6 MARINE ENERGY MULTI-YEAR PROGRAM PLAN

Marine Energy Program MYPP Organization and Structure

The following sections detail FY 2021–2025 plans within each activity and sub-activity area in the Marine Energy Program and are organized as follows:

- Activity 1 – Foundational R&D
- Activity 2 – Technology-Specific System Design and Validation
- Activity 3 – Reducing Barriers to Testing
- Activity 4 – Data Access, Analytics, and Workforce Development.

Each activity area section includes the following components:

- *Activity Overview*: This subsection contains a brief overview of the activity area and scope of effort.
- *Key Results and Performance Goals (2021-2025)*: This subsection highlights certain significant outputs or products within the activity area that are expected within the next five years. The key results and performance goals are critical to achieving the program's 2026-2030 objectives. The list of key results and performance goals is not intended to be comprehensive and may not include every output produced within the five-year timeframe.
- *Follow-on Objectives (2025-2030)*: This subsection identifies short-term outcomes that the program aims to achieve by 2030, resulting from the successful completion of the 2021-2025 Key Results and Performance Goals. These follow-on objectives logically lead to the intermediate and long-term outcomes and ultimate impacts defined in the program's logic model.
- *Additional Details on Activity*: This subsection provides additional background information, context, and details on the program's activity area, such as links or interdependencies between or among the activities/sub-activities.
    - *Sub-Activity Overview*: This subsection summarizes the various elements that the sub-activity covers and highlights major areas of work to achieve overall activity performance goals and follow-on objectives. A flow diagram illustrates the timing and sequencing of major areas of work.
    - *Sub-Activity FY 2021–2025 Research Priorities*: These are the main efforts the Marine Energy Program intends to support within the sub-activity.
    - *Sub-Activity Timing and Sequencing of Research Priorities*: A visual representation of the timing, sequencing, and relation of different research priorities to each other.
    - *Additional Details on Sub-Activity*: Additional background information, context, and details on the program's planned efforts within the sub-activity.

Marine Energy Program Activity 1 – Foundational R&D

Overview

In order to reach cost-competitiveness with other energy resources, marine energy technologies need to see dramatic cost reductions over the next 10-20 years. The Marine Energy Program's Activity 1 – Foundational R&D supports research to drive these cost reductions, both through improving the device performance and reducing costs of existing device designs and by developing new capabilities that can allow for entirely new designs and approaches to harnessing the energy in natural water bodies. These early-stage R&D efforts are typically applicable to a wide range of device archetypes and, in some cases, cut across multiple technology types (e.g., wave, tidal, ocean current).

Activity 1 – Foundational R&D consists of the following sub-activities:

1. Advanced Materials and Manufacturing: Focusing on basic and applied science in materials and manufacturing that can be used by the marine energy industry to increase longevity/reduce operations and maintenance costs, reduce capital costs, and improve energy capture performance.
2. Controls: Enabling broad implementation of advanced control systems across the marine energy industry to dramatically improve performance and reduce cost of marine energy converters.
3. Numerical Modeling: Developing experimental and numerical methods to measure and predict device performance that are needed to design and optimize the next generation of marine energy technologies and lower the cost of marine energy.
4. Components: Optimizing conventional and next-generation subsystems and components with high potential for cross-cutting multiple energy conversion systems and technologies, as well as emphasizing advanced components and systems that are capable of operating in complex marine environments with limited operation and maintenance requirements.
5. Resource Characterization: Providing key information on the opportunities, constraints, and risk for marine energy projects, as well as understanding the value and potential of marine energy technologies.

These sub-activities have been identified to have the highest potential impact on device performance and/or cost. Research undertaken in each of these areas is necessary to understand the difficult and complex ocean environment, drive long-term innovation and cost reduction in different scales of devices and arrays, and ultimately achieve the cost reductions and performance improvements required for deployment of marine and hydrokinetic technologies at scale.

Performance Goals and Objectives

The key results, performance goals, and follow-on objectives are summarized in Table 20.

Table 20. Foundational R&D Performance Goals and Objectives

Key Results and Performance Goals (2021–2025)
• Evaluate applicability and performance of composite and other novel materials for marine energy converter systems and subsystems, such as wave energy converter hulls and tidal energy converter blades. • Develop power take-off (PTO)/control system co-design methodologies and partner with technology developers to pilot the use in marine energy converter device design processes. • Validate foundational modeling tools with data from ongoing water testing projects. • Disseminate high fidelity data sets and models through upgrades of the Marine Energy Atlas and DOE interface to cloud computing services and functional web-based application tools. • Complete resource measurements and assessments in support of marine energy projects to enhance the resilience of specific remote communities. • Test new and important component technologies that support significantly improved IO&M (e.g., wet-mate connectors and distributed energy conversion technologies). • Advance power electronics technologies that support integration of marine energy devices into power at sea and coastal community microgrid system applications.
Follow-On Objectives (2026–2030)
• Integrated, in-water systems testing completed for new, high-priority materials, power electronics, and other components. • First generation in-water tests completed of device designs documented to have used PTO/control system co-design methodologies and tools. • Early technology readiness levels (TRL) system testing of distributed-energy-conversion technology archetypes. • Widespread utilization (along with positive ease-of-use metrics and value reviews from users) of validated foundational modeling tools.

Additional Details

In general, marine energy technologies are at an early stage of development due to the fundamental scientific and engineering challenges of generating power from dynamic, low-velocity, and high-density waves and currents while surviving in corrosive ocean environments. To address these challenges, the program invests in early-stage R&D specific to marine energy applications to generate knowledge relevant for industry to develop innovative components, structures, materials, systems, and approaches to manufacturing. The Marine Energy Program's early-stage foundational R&D focuses on addressing scientific and engineering challenges that facilitate breakthroughs for broad, industry-wide benefits. The Marine Energy Program defines foundational research as research on problems or topics that have broad relevance across large portions of the marine energy industry and often cut across technologies or resource types. A primary value of this type of research is that it enables exploration of complex scientific problems beyond the scope of a single issue, technology design, or narrow area for a greater long-term impact to the industry at-large.

WPTO's marine energy R&D portfolio makes broad investments in foundational research that will increase fundamental knowledge, foster opportunities for breakthroughs, and provide technology options for future advances in marine energy capabilities and systems. The Marine Energy Program seeks to balance risk, opportunity, and potential marine energy impact. The Marine Energy Program's foundational R&D focuses on: (1) advanced materials and manufacturing; (2) controls; (3) numerical modeling; (4) components; (5) resource characterization; and (5) crosscutting R&D. These focus areas are critical cross-cutting elements to WPTO's marine energy R&D

portfolio in order to understand the difficult and complex ocean environment and drive long-term innovation and cost reduction in different scales of devices and arrays. Foundational R&D is a priority area in the near- and mid-terms because resulting data and knowledge from this research will inform many different types of system design improvements. The Marine Energy Program intends to drive innovation in multiple areas. Innovative components, like types of generators, and materials that are capable of operating in the complex marine environment with limited O&M requirements are needed to further the development of commercial marine energy technologies. The Marine Energy Program supports R&D led by industry, academia, and national laboratories to meet these challenges.

Foundational R&D investments provide technology building blocks that can be leveraged by private U.S. marine energy developers for technology improvements and, ultimately, successful commercialization. U.S. marine energy developers are generally small, specialized companies that do not have resources to make large investments in foundational science and engineering. The Foundational R&D activity area supports the development of new, cutting-edge technologies to improve device system performance and establish a strong, competitive industry in the United States.

Sub-Activity 1.1 – Advanced Materials and Manufacturing

Overview

New material capabilities have the potential to drive significant cost and performance improvements in marine energy technologies through increased energy capture performance and reduced costs. Material properties that increase resistance to corrosion or biofouling can have a significant impact on long-term efficiency and O&M costs, while new materials or manufacturing processes can allow for entirely new device shapes, designs, and approaches to energy conversion. This sub-activity comprises basic and applied science into materials and manufacturing that can be used by the marine energy industry, focused on advances that can (1) increase longevity/reduce operations and maintenance costs; (2) reduce capital costs; and (3) improve energy capture performance.

FY 2021–2025 Research Priorities

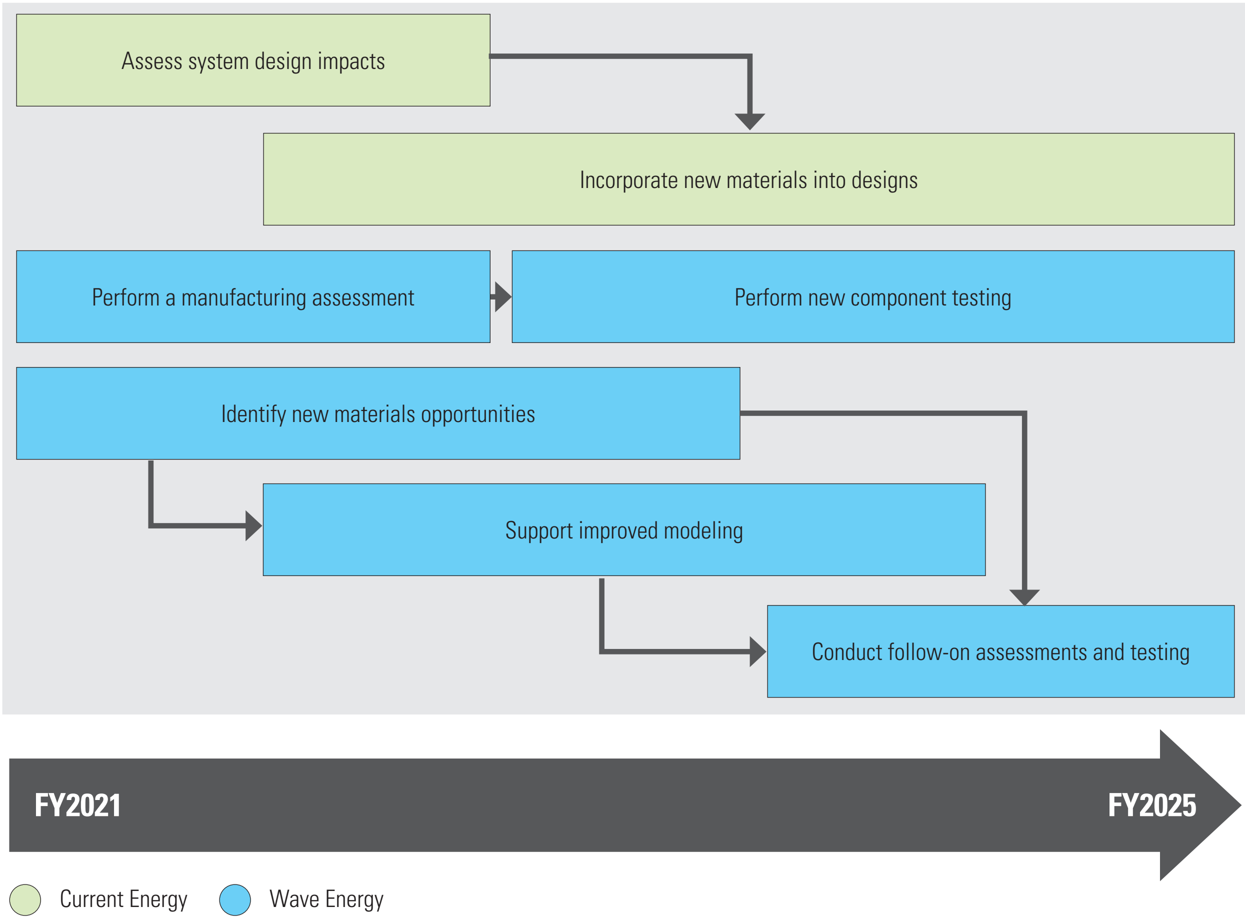
The following are the research priorities that will be emphasized within the Sub-Activity 1.1 – Foundational R&D:

- **Assess system design impacts**: Investigate potential design system impacts for current/tidal energy converters using novel materials and manufacturing materials.
- **Incorporate new materials into designs**: Incorporate novel carbon fiber materials into current/tidal energy converter designs.
- **Perform a manufacturing assessment**: Assess feasibility of additively manufactured wave energy converter components by evaluating potential time savings and quality of finished products. Evaluate the LCOE impact of the additive manufacturing technology with respect to incorporating thermoplastics or other thermosets/resins in WECs.
- **Support improved modeling**: Extend existing numerical modeling capabilities to analyze novel/unconventional material and coating performance.
- **Conduct follow-on assessments and testing**: As needed, further characterize and test materials that show potential for increased performance or reduced costs.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 27.

Figure 27. Sub-Activity 1.1 – Advanced Materials and Manufacturing Research Priorities



Additional Details

Advanced materials are enablers of technologies needed to construct devices for converting the tremendous energy available in water motion into usable electricity. The maritime environment is harsh and marine energy systems need to survive and thrive over long periods of time in order to be cost-effective. Material selection for a marine energy device is important as it has significant impacts on performance, capital equipment costs and operational costs. This sub-activity focuses on basic and applied science into materials that can be used by the marine energy industry, which has different constraints and performance requirements from other maritime industries. The challenges of cost/performance trade-off related to marine energy devices are addressed by utilizing the recent and continuing developments in advanced materials such as carbon fibers and thermoplastic composites, as well as manufacturing technologies such as additive manufacturing. Impacts of the research includes effects on LCOE since materials can impact the price/pound of the marine energy structure, manufacturing, O&M, reliability, and safety.

Marine energy devices will need to reliably operate for 20 or more years in harsh environments of oceans and rivers. These operational parameters place severe performance requirements of structural integrity and durability on the selected materials. Furthermore, water uptake into the material volume and deposition of marine organisms on surfaces create additional performance challenges. This sub-activity plans to support continued R&D to evaluate performance of materials and biofouling protection for devices in marine energy environments. Additionally, consideration will be given for R&D with new applications to marine energy, such as utilization of light weighting and integrated computational materials engineering to evaluate and develop materials with optimal combinations of characteristics to meet the needed performance requirements. Since operation and maintenance costs contribute significantly to the total device LCOE, these research areas focus on reducing this cost.

A significant part of the device capital expenditure cost is in its two main components: the energy-capturing structure and the electricity-generating structure called the PTO. While some of the materials considerations for the energy-capturing structures were discussed above, additional impactful R&D focusing on the PTO is also considered in this sub-activity. Further considerations are also given to new and emerging designs aimed at integrating these two parts in the WECs by utilizing for example flexible membranes and a concept called dielectric elastomer generator. Several materials and manufacturing challenges emerge that need to be addressed before the unconventional WECs with flexible membranes can become commercial devices. This sub-activity will explore the potential of these devices by supporting R&D that synthesizes new polymers, possibly by using nano-scale particles to modify the mechanical and electric conductivity characteristics.

Using advanced materials in marine energy devices requires properly characterizing the materials to determine their performance limits. This in turn requires knowledge of the hydrodynamic loads that act on the devices in the harsh marine environment as well as the materials response to those forces. This sub-activity will therefore support development of tools to calculate those forces and testing methodologies to characterize the material properties and their thresholds.

Sub-Activity 1.2 – Controls

Overview

Advanced controls and controls co-design research remains a major programmatic focus for current energy converters (CECs) and WECs. Previous studies[64] have shown that advanced controls improvements can provide significant increases in energy capture at varying timescales with recent tests doubling the energy capture for WECs over previous methods.[65] And controls have the ability to impact more than energy capture as well. Control systems can reduce both fluctuation frequency (from a large range of incoming wave frequencies or wave periods) and magnitude (from a large range of wave heights), thereby reducing cyclic loading, fatigue potential, and high stress occurrences. Controls can affect the amount of structural design margin needed to better estimate the amount of structural material and reduce capital expenditure. Control systems also effect in-water fatigue loading, impacting operational expenditure. Co-design involves designing and balancing requirements for the control of an marine energy system simultaneously with the design of other systems. The controls system and having a system that is controllable should not be an afterthought but be considered at the earliest stages of design analysis.

FY 2021–2025 Research Priorities

The following are the research priorities that will be emphasized within the Sub-Activity 1.2 – Controls:

- **Perform wave energy controls experiments**: Conduct multiple, diverse studies that consider control design approaches and device variables to produce publicly available data on controls system performance.
- **Advance sensor packages**: Develop and improve sensor packages to improve data collection on controls system performance in laboratory and open-water settings.
- **Perform opportunistic analysis of open-water test data**: Establish partnerships with developers and researchers to aggregate and analyze information on controls system performance from tests not directly funded by DOE.
- **Support third-party comparative analyses**: Support comparative and longitudinal studies of wave energy controls system efficacy by neutral third parties.

