviewers for proposal evaluations and public peer reviews. In the future, the activity area will examine if there is a way to have newly awarded projects perform thorough literature searches that include international research, so that early in a project's performance, the PIs are aware of related existing international opportunities for collaboration.

Recommendation 4: Continue to Develop, Maintain, and Disseminate Open-Source Software Tools

Reviewers provided several positive comments on software and modeling. First, the reviewers noted the open-source modeling nature of the Foundational R&D portfolio is a good investment, and the GitHub dissemination is a strength of the portfolio. WPTO will continue to utilize this open-source software model to the extent practical.

Reviewers also commented on long-term maintenance and compatibility of WPTO's software investments. This is a goal for WPTO, but it must be balanced against funding constraints. All the software WPTO has funded will not be maintained at the level WEC-Sim has been funded. The Portal and Repository for Information on Marine Renewable Energy (PRIMRE) contains more than 40 software items, and it would be expensive to maintain all of them. WPTO will need to think more strategically to determine the long-term plan for each software investment. More funding into software support means less funding for future R&D projects, including new software capabilities.

The need for validation of models also came up. The Foundational R&D portfolio wholeheartedly agrees with this comment. This highlights the need for high quality, open-source datasets to validate and calibrate models and numerical tools. Without datasets for validation, software investments' impact is reduced. However, open-source validation data has proven to be expensive and slow to become available. The Foundational R&D portfolio needs to identify a cost-effective, systematic way to quickly generate open-source data to validate and calibrate many software tools and analytical models year over year.

Recommendation 5: Consider Real Ocean Environments in Foundational R&D Projects

Reviewers noted projects should consider the impact of real ocean environments outside the controlled and groomed environments of numerical analysis, tanks, and flumes and recommended additional lab and bench testing wherever possible. WPTO agrees the more realistic the test, the more will be learned. Additionally, more risk is reduced as more computer simulations are tested on the bench or in the lab before going to the tank or sea, where issues are significantly more costly. WPTO's co-design research, and the foundational projects broadly, do move in the direction of realistic testing. However, funding constrains the hardware and test aspects of research projects. WPTO will need to think more strategically about when to make additional hardware and test investments. Sometimes, it may be preferable to see how the foundational R&D project matures before committing additional funding. More funding into hardware and tests may mean less funding for future R&D projects, including projects focusing on real ocean conditions.

Technology-Specific System Design and Validation

The Technology-Specific System Design and Validation Activity Area aims to validate performance and reliability of marine energy systems through prototype testing, including in-water testing, for grid-scale, power-at-sea, and resilient coastal community markets. Through this activity area, WPTO is working to:

- Validate performance and reliability of systems through prototype testing, including in-water testing, at multiple scales.
- Improve cost-effective methods for installation, operations, and maintenance (IO&M).
- Support the development and adoption of international standards for device performance and insurance certification.
- Expand opportunities to realize the unique value proposition of marine energy systems for community resilience and ocean-based scientific and commercial power applications.
- Evaluate existing and potential future needs for marine energy-specific IO&M infrastructure (e.g., vessels, port facilities, etc.).

The review panel was impressed by the breadth and depth of the work that had been achieved within the activity area, though reviewers pointed to the need for further end-user engagement. Figure 19 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 20 provides an overview of the scoring of all projects within the Technology-Specific System Design and Validation Activity Area.

Figure 19. Technology-Specific System Design and Validation Activity Area Average Weighted Score by Evaluation Criterion

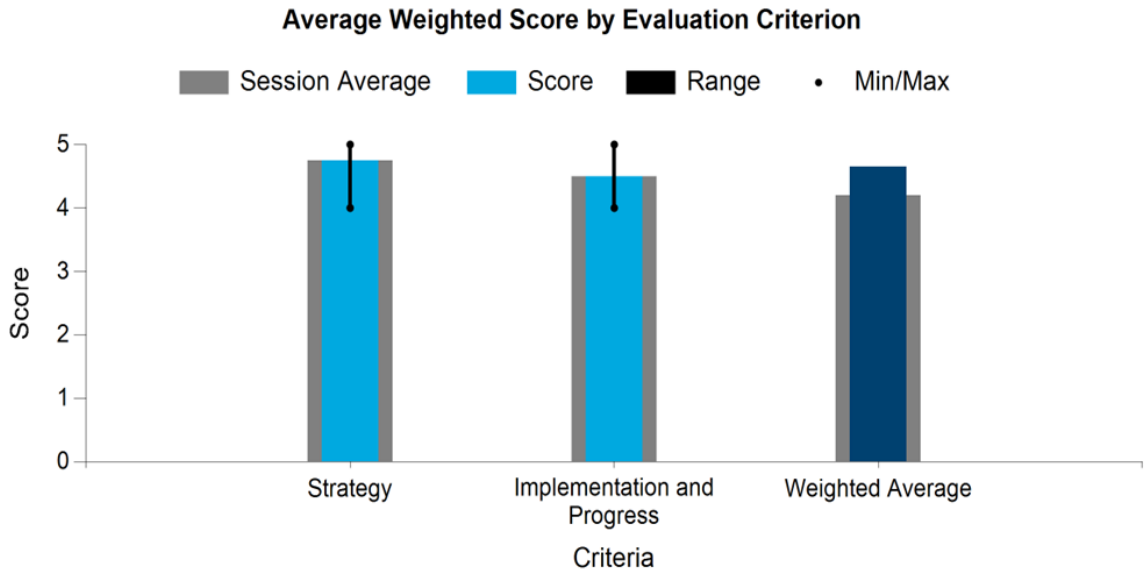
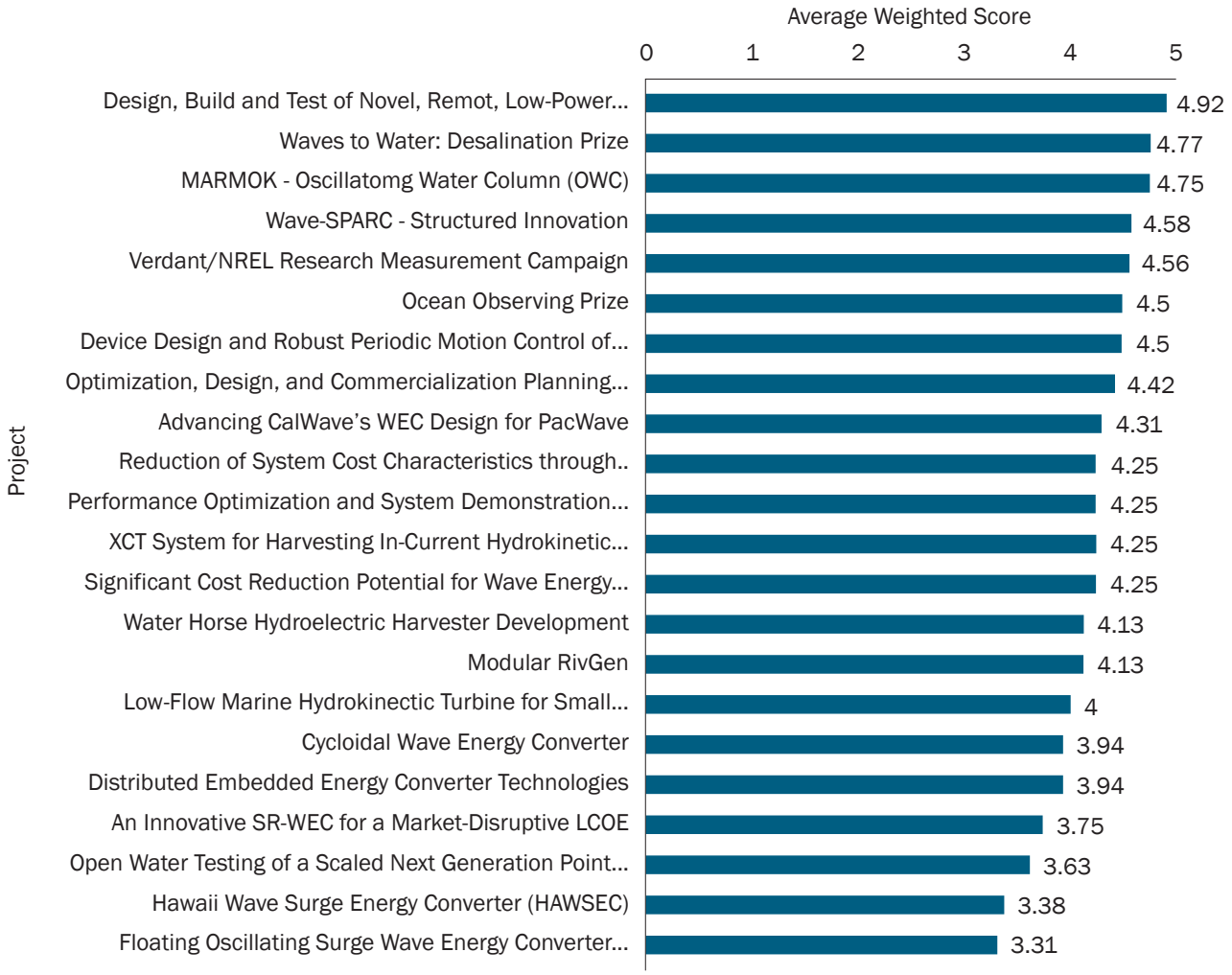


