Marine and Hydrokinetic

Report to Congress
September 2018

United States Department of Energy
Washington, DC 20585

Message from the Secretary

This report examines Marine Hydrokinetic (MHK) Program funding from FY 2008 – FY 2017 and describes the strategy and rationale that the Water Power Technologies Office (WPTO) applies in supporting foundational science and early-stage research and development (R&D) for MHK energy technologies. It provides summary information on the past allocation of funds, including demonstrating diversity in possible public and private partnerships, and diversity in regional locations.

In response to a request in House Appropriations Committee report language accompanying the 2017 Consolidated Appropriations Act passed by Congress and signed by the President on May 5, 2017, this report is being provided to the following Members of Congress:

- **The Honorable Richard C. Shelby**
  Chairman, Senate Committee on Appropriations

- **The Honorable Patrick Leahy**
  Vice Chairman, Senate Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Dianne Feinstein**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Rodney P. Frelinghuysen**
  Chairman, House Committee on Appropriations

- **The Honorable Nita M. Lowey**
  Ranking Member, House Committee on Appropriations

- **The Honorable Michael Simpson**
  Chairman, Subcommittee on Energy and Water Development
  House Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Ranking Member, Subcommittee on Energy and Water Development
  House Committee on Appropriations

If you have further questions, please contact me or Ms. Bridget Forcier, Associate Director for External Coordination, Office of the Chief Financial Officer, at (202) 586-0176.

Sincerely,

Rick Perry

Executive Summary

In the FY2017 House of Representatives Appropriations Committee Report 114-532, Congress requested that the U.S. Department of Energy (DOE) Water Power Technologies Office (WPTO) Marine and Hydrokinetic (MHK) Program issue a report on the past allocation of funds. Specifically, Congress asked WPTO to demonstrate diversity in possible public and private partnerships, and in regional for siting these new methods and technologies. This report examines MHK program funding from FY 2008 – FY 2017 and describes the strategy and rationale that WPTO applies in supporting foundational science and early-stage research and development (R&D) for MHK energy technologies. The development of commercial MHK technologies is complex and difficult and the industry challenges highlight why high-risk, early-stage R&D is necessary to address them. Four different approaches (or Topic Areas) are described in detail. WPTO invests in projects spearheaded by a wide range of organizations, including private industry, national laboratories, universities, local governments, tribal governments, nonprofits, and public utilities, and has developed a portfolio that is both technically and geographically robust. While diversity of funding is of high salience to WPTO, it is also important to measure the effectiveness of dollars spent. This report also summarizes independent peer review of the portfolio, and highlights some of the project success stories contributing to the advancement of the MHK Industry.

Marine and Hydrokinetic

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I. Marine and Hydrokinetic Overview

The Water Power Technologies Office, within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), conducts early-stage research advancing cutting-edge technologies to grow and modernize the U.S. hydropower fleet and drive U.S. leadership in marine and hydrokinetic energy, with the goal of delivering low-cost power, reliability, and resiliency to the nation's power grids. The MHK industry seeks to generate renewable and reliable electricity from waves, tides, ocean and river currents, and ocean thermal gradients. The MHK industry is at an early stage of technological development due to the fundamental scientific and engineering challenges of generating power from dynamic, low-velocity and high-density waves and currents, all while surviving corrosive marine environments. These challenges are intensified by the high cost and arduous permitting processes associated with in-water testing. To address these challenges, WPTO makes strategic investments to support fundamental technology innovations, reduce barriers to prototype testing and validation, address potential environmental and regulatory risks, and analyze the breadth and characteristics of the nation's wave and current energy resources. In this process, WPTO supports the marine energy industry through competitive funding opportunities, and partners closely with stakeholders from a wide range of institutions—academic, business, research, utility, government, and non-government—located across the United States whose expertise can contribute to the advancement of water power technologies.

The DOE MHK Program (Program) focuses on investments in early-stage R&D specific to MHK applications, with the aim of generating foundational knowledge of innovative components, structures, materials, systems, and manufacturing approaches. The DOE currently plays a unique role in supporting the development of new, cutting-edge technologies and the establishment of a strong and competitive industry in the United States. The MHK Program provides substantial financial support to researchers at a wide range of different organizations (universities, private companies, national laboratories, and relevant non-profits), to focus on solutions to high priority challenges where targeted government support at early-stages in R&D processes can generate knowledge benefits that are broadly applicable to many different types of technology developers and researchers.