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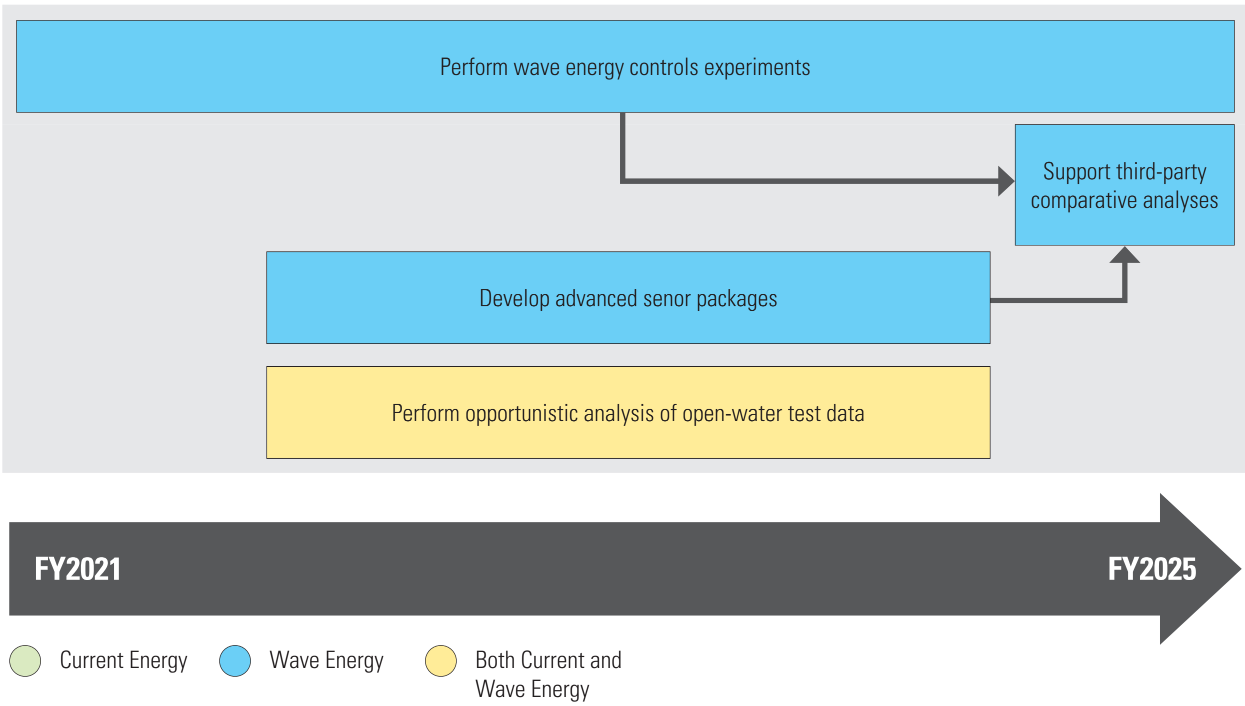
64 Dallman, A., Jenne, S., Neary, V., Driscoll, F., Thresher, R., and Gunawan, B. 2018, "Evaluation of performance metrics for the Wave Energy Prize converters tested at 1/20th scale." https://www.osti.gov/biblio/1492503-evaluation-performance-metrics-wave-energy-prize-converters-tested-scale.

65 Bacelli, G. and Coe, R, 2020. "Comments on Control of Wave Energy Converters." https://ieeexplore.ieee.org/document/9005201.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 28.

Figure 28. Sub-Activity 1.2 – Controls Research Priorities



Additional Details

Controls and controls co-design strategies and technologies are being leveraged from other industries (e.g., aerospace and defense) that can maximize power production over a range of ocean conditions. Other priorities include improving and validating modeling tools and methodologies needed to optimize device and array performance and reliability across operational and extreme conditions. During early-stage R&D, targeted government support can generate knowledge benefits applicable to marine energy technology development and deployment by industry, as well as broader knowledge spillover benefits from innovations in materials, sensors, and modeling capabilities.

Controls are of particular importance in WEC design as these systems are often physically large, must be capable of surviving extreme weather events, and must navigate the trade space of spectrum, intensity, and occurrence. Existing WEC designs produce power efficiently over a narrow band of the full wave frequency spectrum. Wave energy tends to be concentrated at lower frequencies which often translates to low-speed, high-torque PTOs that are physically large and often requiring speed increasing mechanisms such as gearboxes. To achieve commercial viability, WECs must be able to absorb and produce power efficiently across a broad range of frequencies. Projects are developing and validating control strategies to increase power output of WEC devices. To make the difficult leap from theoretical studies to deployable WEC hardware, WPTO has multiple investments performing research on control algorithm development, numerical simulation, and scaled model testing.

WPTO seeks to enable broad implementation of advanced control systems across the marine energy industry to dramatically improve performance and reduce cost of marine energy converters. Investments will be targeted to build a portfolio that can provide foundational knowledge to industry on a broad range of key elements related to PTO and control system design.

Sub-Activity 1.3 – Numerical Modeling

Overview

Physical modeling and testing of scaled marine energy devices in the water, whether tank or open ocean, is complicated, expensive, and can involve long timelines. Numerical modeling partially ameliorates these burdens and accelerates multiple design iterations. Models empower developers to make appropriate design choices based on improved understanding of important fluid-structure interactions, energy capture and conversion, and structural load response, including device/array interactions with the marine energy resource and resultant effect on economic and environmental considerations. The complex fluid-structure interactions between marine energy devices and the marine environment govern device performance and survival and the environmental effects of marine energy devices. The Marine Energy Program supports the development of experimental and numerical methods to measure and predict device performance that are needed to design and optimize the next generation of marine energy technologies and lower the cost of marine energy.

FY 2021–2025 Research Priorities

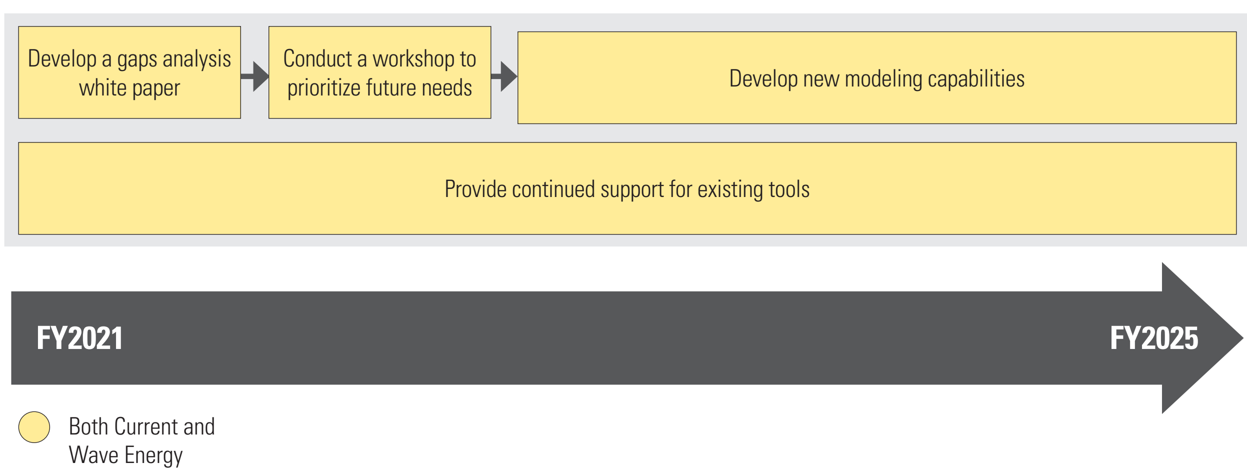
The following are the research priorities that will be emphasized within the Sub-Activity 1.3 – Numerical Modeling:

- **Develop a gaps analysis white paper**: Compile a document assessing existing marine energy software capabilities.
- **Lead a workshop to prioritize future needs**: Leverage the gaps analysis white paper to facilitate a workshop discussion with industry, universities, and researchers to determine what analytical capabilities are either missing or insufficient, and identify the priorities associated with developing these capabilities.
- **Develop new modeling capabilities**: Develop new tools and higher fidelity modeling capabilities using the priorities list established in the gaps analysis workshop.
- **Provide continued support for existing tools**: Maintain existing capabilities and functionality for marine energy numerical modeling tools.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 29.

Figure 29. Sub-Activity 1.3 – Numerical Modeling Research Priorities



Additional Details

WPTO works to stay informed on the continued development of international marine energy tools and commercially available models. International collaboration projects under the OES[66] through International Electrotechnical Commission (IEC) Technical Committee (TC) 114 (IEC TC 114)[67] are future opportunities WPTO can leverage to catalog other numerical tool sets and capabilities.

A quintessential project in this investment area is the development of the wave energy converter simulation tool (WEC-Sim), an open source numerical modeling code initially developed between 2012-2017 by the National Renewable Energy Laboratory and Sandia National Laboratories. Because existing commercial modeling codes were closed source and many were originally developed for offshore oil and gas and naval architecture applications, they were limited in their ability to accurately model wave energy converter dynamics and power performance. WEC-Sim provided other researchers and industry with an essential open-source tool to model wave energy devices.

Between 2021-2025, the WEC-Sim team will continue to disseminate the code (through outreach and publications), host training courses (in person and via webinar) and maintain the GitHub repository (by responding to user questions, merging pull requests, adding features, and resolving bugs). This effort supports DOE's missions by reducing the barrier of entry to new developers and innovative technologies. Success is measured by adoption of the WEC-Sim code by the wave energy community at large. WEC-Sim simulations are being used by OES Task 10.2 for its code verification and validation study.

Over the next five years, development work will continue for extreme conditions modeling (ECM). Efforts will include disseminating the WEC Design Response Toolbox (WDRT) through publications and training courses, conducting a set of WEC design load case studies using the ECM framework and accompanying tools, and developing a best practice document that describes the suggested framework for WEC design load analysis.

Between 2021-2022, WPTO will plan for an in-depth numerical modeling workshop where a broad and comprehensive range of industry stakeholders and other researchers will come together to evaluate existing capabilities, associated costs, challenges, and gaps. The workshop report will provide recommendations for the most impactful R&D that can be conducted to assist industry. Outcomes will be used to inform the strategy for maintenance of existing numerical modeling capabilities as well as future numerical modeling work.

Sub-Activity 1.4 – Components

Overview

Components research will continue to be a central priority for future marine energy R&D. Typical components in most marine energy systems include moorings, PTO systems, power conditioning, generators, speed-increasing mechanisms, control system hardware, seals, bearings, hydrofoils, or other prime movers. Current and past research in this sub-activity area has sought to optimize conventional and next generation subsystems and components with high potential for cross-cutting multiple energy conversion systems and technologies. Research has also emphasized advanced components and systems that are capable of operating in complex marine environments with limited operation and maintenance requirements. Past R&D efforts and experience have shown that power-to-weight ratio (PWR) and availability are central to lowering LCOE and increasing the value proposition for non-electric application of marine energy systems. Improvements in PWR can be achieved by increasing the energy capture and conversion efficiency of the device or by reducing its weight. Improvements in availability can be achieved through reduced maintenance, and improved reliability and survivability. Challenges and costs are amplified by the marine environment and therefore improvements to PWR and availability directly impact LCOE, and indirectly though IO&M (vessel availability and capability requirements, special purpose equipment such as cranes, etc.).

[66] International Energy Agency, 2016. "Wave Energy Converters Modelling Verification and Validation." https://www.ocean-energy-systems.org/oes-projects/wave-energy-converters-modelling-verification-and-validation/.

[67] Additional information on International Electrotechnical Commission Committee 114: https://tc114.us/.

FY 2021–2025 Research Priorities

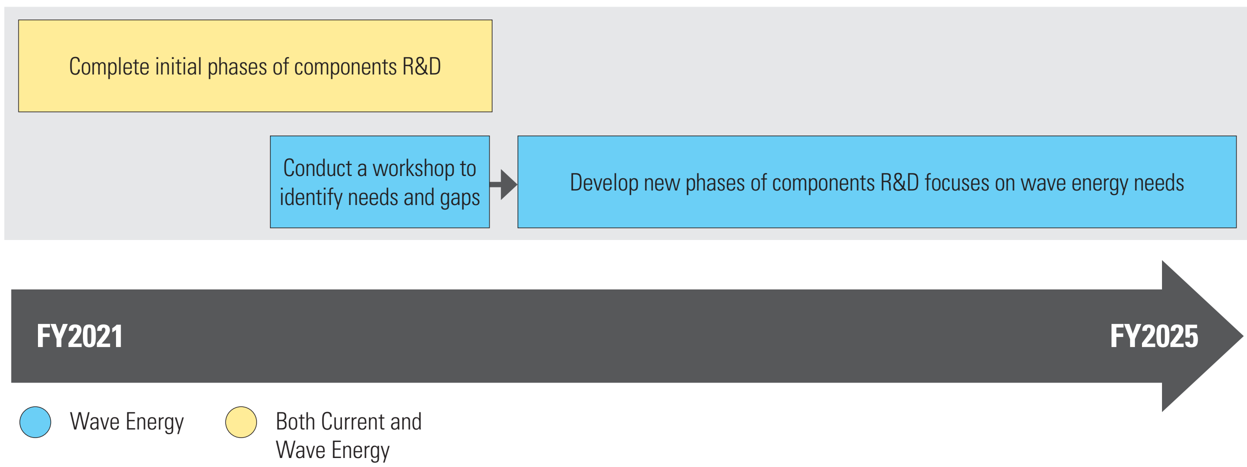
The following are the research priorities that will be emphasized within the Sub-Activity 1.4 – Components:

- **Complete initial phases of components R&D**: Continue work on conventional and next-generation PTO and energy conversion component research and testing.
- **Lead a workshop to identify future needs and gaps**: Engage with stakeholders in a workshop to identify gaps and opportunities to strategically prioritize resources for high-impact solutions in wave energy.
- **Develop new phases of components R&D focused on wave energy needs**: Develop targeted opportunities based on needs, gaps, and priorities.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 30.

Figure 30. Sub-Activity 1.4 – Components Research Priorities



Additional Details

Marine energy resources have large ranges in intensity and present other fundamental difficulties for designing systems to efficiently capture usable energy. These systems often operate in low-speed, high-torque environments resulting in large machines and the need for speed increasing mechanisms, such as gearboxes, which increase system complexity and maintenance requirements. Ongoing R&D includes magnetic gears and springs, magnetically geared generators, hydraulic pumps, and direct drive PTO concepts. As well, traditional means of energy capture and conversion require the use of components and storage elements, to translate energy into a usable form, that may not be optimal or optimized for the marine environment. Past R&D has shown great potential for incorporation of power conversion systems using wide band gap semiconductor devices, superconducting generator technologies, advanced control systems, and materials with enhanced conductivity for application in marine energy. Past experience has also shown mooring and umbilical systems are costly and often site and technology specific, which limit the useful life and ability to use across multiple systems and technologies. Ongoing research has largely focused on modeling and simulation capabilities for these systems. Current and past efforts have also sought to leverage technologies and innovations from other industries (e.g., hydropower, aerospace, defense, on and offshore oil and gas, offshore wind, and transportation) to accelerate the development of impactful solutions in marine energy, and to identify opportunities for co-development and optimization of shared components and subsystems (e.g., transmission, storage, power conditioning, etc.). While this approach facilitates rapid iteration and design evolution, considerable challenges exist with adaptation, integration, and application with marine energy technologies.

Future research efforts in this sub-activity area will target innovations and advancements which specifically address the challenges and opportunities highlighted above. Research activities will continue to support iterative improvements to conventional and next generation component and subsystems which reduce component size and complexity, increase modularity and standardization, and incorporate innovations in materials, controls, and manufacturing. Future efforts will also work to accelerate the development of components and subsystems which will facilitate rapid innovation and adoption of marine energy technologies in the PBE space.

Sub-Activity 1.5 – Resource Characterization

Overview

Resource characterization is fundamental to marine energy R&D, given the relatively early stage of the international industry and lack of convergence on device archetypes. Resource characterization provides key information on the opportunities, constraints, and risks for marine energy projects, in particular, (1) where resources (with target properties of magnitude and quality) are found; (2) how resources could enable different marine energy applications or project types (across scales, including grid and distributed); and (3) what challenges and opportunities resources pose, and in what time frame. The amount of energy capture relies upon not only the magnitude of these resources, but also other resource attributes, including speed, direction, and variability: technology development, optimization, and siting are all guided by characterization of a variety of resource attributes. Resource characterization is also critical for understanding the value and potential of marine energy, such as its predictability, and complementarity with other energy resources.

FY 2021–2025 Research Priorities

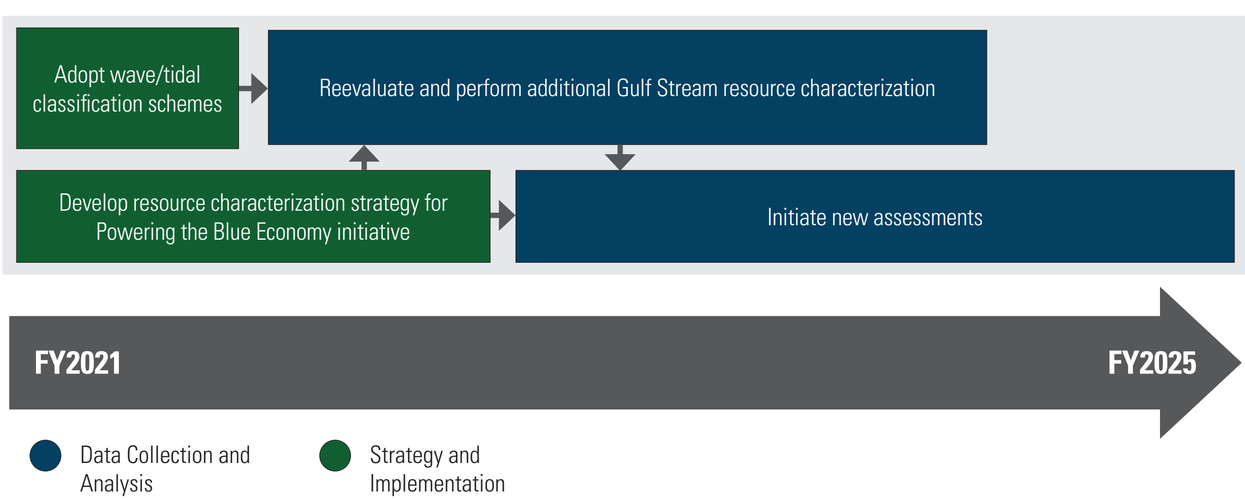
The following are the research priorities that will be emphasized within the Sub-Activity 1.5 – Resource Characterization:

- **Develop resource characterization strategy for the *PBE Initiative***: Determine additional data or analysis needed to characterize new PBE market opportunities.
- **Adopt classification schemes**: Develop wave/tidal classification schemes for IEC standards to streamline technology development and commercialization processes.
- **Initiate new assessments**: Support the development of new assessments for marine-powered desalinization and other emerging community-scale market opportunities.
- **Reevaluate and perform additional Gulf Stream resource characterization**: Evaluate and conduct Gulf Stream characterizations, incorporating feedback from industry.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 31.