Figure 20. Technology-Specific System Design and Validation Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Henry Jeffrey

Feedback from the Review Panel to WPTO

Progress has been made in the Technology-Specific System Design and Validation Activity Area, and reviewers note the key role it plays in WPTO's continued success. However, opportunities exist to add value to the activity area.

The breadth and depth of the portfolio are impressive, and its expansive nature ensures multiple key research areas are targeted and objectives are achieved. It is important to question if this will remain sustainable as technologies achieve higher TRLs. Depending on future funding levels, it may be necessary to focus the portfolio's scope to ensure its continued success and impact.

Value could be bolstered with stronger user engagement, which goes beyond the dissemination of research milestones via publications and conferences. By ensuring that customer needs—whether in a niche or utility-market setting—are well understood, the activity area will be able to support the sector's continued progress. This is an activity DOE could achieve centrally through initiatives or workshops and would have multiple benefits. It would remove the onus from technology developers, which may not be uniquely equipped to deliver strong end-user engagement. It would also ensure end users do not suffer from fatigue or have to reiterate their technological needs and preferences multiple times to different developers.

It is important to ensure a fair approach is taken to compensate for the adverse effects of COVID-19 and its impact on the flexibility and security of supply chains, working conditions, and internal timelines. WPTO will need to ensure that whatever measures taken fairly reflect the challenges faced by all technology developers but are consistent with the understood limitations of COVID-19. This is critical so maximum value is still extracted from the projects.

The national labs' LCOE tool used to underpin predictions and targets must ensure the input values and the values distilled from its calculations are cross referenced to ensure it provides an accurate and substantiated point of reference from which energy costs can be responsibly estimated.

The process of technology transfer is important to ensure that, in the case where any individual project might not meet its long-term goals, there is a mechanism to extract specific successful technological developments or procedural lessons that might be of benefit to the wider sector. In instances where other companies or nations are developing technologies, knowledge transfer will help to limit wasteful duplication and replication of research. Where possible, it would also be beneficial to ensure projects are aligned with funding from other government agencies, such as the Department of Defense.

Assessing the progress of technology developers that have enjoyed sustained exposure to WPTO's support system and have received numerous project awards will safeguard the portfolio's long-term validity and effectiveness. It will also help ensure they remain on the pathway to continued technological innovation.

Prizes appear to be an effective tool to attract innovation in a new project area. However, they need to be analyzed to ensure they are cost effective and have a traceable pathway to serve the sector's innovation needs. It is also important to capture each prize program's lessons learned, including program structure and the technological developments they helped to underpin. Prizes should have a clear pathway for successful developers to continue their journey forward and remove the risk of stranding innovation.

Developers successfully testing at PacWave should be supported with a clear progression path to ensure devices and any supporting technological developments can move smoothly to higher, successive generations of development and deployment.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

WPTO needs the innovation funding and staff resources to ensure the office's depth, breadth, and effective management. There may be a need to focus the portfolio to ensure key projects are not underfunded and investments are not stranded. A comprehensive cost-benefit analysis of the prize program approach will help ensure it continues to be an effective tool and delivers continued innovation without functioning at the expense of time or resources. Additionally, it is advisable to ensure synergies between technologies that underpin both the blue economy and utility-scale applications with common goals and an emphasis on areas of overlapping research expertise. It is also important to ensure all strands of the portfolio have full pathways and funding to commercialization.

Activity Area Strategy

The activity area benefits from having a well-defined strategy in full alignment with the MYPP, including clear objectives and defined research priorities. Although the activity area manages short- and mid-term challenges well, it is less clear how it will evolve to manage the sector's longer-term challenges. Without attempts to refine the scope or expand WPTO's resources, it may be difficult to scale up to comprehensively cover all current areas of development and deployment.

With respect to industry and stakeholder needs, the overall activity area strategy is well considered. However, the strategy should be monitored as the sector evolves, considering technology scale and anticipated differences between niche blue economy and utility-scale technologies. Currently, there is a good rationale to support the sub-activity research areas and priorities. However, these might need to be reconsidered if the activity area chooses to refocus its priorities or as technologies achieve higher TRLs and introduce different challenges. There is a good mixture of funding mechanisms for academia, labs, and industry, supported by a comprehensive range of prizes and competitions. Ensuring complementary and collaborative links between DOE and the Department of Defense will help to foster accelerated technological development and ensure end users in both sectors have the opportunity to fund or engage with projects.