II. DOE Marine and Hydrokinetic Funding Distribution

This report examines the past allocations of WPTO funds dedicated to MHK research, demonstrating diversity in possible public and private partnerships and in regional locations for siting these new methods and technologies. As evident in Figure 1, annual appropriations for MHK R&D increased steadily from 2008 to 2017. Two processes provide the main funding mechanisms for MHK R&D projects: competitive Funding Opportunity Announcements (FOAs) and research undertaken at the DOE National Laboratories. The graph below shows total annual appropriations to the MHK program from fiscal years 2008–2017. In that time, WPTO invested in more than 200 MHK projects.

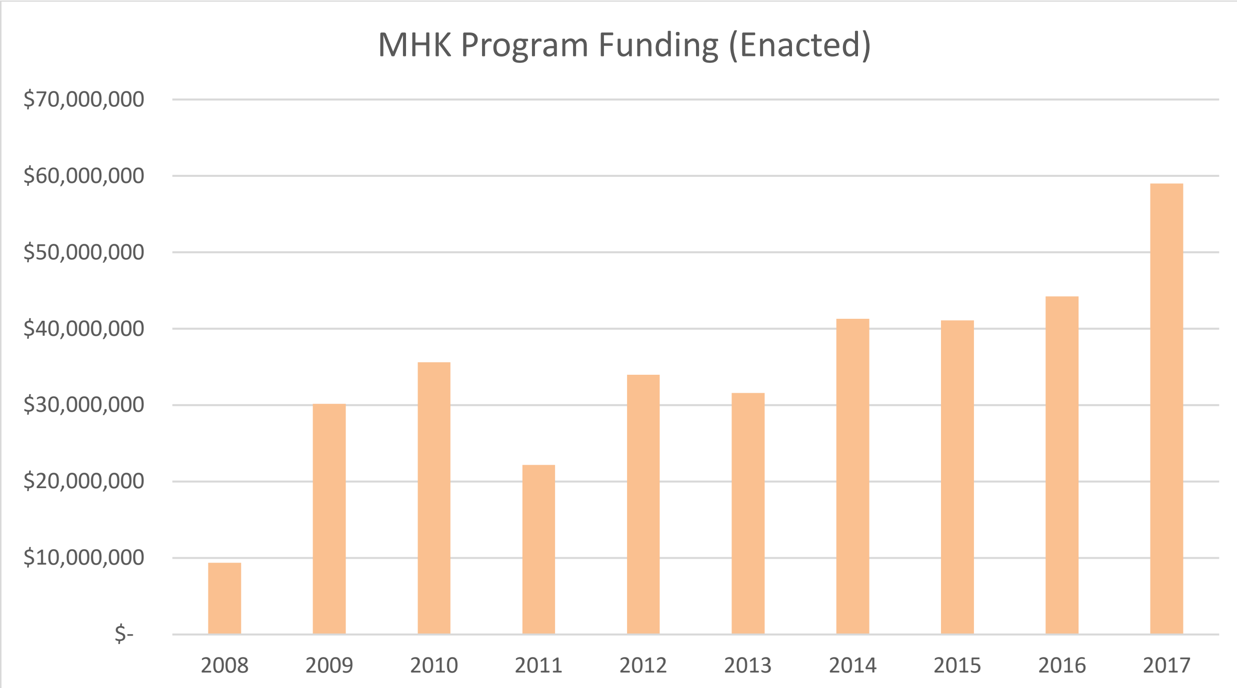


Figure 1: MHK Funding Levels FY 2008 - FY 2017

As demonstrated by Figure 1, WPTO has supported MHK technology development continuously since FY 2008. Funding has continued an upward trend since FY 2013, with almost $60 million dedicated to MHK in FY 2017, including $30 million to support the development of a flagship test facility for wave energy devices at Oregon State University's Pacific Marine Energy Center (PMEC).

Between FY 2008 and FY 2017, WPTO funded MHK research in four main topic areas: (1) MHK system design and validation; (2) testing infrastructure; (3) environmental monitoring and instrumentation development and research; and (4) resource characterization. Work in each topic area provides the MHK industry with fundamental tools, research, and innovations that tackle specific challenges hindering MHK development. These challenges include difficult engineering requirements, harsh deployment environments, prohibitive barriers to testing, and market immaturity. The aggregate result from work in these four main topic areas is fundamental science and engineering knowledge—the bedrock for a successful, market-driven MHK industry. Table 1 illustrates the topic areas receiving investment from FY 2008 to FY 2017.