Figure 31. Sub-Activity 1.5 – Resource Characterization Research Priorities



Additional Details

This sub-activity encompasses research and measurements, modeling and tool development, and data products and their dissemination and implementation. Measurements include both in-situ and remote observations and data processing. Some of these measurement data also feed into models. Modeling efforts include model development, refinement, and validation to generate high-resolution unstructured models of data sets that include a variety of statistics and resource parameters that characterize tidal, current, and wave resources in different geographic regions. Both measurements and models account for variability and extreme conditions that impact device performance and survivability. Measurements and data from models are shared across institutions and publicly through multiple formats including databases, maps, interactive tools, and publications. Users include developers and regulators, among others. Determining and sharing the types, variability, extent, and patterns of resources continues to be an important activity that supports technology development and optimization at multiple scales.

Resource characterization is cross-cutting; it informs and is informed by efforts across other areas of the program. For system development, marine energy resource assessments and characterizations are used to optimize devices and arrays. Resource characterization models and tools also inform how barriers to testing could be reduced. Resource characterization is critical for grid-scale and PBE initiatives as it underlies the development and efficacy of marine energy technologies across regions and scales.

Marine Energy Program Activity 2 – Technology-Specific System Design and Validation

Overview

R&D in the Technology-Specific System Design and Validation activity area focuses on (1) supporting the design, manufacture and validation industry-designed prototypes at multiple relevant scales; (2) improving methods for safe and cost-efficient installation, grid integration, operations, monitoring, maintenance, and decommissioning; (3) supporting the development and adoption of international standards for device performance and insurance certification; (4) supporting the early incorporation of manufacturing considerations into device design processes; and (5) leveraging expertise, technology, data, methods, and lessons from the international marine energy community and other offshore scientific and industrial sectors.

Activity 2 – Technology-Specific System Design and Validation consists of the following sub-activities:

1. System Design and Laboratory Testing: Designing, manufacturing, and testing proof-of-concept systems in laboratory and ocean settings to understand performance characteristics, identify and mitigate reliability risks, and provide data to inform future R&D to improve early-stage designs across the industry.
2. Open Water Testing: Validating systems in open water settings, resulting in data to inform future R&D and improve early-stage designs across the industry.
3. PBE: Developing new, marine energy-enabled technologies to address and relieve power constraints in markets and applications in the blue economy.
4. Standards Development: Developing and adopting international standards through the IEC.

Performance Goals and Objectives

The key results, performance goals, and follow-on objectives are summarized in Table 21.

Table 21. Technology-Specific System Design and Validation Performance Goals and Objectives

Key Results and Performance Goals (2021–2025)
• Complete initial field-testing for modular current energy converter systems that capture hydrokinetic river energy in low-flow environments (less than 2 m/sec) and can incorporate and advance IO&M techniques, which require only limited use of port and deployment vessel infrastructure. • Complete first year-long field tests of wave energy converter device designs in fully energetic wave environments (likely at the PacWave facility). • Complete at-sea, pre-commercial demonstrations of newly developed marine energy-powered ocean observing systems and desalination systems. • Concept refinement, design, and small-scale prototype testing of new wave energy system concepts with high techno-economic potential. • Establish U.S. capabilities for third-party certification of compliance to IEC Technical Specifications to include Power performance assessment, Assessment of mooring systems, Electrical power quality requirements, and Measurement of mechanical loads at PacWave wave energy test facility, and Power performance assessment of Current Energy Converters tested with the Mobile Test Vessel.
Follow-On Objectives (2026–2030)
• New, commercially available marine energy-powered ocean observation systems are deployed for a variety of uses. • Wave powered desalination systems are deployed for the first uses in disaster recovery or international development scenarios. • Documented improvements in energy-water system resilience and security for a number of targeted remote communities, enabled by marine energy systems. • International standards developed for device performance and insurance certification for grid-scale and blue economy market applications. Standards use established as best practice for all device tests and deployments. • First in-water, integrated system tests for newly developed wave energy device concepts. • Design and testing of megawatt (MW) scale current energy converter devices/arrays that incorporates installation, operation, and maintenance lessons.

Additional Details

Activities aligned with this area of work have increased steadily since the Marine Energy Program's initiation, as more component technologies have been developed and more devices have steadily matured. Focus in this area is expected to increase in the near to mid-term, eventually becoming the most significant area of focus within the Marine Energy Program, particularly as new facilities and capabilities become available to conduct in-water prototype testing more efficiently. In the long term, assuming sustained efforts to integrate new technologies into systems and test prototype devices produce successful results, prioritization of these activities would decrease slightly, as attention shifts to efforts focused on array-scale challenges and innovations. Still, persistent, long-term support of a critical mass of activities in this area will remain important to continually test and validate new innovations being introduced throughout in the industry.

Historically, investments to improve performance and reduce costs for multi-device arrays have comprised a small portion of the Marine Energy Program's portfolio, as efforts have been more focused on Foundational R&D and improving the performance of individual devices. Fewer efforts have thus far been dedicated to solving array-scale issues that could also influence how early-stage device designs are evaluated (e.g., considerations of IO&M issues, array interactions, and potential limitations of manufacturing large numbers of devices at scale). As discussed above, efforts focusing on addressing relevant array and plant-scale issues are expected to increase over time slowly and steadily, to the point where they will represent a much larger focus of the Marine Energy Program in the long term.

For industry to advance marine energy technologies beyond smaller-scale prototypes requires not only tank testing, but also open water validation of performance and efficiency, as well as reliability, especially in extreme sea states. Due to complexity in the wave physics of high-energy sea states and the fluid dynamics of sub-sea currents, even simple marine energy prototypes must be validated in open water to acquire data that accurately reflects system performance. This validation is expensive and time consuming due to the unique challenges of the marine environment, and it is generally beyond the capacity of pioneering technology companies that comprise the industry. Furthermore, industry-wide testing specifications and standards are still under development, leading to inconsistencies in how results are reported and ultimately making comparisons in performance data more challenging. Marine Energy Program support for in-water testing facilitates greater consistency between test protocols, test results, and accessibility of test data. The Marine Energy Program will continue ongoing research to develop and evaluate next-generation wave and current system designs, supporting and assessing promising components and early-stage integrated systems through national laboratories and university research, as well as industry partnerships for prototype development and validation.

Through support of device design and testing, the Marine Energy Program has demonstrated cost and performance baselines and improved device-specific efficiency and reliability. The Marine Energy Program has also provided critical, third-party validated data to inform continued early-stage research into new designs, materials, and systems. The Marine Energy Program is committed to investment in early-stage R&D that enables the domestic marine energy industry to advance toward achieving cost competitiveness with local hurdle rates in early adopter markets, including “power at sea” and “resilient coastal community” (RCC) applications, while working toward long-term cost-competitiveness at the utility scale. This will be accomplished by focusing on design concepts that have the potential to increase energy capture and annual energy production of devices, improve reliability and availability, and reduce capital and operating and maintenance costs if further developed and deployed by industry.

Sub-Activity 2.1 – System Design and Laboratory Testing

Overview

The Marine Energy Program’s System Design and Laboratory Testing strategy to help catalyze marine energy development focuses primarily on technology research and design tools to support the efforts of industry to reduce cost and improve performance of marine energy technology concepts at the system, rather than component, level. This research involves designing, manufacturing, and testing proof-of-concept systems in laboratory and ocean settings to understand performance characteristics, identify and mitigate reliability risks, and provide data to inform future R&D to improve early-stage designs across the industry. WPTO is committed to investment in early-stage R&D that supports the domestic marine energy industry to advance toward achieving cost competitiveness with local hurdle rates in near-term markets, where the cost of energy can be near or over $1 per kWh electricity while working toward long-term cost-competitiveness at the utility scale. This will be focused on design concepts that have the potential to increase energy capture and annual energy production, improve reliability and availability, and reduce capital and operating costs if further developed and deployed by industry. Key to this process, this sub-activity includes validation of the computer modeling tools and methodologies developed in Sub-Activity 1.3 – Numerical Modeling, which are needed to optimize device and array performance and reliability across operational and extreme conditions.

FY 2021–2025 Research Priorities

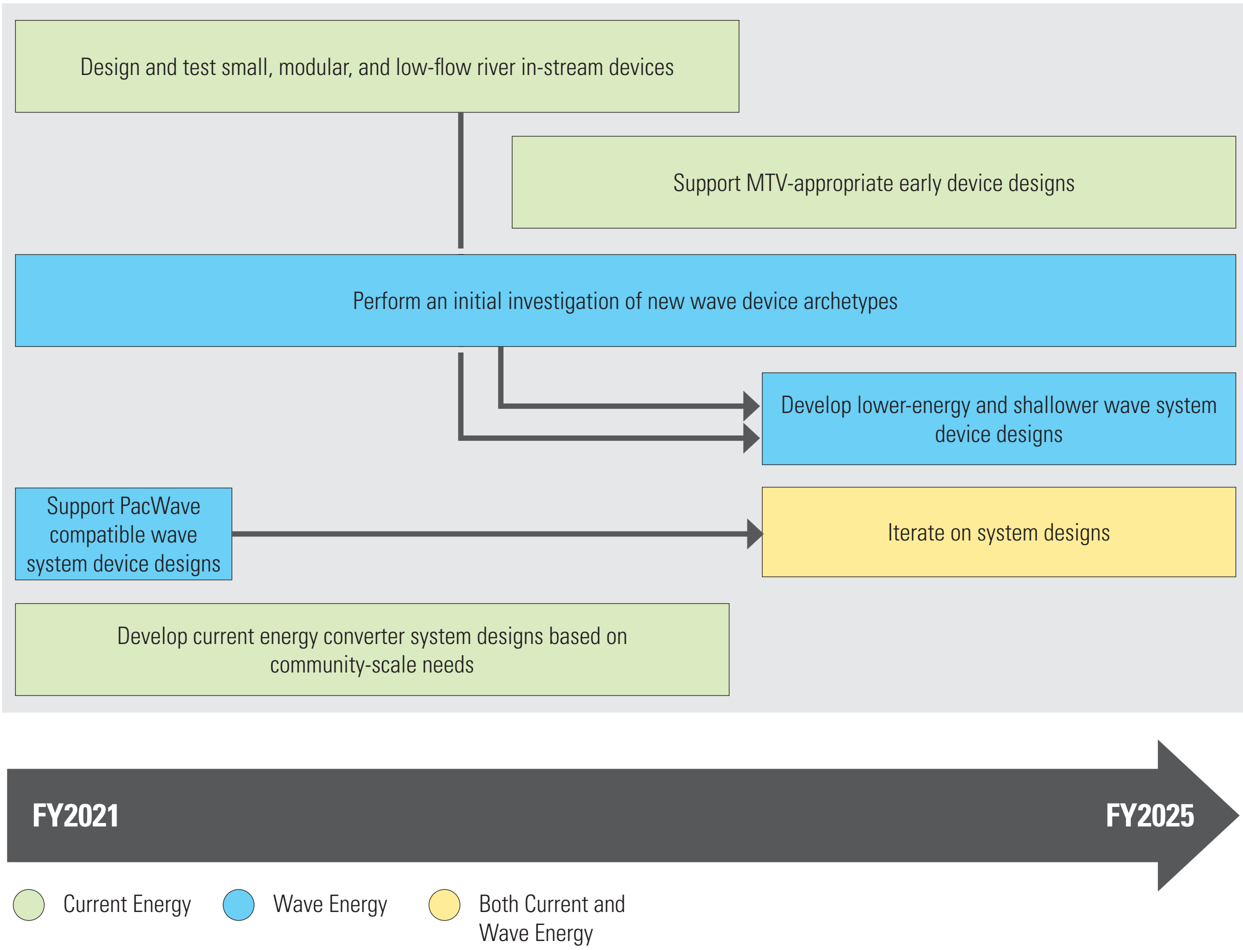
The following are the research priorities that will be emphasized within the Sub-Activity 2.1 – System Design and Laboratory Testing:

- **Design and test small, modular, and low-flow river in-stream devices**: Design and test modular CEC systems that can be efficiently installed and retrieved without the need for significant port or on-site infrastructure and specialized vessels.
- **Support mobile test vessel (MTV)-appropriate early device designs**: Enable CEC system designs whose prototype field validation could utilize the MTV, a fully mobile test platform capable of operations in locations with limited infrastructure support in multiple open-water flow conditions and geographic locations.
- **Perform an initial investigation of new wave device archetypes**: Investigate new wave device archetypes, including flexible, non-rigid-body materials and distributed PTO systems.
- **Develop lower-energy and shallower wave system device designs**: Perform laboratory and tank testing of novel WEC designs with high techno-economic potential.
- **Support PacWave compatible wave system device designs**: Perform system design and laboratory testing of larger wave energy converter devices compatible with a fully energetic wave resource, such as PacWave.
- **Develop current energy converter system designs based on community-scale needs**: Develop current energy converter system designs for the Energy Transitions Initiative (ETI) and microgrids, including energy-storage systems and appropriate community selection.
- **Iterate on systems designs**: Incorporate data analysis and lessons learned from wave and current energy testing to iterate on device designs, which will inform crosscutting foundational R&D innovations and optimization in components (materials, controls, and foundations/anchors), maintenance, and supply chain.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 32.

Figure 32. Sub-Activity 2.1 – System Design and Laboratory Testing Research Priorities



Additional Details

Systems Design and Testing R&D activities will also include a focus on design concepts that have the potential to serve existing or emerging ocean-based technologies that can advance the nation's military, commercial, and scientific capabilities. These include power for remote coastal communities and Department of Defense installations with high electricity costs, charging for ocean-based sensors and underwater vehicles, and non-electric uses like desalination. Development and testing for these applications will provide critical data and experience that will accelerate design improvements and cost reductions for grid-connected power generation.

Previous projects have enabled the marine energy industry to progressively test new designs for wave, current, and tidal energy converter components and systems to enable the performance and reliability improvements required for cost reductions. WPTO's wave energy portfolio has evolved from focusing specifically on component level advancements in controls, structures, and PTOs to the projects focused primarily on innovation and design improvements at the system level. This iterative and systematic design process is necessary to achieve the Marine Energy Program goals for continuous improvements in LCOE.

Designing wave, current, and tidal energy converter systems that meet rigorous marine energy design standards is a goal and a critical step on the path to grid-scale testing at fully energetic environments such as PacWave for wave devices, as well as technology commercialization. The system designs will be verified through rigorous design reviews. There is a focus on WEC designs that are capable of two years of continuous testing and operations utilizing relevant physical characteristics and wave climate. The designs must incorporate the

IEC Technical Specifications (TS) and the Institute of Electrical and Electronics Engineers standards to ensure that designs are final and fully ready to utilize for future shipyard fabrication and open-water testing via future funding opportunities. The development of international standards is critical to increase investor and stakeholder confidence, and reduce project insurance costs, by incorporating best practices developed in related marine industries that have proven designs and operations. Lessons learned and data collected during PacWave testing will be used to inform further development of standards as well as the next generation device designs to expeditiously advance wave energy technologies.

Sub-Activity 2.2 – Open Water Testing

Overview

In order for the marine energy industry to improve performance and reliability of WEC devices and more efficiently extract the maximum energy from the available wave resource, open water testing in a relevant environment is required. The Marine Energy Program's strategy to help catalyze marine energy development focuses primarily on technology research to reduce cost and improve performance of marine energy technology concepts. The open water testing sub-activity focuses on further understanding performance characteristics, as well as identifying and mitigating reliability risks, of the proof-of-concept systems developed under the system design & testing sub-activity. This is accomplished by validating those systems in open water settings, resulting in data to inform future R&D and improve early-stage designs across the industry.

This testing validates modeled system designs to increase energy capture and annual energy production, improve reliability and availability, and reduce capital and operating costs. Research in this area will support industry to overcome the unique challenges of operating, potentially in deep water, to extract the oscillatory and highly energetic the wave energy by supporting wave energy convertor system design, development, and testing at locations such as the Navy's Wave Energy Test Site (WETS) in Hawaii and Scripps Institution of Oceanography off the coast of California; and assessing cost and performance drivers for WEC and farm systems.