Implementation and Progress

The current portfolio is in full alignment with its stated objectives. The activity area is selecting diverse and complementary R&D projects tied closely to the program's direction. The activity area is funding the most relevant technologies, tools, and studies, and is likely to meet its performance goals. However, over the medium and long term, there is an opportunity to reconsider how funding and management environments will adapt as projects scale and advance through multiple TRLs. It is important to question whether WPTO will have the requisite funding for innovation and staffing to support continued progress in the sector. This consideration would allow WPTO to continue to run an effective, well-coordinated, and adequately staffed program.

Activity Area Response

Submitted by Elaine Buck, Technology Manager

The Technology-Specific System Design and Validation Activity Area would like to thank the reviewers for their attention during the peer review and for their diligent comments and insights. The breadth and depth of the portfolio is significant. Undoubtedly, reviewers took the time before and after the peer review to evaluate the projects' materials and generate thoughtful comments. This was no easy task, and the comments are enormously appreciated.

The Technology-Specific System Design and Validation Activity Area will take reviewers' comments and review them thoughtfully. The activity area aims for a high performing and focused cohort of demonstration projects and topics. Reviewers' expert and independent comments will help improve the activity area's strategic direction and program management. It is clear from reviewers' feedback that capturing lessons learned, increasing deployments, and advancing marine operational health and safety (to include developing a methodology for improving the basis of designs in marine energy) is fundamental to the U.S. marine energy industry's success. To sum up, the activity area thanks reviewers for their engagement, which will help the portfolio accelerate demonstrations across all scales of marine energy technologies, enabling a thriving U.S. marine energy industry.

Overall, reviewers outlined several recommendations to (1) improve knowledge sharing, (2) increase in-water testing, (3) focus on health and safety, and (4) emphasize design phase to get back to basics. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Improve Knowledge Sharing

Reviewers commented on some projects running in isolation, where learning from other projects would be of benefit and value. Reviewers recommended stepping up knowledge-sharing opportunities, especially to identify similar risks or issues faced in deployment projects, which could be developed into case studies for industry. These case studies could be presented at conferences and/or highlighted in WPTO or other relevant webinars. Lessons learned for marine operations—including continued support for the development of new standards identified and prioritized for IO&M by Technical Committee 114—will incorporate best practices for U.S. deployments. Establishing deployment debriefs will also ensure lessons learned are captured, and improvements for health, safety, and environment procedures are planned for similar deployments. As future U.S. test sites come online, knowledge-sharing opportunities will organically bring the marine energy industry together to demonstrate best practices. Other lessons learned between the national labs and developers could be better captured and promoted, demonstrating design innovations and new testing methods. The program and project management teams will work together to develop and establish knowledge-sharing tools and habits into existing and future projects.

Recommendation 2: Increase In-Water Testing

Reviewers commented on the value of real-world, at-sea testing as soon as possible. DOE has a clear intent to continue funding for marine energy at-sea testing. The activity area is keenly aware this is where lessons are learned, but it is incredibly important to focus on health and safety in planning. WPTO aims to de-risk all deployments as much as possible, so they fail fast and cheaply onshore in labs and on test benches prior to at-sea deployments. The program is looking to evaluate rapid prototyping projects that focus on repeated wet/dry testing before scaling up and will continue to coordinate closely with the Reducing Barriers to Testing team as appropriate. It is well understood that proving technology performance, reliability, and survivability happens when metal gets wet. The program will continue to de-risk in-water testing through regular assessment of technical progress and disqualification of underperforming technologies, thereby focusing on funding high-performance technologies. The

activity area will improve the defined requirements for in-water demonstrations, including performance testing in the funding opportunities. The program goal is to create a competitive marine energy portfolio that accelerates technology commercialization.

Recommendation 3: Focus on Health and Safety

Reviewers commented on the risk of health, safety, and environmental issues potentially increasing due to tight budgets and underbudgeting for O&M activities. This is a significant priority for the activity area and the Marine Energy Program more broadly. There are health, safety, and environmental activities that will be incorporated into funding opportunity requirements that de-risk offshore deployments through design to IO&M planning. In FY 2023, the activity area plans to develop a U.S.-focused marine energy health, safety, and environmental framework as well as policies, guidance, training, and implementation/audits for before, during, and after deployments to decommissioning.

Recommendation 4: Emphasize Design Phase to Get Back to Basics

Reviewers noted a lack of emphasis on and technical review of the design phase, including connections with standards and lessons learned from the deployments. WPTO recognizes this issue, but there is no common synthesis of design practices used by developers. WPTO has funded the incorporation of assessment tools—like NREL's System Advisor Model for calculating the LCOE and its risk management framework and methodologies for quality control and assurance that will support efforts from concept to design optimization—at key design states. WPTO will continue to improve access to labs and engineering contractors to support preliminary, final design reviews to include factory acceptance criteria prior to at-sea deployments. WPTO will focus on the development of a design framework—such as best practices and the inclusion of key design phase reviews within statements of project objectives to refine and improve go/no-go criteria—to guide developers for wave and tidal devices. There is a lot of work to do to capture, synthesize, and develop a more robust design phase process with marine energy developers. WPTO has seen success through the prize methods that will continue to influence the activity area. Ultimately, the activity area needs to fully understand the methods used with different design-engineering teams, including how they incorporate standards and capture engineering data outputs that influence design decisions and impact their marine energy technology performance.

Reducing Barriers to Testing

The Reducing Barriers to Testing Activity Area aims to enable access to open-water, grid-connected, and non-grid-connected testing facilities and support environmental monitoring technologies, tools, and data collection to understand potential environmental risks and reduce costs. Through this activity area, WPTO is working to:

- Enable access to world-class testing facilities to accelerate 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 on mitigating environmental risks and reducing costs and complexity of environmental monitoring.
- Engage in relevant coastal planning processes to ensure that marine energy development interests are equitably considered.

The review panel was impressed by the breadth and scope of the work being done in this activity area and encouraged the team behind it to consider wider applications of some of the work being produced. Figure 21 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 22 provides an overview of the scoring of all projects within the Reducing Barriers to Testing Activity Area.