Topic Area	Total Funding	Percent of Total
MHK System Design & Validation	$ 214,161,845	65%
Testing Infrastructure	$ 48,795,891	15%
Environmental Monitoring Instrumentation Development & Research	$ 45,776,104	14%
Resource Characterization	$ 18,699,120	6%

Table 1: MHK Topic Area Distribution

MHK system design and validation encompasses the research, design, development, and validation of MHK energy devices and the components that comprise them. By investing time and effort into each component, manufacturers can improve the overall reliability and performance of complete devices and arrays. Major milestones achieved with this funding include the successful Wave Energy Prize competition, which pushed developers to achieve game-changing device efficiency increases, and the Azura wave energy device validation, which showed remarkable device reliability with over 19 months at sea, including survival through two hurricanes. Additionally, funding in this topic area supports the creation of instrumentation, modeling, and simulation tools to enable real-condition analysis of technologies. Modeling tools enable developers to reduce overall costs, reduce design iterations, and gather information on optimal configurations and locations for devices. Modeling tools can also provide baseline information on operation and installation costs and environmental impacts. A quintessential project in this topic area is the development of the wave energy converter simulation tool (WEC-Sim), an open source numerical modeling code developed by the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL). 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 industry with an essential open-source tool to model their wave energy devices.

Testing Infrastructure has supported national assessments of testing infrastructure and needs, the development of testing facilities (including open-water, grid-connected facilities), as well as instrumentation systems dedicated to high resolution data acquisition. Testing of wave energy systems is essential to understanding device-ocean interactions and improving early-stage designs. The program has partnered with five universities to create three National Marine Renewable Energy Centers (NMRECs) to incubate advanced marine and hydrokinetic technologies. The Hawaii National Marine Renewable Energy Center (HINMREC), operated by the University of Hawaii, emphasizes wave energy and ocean thermal energy conversion and supports collaborative research at the wave energy test site operated by the U.S. Navy. The Southeast National Marine Renewable Energy Center (SNMREC), operated by Florida Atlantic University, focuses on ocean currents and ocean thermal energy conversion and specializes in environmental baseline observation systems. The Northwest National Marine Renewable Energy Center (NNMREC), operated by Oregon State University, University of Washington, and

University of Alaska Fairbanks, focuses on wave and currents (tidal and river) and specializes in performing research that fills technical, environmental, and social knowledge gaps of ocean energy technologies. In 2017, Oregon State University's Pacific Marine Energy Center-South Energy Test Site (PMEC-SETS), was selected as the site for a new national wave energy test facility. A pre-permitted, grid-connected, open-ocean test facility in an area with extremely robust wave climates will help device developers bridge a major gap to commercialization—access to economical testing. The site was designed to meet the Energy Department's specifications as well as industry and community needs, letting researchers focus on the technological challenges inherent in testing—instead of spending significant time and funding on permitting and site development issues. The PMEC-SETS site is expected to be a flagship test facility for wave energy devices globally.

Environmental Monitoring Instrumentation Development and Research includes support for research into the potential effects of MHK technologies on aquatic ecosystems, including how to avoid or mitigate such effects when possible. DOE also supports the development of tools and technologies to conduct the research itself and produce the data to validate the compatibility of these new technologies with aquatic ecosystems. Minimizing or retiring potential environmental risks can accelerate the permitting process for MHK devices and significantly reduce overall costs of testing devices and developing MHK energy projects. Florida Atlantic University, for example, developed a potentially revolutionary new monitoring system that uses pulses of light known as LIDAR (light detection and ranging) to determine the location and movement of objects under water where other systems struggle to produce useful results. The system provides automated tracking and classification of marine species near MHK equipment, providing high-resolution imagery of their behavior, which helps reduce the environmental impacts of MHK technologies. Automation in tracking and classification of fish and marine mammals is also essential to lowering the cost of environmental monitoring—limiting both work hours for analysis and the cost associated with collecting enormous amounts of data from around-the-clock observation and recording, known as "data mortgages".

Resource Characterization supports assessments and analysis of MHK energy resources across the United States. Resource characterization is a fundamental step to device design processes to harness the energy available in U.S. rivers and oceans. Creating and using resource assessments will enable the MHK industry to make better informed project siting and investment decisions, which also de-risks projects for potential investors—a prerequisite to commercialization. WPTO assessments have shown that developing just a fraction of available wave energy resources, for instance, could power millions of American homes and businesses. One project underway is helping Department of Defense branches understand which of their bases have the highest potential for MHK deployment. With WPTO funding, NREL is performing in-depth site characterization of the military's most promising bases.

1. Public and Private Partnerships

WPTO invests in projects spearheaded by a wide range of organizations, including private industry, National Laboratories, universities, local governments, tribal governments, nonprofits, and public utilities. From FY 2008 to FY 2017, more than one third (37%) of the 228 projects were awarded to private companies, 28% went to universities or colleges, and 33% went to National Laboratories. The remaining 2% was distributed among tribal governments, local governments, nonprofits, and public utilities (see Figure 2: MHK Funding Distribution by Recipient/Partner).

