Marine Energy – Foundational R&D Portfolio

Bill McShane, Technology Manager

19July2022
10:00 AM to 10:40 AM ET

Agenda – Foundational R&D Portfolio Overview

Activity Area Overview
- Challenges the Activity Area Addresses
- Stakeholder Engagement

Strategy
- Performance Goals (from MYPP)
- Objectives (from MYPP)

Implementation and Progress
- Research Priorities (from MYPP)
- Key Accomplishments
- Future Work

Agenda Overview

Reviewer Introductions

Foundational R&D Portfolio – Activity Overview

Foundational R&D Activity Area 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).

Foundational R&D Research Areas	
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.
Controls	Enabling broad implementation of advanced control systems across the marine energy industry to dramatically improve performance and reduce cost of marine energy converters.
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.
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.
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.

Challenges the Foundational R&D Activity Area Addresses

Difficult Engineering to Convert Marine Energy

- Fundamental difficulties for designing systems to efficiently capture usable energy, due to the unique physics of the systems.
- Open scientific and engineering questions about how devices interact with these complicated resources or with other devices, and efforts to develop validated methods to measure, model, and predict these interactions are ongoing.
- Lack of well-developed manufacturing and supply chains for marine energy applications, resulting in long lead times and high costs for materials and components.
- Lack of established, commonly-accepted performance metrics to evaluate the wide range of existing technologies.

Marine energy device performance is governed by complex fluid-structure interactions between the devices and the marine environment. Fundamental scientific and engineering challenges remain in understanding how to design the most efficient systems to harness high energy-density and dynamic marine resources. Resource characteristics can vary significantly on very short timescales, such as the passing of an ocean wave or turbulence in water currents, and the ranges of energy intensity that devices experience can vary by several orders of magnitude. Devices must be designed to minimize the cost of energy while still operating reliably for the design life of a project, which can be 20 years or more. Therefore, developing marine energy devices is a multifaceted system design and optimization problem that encompasses many engineering disciplines.

Stakeholder Engagement Informs the Foundational R&D Strategy

Structured Process

- Feedback from past public Peer Reviews
- Feedback from past public Requests For Information (RFI) requests
- Public comment period on draft documents
- Prize rules document public comment
- Questions on applications: FOAs, SBIRs/STTRs, prizes, AOPs, Seedlings / Saplings, TCFs, EPSCoR

Public Interactions

- Conference interactions: track and panel chair, panel members, audience discussions
- Industry trade organizations (example – Marine Energy Council)
- Webinar discussions, public workshops
- Publications, journals, and literature searches
- Website download metrics (PRIMRE, MHKDR, Tethys, GitHub)

Project Interactions

- Feedback from past and present principal investigators (PIs)
- Industry collaborations
- TEAMER network (expecting from UMERC in the future)
- International Energy Agency Ocean Energy Systems (IEA OES) feedback
- International Electrotechnical Commission Technical Committee (IEC TC 114) feedback
- Environmental assessments (NEPA)

Commercialization Feedback

- Energy iCorp participant feedback
- Commercialization review feedback
- Patent analysis