Figure 21. Reducing Barriers to Testing Activity Area Average Weighted Score by Evaluation Criterion

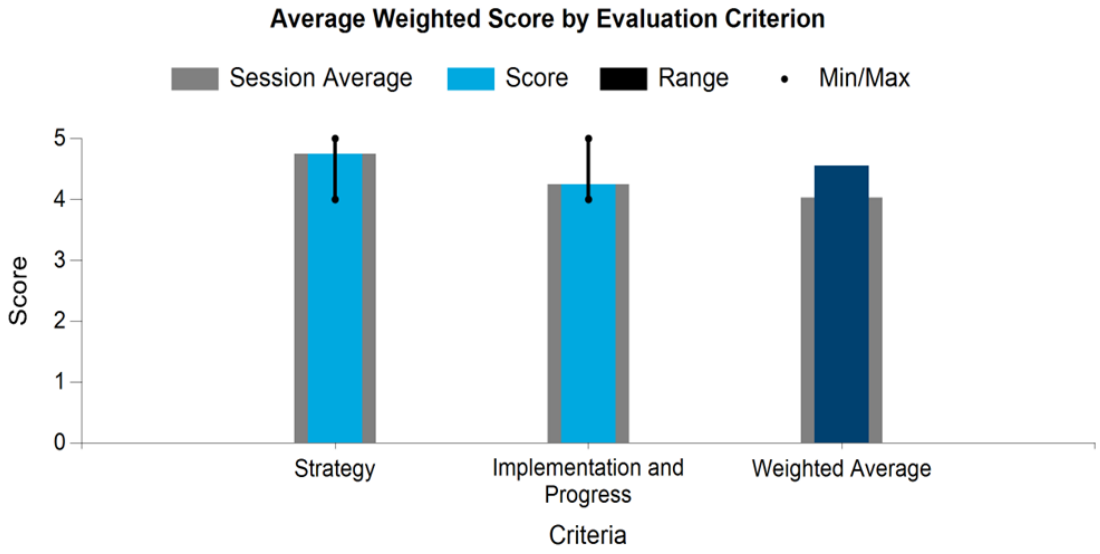
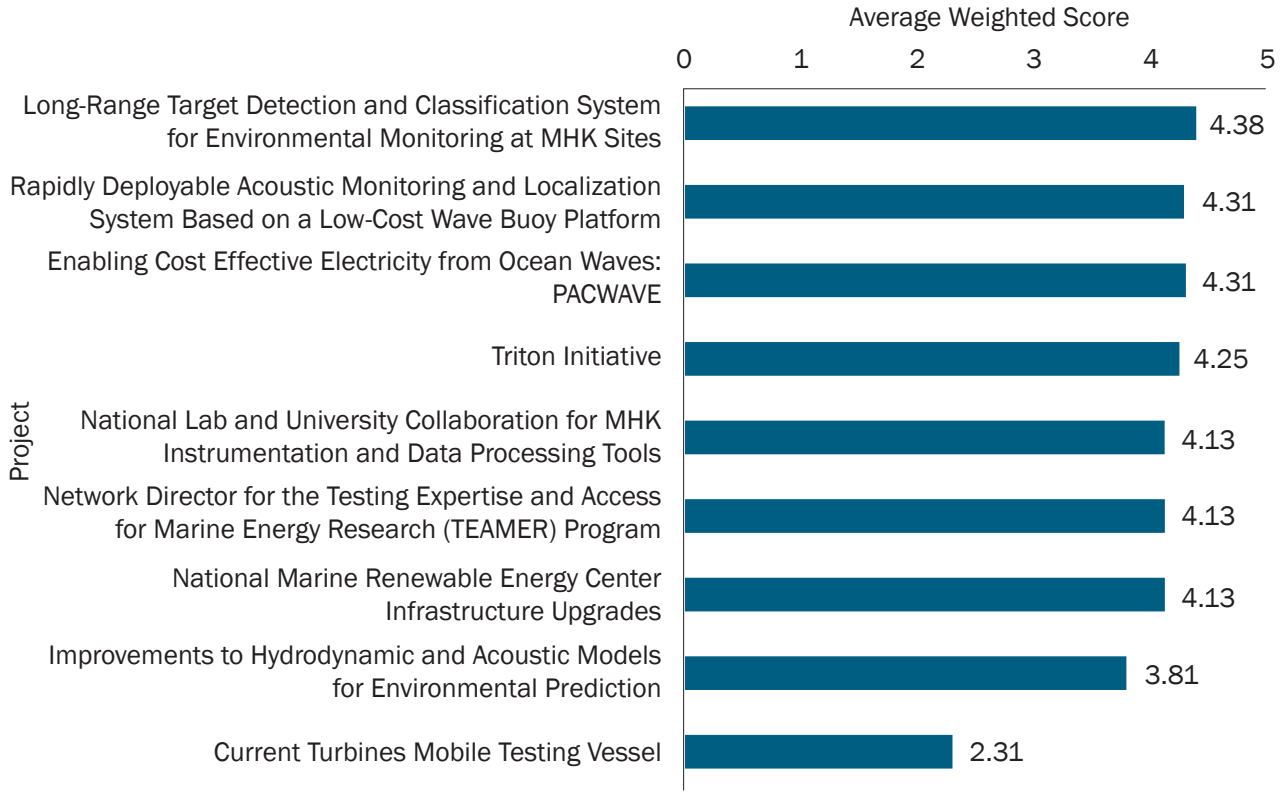


Figure 22. Reducing Barriers to Testing Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Sue Barr

Feedback from the Review Panel to WPTO

Overall, the panel reviewing the Reducing Barriers to Testing Activity Area is highly impressed with the range and scope of the nine projects presented. In some instances, there is clear alignment and collaboration between projects, which will allow for cumulative successful outcomes. The activity area and program in general are well run and effectively coordinated.

However, it is often challenging to match projects' progress, budgets, and outputs clearly against the assessment criteria, which may be a function of the short time for presentations. Reviewers propose that, alongside the project presentations, project teams provide a short evaluation report to allow for a more effective review process. These projects are highly complex with a range of successful outcomes, and it is challenging to provide a full assessment of all successes and weaknesses in the time provided.

While the activity area appears to focus predominately on wave energy conversion, some of the technology solutions presented could be equally applicable to tidal energy applications. The projects are not explicit on this area, and the panel thinks, in some cases, the technology or solution proposed could have multiple end-user applications or even be a cross-sector solution to several marine research requirements. Providing technology and/or test sites for marine energy could also serve several maritime end users, thus creating additional end-user value. Reviewers recommend WPTO consider how projects will deliver both near- and long-term results for the sector's continued use. This could support future broader uptake. Reviewers are also concerned about projects' abilities to transition to commercial business models, and this is an area WPTO should explore more.

It would be helpful to provide slightly longer for the project presentations and review sessions because it was challenging to fully explore each project in the time provided. Reviewers need more time to focus on project budgets and go/no-go decision processes. In nearly every project, reviewers find stakeholder engagement is often secondary to the delivery of project goals and objectives. In most cases, engagement could be expanded to help achieve project objectives, particularly with regulators (in relation to data use in regulatory decision making) and the marine energy sector itself based on how, when, and why they use research or facilities.