WPTO's focus on driving down the cost of MHK energy places an emphasis on selecting the appropriate funding recipients for a particular project, based on expertise, the type of research needed, and other considerations. Typically projects pertaining to device-specific design and manufacturing are awarded to private industry, as they are well-suited to develop and hold patents and can leverage cost-share funds. For example, WPTO selected both ABB and Columbia Power Technologies to develop innovative generators intended for specific wave energy devices. Providing industry with support to develop early-stage, high-risk technology will lead to the creation of a deep pipeline of projects with larger cost shares at later stages of development. On the other hand, projects that are technology-neutral and apply to the industry broadly—such as resource characterization, instrumentation, or computer modeling tools—are usually undertaken by national laboratories or universities. The Pacific Northwest National Laboratory (PNNL), for example, is focused on developing new environmental monitoring technologies through its Triton initiative. Triton takes advantage of the DOE's only marine sciences laboratory by providing a site that is pre-permitted for the testing of environmental monitoring technologies, while also providing on-site testing and logistical support. The Project aims to make environmental monitoring more effective and improve the understanding of sensitivities and risks around interactions with devices; thus reducing the cost in time and money of permitting through a more streamlined environmental evaluation process.

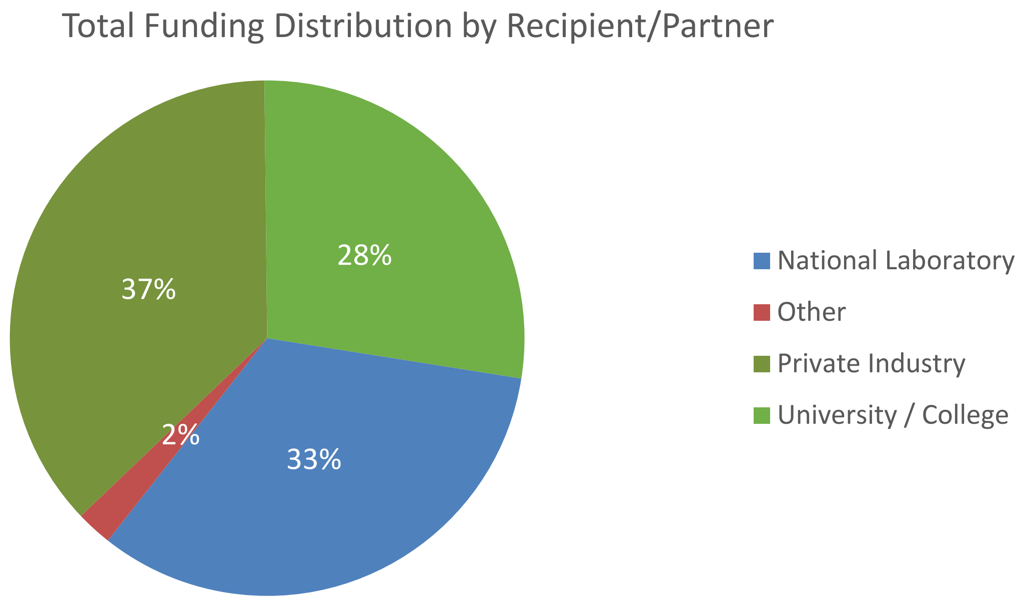


Figure 2: MHK Funding Distribution by Recipient/Partner

2. Project Partnerships

In addition to the 87 unique recipients of FOA awards and Annual Operating Plan (AOP) funding, many strategic partnerships have been fostered by WPTO. As an example, the original NMRECs established in 2008 are led by Universities, though bring in National Lab expertise. Together, they collaborate on the overall goal of supporting and advancing the MHK industry and have partnered with dozens of industry members as a result; the Northwest Marine Renewable Energy Center has grown its Industry Partner Network (IPN) to more than 30 members. Many recipients rely on subcontractors and other industry specialists for subject matter expertise, advanced technologies, and best practices. These partnerships were achieved through collaboration among the WPTO, private industry, universities, and a variety of other entities. This expands the diversity of the WPTO network and allows for greater information sharing. For example, North Dakota State University (NDSU) partnered with SNL for a project focused on developing advanced materials in 2014. This project, aimed at improving materials and coatings for composites in MHK device designs, provided a tremendous opportunity for the experts at NDSU to share key information on antifouling coatings and biofouling evaluation. The project was successful in providing an open-source database on composite materials and structures, mitigating biofouling effects, and diminishing metal-carbon fiber interconnect corrosion in salt water. Because of the previously limited datasets available on MHK composite performance, the open-source database is an invaluable tool for the MHK industry, contributing to lightweight modular designs and corrosion resistance.