FY 2021–2025 Research Priorities

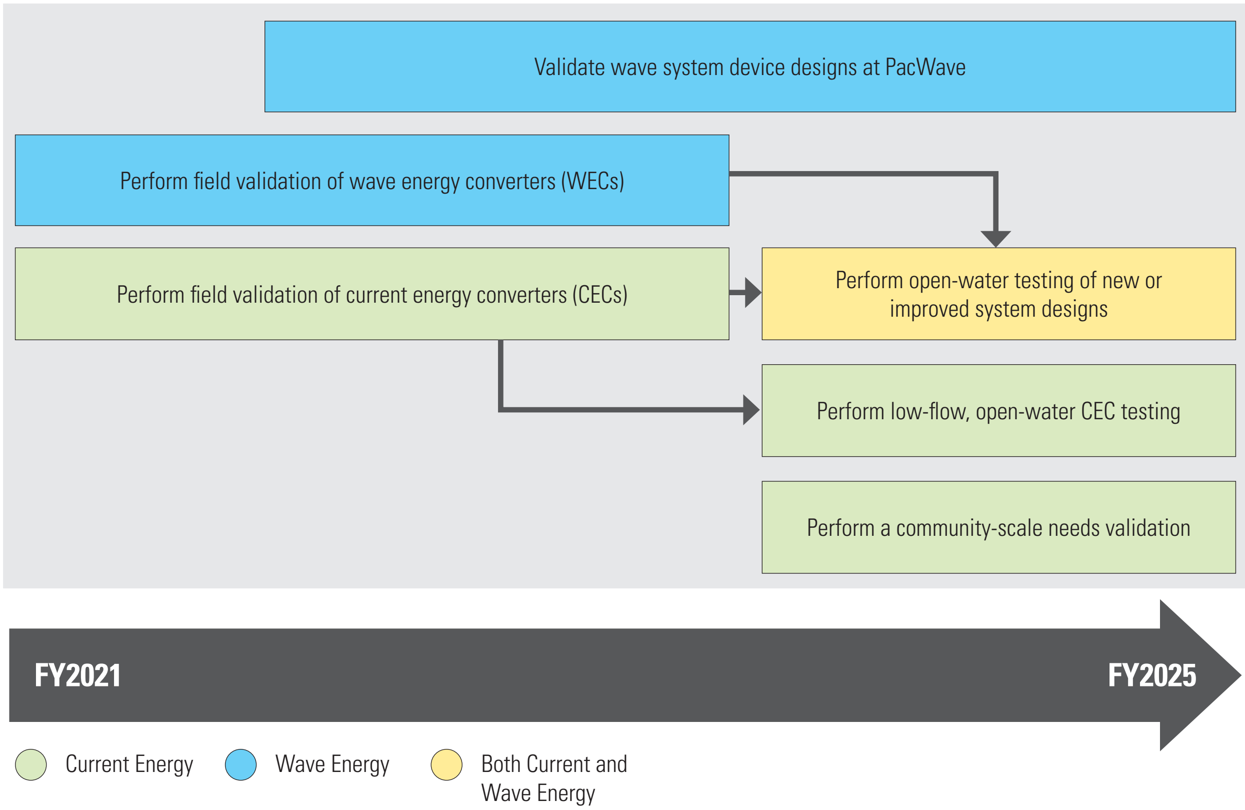
The following are the research priorities that will be emphasized within the Sub-Activity 2.2 – Open Water Testing:

- **Validate wave system device designs at PacWave**: Perform grid-connected field testing of WEC devices in open water at PacWave.
- **Perform field validation of WECs**: Perform open-water field testing of WEC devices in resources that produce less than 20 kW of annual average power (e.g., WETS, Scripps).
- **Perform field validation of CECs**: Perform open-water field testing of current and tidal energy converter devices at locations such as Roosevelt Island Tidal Energy and Igiugig.
- **Perform open-water testing of new or improved system designs**: Test novel and revised wave and current energy technologies for improved performance and reliability, as well as reduced IO&M costs.
- **Perform low-flow, open-water CEC testing**: Perform field testing of CEC optimized for different flow characteristics, such as low-flow environments.
- **Perform a community-scale needs validation**: Perform field testing of CEC system designs for ETI and microgrids, including energy-storage systems, at communities.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 33.

Figure 33. Sub-Activity 2.2 – Open Water Testing Research Priorities



Additional Details

Activities in this area will inform performance estimates to validate numerical models for sub-MW annual average power systems. This will in turn improve American Electric Power estimates and inform performance optimization opportunities. Additionally, testing in this sub-activity area informs refinement of operation and maintenance strategies for single device and array systems, which in turn will identify O&M cost reduction opportunities to decrease LCOE.

A process similar to that described above for wave energy technologies also applies to improve performance and reliability of CECs; validation of tidal and current energy capture devices in open water is required to more efficiently extract the maximum energy from tidal, ocean current, and river current resources. Continued R&D to overcome unique current energy challenges is anticipated by supporting current energy convertor system design, development, and field testing in multiple open water flow conditions, including locations in Alaska, New York, and Maine. Work in this sub-activity to design, fabricate, and test CECs will also be used to inform preliminary work to better understand the desired characteristics and requirements for a CEC test facility in the United States—for example, what are the best characteristics of the point of integration between the test facility and grid, what are the desired resource characterizations for test facility, and what are the critical risks to permitting the facility. Efforts focusing on addressing relevant array and plant-scale issues are expected to slowly and steadily increase over time, through collaboration with other DOE offices interested in extracting energy from current and tidal resources, testing of innovative CEC designs, and informing improvements in deployment and retrieval techniques.

Sub-Activity 2.3 – Powering the Blue Economy

Overview

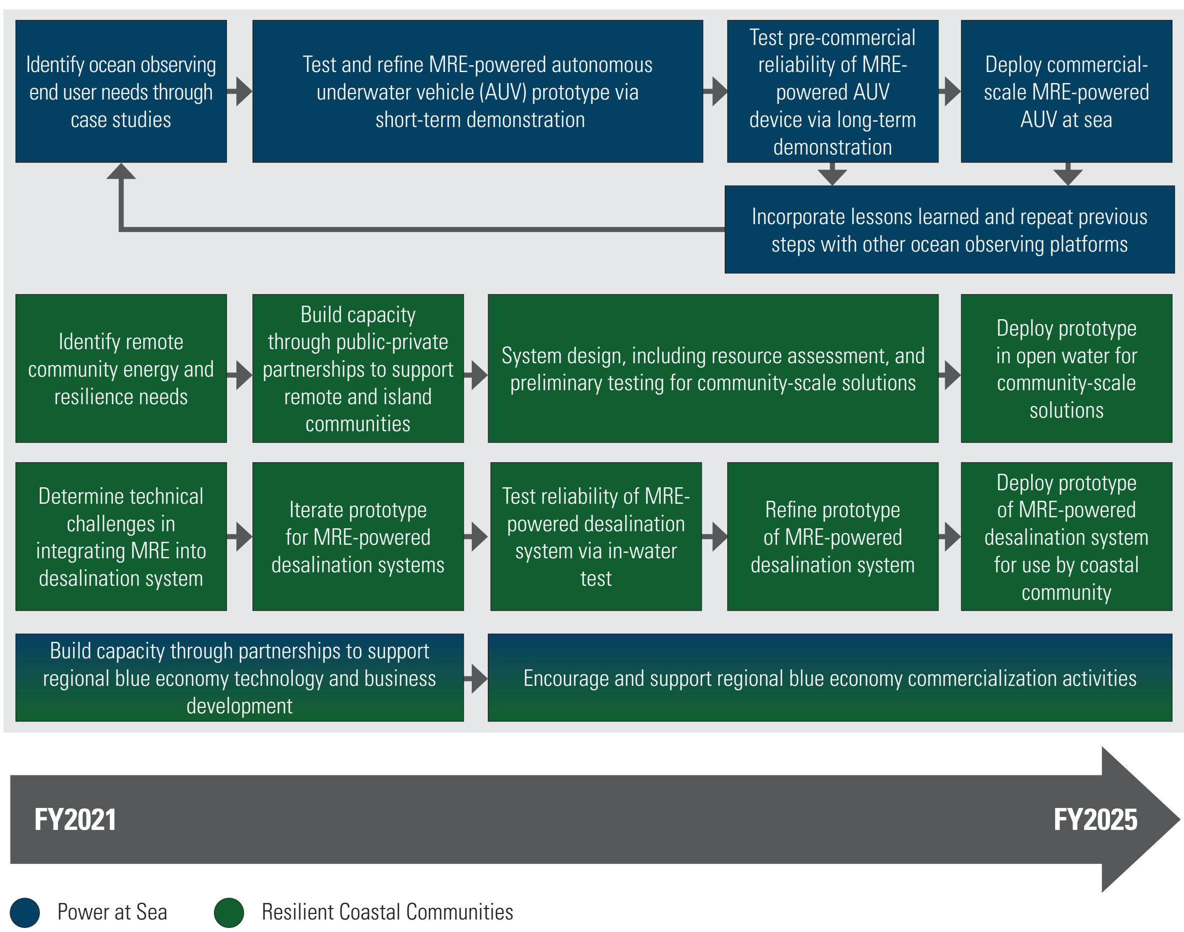
The PBE initiative seeks to develop new, marine energy-enabled technologies to address and relieve power constraints in markets and applications in the blue economy. This will be accomplished by focusing on the R&D of technologies that address the power requirements of multiple different coastal and maritime markets. There is enormous potential to support existing needs of mature markets like ocean observing, while also potentially creating new markets by relieving the energy constraints. Previous analysis[68] has shown that marine energy resources could be particularly well-poised to address power constraints in the blue economy because they are abundant, geographically diverse, energy dense, predicable, and complimentary to other energy sources. Since 2017, WPTO has been building a portfolio of R&D to better understand energy constraints and requirements in the blue economy, established partnerships to advance marine energy solutions in the blue economy, and launched activities to support the R&D of prototypes to realize the potential of an ocean energy-enabled blue economy.

While PBE is a specific sub-activity within marine energy, the success of PBE will also include work that draws from foundational R&D, technologies will be supported through testing and infrastructure, and ultimately lessons learned from PBE will be critical to translating findings for grid-scale marine energy applications. More information on PBE, including the goals, key principles, and partnerships critical to success of this initiative can be found in the detailed PBE section.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 34.

Figure 34. Sub-Activity 2.3 – Powering the Blue Economy Research Priorities



[68] U.S. Department of Energy, 2019, "Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets." https://www.energy.gov/eere/water/powering-blue-economy-exploring-opportunities-marine-renewable-energy-maritime-markets#pbereport.

Additional Details

While PBE is a specific sub-activity within marine energy, the success of PBE will also include work that draws from foundational R&D, technologies will be supported through testing and infrastructure, and ultimately lessons learned from PBE will be critical to translating findings for grid-scale marine energy applications. There are three focus areas within PBE, including:

- **Power at Sea**: From ocean exploration and navigation to aquaculture, many marine-based applications and markets are located far from shore and sometimes in deep water. Delivering power to these systems can be expensive and difficult but powering these systems with energy derived from the ocean offers a cost-effective alternative. Markets considered within this focus area include ocean observation, underwater vehicle charging, marine aquaculture, marine algae, and seawater mining.
- **RCC**: Marine energy can help support coastal communities, making them more resilient in the face of extreme events such as tsunamis, hurricanes, floods, or droughts. Many marine energy applications are ideally suited to coastal development by offering relatively easy access for installation and operation and maintenance activities, providing a predictable and uninterrupted energy supply, and potentially reducing land requirements needed by many land-based energy solutions. Markets considered within this focus area include seawater desalination, coastal resilience and disaster recovery, and isolated communities.
- **Crosscutting Activities**: In addition to market and application specific work conducted under the Power at Sea and RCC focus areas, there is key crosscutting research that is needed to enable marine energy-powered systems for the blue economy, including but not limited to storage integration, reliability measures, mooring designs, and the development of small-scale marine energy systems. Additionally, these crosscutting activities include creating partnerships necessary for the commercialization of all PBE applications and supporting the development of incubation and entrepreneurial support networks and programs.

Power at Sea

As a focus area within of PBE, Power at Sea activities target energy innovation to both augment existing offshore activities and enable future offshore missions or markets. To better understand the engineering and R&D challenges for these markets and applications, the development of case studies where clear end user needs identified are instrumental in identifying foundational R&D needs. This deep analysis of customer needs and the identification of R&D to address these needs is key for both marine energy integration into existing deep offshore platforms and applications like integration of marine energy into existing offshore observation platforms as well as future consideration for providing power at sea for new offshore activities like deep offshore aquaculture. The core focuses within Power at Sea include defining energy needs for various activities or missions at sea, supporting development of prototypes that are ready in the near-term and reduce design iteration timelines, and identifying potential commercialization pathways for novel solutions. Some of the major elements of work related to Power at Sea goals include:

- Undertake case studies that examine the functional requirements of existing applications, like ocean observing platforms currently deployed, and identify key challenges to the development of these systems for at-sea applications.
- Build on the results of the joint NOAA-DOE Ocean Observing Prize, which was launched in 2019, to advance the development of marine energy-powered ocean observation platforms, including the recharging of autonomous underwater vehicles. This includes refining and maturing solutions that are supported through the prize through mechanisms like interagency solicitations.
- Develop deployment-ready prototypes in partnership with the ocean observing community, including working with federal partners like NOAA to build systems that meet the needs of this community.
- Develop R&D and understanding needed to develop devices could serve multiple end-uses, where a marine energy system could be deployed to serve multiple markets, like ocean observing, aquaculture, and desalination all through electricity delivery.

Resilient Coastal Communities
As a focus area of PBE, RCCs supports energy innovation for remote coastal and island communities with a focus on end-user needs, emergent blue economy markets, and technology optimization. Identifying R&D challenges and building the foundations of collaborations and partnerships are fundamental to success of RCC objectives. Core focus areas are technology optimization in remote communities, system integration, and energy storage. Some of the major elements of work related to RCC goals include:

- Build connections, partnerships, and capacity for remote coastal and island communities to consider their energy planning and resilience goals with the ability to orient around evolving marine energy R&D questions and the deployment of marine energy devices.
- Test marine energy devices in a variety of remote communities to validate grid-forming and baseload generation capabilities, integrating and hybridizing energy services.
- Demonstrate and commercialize wave powered desalination for disaster recovery, military applications, international development, or other specific water market segments as cost-competitive with existing systems.
- Identify designs and research for integrated energy systems (microgrids, energy storage, and hybrid renewable systems) for coastal and island systems focused on local industries, transportation, conservation, and resilient systems.
- Develop key connections with blue economy finance and accelerators to support adoption of technologies ready for deployment.

Crosscutting Activities
In addition to the above targeted activities, the PBE initiative includes crosscutting activities aimed at developing platform R&D to support marine energy-powered systems and grow the capabilities to connect end-users and customers with new technological solutions across the blue economy. These activities include:

- Identifying crosscutting R&D needs through the undertaking of market-specific use case studies for marine energy.
- Designing strategies to enable the adoption of marine energy technologies for a large customer base and blue economy markets, including conducting analysis to demonstrate the value of these systems for the customers.
- Forging partnerships with other agencies to enable the uptake of marine energy enabled devices.
- Establishing partnerships to encourage entrepreneurial training and growing an ecosystem to support the incubation of blue economy industries.

Sub-Activity 2.4 – Standards Development

Overview
The standards development sub-activity focuses on the development and adoption of international standards through the IEC. These standards have proved critical in the development of related renewable technologies (e.g., wind), so pursuing them for early-stage technology like marine renewable energy is likely to advance the development here as well. Internationally accepted standards for marine renewable energy are currently being developed through IEC TC 114. These international standards can accelerate economic growth by reducing barriers to global trade and enabling companies to enter new markets more quickly and cost-effectively. Additionally, standards can help governments write regulations that have the input of the industry and ensure safety for consumers. Standards also facilitate international collaboration, provide high-quality, reproducible test results, improve the quality of the devices, stimulate innovation, lower development risk to investors, increase transparency to regulators and public, and, ultimately, reduce costs. WPTO will also continue to support U.S. participation in other international bodies, like OES, to foster international collaboration in the marine energy sector.

FY 2021–2025 Research Priorities

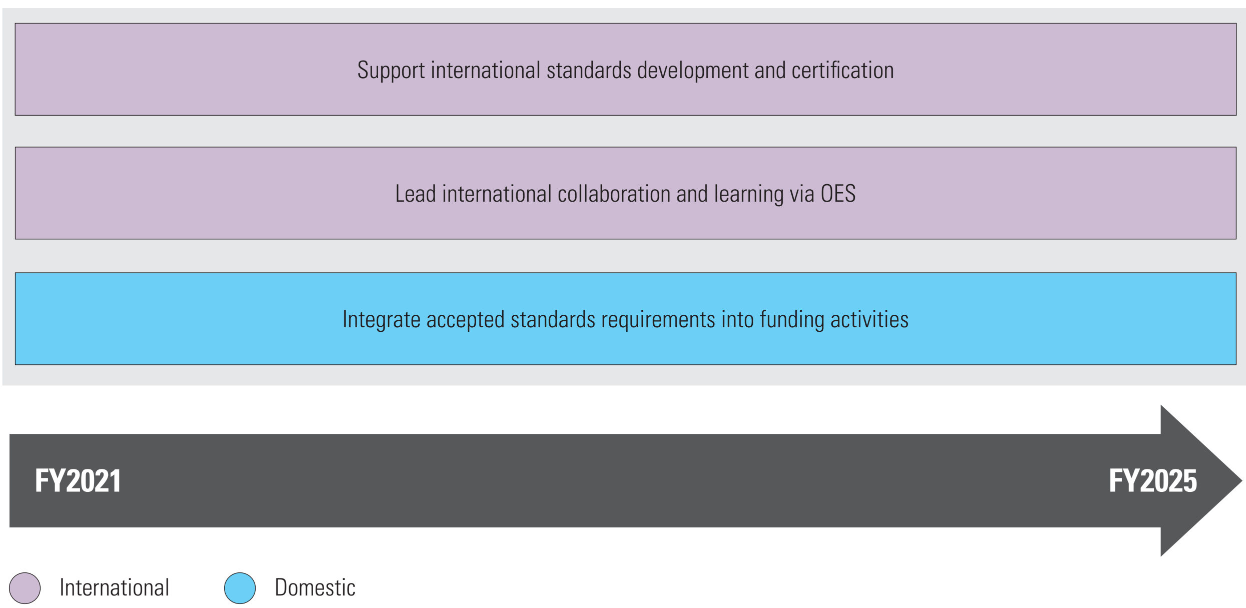
The following are the research priorities that will be emphasized within the Sub-Activity 2.4 – Standards Development:

- **Support international standards development and certification**: Continue to support U.S. involvement in TC-114 standards development and IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications certification activities.
- **Lead international collaboration and learning via OES**: Continue to lead U.S. involvement in the growing OES technology collaboration.
- **Integrate accepted internationals standards into funding activities**: Encourage and/or require funding recipients to utilize international standards during their DOE-funded projects.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 35.

Figure 35. Sub-Activity 2.4 – Standards Development Research Priorities



Additional Details

Accordingly, WPTO will continue to support U.S. experts to enable participation in the U.S. Technical Advisory Group and IEC TC 114, ensuring U.S. priorities are represented. Additionally, WPTO will encourage standards and conformity in assessment-relevant WPTO projects to feed into the international standards process through DOE expert participation, data sharing, and communicating lessons learned. As more standards are written and tested, WPTO will increase participation equivalently as well as track usage to supplement the data collected by the U.S. National Committee and the IEC. WPTO will advocate for standards to be incorporated into WPTO project planning when appropriate, ensuring that the draft technical specifications are put into practice and future iterations incorporate any lessons learned.

In the future, WPTO will consider the role of standards in developing and demonstrating non-grid, smaller scale marine renewable energy devices, and follow best practices established during the development of grid-scale standards to ensure lessons learned are incorporated as standards are used in the field. Additionally, WPTO will consider other relevant standards such as environmental standards in other maritime markets, like aquaculture when developing devices of a relevant scale.