Reviewers recommend projects provide a brief, two-page evaluation report of project progress against program criteria as a supporting document to the project presentation. WPTO should consider the long-term application of technology and facilities and establish criteria to review projects' long-term commercial or business applicability. WPTO should also consider whether the technology, project, or test site being funded has multiple applications, not only in terms of whether it can be transferred between the types of kinetic energy being extracted (wave and tidal), but also whether the technology or site could be applicable or transferable to a broader marine application.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

Reviewers found several key strengths in the activity area, including the broad spectrum of applicable research and activities covered in the projects and the overarching compatibility between projects (even some co-dependencies). If all the projects are successful, there will be a good suite of monitoring technologies, facilities, and sites for marine energy device testing. This activity area has a broad set of aims to include removing barriers, increasing the availability of testing infrastructure, reducing time for testing cycles, providing testing infrastructure, and supporting data collection and use in a way that supports multiple end-user requirements (including regulatory). The projects show a good range of scope to fulfill the portfolio's aims. General weaknesses include projects' ongoing commercial applicability and a lack of focus on broader sector uptake.

Activity Area Strategy

Reviewers agree the MYPP gives an effective set of research priorities and a means by which to measure performance and objectives. The activity area's strategy is clear and understood.

Reviewers agree there is a strong understanding of the near-term challenges to getting technology in the water and tested. Some reviewers question this activity area's ability to support the sector's long-term challenges related to testing, whether at scale or for new and emerging technologies. To realize and deliver the portfolio's full value, there should be ongoing engagement with the marine energy industry and other marine sectors and stakeholders given opportunities for cross applicability. For example, the measurement of underwater sound is key to marine energy deployment, but the ability to understand more about species' behaviors based on anthropogenic activity in the marine environment is a broad subject. Reviewers are keen to see marine science and this portfolio's outputs be available to a broad range of marine stakeholders.

Reviewers agree the activity area's strategy fully considers industry and stakeholder needs and builds on past work. However, it is unclear to reviewers whether the research will lead to meaningful results for regulators and whether outputs will be taken up by the broader sector and stakeholders. The consideration of industry and stakeholder needs is apparent, but reviewers think projects are often aimed at specific end-user needs that could be expanded to explore additional needs.

Reviewers fully understand and agree with the rationale and organization of the sub-activity areas and research priorities. It is clear why this activity area has been identified and, largely through the project presentations, how it fits among research priorities and broader program aims.

It is clear WPTO funding is additive in terms of the ability to raise additional funds to support a project without compromising program deliverables.

Implementation and Progress

Reviewers are impressed by the range of R&D projects presented—from test site facilities to the development of monitoring equipment that would help remove regulatory barriers. Reviewers could question the value of project outputs in only one case. This relates to the design and build of a vessel for testing of tidal energy devices. It is unclear how the uptake and application of this vessel has been market tested against end users, and reviewers feel it may be highly limited in its application in real-time environments. Many projects complement one another, but reviewers question if there would be overlap between some areas of research, particularly in relation to the establishment of live test sites offshore.

Reviewers primarily represent testing and regulatory fields, so the value of data, time in the water, and dissemination of real-time evidence on these new and emerging technologies are key areas of focus. While reviewers agree the scope of projects funded is excellent, there were some questions on the degree to which projects engage with end users of the technologies, tools, and studies. Reviewers only question one project on its relevance in the program, and this relates to applicability to the end user rather than the overall MYPP. All other projects are highly relevant.

Given the limited time to assess the nine projects presented and the breadth of activity within each project, reviewers take a reasonable view as to projects' likely abilities to deliver performance goals and objectives. There are two areas where this was challenging—in the readiness of wave and tidal technologies to utilize test sites, which is not a risk the projects could have mitigated, and within risks identified in the delivery of cables and subcomponents from suppliers, coupled with offshore risk in methodologies. However, reviewers do not feel the risks to delivery are insurmountable. In fact, these risks are clearly identified in the project risks slides with proposed mitigation efforts. Reviewers believe WPTO should continue to support these projects while fully disclosing the risks of non-delivery.

This is a challenging area in terms of providing technology and test sites in high energy environments, and the risks to timing and delivery should be flexible to meet program needs.

Activity Area Response

Submitted by Lauren Ruedy, Technology Manager

The activity area would like to thank the reviewers for their time and evaluation of the Reducing Barriers to Testing Activity Area. Reviewers asked thoughtful questions and engaged in meaningful dialogue with the presenters, providing the program with significant insight into projects and the portfolio. This feedback will be incorporated into project and program planning moving forward to continue addressing testing and demonstration barriers for the marine energy sector.

The activity area would also like to thank the reviewers for their positive comments on the portfolio's organization and execution. Reviewers observed the strategy was clear and well understood, with an effective set of research priorities, and that the portfolio included an impressive breadth and depth of work that was effectively coordinated. Reviewers further speculated that if all the projects are successful, there would be a good suite of monitoring technologies, facilities, and sites for the testing of marine energy devices, accomplishing the portfolio's aims.

Reviewers noted that while the strategy builds on past work and was informed by industry and stakeholder needs, there were concerns regarding the broader sector's and stakeholders' uptake of project outputs. Reviewers recommended expanded and regular engagement with industry, end users, supply chain providers, and regulators. Furthermore, reviewers recommended considering how research project objectives and deliverables may be applicable to other marine energy resource types (e.g., some technologies, such as environmental monitoring devices and equipment, presented for wave energy could have tidal energy applications as well). The program appreciates the suggestion to consider applying a broader, high-level criterion to evaluate uptake to determine how projects will meet industry and end-user needs over the near and longer term.

In addition to feedback at the activity area level, reviewers also offered a few project-specific recommendations, which the program will address directly with project PIs, including:

- **TEAMER**—One reviewer went above and beyond to identify gaps and offer recommendations on the facility network. This feedback is greatly appreciated and will be discussed with the Network Director to identify opportunities for additional testing access.
- **PacWave**—When the site is operational, reviewers recommended running a lessons learned workshop and evaluating how operational data and experience can be shared more widely with the sector. Additionally, reviewers identified the lack of a universal mooring system as a potential concern to increase costs and delay schedules. These are valuable recommendations that will be discussed with the PacWave team.
- **Triton**—Triton has done a good job disseminating the results of its research, but the key next step is determining whether the recommendations are adopted.

Overall, reviewers outlined several recommendations to (1) consider the long-term application(s) of technologies and facilities, (2) evaluate project applicability across marine energy resources and market applications, (3) increase outreach with stakeholders, (4) critically review needs for test infrastructure investments, and (5) actively manage risk associated with development and utilization of test sites and assets. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Consider the Long-Term Application(s) of Technologies and Facilities

Reviewers observed that many projects within the activity area successfully engaged with industry and potential end users to inform the project and ensure alignment with their needs. However, reviewers also commented that further consideration should be given to the sector's long-term needs and how that would translate to commercial business models for these projects and test sites. The program appreciates this recommendation and will investigate the potential to incorporate a "sectoral uptake" criterion for projects across the program as reviewers suggested.