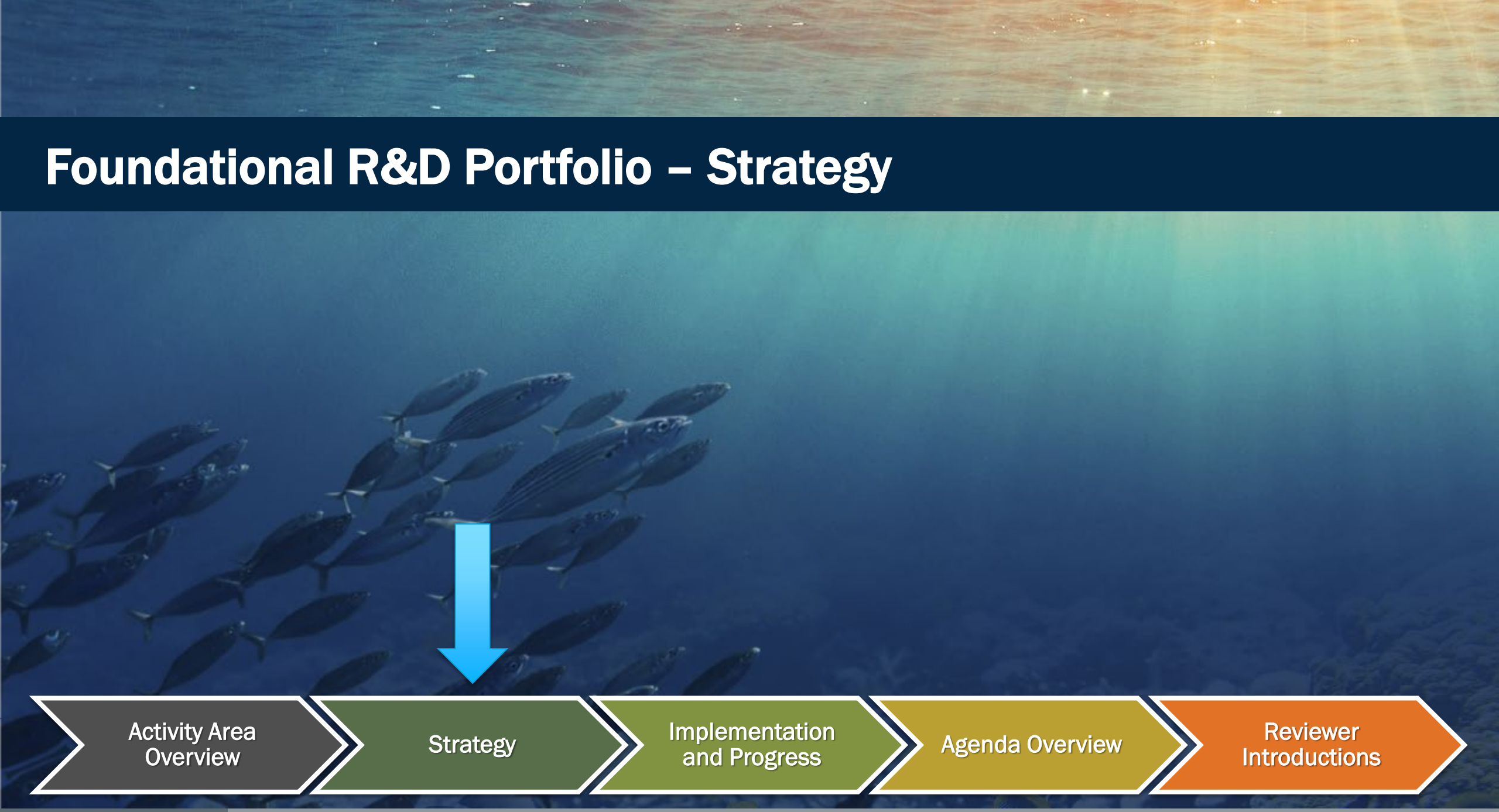
Interactions with Outside Funding Activities

- Other EERE Offices (WETO, AMO, HFTO, …)
- ARPA-E
- NOAA, DoD and Navy, NASA
- Interagency Working Groups
- International

WPTO undertakes multiple stakeholder engagements for a broad understanding of industry's Foundational R&D challenges

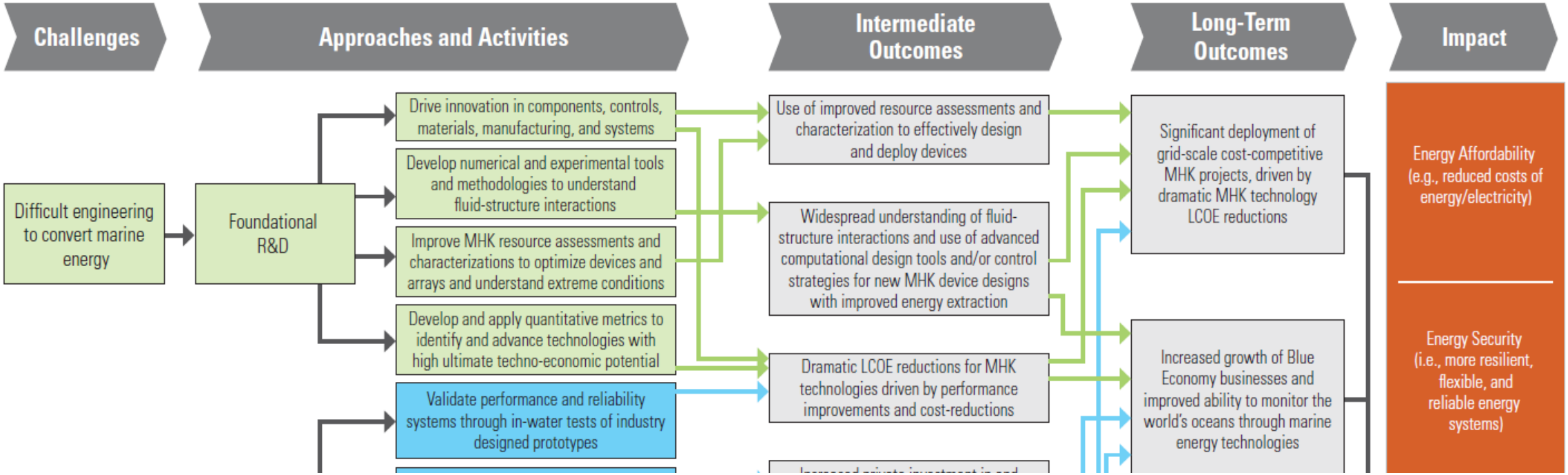
The Foundational R&D program area recognizes the need for capturing and evaluating R&D priorities from multiple stakeholder communities so we can advance the Foundational R&D portfolio. We'd be glad to receive comments from the Peer Reviewers.