Examples of successful partnerships are found in the private sector, as well. In 2015, the engineering firm Andrews-Cooper formed a partnership with SNL for their wave energy converter modeling project. The project developed open-source wave energy converter simulation tools to reduce design uncertainty, improve power performance, and improve survivability in extreme conditions. To effectively develop the software, SNL needed the simulation features to be experimentally validated through scale-model testing. Andrews-Cooper provided a custom design to fit that need and tested their model in the O.H. Hinsdale Research Laboratory at Oregon State University. Not only did this test validate software parameters, but also provided a repeatable methodology for extreme condition modeling analysis that can be adopted elsewhere in the wave energy industry.

Additionally, WPTO awards catalyze partnerships among private companies. During the ongoing project "Survivability Enhancement of a Multi-Mode Point Absorber," awardee Oscilla Power formed a partnership with the engineering firm Glosten to reduce the cost of survivability for Oscilla Power's Triton wave energy converter (WEC). The project sought to mitigate the risk of component, tether, and system failures in extreme conditions by developing and optimizing survival configurations for the WEC. Glosten offered expertise in naval architecture and marine engineering in development of survival configurations. Improvements from this project are highly transferrable to other WECs, leading to lower cost and risk for developers and investors throughout the MHK industry. This knowledge transfer not only brought value to Oscilla Power, but also improved other WEC designs, as well.

Partnerships like these encourage the industry to build upon itself and share best practices throughout the community. They are a vital part of the overall success of MHK technology development. An expanded list of project partners can be found in Appendix 1: Expanded List of Partnerships.

3. Geographic Distribution of MHK projects

MHK technologies convert the energy from waves, tides, and currents into electricity. Just as many early wind farms and solar projects were situated in high-resource areas, MHK projects have also gravitated toward regions with plentiful resources. The coasts—and the Pacific Northwest, in particular—have been attractive to MHK researchers and technology developers alike, including the NNMREC, PNNL, AquaHarmonics, Columbia Power Technologies, Northwest Energy Innovations, M3 Wave, and Oscilla Power just to name a few. Nevertheless, WPTO has developed a geographically diverse research and development portfolio, with significant efforts occurring countrywide. At Sandia National Laboratories, in Albuquerque, New Mexico, critical early stage research is moving the market forward with high-fidelity computer models to simulate ocean-device interactions, leading-edge advanced materials research to drive down device cost, and innovative controls development to increase device efficiency, among other projects. Another industry-led research project with the Electric Power Research Institute (EPRI) and U.C. Davis in California, which was co-funded with the Bureau of Ocean Energy Management, produced a seminal study evaluating potential electro-magnetic field (EMF) impacts to marine life from existing subsea transmission cables, finding no significant impacts. This type of work, which retires or increases our understanding of environmental risks, is fundamental to the long-term success of the MHK industry. Increased knowledge about risks shortens and reduces the cost of permitting, a complex hurdle to testing and eventual commercialization that prohibitively burdens MHK developers in the early stages of the industry's growth, when information and data are not readily available and perceived risks are high.

Funding recipients also represent a broad range of industry stakeholders located throughout the country. The distribution of regional spending is demonstrated in Table 2 below:

Region	Region Total Funding	Division	Division Total Funding
West	$241,455,910	Mountain	$83,857,543
		Pacific	$157,598,366
South	$25,746,438	East South Central	$5,025,529
		South Atlantic	$18,937,008
		West South Central	$1,384,503
Northeast	$41,055,484	Middle Atlantic	$11,004,174
		New England	$30,051,310
Midwest	$10,361,500	East North Central	$9,202,954
		West North Central	$159,972
Multi-regional	$10,211,600	Multi-regional	$10,211,600
Grand Total			**$327,432,959**

Table 2: Regional Distribution of MHK Funding

The map below demonstrates the distribution of WPTO funding relative to MHK energy resource opportunity areas.