Marine Energy Program Activity 3 – Reducing Barriers to Testing

Overview

Testing marine energy technologies is inherently more complex, expensive, and time consuming than for land-based energy generation technologies. The already slow pace of design and in-water testing cycles is further exacerbated by the limited availability of testing infrastructure at various scales, complex and time-consuming permitting processes, and expensive environmental monitoring (again, driven by being in-water). These challenges severely limit the ability of technology developers to quickly assess the performance of devices and components, innovate solutions where necessary, and iteratively test the next generations of devices. Because of the complex physics of the ocean wave and current environments, marine energy prototypes must be tested in real-world environments to fully characterize their performance and reliability. These challenges associated with testing, deploying, and optimizing technologies in a timely and cost-effective manner must be overcome to accelerate the pace of marine energy technology development. This activity area supports national assessments of testing infrastructure and needs, the development of testing facilities (including open-water, grid-connected and non-grid connected facilities) and NMRECs, instrumentation hardware and software dedicated to high resolution data acquisition, as well as environmental data collection.

This activity area connects to all other activity areas within the Marine Energy Program. Test infrastructure enables developers to iterate on their design and advance systems towards commercialization (Activity 2 – Technology-Specific System Design and Validation). Through testing, early-stage foundational research and models are also improved and validated (Sub-Activity 1.3 – Numerical Modeling). Furthermore, critical performance and cost data is collected during testing and is widely distributed to support industry to the greatest extent possible (Sub-Activity 4.1 – Data Access and Workforce Development).

Activity 3 – Reducing Barriers to Testing consists of the following sub-activities:

1. Testing Infrastructure Access and Development—Laboratory Facilities: Reducing barriers to laboratory testing and validation for technology innovation.
2. Testing Infrastructure Access and Development—Open Water Testing: Developing a pre-permitted, grid-integrated, open water test facility to provide marine energy developers a fast and streamlined process to install and test large-scale devices in a relevant ocean environment.
3. Environmental Research and Instrumentation Development: Gaining a greater understanding of the potential environmental risks associated with marine energy technologies through environmental monitoring technology and tool development, and targeted environmental research studies and data collection.

Performance Goals and Objectives

The key results, performance goals, and follow-on objectives are summarized in Table 22.

Table 22. Reducing Barriers to Testing Performance Goals and Objectives

Key Results and Performance Goals (2021–2025)
• Complete a minimum of 100 technical support actions under the Testing Expertise and Access for Marine Energy Research (TEAMER) initiative in collaboration with U.S. universities and national laboratories. • Develop a U.S testing network of at minimum 30 facilities, including a range of capabilities across traditional marine energy research facilities as well as new incumbent facilities with interdisciplinary expertise including non-grid applications. • Identify testing infrastructure gaps, including needs for non-grid applications, at universities and the national laboratories and, as appropriate, address those needs through infrastructure upgrades and development of new capabilities. • Commission, initiate testing, and gain accreditation for the PacWave grid-connected, open-ocean, wave test facility. • Demonstrate the improved technical performance of seven environmental monitoring technologies in relevant marine energy environments while opportunistically collecting data on acoustic outputs, electromagnetic field signatures, benthic habitats, and marine organism interactions with marine energy devices.
Follow-On Objectives (2026–2030)
• Significantly reduced timelines of design iterations for developers and researchers working in the marine energy industry, ultimately accelerating the iterative R&D process. • Validate cost and performance of devices through industry standards, providing confidence to regulatory, investor, and insurance communities. • Adoption of best practices for environmental monitoring technologies resulting in more consistent data collection across projects and greater confidence in the conclusions about the level of risk of specific environmental concerns.

Additional Details

At this time, open water testing capabilities are limited for all variations of marine energy technologies (wave, ocean current, tidal, river current). Gaps also exist in smaller scale tank testing for systems and components. In some cases, a new capability is required, and in other cases, upgrades to existing facilities or equipment are required to enable higher fidelity testing in support of industry needs. This activity area supports efforts to ensure a robust suite of testing capabilities at all levels of technology development are available to industry to help improve device performance and reduce costs and timelines associated with permitting. Providing industry with access to an economical, world-class infrastructure is an important part of WPTO's long-term marine energy strategy. There is a distinct inefficiency associated with developers independently investing in either their own or separate testing facilities, and through strategic investments, this activity area will enhance and enable broader industry usage of testing facilities while reducing costs to both developers and to WPTO.

Sub-Activity 3.1 – Testing Infrastructure Access and Development—Laboratory Facilities

Overview

This sub-activity focuses on the strategic investments made by WPTO to support reducing barriers to laboratory testing and validation to achieve technology innovations. marine energy device developers often face challenges raising the capital needed to conduct necessary laboratory and tank testing, as facilities with the necessary infrastructure are relatively rare, costly, and difficult to access. This challenge slows the pace of design iterations required to reduce LCOE, as appropriate testing infrastructure is critical to verifying and validating design assumptions and numerical models. By providing access to testing facilities and expertise on how to perform experiments in controlled environments and numerical modeling in operational and extreme conditions, as well as making investments to upgrade and improve existing facilities and capabilities, testing costs are reduced and more robust testing at smaller scales is enabled. This in turn supports work in the Foundational R&D activity area and Technology-Specific System Design and Validation activity area by:

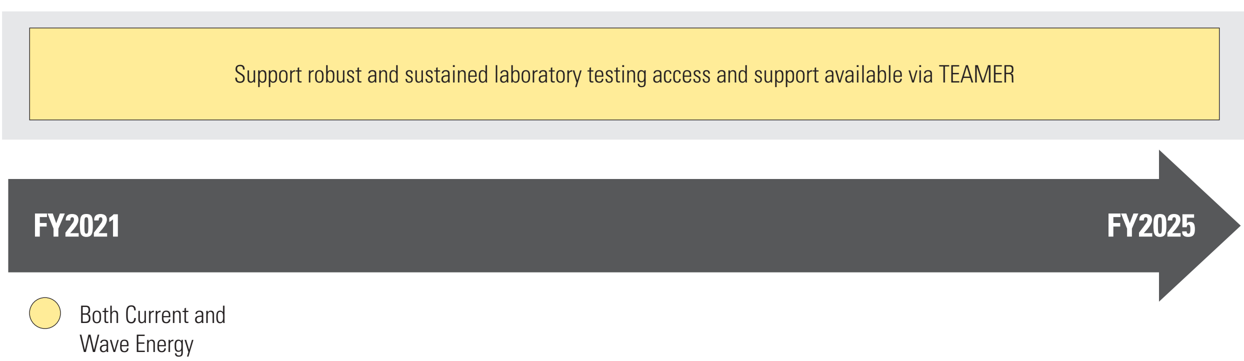
- Informing design decisions at an early stage.
- Validating numerical and analytical models through testing of physical models.
- Increasing credibility and comparability of performance test data.
- Enabling use of common performance metrics and testing standards.
- Providing world-class research and testing expertise to improve marine energy technologies.

FY 2021–2025 Research Priorities
The following are the research priorities that will be emphasized within the Sub-Activity 3.1 – Testing Infrastructure Access and Development—Laboratory Facilities:

- **Support robust and sustained laboratory testing access and support available via TEAMER**: Oversee the release of two to four requests for technical support per year for the initial period for the TEAMER program; expand the testing network; identify any additional infrastructure needs/gaps; and, as appropriate, address those needs.

Timing and Sequencing of Research Priorities
The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 36.

Figure 36. Sub-Activity 3.1 – Testing Infrastructure Access and Development—Laboratory Facilities Research Priorities



Additional Details

Insufficient laboratory validation and measurements of components and systems can lead to potential in-water deployment failures, propagation of design errors, and slow technology advancement. To prevent this and maintain water power mission readiness, investments in this sub-activity area include facilities and testing capabilities infrastructure, such as dynamometers, hardware-in-the-loop equipment, micro-grid infrastructure, and structural and materials bench testing capabilities. As marine energy technologies advance in maturity and new design concepts are developed, laboratory testing capabilities must also be maintained and advanced.

To be impactful, these well-maintained facilities, advanced capabilities, and expertise must also be accessible. To facilitate this access, this sub-activity includes work to support a multi-year test campaign in collaboration with U.S. universities and national laboratories for early-stage marine energy systems. This initiative leverages the robust network of lab, university, and government facilities and maintains capabilities to perform cutting edge research, while simultaneously emphasizing component and system early learning opportunities via advanced numerical modeling and analysis. Researchers leveraging and supported through this network will also identify gaps in testing needs through an ongoing, iterative assessment of the available network facilities.

Sub-Activity 3.2 – Testing Infrastructure Access and Development—Open Water Testing

Overview

As the marine energy industry continues to advance technologies towards commercialization, there is an ongoing need for testing at all levels of technological development, including large-scale devices in the open water. Marine energy converter prototypes must be tested in real-world environments to fully characterize and validate the performance, reliability, maintainability, and potential environmental impact. However, open water testing can be the most expensive and cumbersome of all, requiring complex and time-consuming permitting processes, and expensive environmental monitoring. DOE supports the development of a per-permitted, grid-integrated, open water test facility—PacWave, off the coast of central Oregon—to provide marine energy developers a fast and streamlined process to install and test large-scale devices in a relevant ocean environment.

FY 2021–2025 Research Priorities

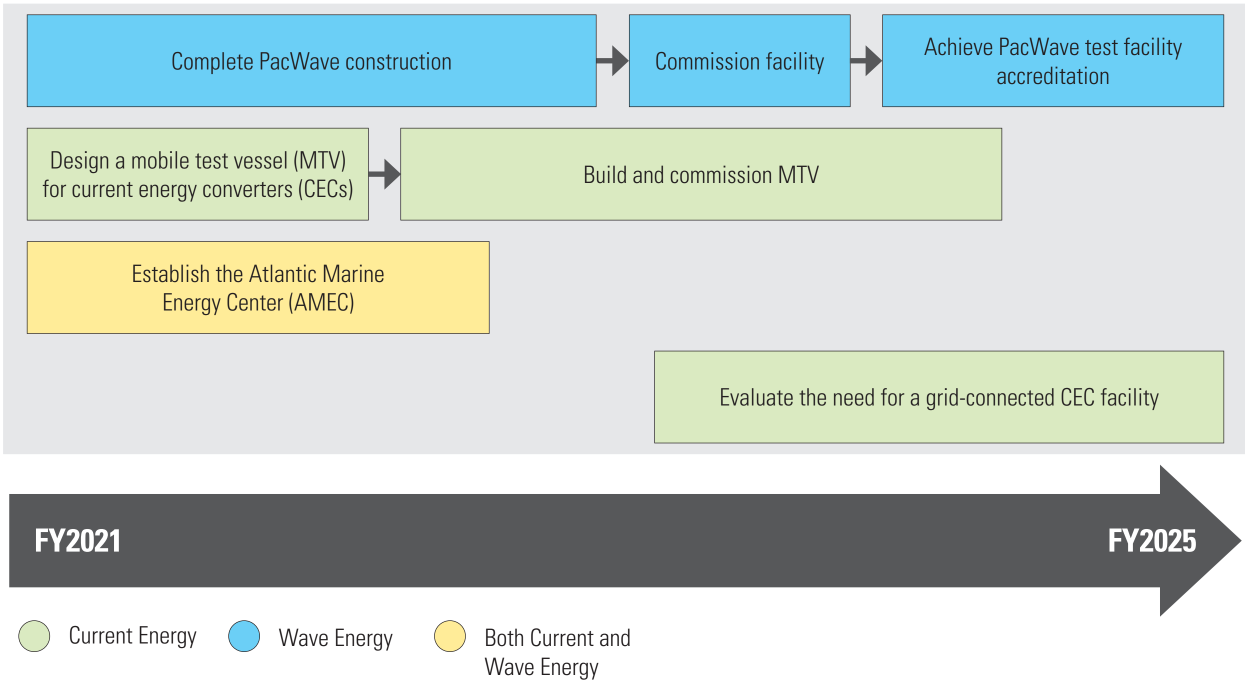
The following are the research priorities that will be emphasized within the Sub-Activity 3.1 – Testing Infrastructure Access and Development—Open Water Testing:

- **Complete PacWave construction**: Complete a first-of-its-kind, state-of-the-art, grid-connected test facility to evaluate utility-scale WEC performance, environmental interactions, and survivability. The facility will also be suitable for WECs that are not equipped to be connected to the grid.
- **Commission facility**: Successfully prepare systems and facilities to be 100% operational, including the development of accreditation strategies with the vision to accommodate the world's WEC needs.
- **Achieve PacWave test facility accreditation**: Qualify and train staff within the first year of device testing operations, which will be led by National Renewable Energy Laboratory, in partnership with the European Marine Energy Centre.
- **Design an MTV for CECs**: Design an MTV that will accommodate a variety of CEC systems to be tested and accredited by nationally and internationally recognized standards.
- **Build and Commission an MTV**: Fabricate an MTV which will be recognized as an accredited testing facility for leading and developing CEC technology.
- **Establish Atlantic Marine Energy Center**: Establish Atlantic Marine Energy Center (AMEC) that will be operated by a university or university-led consortium, with a focus on advancing the commercial availability and application of marine energy technologies by providing additional choice of and access to test facilities in the Atlantic region.
- **Evaluate the need for a grid-connected CEC facility**: Evaluate industry need, characteristics, and costs for a MW-scale, open-water, grid-connected CEC test facility (ocean current and/or tidal).

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 37.

Figure 37. Sub-Activity 3.2 – Open Water Testing Research Priorities



Additional Details

Providing the marine industry with access to economical, world-class infrastructure is an important part of WPTO's long-term marine energy strategy to reduce costs of testing. WPTO will collaborate with WETO where possible to address similar research needs. As a continued effort to reduce the barriers of testing to further develop the marine energy industry, WPTO selected the University of New Hampshire—partnered with various universities, national labs, and the European Marine Energy Center—to develop an AMEC on its campus. This facility will conduct marine energy testing, help address the need for ongoing research into marine energy, and support the PBE initiative.

There are currently three additional NMRECs, established through past WPTO funding: (1) the Pacific Marine Energy Center led by the University of Washington, Oregon State University, and University of Alaska, Fairbanks; (2) the Hawaii National Marine Renewable Energy Center led by the University of Hawaii; and (3) the Southeast National Marine Renewable Energy Center led by Florida Atlantic University.

During the past decade, increased interest in marine energy activities along the East Coast has resulted in the creation of an initial base of capabilities throughout the eastern U.S. By leveraging work done to date, establishing the new AMEC will support and further develop the marine energy industry in this region. AMEC will be established and operated by an institution of higher education or a university-led consortium with a focus on advancing marine energy technologies in the Atlantic region of the U.S. Applicants must have access to and utilize the marine resources in the eastern U.S.

Similar to the existing NMRECs, AMEC will (1) serve as a coordinating body on the East Coast and develop a robust strategy for supporting commercialization of marine energy; (2) conduct R&D relevant to marine energy; and (3) provide research capabilities and access to test facilities for developers.

Testing infrastructure investments have mainly focused on the ocean's wave energy, including the construction of the utility-scale PacWave wave energy test facility. Nevertheless, testing infrastructures that mainly focus on wave energy are of great importance reducing the barriers for testing due to the wide range of energy characteristics each specific location provides.

WPTO has identified a gap in the U.S. marine testing capabilities, specifically in testing CECs. Existing testing infrastructure in the U.S. can only accommodate small scale CECs with rotors 2-3 meters in diameter. There is a need for a mobile testing capability that can accommodate CECs with up to 8-meter diameter rotors for testing turbines under different flow conditions in a wide range of test conditions. Since CEC technologies are utilized in river, tidal and ocean environments, the mobile testing capability shall be adaptable for utilization at river, tidal and ocean test sites in a wide variety of current speeds, depths, wave conditions, and bottom types.

To address this gap, as part of the DE-FOA-0002234, WPTO will be funding an open water, non-grid connected mobile testing capability for CECs. Specifically, to design, fabricate, test, maintain and operate a mobile CEC test vessel in accordance with IEC TC 114 with a focus on IEC TS 62600-200 and IEC TS 62600-300 which define the power performance assessment requirements for CECs. This MTV will help accelerate CEC technology development by providing timely opportunities to test in multiple open water flow conditions, with anchoring capabilities for both ocean and river water depths and operate in current speeds up to 4 m/s and be capable of operations in locations with limited infrastructure support, such as remote Alaskan communities, or areas where installation of larger civil works is difficult, prohibitively costly, or environmentally unacceptable.

Sub-Activity 3.3 – Environmental Research and Instrumentation Development

Overview

As relatively new and novel technologies, marine energy devices have raised a number of questions in the regulatory and research communities about potential environmental effects and any unintended consequences of deployment. Understanding the impacts of single devices is important not just for future commercial deployment but also helps obtain the necessary permissions to demonstrate and test initial prototypes in public waters. Significant investigation of these potential issues over the past decade has improved our understanding of the issues and indicated that the ultimate likelihood of risks from a single marine energy device or small array is low.[69] While many uncertainties have been addressed via this research, some uncertainties remain. Focusing on uncertainties has historically led to perceptions of high risk and applications of the precautionary principle by marine energy technology regulators, resulting in higher costs and timelines associated with permitting. The Environmental Research and Instrumentation Development sub-activity focuses on gaining a greater understanding of the potential environmental risks associated with marine energy technologies through two work streams: 1) environmental monitoring technology and tool development, and 2) targeted environmental research studies and data collection.