Foundational R&D Portfolio – Strategy



Foundational R&D Portfolio – Logic Model

Figure 11. Marine Energy Program Logic Model



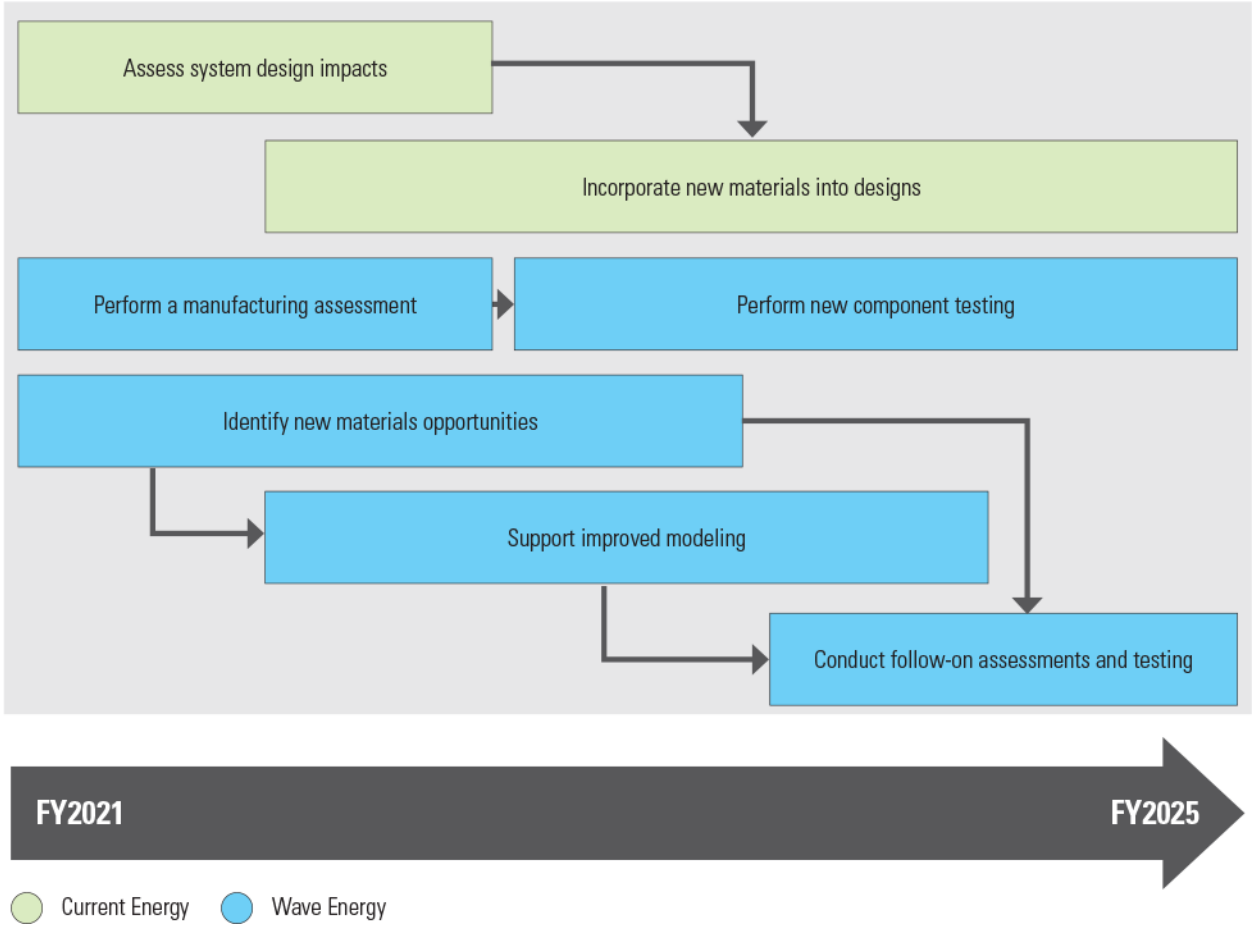
Strategy – Key Results and Performance Goals (2021–2025)

- 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.

Future Work - 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.