Recommendation 2: Evaluate Project Applicability Across Marine Energy Resources and Market Applications

Reviewers found the projects presented during this peer review focused predominately on wave energy applications, though some solutions could have equal applicability to tidal energy applications and/or additional end-user applications and markets. The program appreciates this insight and will explore with project researchers whether additional applications and opportunities exist for project outcomes and outputs that would increase the impact or broaden the relevance of the technology or site for additional uses. Furthermore, for newly developed, advanced environmental monitoring technologies specifically, the program will investigate opportunities to expand the range of conditions under which these technologies can be demonstrated.

Recommendation 3: Increase Outreach with Stakeholders

To potentially accelerate uptake and commercial viability, reduce time to permitting, and create a wider understanding of the transferability of the technologies and methodologies tested and developed, reviewers recommended expanded and regular engagement with stakeholders (industry, end users, supply chain providers, and regulators). Reviewers specifically recommended developing a series of workshops to better aggregate and disseminate the portfolio's work to researchers, developers, and regulators domestically and internationally. WPTO currently uses several mechanisms to engage with stakeholders—including webinars, publications, newsletters, requests for information, conferences, and peer review—and to disseminate information, request feedback, and share opportunities. WPTO strives to ensure information is received and not just disseminated. WPTO considers stakeholder feedback to be a critical component of strategy development and will investigate opportunities to increase engagement to ensure investments' relevance and impacts within the Reducing Barriers to Testing portfolio.

Recommendation 4: Critically Review Needs for Test Infrastructure Investments

Reviewers noted that while all test infrastructure investments in the portfolio were clearly intended to address articulated gaps, it was not immediately apparent that all gaps in testing infrastructure were also critical needs for the marine energy industry at this time. WPTO appreciates this insight and will examine both existing and potential future infrastructure investments with this distinction in mind. Additionally, the stakeholder engagement mechanisms described in recommendation 3 can be better used to distinguish the needs from just gaps.

Recommendation 5: Actively Manage Risk Associated with Development and Utilization of Test Sites and Assets

The Reducing Barriers to Testing portfolio contains a high degree of diversity, ranging from developing effective technology to monitor underwater sound and its impact to delivering a full-scale wave technology testing facility offshore. Reviewers acknowledged the challenges of testing and developing test sites in high energy environments and recommended continuing to maximize flexibility to accommodate risks with timing and delivery. WPTO concurs with the reviewers' recommendations and will continue to maintain flexibility with project management to the extent practicable.

Marine Energy Data Access, Analytics, and Workforce Development

The Marine Energy Data Access, Analytics, and Workforce Development Activity Area aims to improve access to and use of data, tools, and STEM resources to increase awareness of marine energy technology advances and lessons learned; reduce cost, time, and uncertainty for marine energy permitting; and develop a skilled marine energy workforce. Through this activity area, WPTO is working to:

- Assess and communicate potential marine energy market opportunities, including those relevant for other maritime markets (e.g., desalination, powering subsea sensors, charging for underwater vehicles).
- Aggregate and analyze data on marine energy performance and technology advances and maintain information-sharing platforms to enable dissemination.
- Leverage expertise, technology, data methods, and lessons from the international marine energy community and other offshore scientific and industrial sectors (e.g., offshore wind, oil, and gas).

The review panel found that the portfolio of projects within this activity area reflected a clear and ambitious strategy. However, they did recommend some additional outreach, especially to regulators. Figure 23 summarizes the reviewers' quantitative assessment of how the activity area is performing overall, and Figure 24 provides an overview of the scoring of all projects within the Reducing Barriers to Testing Activity Area.

Figure 23. Marine Energy Data Access, Analytics, and Workforce Development Activity Area Average Weighted Score by Evaluation Criterion

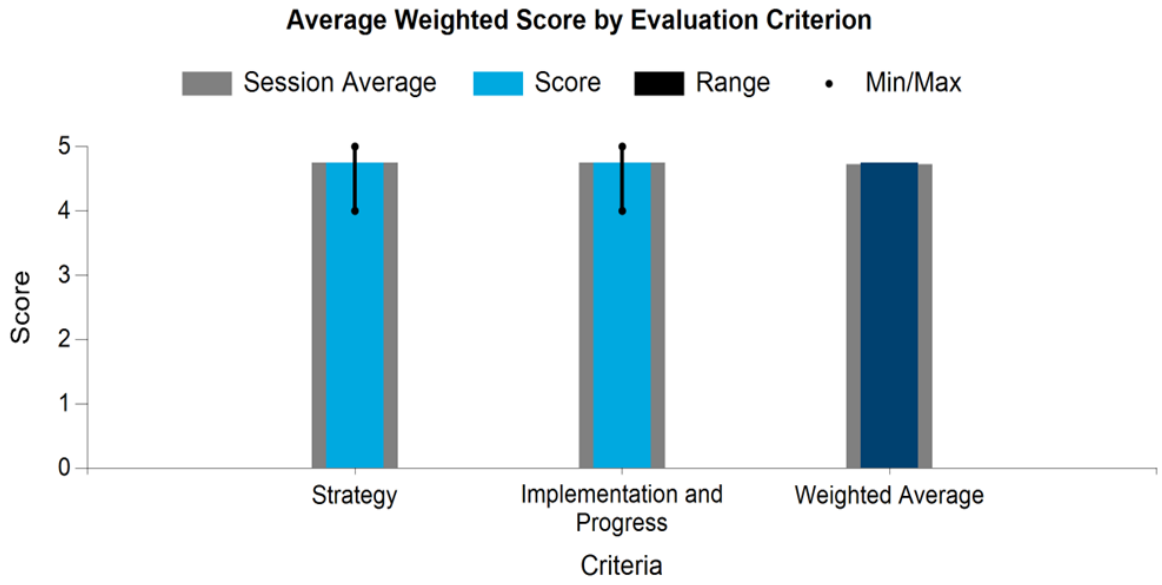
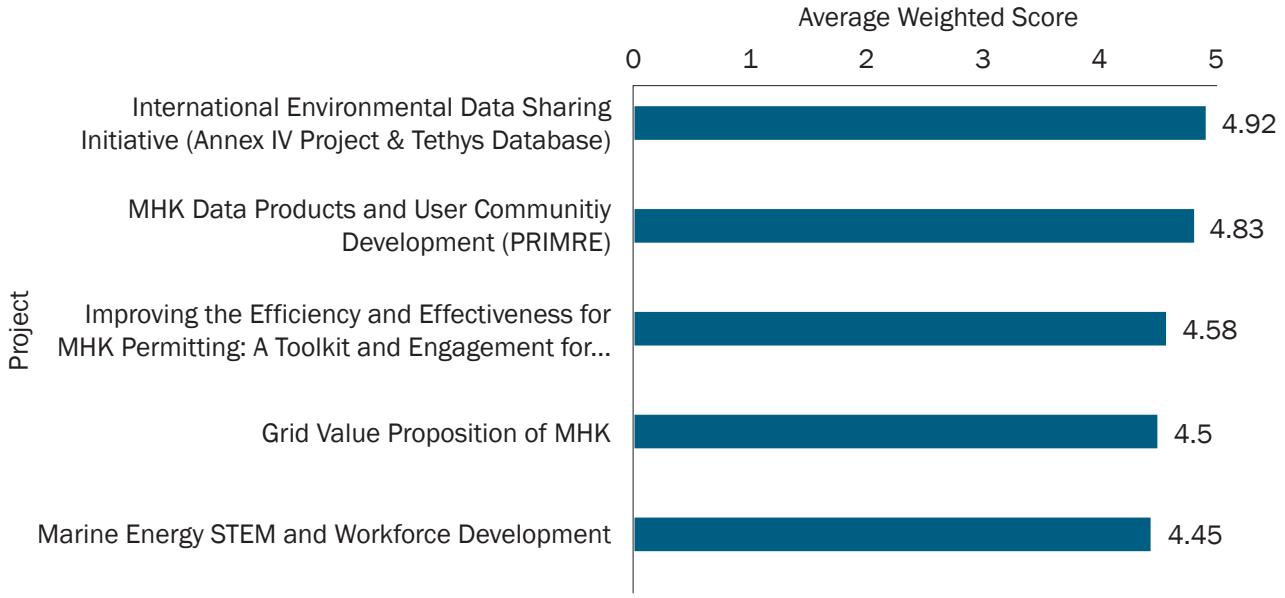