FY 2021–2025 Research Priorities

The following are the research priorities that will be emphasized within the Sub-Activity 3.3 – Environmental Research and Instrumentation Development:

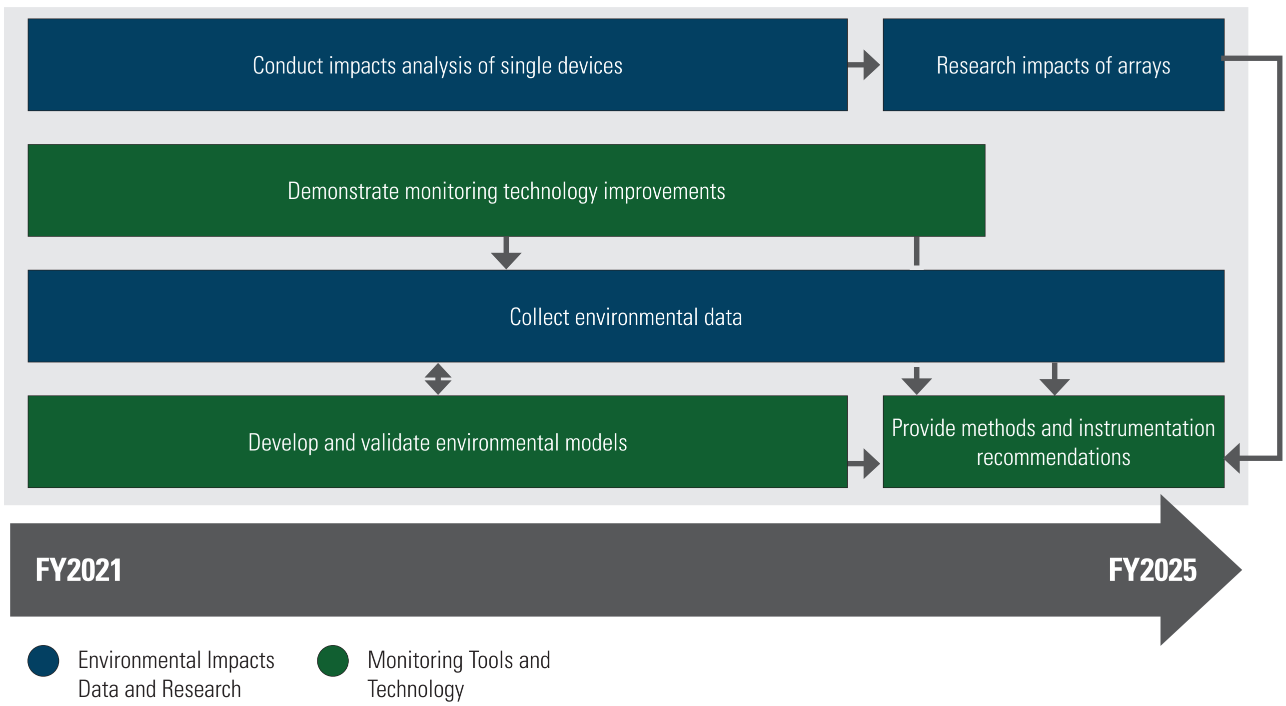
- **Conduct impacts analysis of single devices**: Conduct targeted research for the environmental impact of single devices or small arrays.
- **Research impacts of arrays**: Begin targeted research on possible environmental impacts of larger arrays and population-level impacts.
- **Collect environmental data**: Collect relevant environmental data prior to installation where feasible and as marine energy, or other relevant industries’ (e.g., offshore wind), deployments occur.
- **Complete environmental model development and validation**: As new data is collected, ensure transferability and usability for validation of existing models.

[69] Copping, A.E. and Hemery, L.G., 2020. ”OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES).“ https://tethys.pnnl.gov/publications/state-of-the-science-2020.

- **Demonstrate monitoring technology improvements**: Demonstrate improvements in environmental monitoring technologies and develop new tools to fill remaining gaps.
- **Provide methods and instrumentation recommendations**: Support the development of recommendations for methods and monitoring instrumentation to be used in environmental assessments.

Timing and Sequencing of Research Priorities
The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 38.

Figure 38. Sub-Activity 3.3 – Environmental Research and Instrumentation Development Research Priorities



Additional Details

The Marine Energy Program also supports the development of numerical modeling tools to help assess potential effects when empirical data is insufficient to address regulatory concerns. Modeling work also benefits from and overlaps with efforts under [Sub-Activity 1.3 – Numerical Modeling](), as some of the same underlying codes can be utilized for multiple objectives like assessing both array energy extraction efficiency and changes to benthic habitat or beach formation processes for instance. Specifically, modeling efforts address marine energy produced sound, changes in circulation patterns, wave heights and nearby habitats as well as the refinement of encounter and collision risk models for interactions of marine mammals, fish, and seabirds with marine energy devices.

Additionally, there are ongoing efforts to develop and evaluate the environmental monitoring technology necessary to collect and process the data needed to understand potential environmental risks. Existing oceanographic equipment does not always have the ability to meet specific regulatory requirements or may not perform well in harsh marine energy environments. To reduce the cost of and enable environmental monitoring of deployed devices, the Marine Energy Program supports technical improvements to monitoring technologies and data processing tools. Additionally, continuing efforts will identify the most appropriate tools and methodologies for data collection and analysis in marine energy environments. Best practices will be formulated to promote more standardized data collection across projects and enable greater confidence in the data transferability among sites and devices. This will allow future projects to benefit from the invaluable environmental data that has been collected by previous projects.

The program also supports targeted research efforts in laboratory and field settings to gain a greater understanding of specific environmental risks. While current research focuses primarily on effects from a single device or small arrays on individual organisms (fish or marine mammals), future efforts will begin to address potential effects of larger arrays and population level impacts. To complement the research efforts, there will be a concerted effort to support the collection of relevant environmental data around deployed marine energy devices to provide the information necessary to retire or mitigate concerns.

Efforts will also focus on identifying collaboration opportunities with DOE's WETO as well as other federal or state agencies to address similar research needs marine energy and offshore wind share many of the same potential environmental concerns and may greatly benefit from coordinated efforts to develop and test environmental monitoring and mitigation technologies.

Marine Energy Program Activity 4 – Data Access, Analytics, and Workforce Development

Overview

As a public research agency and the primary funder of U.S. marine energy R&D, DOE is uniquely capable of aggregating and disseminating objective and accurate information about marine energy. The Marine Energy Program ensures that data and analysis produced are easily accessible and useful to multiple audiences, such as technology developers, researchers, regulators, or students. Improved access to and use of data, tools, and STEM resources or programs can lead to: (1) improved awareness of marine energy technology advances and lessons learned; (2) reduced cost, time, and uncertainty around the marine energy permitting processes; and (3) increased opportunities for students to develop skills needed to enter the marine energy workforce. In the long-term, these outcomes can support innovation, increase the development and testing of devices at scale, provide a greater understanding of opportunities for marine energy across the blue economy, enhance energy resilience of coastal and river communities, improve marine resource management, and prepare a skilled workforce to advance marine energy into the future.

Activity 4 – Data Access, Analytics, and Workforce Development consists of the following sub-activities:

1. Data Access and Workforce Development: Aggregating and providing access to marine energy data and informational resources created through WPTO's funded projects, improving the connectivity of WPTO's databases to other U.S. and international data portals, and increasing opportunities for students to develop skills needed to enter the marine energy workforce.
2. Data Analytics: Leveraging data to produce lessons learned and useful analysis across a range of topics.

Performance Goals and Objectives

The key results, performance goals, and follow-on objectives are summarized in Table 23.

Table 23. Data Access, Analytics, and Workforce Development Performance Goals and Objectives

Key Results and Performance Goals (2021–2025)
• Publish an assessment of marine energy industry and researcher data needs. • Collect, analyze, and publish data from the existing in-water testing projects to generate new foundational understanding of marine energy devices and identify promising areas for additional research. • Complete integration of publicly available, WPTO-funded marine energy databases with interconnected search functionality. • Launch a new marine energy permitting toolkit to improve regulators' access to and understanding of information about marine energy resources, devices, and potential environmental effects. • Release a new marine energy STEM portal consisting of educator and student resources and curricula. • Improve targeted outreach with the intention of diversifying the pool of students participating in WPTO workforce development programs such as the graduate student research fellowship and Marine Energy Collegiate Competition.
Follow-On Objectives (2026–2030)
• Increased usage of WPTO-developed data, along with supported marine energy databases and toolkits (including the Marine Energy Environmental Toolkit, Marine Energy Permitting Handbook, and State of the Science Report) by a diverse set of stakeholders (along with positive value and ease-of-use metrics collected from users). • Dramatic improvement in regulators' access to useful marine energy data, helping to reduce uncertainty, improve their ability to assess risk, and achieve efficiency gains when permitting projects. • Measurable and significant increases in use of marine energy STEM portal by educators and individuals. • Measured improvement in the diversity of students and student teams participating in WPTO's fellowship programs and Marine Energy Collegiate Competition, including minority students as well as students from minority-serving institutions, such as historically Black colleges and universities, Hispanic-serving institutions, and tribal colleges.

Additional Details

Given the nascent stage of the marine energy industry and with relatively few open water test or deployments to date, there is a lack of validated, publicly available, and usable data and analyses regarding many different aspects of marine energy technologies. Existing data are found in disparate locations, which creates access and discoverability challenges for marine energy researchers and developers, regulators, investors, potential supply chain vendors, and the general public. In addition, there are few resources and programs to help students and those interested in pursuing possible clean energy careers gain familiarity with these technologies. This workforce challenge is exacerbated by infrequent testing and demonstration of new technologies, meaning interested individuals, and the marine energy community overall, rarely have opportunities to gain real-world experience. Improved access to and usability of data and analyses produced by WPTO-funded projects, as well as the development of new educational resources and programs, are needed to reduce uncertainty around marine energy technologies, maximize the impact of federal R&D, and support long-term marine energy industry growth.

Sub-Activity 4.1 – Data Access and Workforce Development

Overview

The Data Access and Workforce development sub-activity primarily focuses on aggregating and providing access to marine energy data and informational resources created through WPTO's funded projects, improving the connectivity of WPTO's databases to other U.S. and international data portals, and providing the next-generation of marine energy innovators access to the industry and workforce development opportunities. Data Access efforts focus on identifying, aggregating, and providing public access to data produced by projects across the Marine Energy Program, including both technology-specific projects and technology-agnostic projects (the latter largely representing data and tools developed under the Foundational R&D activity area) as well as educational resources for students and educators. A large amount of new information is generated as the result of DOE-funded research, and these data must be quickly and transparently made available. This requires collaborating across the portfolio, developing, and ensuring use of best practices for formatting and curating content, implementing metadata structures and standards, creating, and maintaining database and data portal interconnectivity, enhancing usability, and other data management issues. Additionally, with the United States becoming an emerging leader in marine energy, international collaboration is important to ensure that our data is available internationally, and to connect U.S. marine energy stakeholders with international partners to learn from what has been done in other countries. Additionally, the future of marine energy is dependent on the availability of a skilled workforce, which WPTO supports by offering workforce development programs such as a collegiate competition and fellowship opportunities, which are advertised and disseminated through WPTO's main data portal. To achieve success in this sub-activity, WPTO continuously seeks stakeholder feedback and continues to adapt data access projects to meet the needs of the greatest number of users.

FY 2021–2025 Research Priorities

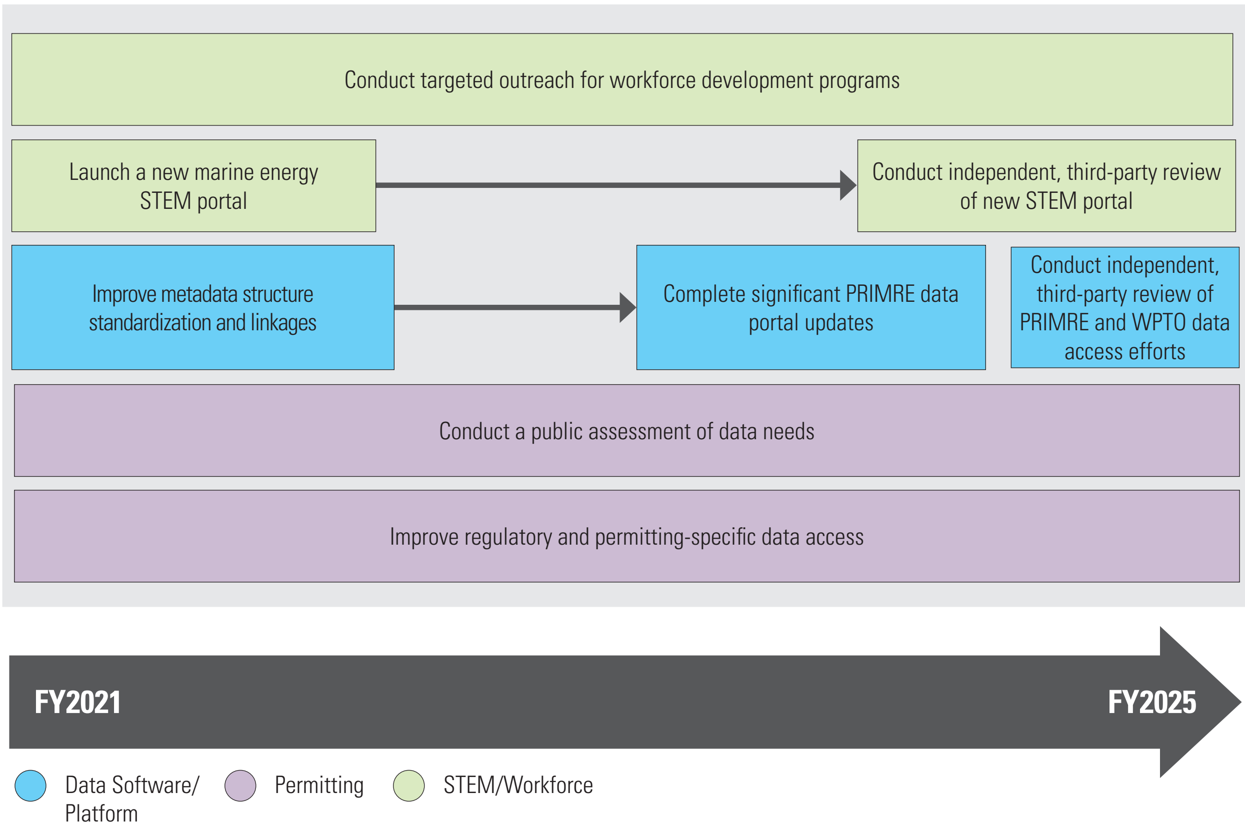
The following are the research priorities that will be emphasized within the Sub-Activity 4.1 – Data Access and Workforce Development:

- **Conduct targeted outreach for workforce development programs**: Target outreach to universities, student associations, and professional societies across the nation to improve awareness of workforce development opportunities such as the graduate student research fellowship and Marine Energy Collegiate Competition.
- **Launch a new marine energy STEM portal**: Launch new portal within the Portal and Repository for Information on Marine Renewable Energy (PRIMRE) consisting of educator and student resources and curricula. Add new curricula resources to the portal as they are developed.
- **Conduct independent, third-party review of new STEM portal**: Gather feedback from students, educators, and marine energy employers on portal's ease of use, as well as the quality of the content, and incorporate recommendations in portal.
- **Improve metadata structure standardization and linkages**: Improve connectivity between existing WPTO-funded marine energy databases by implementing consistent metadata, enabling a search function across multiple databases, and providing linkages to non-WPTO resources domestically and internationally.
- **Complete significant PRIMRE data portal updates**: Update PRIMRE data to support highest-priority industry and stakeholder use-cases identified through a data needs reassessment.
- **Conduct independent, third-party review of PRIMRE and WPTO data access efforts**: Assess the usability and usefulness of data portals, as well as gaps in our data access portfolio. Seek feedback and incorporate into longer-term direction.
- **Conduct a public assessment of data needs**: Conduct and publish results of a reassessment of marine energy industry and researcher data needs, not limited to but including access to data produced via DOE-funded projects.
- **Improve regulatory and permitting-specific data access**: Launch a new permitting and regulatory toolkit to improve marine energy data access for regulators and other stakeholders involved in the permitting of marine energy.

Timing and Sequencing of Research Priorities

The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 39.

Figure 39. Sub-Activity 4.1 – Data Access and Workforce Development Research Priorities



Additional Details

Currently, WPTO supports several data portals and works to improve their accessibility and interconnectivity through PRIMRE.[70] PRIMRE provides a central access point to existing marine energy databases and other informational resources. PRIMRE also provides standardization, community building, and integration of federally funded marine energy data in order to reduce barriers to access information and data on technology, research, design, and testing. There are a number of databases and tools funded under data access, which are already integrated into PRIMRE or are working towards integration, including:

1. **The Marine Hydrokinetic Data Repository (MHKDR)** which contains data collected during WPTO-funded projects, including data on marine energy devices, testing, resource and environmental impact assessments, cost analyses, and more.
2. **Tethys** which facilitates the exchange of information and data on the environmental effects of wind and marine renewable energy technologies.
3. **Tethys Engineering** which stores documents from around the world about the technical and engineering aspects of marine renewable energy.
4. **The MRE Technology Database** which provides information on existing marine energy technologies, companies active in the field, and development of projects in the water.

[70] For more information, visit https://openei.org/wiki/PRIMRE.

5. The **MHK Instrumentation & Sensor Database** which shares information on instrumentation and lessons learned from laboratory testing and field deployments.
6. A collection of open-source **marine energy relevant software**, including a code hub and code catalog.
7. The **Marine Hydrokinetic (MHK) Environmental Toolkit for Licensing and Permitting** which seeks to increase regulators' understanding of marine energy projects and their potential environmental effects.
8. The **STEM for Marine Energy portal**, an information-sharing portal designed to support workforce development by connecting educators and students with educational and training resources.
9. **Marine Energy Atlas**, an interactive mapping tool which displays the potential for marine and hydrokinetic resources.

Given the existing number of WPTO projects focused on marine energy data access, the Marine Energy Program considers it imperative to conduct a thorough assessment of stakeholder data needs with respect to current investments. As part of this assessment, the Marine Energy Program will consider: (1) more efficient and effective means to collect, organize, and analyze high-quality data and the storage needs/implications for such data; (2) whether the current form of PRIMRE has helped address marine energy data challenges; and (3) metrics to quantify the impact of this work that are more meaningful than the number of downloads of datasets or visits to a site. The Marine Energy Program acknowledges that this could be a multiyear effort and that our existing approach to data access—through a number of different inter-connected databases—may or may not prove to be the most desirable long-term approach.