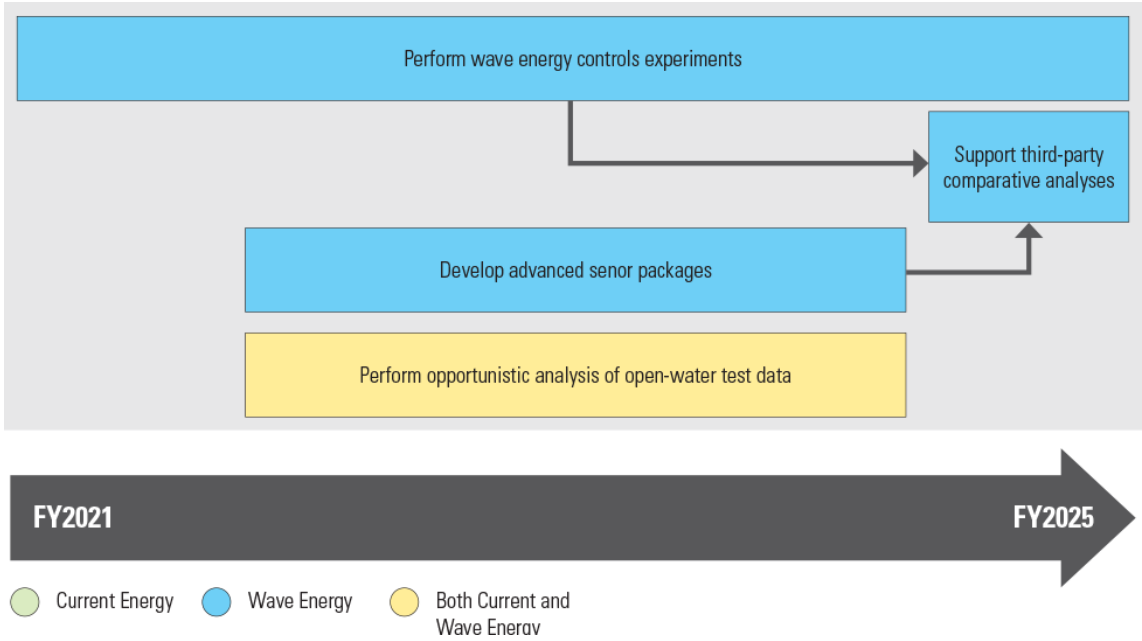
Advanced Materials and Manufacturing Research Priorities



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.

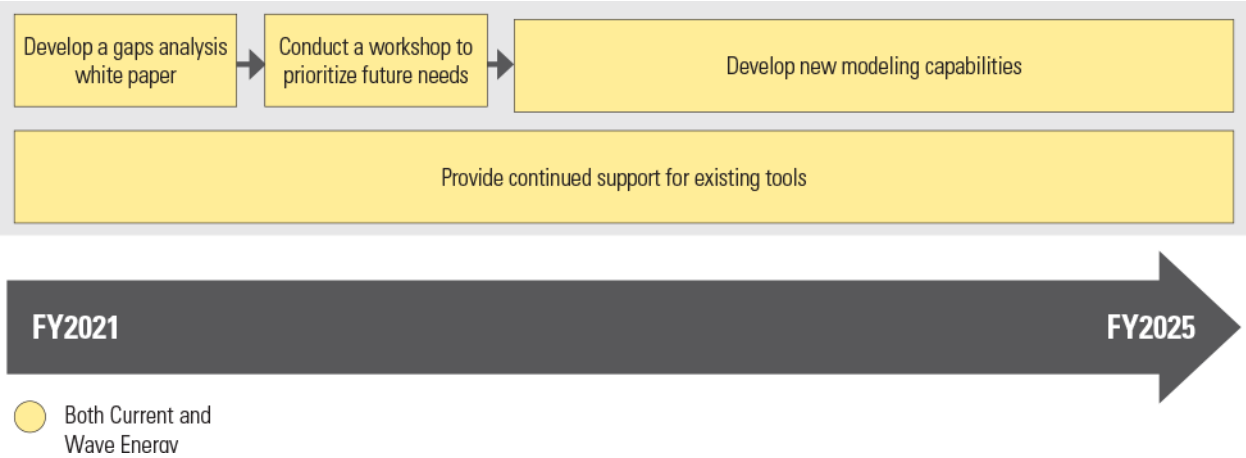
Controls Research Priorities



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.

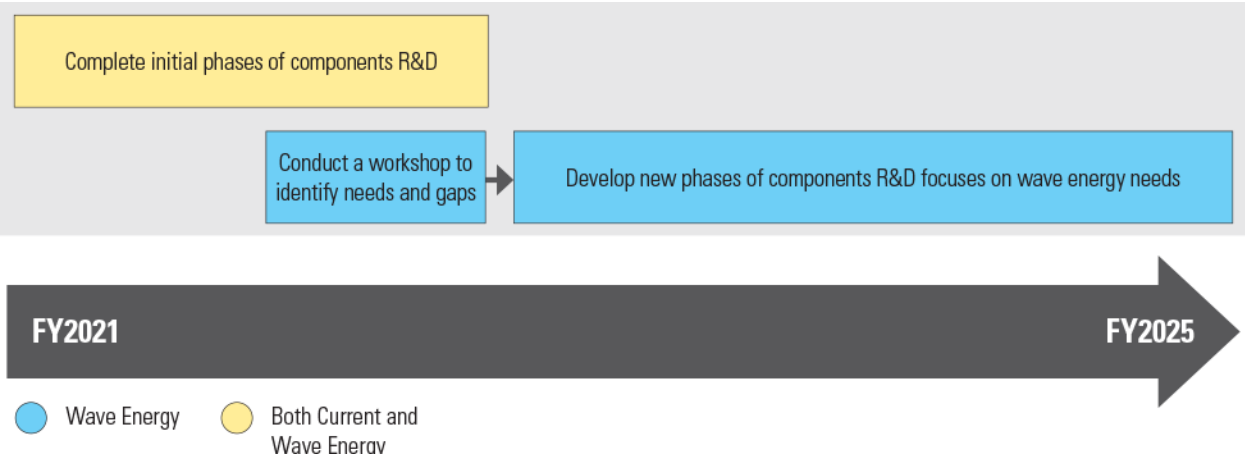
Numerical Modeling Research Priorities



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.