Figure 24. Marine Energy Data Access, Analytics, and Workforce Development Activity Area Weighted Average Score by Project



The following subsections include the review panel lead's summary of reviewer comments and the WPTO activity area lead's response to reviewer feedback. The full evaluation results for the activity area and the portfolio of projects can be found in Volume II of this report. For more information about the activity area's structure, strategy, and R&D priorities, please refer to the MYPP or the corresponding activity area overview slide deck presented during the review.

Activity Area Evaluation Summary

Submitted by Michael Atkinson

Feedback from the Review Panel to WPTO

The activity area's strategy is clear, comprehensive, and ambitious. Given the portfolio's relative novelty, there is a vast amount of work focused on tool and knowledge development to address the marine energy sector's needs and challenges. If funded property, there are diverse activities that will help facilitate and sustain multidisciplinary growth.

While there is a strong drive to develop sea-ready, full-scale devices such as WECs, there is a need for more investments and projects focused on fundamental research to better characterize realistic ocean conditions. This can be accomplished with increased funding at the university level where publishing fundamental research is key, and peer-reviewed articles can add credibility to this new technology. Increased collaboration with academia can also help guide full-scale designs before costly testing at sea.

The improved engagement with regulators is highly encouraged and necessary to reduce barriers to testing. Most reviewers agree an increased effort is needed focused on recognizing and mitigating possible negative environmental impacts. While this may be a result of many projects being in the early stages of development, funding projects that genuinely explore eco-friendly solutions should be prioritized.

Workforce diversification is a stated objective and focus of the portfolio. The Marine Energy Collegiate Competition (MECC) engages international undergraduate and graduate students to design marine energy technologies and develop business plans, and this has led to students starting companies or pursuing careers in the industry after graduation. Furthermore, there is strong evidence of successful diversity, equity, and inclusion (DEI) efforts as demonstrated by the participation of several historically Black colleges and universities and minority-serving institutions in the competition. The outcome of this competition broadens the skillset of recently graduated engineers and entrepreneurs that will hopefully infuse the blue economy with a labor force poised to meet this growing industry's demands. While this effort is beneficial, workforce development should be expanded to increase student engagement. Additionally, there should be more investment in inspiring experts in other fields to enter marine energy.

Summary of Reviewer Feedback on the Activity Area

Overall Impressions

Tools developed through this activity area, such as PRIMRE, provide end users (e.g., researchers, developers, and regulators) with relatively easy access to data and information that would otherwise be difficult to locate and compile. Workforce development in this area involves the creation of MECC and, overall, reflects industry and stakeholder needs and the challenges they face. However, the education and workforce aspects of the program seem very bifurcated. A lot of educational content is being created, but it is unclear how this connects to opportunities for potential employers and employees other than as a resource.

Activity Area Strategy

The strategy outlined in the MYPP includes clear performance goals, objectives, and research priorities. Reviewers agree this activity area has a defined strategy. Two reviewers feel more engagement is needed to attract new people to the field. Mostly, reviewers believe the strategy reflects an understanding of goals. However, two reviewers believe it is not clear all projects' objectives and outcomes lead to opportunities for potential employers and employees. While all reviewers like PRIMRE, one reviewer mentioned it is not clear who is using the data.

Projects consider industry and stakeholder needs and build on past work. There is a consensus that stakeholder feedback is especially helpful, and it is good to see WPTO is attempting to address workforce development and education gaps identified in stakeholder surveys. However, specific to data and tool projects focused on environmental regulations, one reviewer finds there is not yet enough evidence these projects have resulted in improved regulatory efficiencies or reduced uncertainty around environmental impacts from a regulatory perspective.

Overall, the sub-activity areas' direction is good, but one reviewer had concerns focused on being mindful of what educators need at each level. K-12 teachers need to understand the energy system and clean energy's role. It is good marine energy materials are woven into existing curricula rather than created as standalone materials the program would expect individual teachers to grasp. Community college and university professors have their own needs, which often trump what students and potential employees want and need.

The activity area leverages appropriate funding mechanisms (e.g., financial assistance to industry and academia, national lab procurement, and prizes/competitions) to achieve intended goals and objectives. All reviewers like MECC, but two reviewers believe it should be expanded to engage people who do not have an existing interest in the area or knowledge of the field. Furthermore, it would be useful to clarify the audiences the NREL team has shared educational resources with and what types of users are leveraging the marine energy STEM portal.

Implementation and Progress

Reviewers agree diverse and complementary R&D projects are closely tied to the program's strategic direction. There is overwhelming praise for the breadth of projects in this portfolio. The activity area is funding the most relevant technologies, tools, and studies to achieve the goals and objectives stated in the MYPP.

Reviewers agree the projects represent relevant technologies and the tool development is impressive. Reviewers are impressed with the projects' diversity and data generation. However, two reviewers explicitly note the need to develop a metric to better understand who is using this data.

The activity area is likely to meet performance goals and objectives defined in the MYPP based on the current portfolio of projects. Most reviewers agree the goals and objectives defined should meet performance goals. One reviewer recommends connecting information to actual paid work as the best way to advertise marine energy opportunities. Potential employees may visit PRIMRE if a job or internship exists, but they are unlikely to find or visit PRIMRE by itself.

Activity Area Response

Submitted by Allison Johnson, Engagement and Outreach Lead

The program would like to thank the reviewers from the data and workforce panel. They asked great questions and offered important perspectives on WPTO's work. This feedback will help WPTO and its partners in efforts to enable knowledge sharing and develop a skilled workforce for the growing marine energy sector.