Sub-Activity 4.2 – Data Analytics

Overview

Marine energy technologies are evolving rapidly, both in the United States and around the world. In addition to the need to aggregate otherwise disparate marine energy data, there is also a significant need to leverage these data to produce lessons learned and useful analysis across a range of topics. These lessons learned and analyses will help improve performance, cost, and reliability of new marine energy systems, location and characteristics of available resources, new market applications and business development pathways, and research and monitoring of any potential environmental impacts of technologies. There are many technical and operational challenges in developing new marine energy systems and increasing opportunities to analyze and glean insights from completed research can aid in increasing the speed of future design cycles. Improved abilities to access, compare, and analyze many types of information will focus new research efforts on priority needs; allow technology developers to keep pace with changes across the industry; convey the state of various technologies to financers, insurers, and policymakers; and provide relevant information to regulators for timely and well-informed decision-making. As a technology-neutral, national research entity with significant core capabilities in data management and analysis, DOE is also in a unique position to help serve as an objective and unbiased aggregator for relevant non-DOE-generated data. DOE also interacts with similarly interested international parties through engagements with the IEA's OES Implementing Agreement. Some business-sensitive cost and performance information for new technologies is also collected for internal analytical purposes to inform WPTO's long-term research strategies and compare the performance of ongoing awards to industry trends.

FY 2021–25 Research Priorities

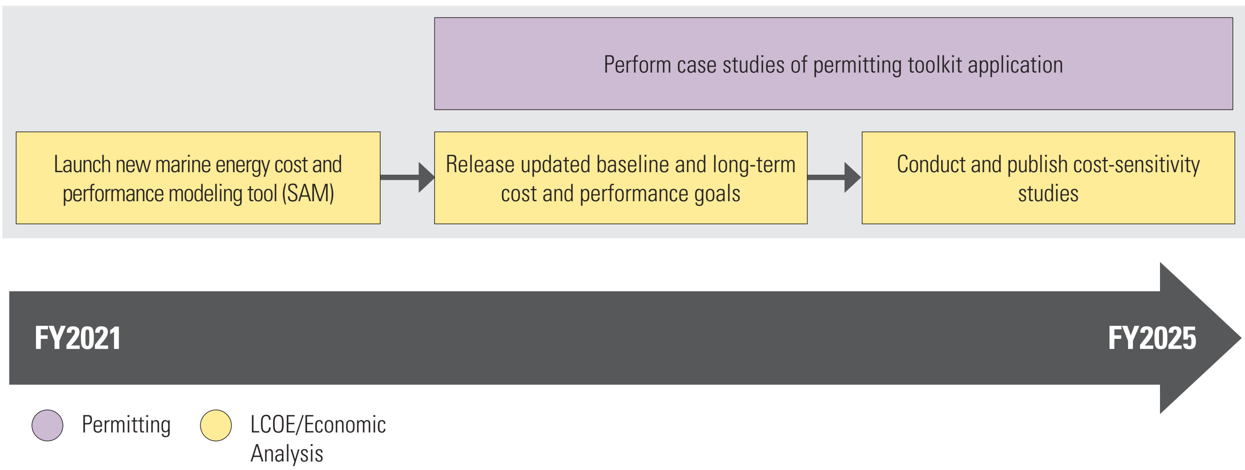
The following are the research priorities that will be emphasized within the Sub-Activity 4.2 – Data Analytics:

- **Perform case studies of permitting toolkit application** to inform further improvements or new analytical capabilities.
- **Launch new marine energy cost and performance analysis tool (SAM)** to underpin WPTO, awardee and researcher-led studies.

- **Release updated baseline and long-term cost and performance goals** in line with DOE and GPRA requirements.
- **Conduct and publish grid-scale marine energy cost-sensitivity studies** specifically investigating cost relationships for manufacturing, transportation, deployment, operations, and maintenance for large-scale potential future deployments.

Timing and Sequencing of Research Priorities
The timing and sequencing of FY 2021–2025 research priorities are summarized in Figure 40.

Figure 40. Sub-Activity 4.2 – Data Analytics Research Priorities



Additional Details

In contrast to other renewable energy industries, such as wind and solar, the marine energy industry has not yet converged on a specific device archetype or archetypes. Given the limited public and private resource available to develop marine energy technologies, it is critical to identify and direct R&D efforts towards design innovations that have the greatest techno-economic potential. The Marine Energy Program will continue to update its long-term cost and performance related goals and underlying analysis informing year-to-year research strategies. The Marine Energy Program will also continue work to collaboratively develop and apply quantitative metrics to identify and advance technologies with high ultimate techno-economic potential for their market applications. The Marine Energy Program is working with industry stakeholders and international collaborators to develop transparent and publicly disseminated performance metrics that can be used to identify promising technology improvements most effectively.

Powering the Blue Economy

Introduction

The PBE Initiative formally launched out of WPTO in 2019. Built out of an analytically driven process that focuses on the need to understand the potential for using marine energy within the blue economy, the program is strategically growing a portfolio of investments to accelerate development and deployment of marine energy technologies. Investments in the portfolio include supporting foundational research, access, and upgrades to testing assets, entrepreneurial ecosystem development, and fostering the partnerships with government and private sector stakeholders needed for successful development and adoption of marine energy systems that power the blue economy.

Importance of the Blue Economy and Energy Needs

The oceans are critical to the global ecosystem and are important to both human health and productivity. The oceans present myriad opportunities, including new sustainable sources of protein, production of freshwater, new medicines, enhanced security, data, and systems to protect against and detect catastrophic weather events, carbon mitigation strategies, and energy. To fully realize these opportunities, there is a need for new technologies, partnerships, and enhanced government coordination.

The expanding demand for ocean-derived food, materials, energy—and a more thorough knowledge about the ocean—is driving rapid growth in the emerging blue economy. This expansive view of how oceans can serve fundamental human needs and drive economic growth include everything from harnessing the power of oceans to generate energy, to sustainable aquaculture, to enabling observations that expand the understanding of the ocean by mapping and observing the more than 90% of the ocean that remains unobserved.

From a purely economic perspective, the blue economy is a rapidly growing sector of the world economy. The Organization for Economic Cooperation and Development predicts the global economic value attributable to ocean-related activities will double from $1.5 trillion in 2015 to $3 trillion by 2030, growing at twice the rate of the rest of the global economy.[71] And from a domestic policy perspective, developing and advancing the blue economy is a federal government priority.[72] There is a growing recognition of the importance of technologies to support the blue economy. Some sectors and opportunities, such as aquaculture, ocean observing, and mineral extraction, are expanding further offshore, but moving further from shore requires systems that allow for access to consistent, reliable power that are untethered to land-based power grids. And these opportunities are not limited to the offshore environment. Coastal communities are also looking to the ocean to develop resilient energy, food, and water systems.

However, growth in many blue economy sectors is constrained by the lack of available energy and energy sources that require frequent refueling or battery changes, limiting the growth potential. There are many opportunities to innovate and improve on existing energy solutions that are often unfit for purpose, limited in capacity, damaging to the environment, and expensive. There is significant potential to develop technologies to serve both deep offshore and nearshore energy solutions. And while these technology breakthroughs in the blue economy are possible, they will require new thinking about energy development, multidisciplinary approaches, co-development of energy solutions embedded within or tied to blue economy platforms, and innovation across multiple technology domains.

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71 Organisation for Economic Co-operation and Development, 2016. "The Ocean Economy in 2030." https://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm.

72 Federal Register, 2020. "National Ocean Month, 2020." https://www.federalregister.gov/documents/2020/06/05/2020-12428/national-ocean-month-2020.

Marine Energy and the Potential to Power the Blue Economy

Energy is foundational to nearly all blue economy sectors. Removing and addressing energy constraints in the blue economy could accelerate economic growth by strengthening existing—and creating or enabling new markets and applications for sustainable economic development. Because there are myriad federal partners and organizations committed to the sustainable growth of the blue economy, DOE serves an especially critical role as a research organization and nexus point among other federal agencies. DOE is a primary funder of energy technologies and solutions that could serve the blue economy and already works with a diverse set of federal and other stakeholders with equities in the blue economy. DOE is poised to convene diverse stakeholders to achieve common goals to address energy barriers, constraints, and opportunities in the blue economy. Offices within DOE that will play an increasing role in enabling the blue economy include the EERE, Office of Science, the Advanced Research Projects Agency—Energy, the Office of Fossil Energy, and the Office of Electricity, among others.

EERE has a critical role in the development and advancement of solutions to address energy needs in the oceans. There are two main areas that EERE has within its mission space to support the blue economy: (1) grid-scale electricity solutions to power energy needs for coastal, grid-tied communities; and (2) power for the expanding blue economy, like solutions that can increase the resilience of remote and coastal communities and provide energy for offshore applications. R&D supported by EERE for grid-scale electricity includes wave energy, tidal energy, thermal ocean gradients, offshore wind, and floating solar. In addition to powering the electricity grid, R&D of these technologies could also address remote and island communities' access to energy and water; development of energy-enabled systems to understand, observe, protect and clean oceans; harnessing the potential energy from the ocean to power markets of the future like aquaculture and seawater mineral mining; directly desalinating water through the power of the ocean; and the advancement of technologies to advance the maritime sector, including maritime transport.

Marine energy resources, such as wave, tidal and ocean currents, could be particularly well poised to address these power constraints in the blue economy, as they are abundant, geographically co-located, geographically diverse, energy dense, predictable, and complementary to other energy sources. Over the last decade, WPTO has made progress in both R&D focused on marine energy technology development as well as in understanding how these resources could and should serve grid-scale electricity needs. But to better understand the opportunities specific to marine energy's role in the blue economy, WPTO, with the National Renewable Energy Laboratory and the Pacific Northwest National Laboratory investigated the potential opportunities for marine energy in blue economy sectors. From 2017 through early 2019, WPTO, National Renewable Energy Laboratory, and Pacific Northwest National Laboratory conducted extensive analysis and stakeholder engagement as part of this effort.

Powering the Blue Economy Initiative: Overview

This foundational discovery analysis to understand marine energy's role in the blue economy resulted in the release of a report in April 2019, entitled Powering the *Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets*.[73] The report was a landscape analysis of the different ways marine energy could be used in the blue economy aside from powering the regional electrical grid. It demonstrated that WPTO's marine energy program has an important role to play in enabling innovation and growth in the blue economy by engaging directly with the relevant communities and public and private sector organizations.

The report identifies potential opportunities and challenges for marine energy in eight different ocean applications and markets, including those far out at sea—like ocean observation and seawater and mineral mining—and those nearshore, like desalination and coastal resilience. The eight identified markets are outlined in Figure 41.

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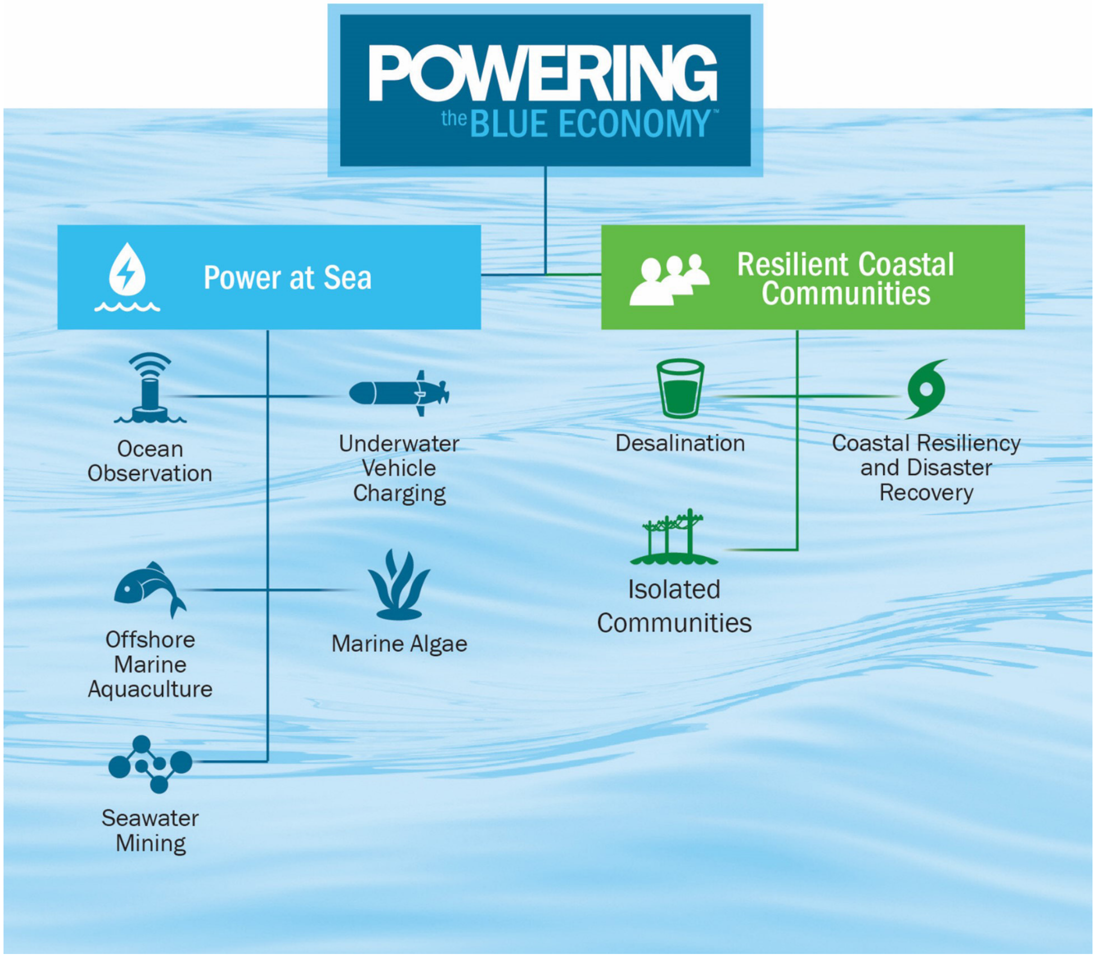
[73] U.S. Department of Energy, 2019, "Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets." https://www.energy.gov/eere/water/powering-blue-economy-exploring-opportunities-marine-renewable-energy-maritime-markets#pbereport.

Figure 41. Blue Economy Market Applications



Additional markets, like powering offshore data centers or small consumer goods are also included in an additional Other Applications chapter. Building on this report, WPTO is exploring partnerships between the marine renewable energy industry, coastal stakeholders, and blue economy sectors to address two thematic challenges: Power at Sea and RCCs.

- **Power at Sea**: From ocean exploration and navigation to aquaculture, many marine-based applications and markets are located far from shore—sometimes in deep water. Delivering power to these systems can be expensive and difficult. Powering systems that use energy derived from the ocean offers a cost-effective alternative. Markets considered within the report include ocean observation, underwater vehicle charging, marine aquaculture, marine algae, and seawater mining.
- **RCCs**: Marine energy can help support coastal communities, making them more resilient to address their long-term energy and water needs, and in the face of extreme events such as tsunamis, hurricanes, floods, or droughts. Many marine energy applications are ideally suited to coastal development by offering relatively easy access for installation and operation and maintenance activities, providing a predictable and uninterrupted energy supply, and potentially reducing land requirements needed by many land-based energy solutions. Markets considered within this theme include seawater desalination, coastal resilience and disaster recovery, and isolated communities.

Since the release of the report, WPTO has established the PBE Initiative. This initiative seeks to understand the power requirements within the thematic challenges, and to advance technologies that integrate marine renewable energy to relieve power constraints and promote economic growth. As part of this initiative, understanding and realizing marine energy's value requires an end-user centric, cross-sector, and systems-focused approach. Through the PBE initiative, WPTO has been building a portfolio of R&D to better understand energy constraints and requirements in the blue economy, established partnerships to advance marine energy solutions in the blue economy, and launched activities to support the R&D of prototypes to realize the potential of an ocean energy-enabled blue economy.

PBE Initiative Goals and Principles

The PBE initiative expands WPTO's strategic vision to more fully encompass an ocean-centric view of marine energy innovation in close partnership with other offices within DOE, other federal agencies, and the diverse set of industries and sectors that make up the blue economy. This creates opportunities to understand and obtain new value from marine energy to address the energy needs of the blue economy, and where those needs intersect with the unique attributes and advantages of wave, tidal, ocean current, ocean thermal, and river current energy.

WPTO has set out three interwoven goals for PBE to quantify the value of marine energy in the blue economy, support individuals and companies in the development of prototypes and solutions to provide power in these markets, and partner with the end-users who need these solutions and ultimately can make them successful. The PBE initiative goals are:

- Goal 1: Understand end-user needs and **quantify the value of marine energy** in emerging ocean markets uniquely suited to marine renewable energy technology attributes.
- Goal 2: **Accelerate marine energy technology readiness** through near-term opportunities, supporting WPTO marine renewable energy strategy and mission.
- Goal 3: Enable broader blue economy goals by **developing solutions to meet energy challenges facing private and public sector blue economy partners**, including unlocking the potential of new ocean-enabled technologies, enhancing scientific capabilities in the ocean, and the development of more resilient coastal and island communities.

To accomplish the goals of PBE, WPTO has identified five key principles that drive decision making and the establishment of a portfolio of research, analysis, development, and partnership.

1. ***Analytically driven opportunity identification***: Analytical efforts will focus on understanding which applications and markets are best suited to marine energy and quantifying the full value of marine energy within the blue economy.
2. ***Start with near-term opportunities; learn by doing***: Starting with such near-term opportunities provides the best pathway towards meeting PBE goals through early wins and rapid learning within the marine energy industry. Additionally, by pursuing multiple lower-cost opportunities through investing in smaller scale PBE opportunities, the program has a higher likelihood of successfully development commercial-ready devices in the long-term.
3. ***Exploring and using all available financing mechanisms to accelerate growth***: Funding decisions for PBE projects are driven by evaluating all of the financing mechanisms at WPTO's disposal and correlating them with the appropriate outcomes sought. All funding opportunities will require evidence of market demand and end-user need.