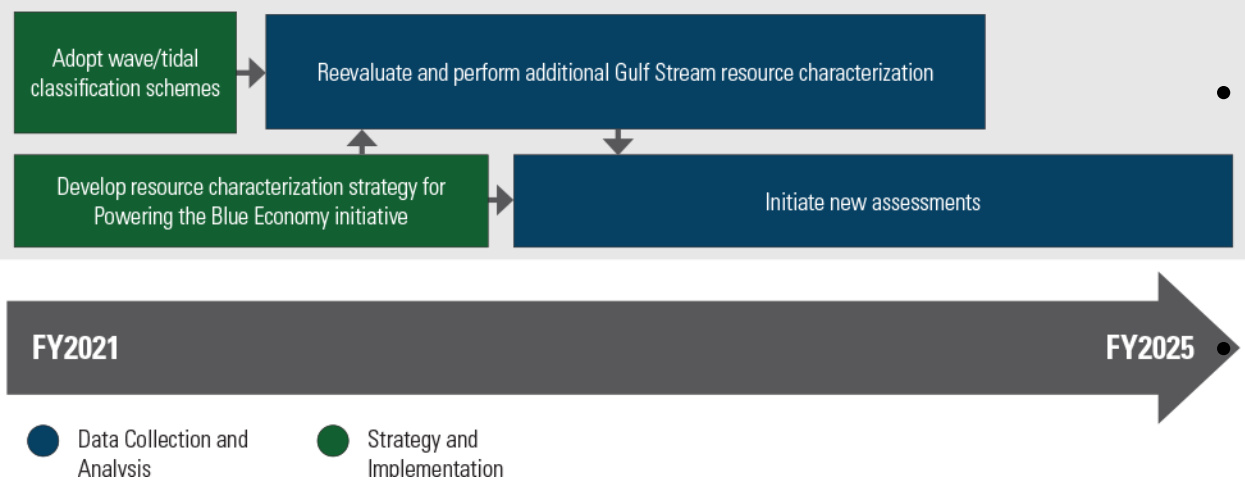
Components Research Priorities



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.

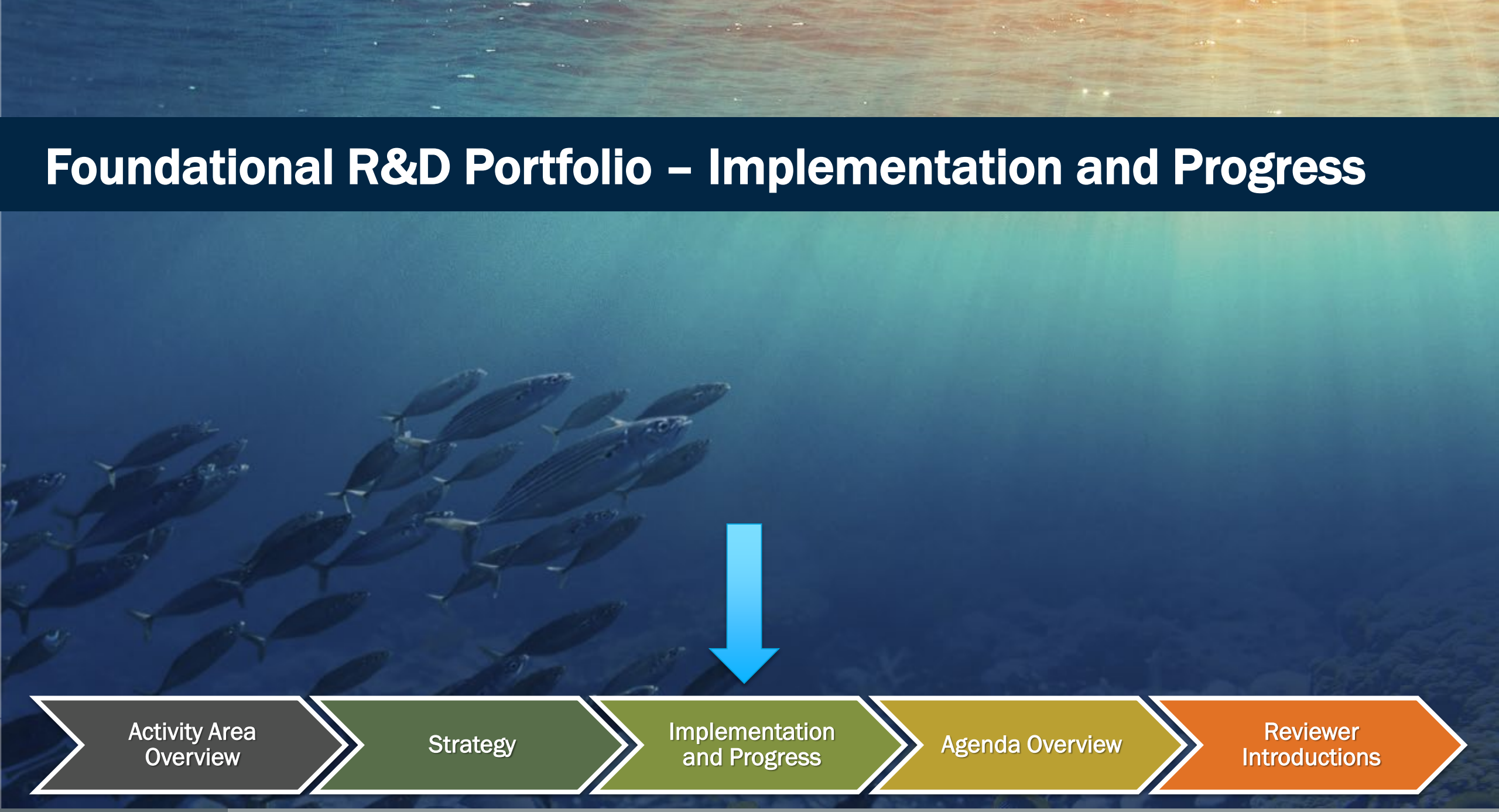
Resource Characterization Research Priorities