The program appreciates the reviewers' praise of the activity area's strategic direction. Reviewers wrote that the strategy for this portfolio is clear, comprehensive, and ambitious, and they believed the activities presented have the potential to support the sector's sustained multidisciplinary growth.

Reviewers noted that informational tools and databases developed, like PRIMRE and the Marine Energy Permitting Toolkit, provide easy access for diverse end users to data and information that would otherwise be difficult to locate and compile. The program agrees with the reviewers' comment that, as good as these tools seem to be, the impact of these projects depends largely on developer and regulator uptake. Reviewers also had positive comments on PNNL's State of the Science report and derivative products as a trusted, respected source on marine energy's environmental impacts. In a similar vein, reviewers commented that PNNL's grid value analysis provides a balanced and novel framework for considering marine energy's value in a holistic way.

Reviewers had positive comments about the MECC, which is one of the main ways WPTO exposes students to marine energy. The panel lead noted the MECC attracts students of different disciplines and backgrounds, resulting in cohorts that are diverse, skilled, and well positioned to enter the marine energy workforce. NREL and WPTO have been thrilled with the competition's ability to attract multidisciplinary, diverse teams and engage educational institutions that previously had limited or no experience working with WPTO or DOE more broadly.

While the reviewers scored projects highly and provided mostly positive comments, they also offered constructive feedback and several useful recommendations, which the program will consider further. Overall, reviewers outlined several recommendations to (1) support more university-led, foundational research, (2) develop clear metrics for success and collect more data on who is using data and tools, (3) consider incorporating broader datasets into PRIMRE, (4) invest more in workforce development activities to reach a broader audience of students and connect youth with job opportunities, (5) be mindful of what educators need at different levels, and (6) increase efforts to understand and mitigate possible negative environmental impacts. The following sections outline the activity area's response to the reviewers' key recommendations.

Recommendation 1: Support More University-Led, Foundational Research

The reviewers noted more foundational research and collaboration between industry and academia are needed to prepare the industry to develop sea-ready, full-scale devices. The activity area agrees universities are invaluable to the marine energy field, and WPTO has plans to deepen and expand investments in universities within the next couple of years. When DOE first started growing its marine energy portfolio more than a decade ago, its first funding opportunity supported academic research and designated new NMRECs. The NMRECS and other universities across the United States are actively supporting university- and industry-led projects and device development through initiatives like the TEAMER network, and WPTO will continue to foster university-led, industry-relevant research through efforts like UMERC. While continuing to invest in UMERC, TEAMER, and the NMRECs' capabilities, WPTO plans within the next year to support new foundational research at universities that are not already members of these networks.

Recommendation 2: Develop Clear Metrics for Success and Collect More Data on Who Is Using Data and Tools

Two reviewers explicitly stated the need to improve metrics to better understand who is using WPTO-funded databases and tools. While it is relatively simple to develop and measure against quantitative metrics for these types of resources (e.g., number of unique visits to a webpage or number of times a dataset was downloaded), qualitative metrics are more challenging. This reality is exacerbated by legal limitations in the federal government regarding tracking detailed user data and personally identifiable information. While these facts make the endeavor challenging, they are not excuses, and the program will work to address this weakness. Some relevant efforts are already underway; for example, the PRIMRE team will soon establish user-driven metrics for the Marine and Hydrokinetic Data Repository by allowing users to provide direct, qualitative feedback on a dataset that other users can also see. In workforce development, NREL is establishing a sub-contract with an objective evaluator who will help develop meaningful metrics and evaluate project outputs. The program hopes to be able to share more meaningful metrics and datapoints to illustrate impact by the next peer review.

Recommendation 3: Consider Incorporating Broader Datasets into PRIMRE

Two reviewers wrote that they believed PRIMRE would be even more valuable if it could host more data and information about projects not funded by WPTO or DOE, including international R&D efforts. WPTO acknowledges the incorporation of international data would make PRIMRE a more comprehensive and, thus, valuable resource. At the same time, the program realizes this would be a big undertaking for one country or government agency to lead on its own, and it is beyond the program's scope as a funder of U.S. marine energy research. However, WPTO welcomes other countries' or funding agencies' collaboration on data sharing and, with financial and in-kind support from international partners, is more than willing to host data produced outside of WPTO-funded projects. The IEA's OES is already making such an investment by co-funding a new international marine energy geographic information system (GIS) tool, which will be built by staff at NREL, PNNL, and Sandia National Laboratories (Sandia) and hosted on PRIMRE. WPTO welcomes further engagement by international partners and would be happy to support additional international data-sharing efforts.

Recommendation 4: Invest More in Workforce Development Activities to Reach a Broader Audience of Students and Connect Youth with Job Opportunities

One reviewer importantly noted the education and workforce development aspects of the portfolio seem bifurcated and more is needed to ensure the work underway results in connections for youth to job opportunities. Two reviewers noted the portfolio should be expanded to engage students who did not have a previous interest in or exposure to marine energy, and reviewers provided useful suggestions for ways the program can expand its reach and support students beyond those in the MECC, such as by providing funding for students to participate in international competitions and conferences, supporting established student organizations, targeting experts in adjacent fields to transition to marine energy, better linking students to job opportunities, and connecting programming to broader efforts across DOE and the federal government. The program appreciates reviewers' specific, tangible suggestions and will pursue all of them.

Recommendation 5: Be Mindful of What Educators Need at Different Levels

One reviewer cautioned WPTO and its partners to consider what educators need at different grade levels when designing and implementing education and workforce development programming. For example, K-12 educators need to teach the energy system as a whole and clean energy's role within it. For this reason, the reviewer noted it is good that educational materials developed by WPTO's partners are woven into existing curricula. WPTO acknowledges this important reminder to always consider the needs of educators at different levels, particularly since the program hopes to have some influence at various levels of the educational spectrum.

Recommendation 6: Increase Efforts to Understand and Mitigate Possible Negative Environmental Impacts

Reviewers agreed the regulatory engagement activities carried out were important and advised WPTO to increase its efforts to recognize and mitigate potential environmental impacts of marine energy technologies. Additionally, one reviewer stated there is not yet enough evidence that WPTO-funded projects in this area have resulted in improved regulatory efficiencies or reduced uncertainty around environmental impacts from a regulatory perspective. The program agrees with the reviewers that there is insufficient evidence these projects have resulted in improved regulatory efficiencies. The program also acknowledges that for WPTO-funded resources, like the permitting toolkit and the State of the Science, to make maximum impact, both regulators and developers must use them. For this reason, WPTO will continue to prioritize regulator engagement and invest in projects that improve scientific understanding of potential environmental impacts. WPTO has a robust portfolio of projects focused on understanding and mitigating potential environmental impacts of marine energy technologies, but those projects were not presented to this panel of reviewers and were instead covered in a different panel.