4. ***Emphasis on partnerships***: Stakeholder and industry outreach processes have been and will be designed to understand blue economy end-user needs and to create connections and collaboration opportunities between end-users and energy innovators. Additionally, within the government, intra- and interagency outreach mechanisms are aimed at coordinating missions and pooling resources supporting federal policy, R&D, and energy innovation within the blue economy.
5. ***Marine energy as part of the broader set of solutions***: PBE opportunities present multi-disciplinary challenges; no one sector, institution, or laboratory has the capacity or capability to solve these problems in isolation. Therefore, there is a need for establishing an enduring cross-disciplinary and cross-sector foundation for innovation in the blue economy that leverages the unique strengths of WPTO's core partners (the marine energy industry, the national laboratories, NMRECs, and existing university partners), as well as a new set of blue economy partners and stakeholders working to address technology challenges.

How PBE Fits Within the Marine Energy Program

The PBE portfolio within WPTO consists of activities to support R&D, engagement, and innovation that encompass the marine energy program. PBE portfolio investments leverage traditional and emerging innovation tools available to DOE and are actively coordinated across activities to maximize impacts. As described in the marine energy section of this strategy document, there are several key activities within the PBE sub-activity of the marine energy program.

PBE market success will deliver benefits to marine energy technologies that will ultimately target large-scale grid applications, including critical near-term revenue, design and operational experience in water, supply chain development, and a skilled workforce, as well as the opportunity to increase public familiarity and real near-term understanding of how harnessing ocean energy can provide benefits. The foundational research and accelerated development of systems that are part of PBE can inform and support the maturation and cost reduction of grid-scale marine energy systems. Specifically, innovation at smaller scales provides cost-effective, accelerated pathways and learning for grid-scale markets; challenges like the integration of marine energy with storage or advanced microgrid systems could directly influence grid-scale power markets. Conversely, WPTO-supported advancements over the last 10 years in grid-scale markets benefit PBE markets and applications, including the development of systems to power off-grid markets, like tidal and current applications for remote communities.

Implementing the PBE initiative and fully realizing the potential for marine energy in the blue economy involves aligning the following activities with the three primary PBE goals:

- **Goal 1**: Understand end-user needs and quantify the value of marine energy in emerging ocean markets uniquely suited to marine energy technology attributes.
  - Develop and release a PBE R&D strategy and execution plan.
  - Develop analytical products to quantify market and application opportunities; use these products to assess impacts of and value propositions for individual applications and develop engineering-based use case studies to understand critical R&D and adoption challenges within applications.
  - Understand end-user needs through focused outreach activities (surveys, interviews, conferences). Use this information for R&D planning and to ensure alignment of funded opportunities with end-user needs to encourage and increase the likelihood of successful technology commercialization and adoption.
- **Goal 2**: Accelerate marine energy technology readiness through near-term opportunities, supporting WPTO marine energy strategy and mission.
  - Support a robust portfolio of R&D through the national laboratories to develop a deeper understanding of research challenges critical to unlocking near-term opportunities for industry to address through prototype development.

  - Fund research, development, and training at universities nationwide to address both crosscutting research and prototype development to advance technologies in the blue economy.
  - Launch prizes that attract a diverse set of problem solvers and identify new ways to solve challenging problems in near term markets. Prizes highlight near term opportunities, expand the problem-solving community, and galvanize innovation towards meeting initial technology development goals.
  - Leverage opportunities through the SBIR/STTR programs to support development of prototypes and commercial-ready solutions. SBIR projects, if successful, can quickly and effectively move from design, to prototype, to commercial solution.
    - Maximize use of SBIR/STTR Phase 1 to identify promising industry partners and concepts on marine energy/blue economy system integration.
    - Use SBIR/STTR Phase 2 to advance early-stage, component-scale R&D and initial prototype development.
    - Implementing a multi-year commitment to the maturation of solutions through SBIR can help to ensure commercial adoption. SBIR provides commercialization services beyond the Phase 1 and 2 grants, which can help to increase the likelihood of adoption of solutions post period of performance.
  - Include PBE markets, applications, challenges, data, and information in WPTO's marine energy FOAs.
  - Leverage existing testing investments and identify new assets uniquely suited to PBE markets. This includes incorporating PBE themes within the TEAMER program and in large investments such as PacWave.
  - Develop, promulgate, and facilitate access to existing knowledge repositories to the extent that they are suited to PBE markets, including Tethys, Tethys Engineering, PRIMRE, MHKDR, Marine and Hydrokinetic Toolkit (MHKit), etc.

- **Goal 3**: Work directly across EERE, with other DOE offices, and with public sector partners to address blue economy energy system needs and contribute to national goals set by the federal government; align activities with private and public sector needs to attract investment and interest to support development of solutions to tackle energy challenges.
  - Develop interagency partnerships that jointly support blue economy energy innovation. This includes representing DOE and energy system expertise within national ocean policy frameworks such as the National Oceanographic Partnership Program (NOPP) and the White House Ocean Policy Council. This also includes the development of interagency funding mechanisms to achieve shared blue economy goals.
  - Cultivate intra-agency partnerships that support cross-sector technology innovation to address the complex set of energy opportunities and challenges in the blue economy.
  - Develop a sustainable, early-stage, cross-market R&D, testing, and demonstration ecosystem within laboratories and university partners that supports industry activities in near-term and future markets and applications.
  - Leverage and invest in emerging and existing blue economy regional clusters, accelerators, and incubators to connect R&D and demonstration projects to investors, capital providers, and market opportunities.
  - Develop effective engagement strategies with potential funders and adopters of solutions and communicate opportunities in energy innovation in the blue economy, including specifically innovation emerging from PBE.

Marine Energy Strategic Partnerships and Crosscutting Activities

Coordination and collaboration with other DOE offices and government agencies is essential to optimize federal investments, leverage limited resources, avoid duplication, ensure a consistent message to stakeholders, and meet national energy goals.

WPTO coordinates and collaborates with other DOE offices and federal agencies as shown in Table 24.

Table 24. Summary of Collaborations with Other DOE Offices and Federal Agencies

DOE Office	Description
Fossil Energy and Carbon Management (FECM)	WPTO coordinates with FECM on issues of subsea instrumentation development and inspection/observational equipment and related needs for offshore/subsea power.[74]
EERE Office	**Description**
AMO	WPTO coordinates with AMO to better understand the opportunities for advanced manufacturing and materials for marine energy, and WPTO supports the office's respective desalination research.
Bioenergy Technologies Office (BETO)	WPTO coordinates with BETO to meet the goals of EERE's Plastics Innovation Challenge.
ETI	ETI works to advance self-reliant island and remote communities through the development of resilient energy systems. In collaboration with SETO, WPTO is working to establish a public-private partnership to provide technical assistance and expertise to remote coastal and island communities.
Hydrogen and Fuel Cell Technologies Office (HFTO)	WPTO works with the Hydrogen and Fuel Cells Technologies Office to examine the potential for marine-powered systems for hydrogen production.
SETO	In addition to supporting technical assistance in partnership with ETI, WPTO works closely with SETO on its various prizes, including its desalination prize.
WETO	WPTO coordinates with WETO to support examination of environmental monitoring technologies, resource assessment, and joint opportunities to support coastal energy workforce opportunities.
Federal Agencies	**Description**
U.S. Department of the Interior (DOI), Bureau of Ocean Energy Management (BOEM)	WPTO has historically coordinated and worked with BOEM via the National Oceanographic Partnership Program (NOPP) and continues to engage via projects developing new environmental monitoring technologies and studies to monitor potential effects.

[74] National Energy Technology Laboratory, 2019, "Energy Department Invests $9 Million in Offshore Projects in Support of Enhanced Oil Recovery." https://www.netl.doe.gov/node/9170.

Federal Agencies	Description
U.S. Department of the Navy	WPTO has several ongoing projects with the U.S. Navy, including Naval Facilities Engineering Command and Office of Naval Research. Specifically, WPTO leverages Navy facilities, like WETS in Hawaii and the Carderock Wave Basin in Maryland to conduct marine energy R&D. Both DOE and the Navy also sponsor university-led research at universities including the University of Washington and the University of Hawaii at Manoa) via the NMREC and University-Affiliated Research Center (UARC) initiatives, respectively.
NOAA	WPTO has launched a joint prize on ocean observing technologies, but is also coordinating with NOAA on marine debris, resource assessment, and is exploring opportunities to work closely with NOAA Sea Grant.
U.S. Economic Development Administration (EDA)	The U.S. Department of Commerce's EDA and WPTO released a joint solicitation[75] in 2020 to fund organizations supporting entrepreneurship in the blue economy.
U.S. Maritime Administration (MARAD)	With the Department of Transportation's Maritime Administration, WPTO has convened R&D organizations government-wide to better understand and address R&D challenges in the maritime sector.

Oceans for Climate

The oceans are critical to the global ecosystem and are important to human health and productivity. The oceans present opportunities for new sources of energy, protein, freshwater and medicines, with significant implications for global and environmental security. Ocean policy and managing associated economic and environmental equities presents a challenge and an enormous and timely opportunity to reimagine oceans as an asset in the fight against climate change. Oceans already support millions of jobs, underpin our food system and contribute $304 billion to our national GDP, with the potential to grow. The Organization for Economic Cooperation and Development predicts the global economic value attributable to ocean-related activities will double from $1.5 trillion in 2015 to $3 trillion by 2030, growing at twice the rate of the rest of the global economy. They also have the potential to be one of our strongest tools in the fight against climate change. in fact, a recent analysis commissioned by the *UN High Level Panel for a Sustainable Ocean Economy* found that ocean-based climate mitigation and carbon storage options could contribute 21% of the emissions gap to achieve 2050 net-zero emissions targets.[76]

Developing the technologies and approaches of the future that can serve to protect, understand, and leverage the natural assets of the ocean is a critical challenge in the coming decade. And there is a need to focus on coastal communities as they adapt to climate impacts, and as partners in an equitable energy transition. To fully realize these opportunities, there is a need for new technologies, partnerships, and enhanced government coordination. A new, bold federal initiative is needed to convene relevant agencies, develop a strategy to understand and maximize the potential to have the planet's oceans serve as an asset in the fight against climate change, and deploy the technologies and solutions needed.

[75] U.S. Economic Development Administration, 2020. "Build to Scale Industry Challenge." https://www.eda.gov/oie/buildtoscale/industry/.

[76] High Level Panel for Sustainable Ocean Economy, 2019. "The Ocean as a Solution to Climate Change." https://oceanpanel.org/sites/default/files/2019-10/HLP_Report_Ocean_Solution_Climate_Change_final.pdf.

The oceans are key to enable a net-zero emissions economy that benefits the environment and communities that rely on them. The ocean's contribution to emissions reductions, and a more equitable climate future, derive from four primary sectors:

- **Ocean energy**: Cross-technology and community-focused approaches are needed to accelerate offshore renewable energy—including offshore wind, marine energy, floating solar, and integrated storage. These technologies range in maturity but can all serve critical roles in the pursuit of a 100% clean energy future for terrestrial power consumption. Additionally, harnessing power out in the ocean can serve as energy resources for markets of the present and future, like enhanced ocean observations in extreme environments necessary to underpin both environmental and security policies.
- **Maritime decarbonization**: Decarbonization is critical for maritime transportation, which includes both ships and port infrastructure. This could include electrification and new replacement fuels like hydrogen, ammonia or biofuels, to replace existing fuels—as global shipping contributes approximately 3% of annual CO_2 emissions, equivalent to three times the annual emissions of France.
- **Low-emission sustainable food**: The ocean can serve as a source of low emission food production to reduce agricultural emissions. Sustainable fisheries, "regenerative" aquaculture, and seaweed cultivation all present opportunities for coastal communities to expand their economies and serve a growing population. Some of these solutions also have additional benefits, like cleaning the water of the local environment and serving as a carbon sink.
- **Ocean and coastal habitats, blue carbon, and carbon dioxide removal/storage**: There is a need to protect the critical function the ocean plays as the world's largest sink of atmospheric CO_2, and to pursue strategies that enhance this function and store carbon long term, which could include both natural and technology-focused solutions.

Plastics Innovation Challenge

In November 2019, DOE launched the Plastics Innovation Challenge, which aims to accelerate innovations in energy-efficient plastics recycling and collection technologies.[77] Led by DOE's EERE, the Plastics Innovation Challenge is a multi-pronged R&D initiative that focuses on:

- Collection technologies to prevent plastics from entering the ocean.
- Deconstructing plastic waste, including from rivers and oceans, through biological and chemical methods.
- Upcycling waste streams into higher-value products.
- Developing new plastics that are recyclable-by-design.
- Supporting a plastics upcycling supply chain in domestic and global markets.

With 90% of global marine debris attributed to just ten rivers, inland waterways such as rivers and canals are key to remediation efforts. Marine and hydrokinetic energy is uniquely positioned to help power promising technologies for remediation of marine debris. As part of the Plastics Innovation Challenge, WPTO conducts R&D to develop marine energy-powered systems to remove trash from waterways before it has a chance to enter the ocean.

In addition, WPTO is collaborating with BETO to characterize the plastic and marine debris 'resources' available in order to inform collection, deconstruction, and upcycling activities. Collection, deconstruction, and upcycling of plastic waste depends on an understanding of the geographic distribution and prevalence of plastic waste in order to deploy solutions in the most impactful locations.

[77] U.S. Department of Energy, 2019, "Department of Energy Launches Plastics Innovation Challenge." energy.gov/articles/department-energy-launches-plastics-innovation-challenge.

There are many challenges associated with converting plastics collected from oceans and waterways into useful products, such as contamination and a lack of collection infrastructure. By working to understand how to handle contaminated ocean plastics and their impacts on collection, recycling, and upcycling processes, we can find cost-effective ways to collect and process ocean plastic. This helps to close the recycling loop and ensure that recycled plastics are reused for other consumer products, resulting in less virgin plastic used in production. Ultimately, this collaboration between WPTO and BETO could inform potential deployment locations of marine energy-powered collection systems and provide a valuable waste stream for deconstruction and upcycling.

Water Security Grand Challenge

Launched in 2018 by the White House, the Water Security Grand Challenge is a framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. Led by DOE, the Grand Challenge is a coordinated suite of prizes, competitions, early-stage R&D, and other programs supporting five specific goals for the United States to reach by 2030.

As part of the Water Security Grand Challenge, WPTO's Marine Energy Program launched the Waves to Water Prize in 2019. Waves to Water is a five-stage, $3.3 million project to accelerate technology innovation through a series of contests to design, develop, and demonstrate desalination systems that use the power of the ocean to provide potable drinking water to remote coastal and island communities. Waves to Water was the first prize released to support the Secretary's Water Security Grand Challenge and specifically aligns with two of the challenge's 2030 goals: to launch desalination technologies that deliver cost-competitive clean water and to develop small, modular energy-water systems for urban, rural, tribal, national security, and disaster response settings. In addition to the prize, WPTO is developing a national lab-designed test system to understand some of the novel challenges of wave powered desalination, as well as conducting customer discovery, researching the sizing and optimization of systems, and conducting research to better understand the ability to scale systems for small-scale applications such as remote communities. WPTO expects a number of lessons learned via these activities will have broad and transferable knowledge under the Secretary's Water Security Grand Challenge.

In the future, the program seeks to support opportunities focused on critical field test conditions over longer duration test periods (2 week – 6 months), collecting specific device performance data across a number of deployment scenarios, advancing the testing of modular and novel mooring designs, and advancing the sizing and optimization of integrated wave desalination systems. These outcomes are critically important for establishing the reliability and robustness of designs as industry looks to find investment off-ramps and specific customers focused on disaster relief, military operations, and remote community energy/water services.

Science and Technology for America's Oceans: A Decadal Vision

Ensuring responsible ocean stewardship with science and technology (S&T) breakthroughs relies on a strategic federal portfolio supported by foundational basic research. *Science and Technology for America's Oceans: A Decadal Vision*[78] identifies pressing research needs and areas of opportunity within the ocean S&T enterprise for the decade 2018-2028. The Vision was published by the Subcommittee on Ocean Science and Technology (SOST), under the Committee on Environment, which is part of the National Science and Technology Council[79] (NSTC), a cabinet-level council chaired by the President.

[78] Federal Register, 2018. "Science and Technology for America's Oceans: A Decadal Vision." https://www.federalregister.gov/documents/2018/06/28/2018-13926/science-and-technology-for-americas-oceans-a-decadal-vision.

[79] For more information, visit whitehouse.gov/ostp/nstc/.

The Vision outlines a need for research into new potential energy sources, including waves and currents, that are necessary for achieving American leadership in energy generation and innovation. Outcomes from new energy resource capture include economic development in coastal communities. Pairing marine renewable energy with growing and emerging markets can benefit other industries including aquaculture, ocean mineral mining, and oceanographic research, which are highlighted in the PBE Report.[80] The development of these technologies can improve technology transfer and increase U.S. competitiveness in the global market, which is a priority across all federal agencies.

Ongoing coordination with high-level ocean policy activities has facilitated the integration of WPTO equities into the Vision. WPTO representation in NSTC, SOST, and the Ocean Policy Committee, a White House level committee responsible for coordinating ocean-related agency work, continues to help foster high-level, interagency support for marine renewable energy and its applications. Agencies represented across these high-level committees also coordinate through the NOPP.[81] This interagency initiative facilitates partnerships between federal agencies, academia, and industry to advance ocean science research and education by leveraging funding from multiple agencies. WPTO is also an active participant in NOPP.

[80] U.S. Department of Energy, 2019, "Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets." https://www.energy.gov/eere/water/powering-blue-economy-exploring-opportunities-marine-renewable-energy-maritime-markets#pbereport.

[81] For more information, visit www.nopp.org.