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.

Foundational R&D Portfolio – Implementation and Progress



Foundational R&D Project Portfolio

Advanced Materials

- Three Labs collaborating on Advanced Materials and Manufacturing Reliability
- DE-EE0009447 University of Illinois, Urbana-Champaign New Blade Materials for Marine Energy Converters Operating in Highly Turbulent Currents (FOA 2234)
- DE-EE0009448 University of Maine Research and Development of Additive Manufacturing Technologies for Marine Energy System (FOA 2234)

Controls

- Next Generation WEC PTO Co-design
  - Advanced WEC Controls IAA (2015 Project)
- Fatigue and Structural Load Analysis and Control for Variable Geometry Wave Energy Converters
- CalWave Power Technologies, Inc. (FOA 1837)
  - NREL Support to CalWave (FOA 1837)
  - SNL Support to CalWave (FOA 1837)
- DE-EE0009444 Monterey Bay Aquarium Research Institute Open Wave-Energy Control System Development Platform (FOA 2234)
- SPA I and II: supporting HQ evaluation of awardee technical progress in controls and structures

Modeling

- Wave Energy Converter Modeling
- WEC Array Power Management And Output Simulation Tool
- WEC Design Optimization
- DE-EE0009446 University of Washington A Unified Multiphysics Approach for Modeling, Control, and Optimization of Wave Energy Converters (FOA 2234)
- WECCOMP Control Competition

R&D 100 AWARDS

Components

- DE-EE0008385 Resolute Marine Energy, Inc. Seawater Compatible Rotary Pump for Wave Energy Conversion (FOA 1663)
- DE-EE0008100 Portland State University Performance Testing of an Integrated Magnetic Power Take-Off (FOA 1663)
- DE-EE0008631 Portland State University Performance Testing of an Integrated Magnetic Power Take-Off (FOA1837)
- 2020 SBIR/STTR Affordable, Grid-Friendly, High-Torque Direct-Drive Generators – 2 awards

Resource Characterization

- Model Validation and Site Characterization for Early Deployment MHK Sites and Establishment of Wave Classification Scheme
- 2021 SBIR/STTR Low-Cost, User-Friendly Monitoring Tools for MHK Sites – 5 awards

8 lab projects
8 industry FOA Awards
7 SBIRs
1 prize competition
TEAMER Support
Seedlings and Saplings

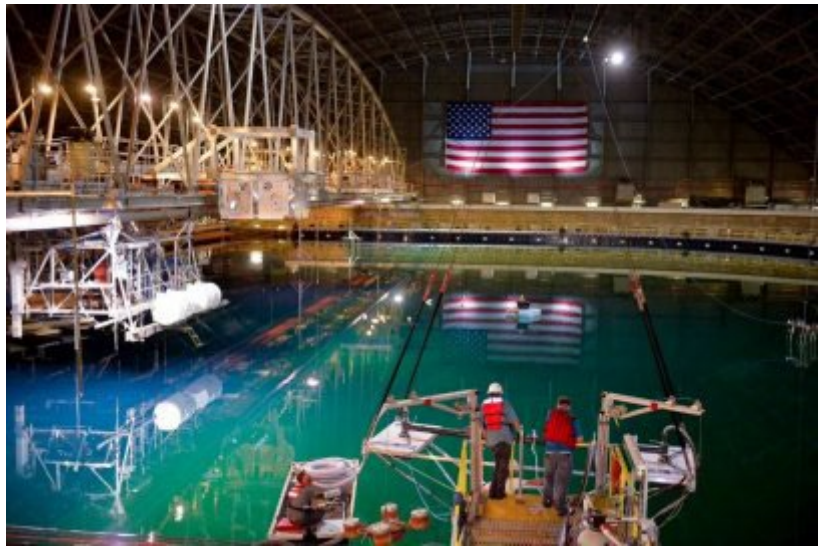
TEAMER
Testing & Expertise for Marine Energy

Seedlings / Saplings

Key Accomplishments – Foundational R&D Portfolio
From the 2019 – 2020 Year End Accomplishment Report

Co-Design is Key for Future Wave Energy Systems

From 2014 to 2020, Sandia National Labs and MRE developer Re Vision Consulting investigated advanced controls techniques in wave energy systems.