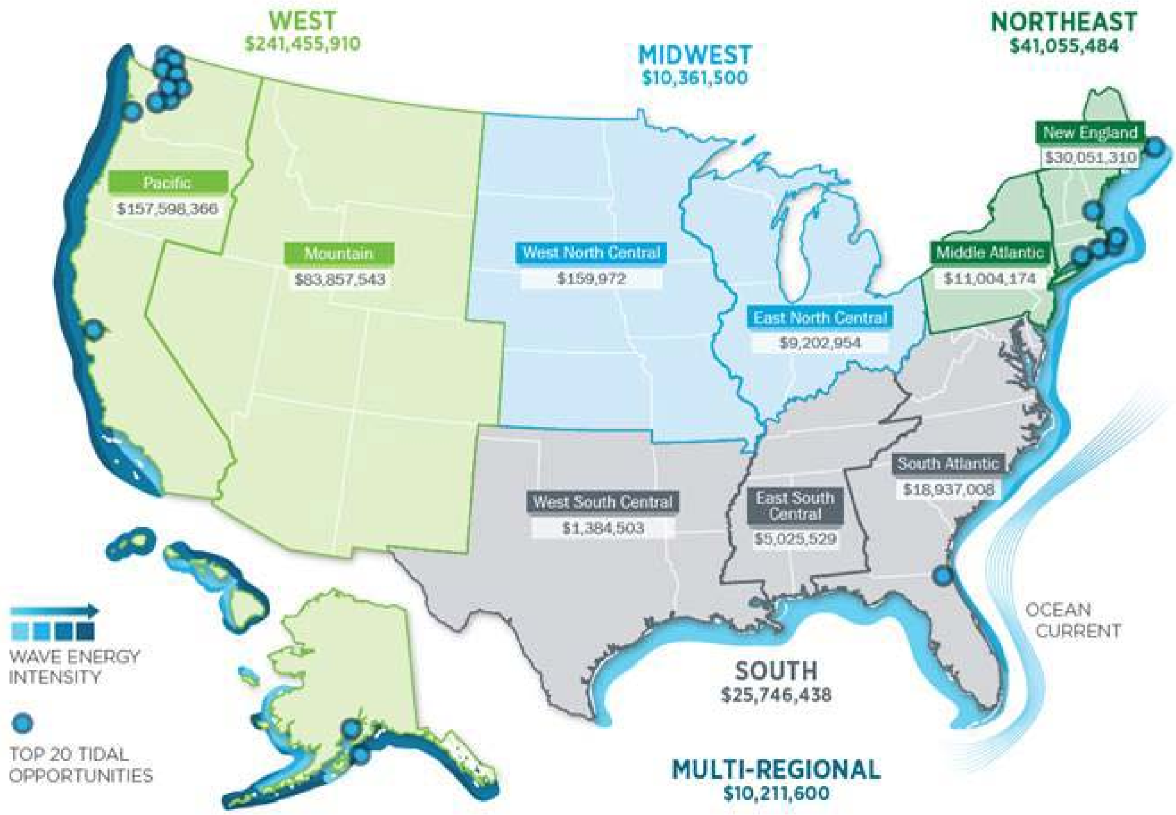


Figure 3: Combined MHK Funding Distribution from 2008 to 2017 and MHK Resource Potential

Figure 3 illustrates WPTO funding for MHK projects in geographic regions and MHK resource potential across the United States. Greater wave energy resources are indicated with darker blue shading along the coasts. As previously described, MHK research tends to occur near areas with substantial MHK resources, such as in Pacific states and New England. Still, several projects focused on topics ranging from resource characterization projects at Georgia Tech University to development and testing of a new river-current technology design in Minnesota, have occurred and are occurring across the country. In fact, there have been and currently are 27 states with projects related to MHK.

WPTO funding flows through multiple vehicles, topic areas, and locations. This breakdown across multiple variables is illustrated in the Sankey-style diagram below, which shows the proportional flow of funding across the portfolio.