Resource Mapping Expands U.S. Wave Energy Estimates

In 2020, WPTO's multi-lab resource characterization project released the highest resolution, most comprehensive wave dataset publicly available.

Key Accomplishments – Foundational R&D Portfolio (cont.)
From the 2020 - 2021 Year End Accomplishment Report

Open-Source Wave Energy WEC-Sim Software Receives R&D 100 Award and Contributes to Space Exploration

The open-source WEC-Sim software is recognized with a 2021 R&D 100 Award, while researchers at NASA and Lockheed Martin apply the software to help ensure the safety of the future crew of the Artemis I mission.

AquaHarmonics Completes First Industry Developer Testing at Sandia Wave Energy Power Take-Off Lab

Sandia Wave Energy Power Take-Off Lab provides its first simulations for an industry partner, AquaHarmonics, leveraging its unique capabilities to evaluate performance on the wave energy converter device in advance of open-ocean testing in Hawaii.

Key Accomplishments – Foundational R&D Portfolio (cont.)
From the 2020 - 2021 Year End Accomplishment Report

Wave-Powered SeaRAY Completes On-Land Preparation Before Offshore Trial

Researchers at the National Renewable Energy Laboratory outfitted the SeaRAY autonomous offshore power system with a customized Modular Ocean Data Acquisition system, which will allow handlers to control the device from afar and collect real-time data.

Labs Release New Data and Report on the Powerful Potential of U.S. Marine Energy Resources

A multilab team of researchers identifies renewable marine energy resource potential and continues to refine these assessments as resources are further developed.

Key Accomplishments – Foundational R&D Portfolio (cont.)
From the 2020 - 2021 Year End Accomplishment Report

Inaugural R&D Showcase Cultivates Awareness of Novel Projects at National Labs

The Virtual Seedling Water Power Innovation R&D Showcase brought together more than 40 researchers to provide details and insight into innovations funded through the WPTO Seedlings program, a novel effort funding advancements in marine energy.

Tidal Power Turbine Demonstrates Thermoplastic Blades

Research demonstrates the potentially game-changing thermoplastic resin material for marine applications at a meaningful scale.

Key Accomplishments – Other Foundational R&D Activities

- Joint project with the Hydrogen Fuel Cell Technology Office (HFTO)
  - Unlocking the Potential of Marine Energy Using Hydrogen Generation Technologies report published (2022) https://www.nrel.gov/docs/fy22osti/82538.pdf
  - Industry workshop (2021) https://www.energy.gov/eere/fuelcells/marine-energy-hydrogen-working-meeting
- WPTO and WETO in discussions to formulate joint projects where synergies exist with offshore wind, e.g. electrical infrastructure, anchors/moorings, O&M advanced technologies
- Materials and Manufacturing for Marine Energy Technologies workshop report posted (2021)
  - Materials and Manufacturing for Marine Energy Technologies | Department of Energy
- WPTO has funded 98 projects through the Marine Energy Seedlings Request for Innovation program from FY2020-2022 for a total of $6.55 million at six national labs. Each project has been funded at $50,000 - $100,000.
  - Seedling projects conduct discovery research or produce prototypes and models in a short timeline with discrete deliverables.
  - Saplings conduct comprehensive research, development, demonstration, and commercialization activities. WPTO has funded 5 Sapling projects at more than $1.5 million
- The Influence of Marine and Hydro Kinetics Patents Funded by the U.S. Department of Energy's Water Power Technologies Office and other DOE Offices (2021)

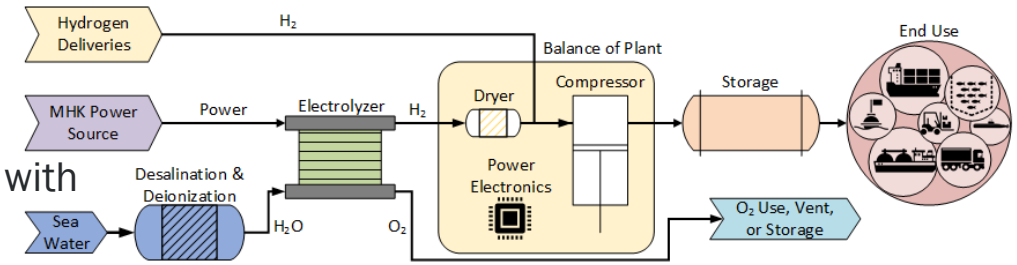
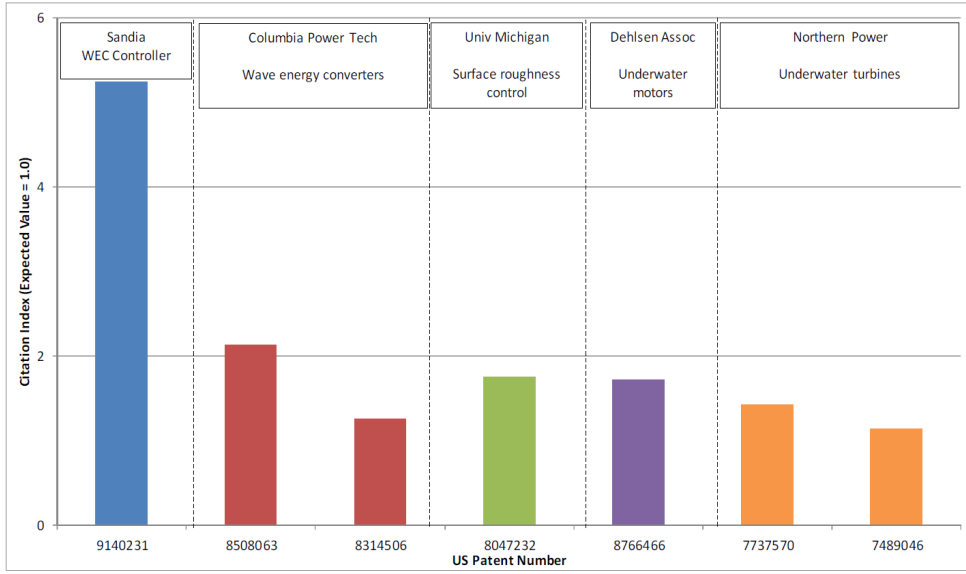


Figure E-3 – Examples of Highly-Cited WPTO-funded MHK Patents



Future Work

- Assess the current MRE Software landscape and identify future development needs
  - Solicit public feedback via MRE Software Workshop (e.g. OREC-METS 2022) and online webinar
  - Draft report on current MRE Software landscape, identifying gaps and potential needs for public feedback
- WEC-Sim code maintenance and code improvements
- Controls and codesign research
  - Tank testing prototypes for variable geometry controls
  - MASK basin workshop
  - FOSWEC digital twin control competition
- Marine Energy Materials and Manufacturing
  - Workshop article and amplification tool kits in process
  - Second Marine Energy Materials and Manufacturing Workshop in planning

Foundational R&D Portfolio – Agenda Overview

Agenda Overview – July 19

START (ET)	END (ET)	PRESENTATION TOPIC	ORGANIZATION	SPEAKER
10:00 AM	10:40 AM	Foundational R&D Activity Area Overview	WPTO	William McShane
10:40 AM	11:10 AM	Demonstration of an Advanced Multi-Mode Point Absorber for Wave Energy Conversion	Oscilla Power, Inc.	Tim Mundon
11:10 AM	11:35 AM	Seawater Compatible Rotary Pump for Wave Energy Conversion	Resolute Marine Energy, Inc.	Marcus Gay
11:35 AM	11:45 AM	**BREAK**		

Agenda Overview – July 19

11:45 AM	12:10 PM	Design of High-Deflection Foils for MHK Applications	Ocean Renewable Power Company, LLC	Jarlath McEntee
12:10 PM	12:35 PM	Performance Testing of An Integrated Magnetic Power Take-Off	Portland State University	Jonathan Bird
12:35 PM	1:25 PM	**LUNCH BREAK**		
1:25 PM	1:50 PM	Holistic Control Embedded Power Take Off (PTO) Development	CalWave Power Technologies Inc.	Thomas Boerner, Marcus Lehmann, Dan Petcovic
1:50 PM	2:15 PM	**Reviewer Debrief**	**Reviewers**	

Agenda Overview – July 20

START (ET)	END (ET)	PRESENTATION TOPIC	ORGANIZATION	SPEAKER
10:00 AM	10:25 AM	Fatigue and Structural Load Analysis and Control for Variable Geometry Wave Energy Converters	NREL	Nathan Tom
10:25 AM	10:50 AM	Next Generation WEC PTO Co-Design	SNL	Ryan Coe
10:50 AM	11:15 AM	Wave Energy Converter Modeling	NREL, SNL	Dave Ogden, Kelley Ruehl
11:15 AM	11:25 AM	**BREAK**		
11:25 AM	11:50 AM	WEC Array Power Management and Output Simulation Tool	NREL, PNNL	Toan Thanh Tran

Agenda Overview – July 20

11:50 AM	12:15 PM	WEC Design Optimization	SNL	Ryan Coe
12:15 PM	1:00 PM	**LUNCH BREAK**		
1:00 PM	1:25 PM	Wave Energy Converter Interlink Umbilical Cables Design Requirements, Best Practices and Recommended Design Improvements	PNNL	Leo Fifield
1:25 PM	1:50 PM	Model Validation and Site Characterization for Early Deployment MHK Sites and Establishment of Wave Classification Scheme	NREL, PNNL, SNL	Levi Kilcher, Vincent Neary, Zhaoqing Yang
1:50 PM	2:15 PM	**Reviewer Debrief**	**Reviewers**	

Foundational R&D Portfolio – Reviewer Introductions

Q&A