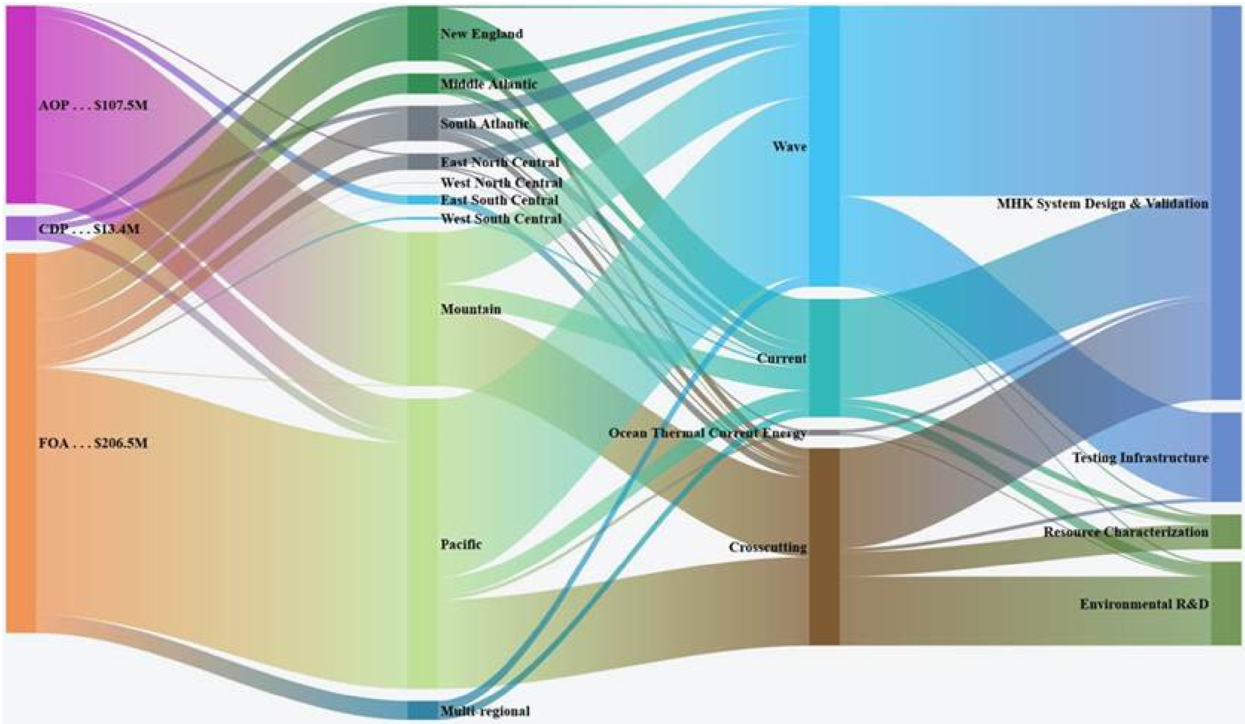


Figure 4: Representation of WPTO MHK R&D Funding Across Multiple Variables

As demonstrated in Figure 4, between FY 2008 and FY2017 the vast majority of WPTO funding was distributed through FOAs and to the national labs through AOPs, with a few additional Congressionally Directed Projects (CDP). Funding distributions are also represented across different regions within the U.S., with each distinct region showing some MHK R&D footprint. Next, funding is classified by the resource type to which the research applies. Wave energy represents a large portion of funding, but many other projects can be considered crosscutting (meaning they will produce results that benefit multiple technology/resource types). Finally, the breakdown of funding on the right side of the diagram illustrates the four research topic areas previously mentioned, with MHK system design and validation receiving the largest percentage of funding. This diagram demonstrates the vast array of topic areas, geographies, resource types, and funding vehicles that WPTO utilizes in order to achieve a fully ubiquitous MHK footprint across the country.

4. Program Performance

While diversity of funding is of high salience to WPTO, it is also important to measure the effectiveness of dollars spent. In February 2017, WPTO conducted an independent, public peer review of its portfolio of projects. The intent of peer review is to provide third-party, unbiased, and broad-minded review of WPTO strategy and the success/relevance of individual projects. Approximately 90% of the program funding allocated to projects was reviewed. Peer review is defined as:

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

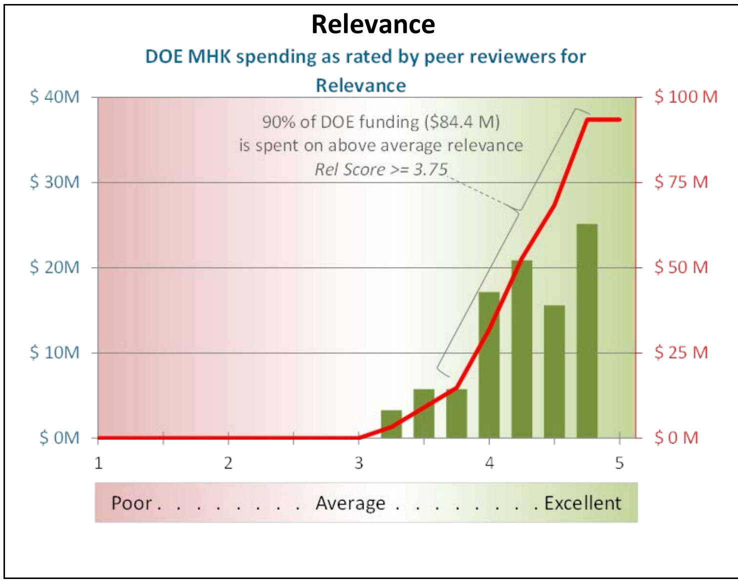
Peer reviewers score a set of metrics on a scale of one (low) to five (high). The individual metrics are scaled down to two important measures: relevance and performance. They are defined below.

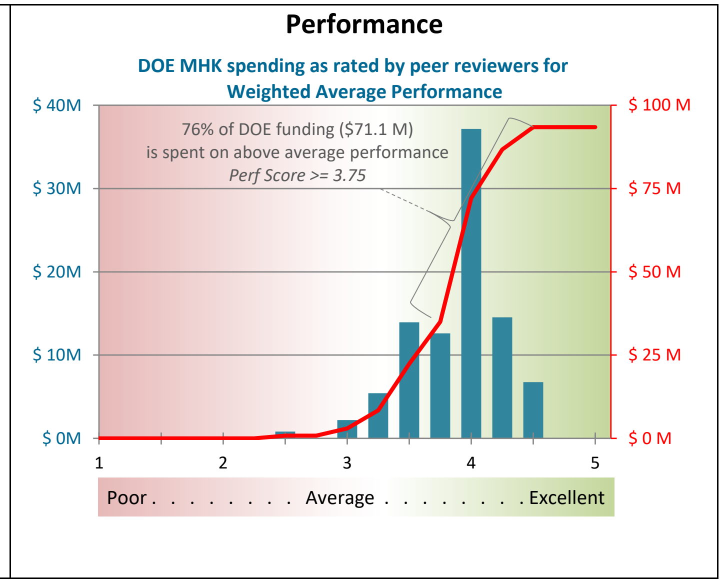
- Relevance: The degree to which the project aligns with objectives and goals of the Water Power Technologies Office and meets the needs of the water power industry at-large.
- Performance: A collection of factors including research methodology, technical accomplishments, project management, collaboration and technology transfer, and proposed future research.

Using these two measures, the 2017 peer review findings represent a useful aggregated assessment of accomplishments and value of WPTO-supported R&D activities for the time period being considered for this review (projects which received some amount of funding in either FY 2014, FY 2015, or FY 2016). The graphs below show how much funding, of the projects subject to review in 2017, was allocated at each scoring bin (0.25 points per bin). Using a scoring threshold of >= 3.75 to indicate positive reviewer scores:

- Relevance: 90% of all WPTO funding reviewed received positive relevance scores.
- Performance: 76% of WPTO funding reviewed ($71.1 M) received positive performance scores.

According to third-party peer reviewers, the MHK program is allocating the majority of its resources to relevant and high-value research topics and generally getting positive and impactful results.

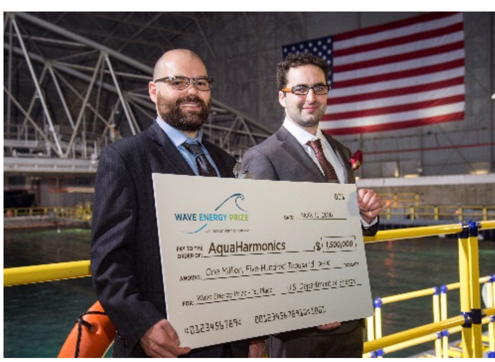


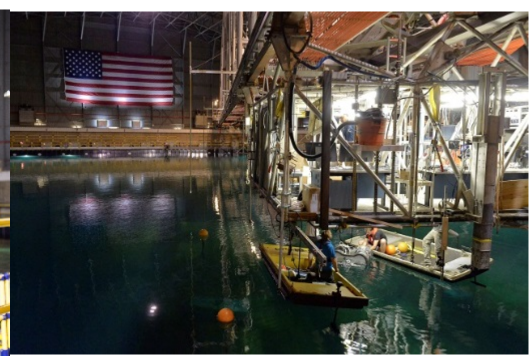


5. Selected Results

The selected results below exemplify success in early stage research, contributing greatly to the development of MHK technologies. A list of projects and more information can be found on the Water Power Technology Office's online projects map [https://energy.gov/eere/water/water-power-technologies-office-projects-map].

Carderock, Maryland: The Wave Energy Prize (2016)





This project catalyzed a major technology leap in wave energy. The winning team, a brand new wave energy device development company at a very early stage of design, demonstrated a five-fold improvement upon established baseline device efficiency and showed the tremendous potential for continued future cost-reductions. Ninety-two teams registered for the prize, and four teams exceeded the DOE goal of doubling energy capture potential from wave energy devices. The DOE partnered with the U.S. Navy on the competition, with final tests occurring at the Naval Surface Warfare Center's Maneuvering and Seakeeping Basin at Carderock—the Nation's most advanced wave-making facility—during the summer of 2016.

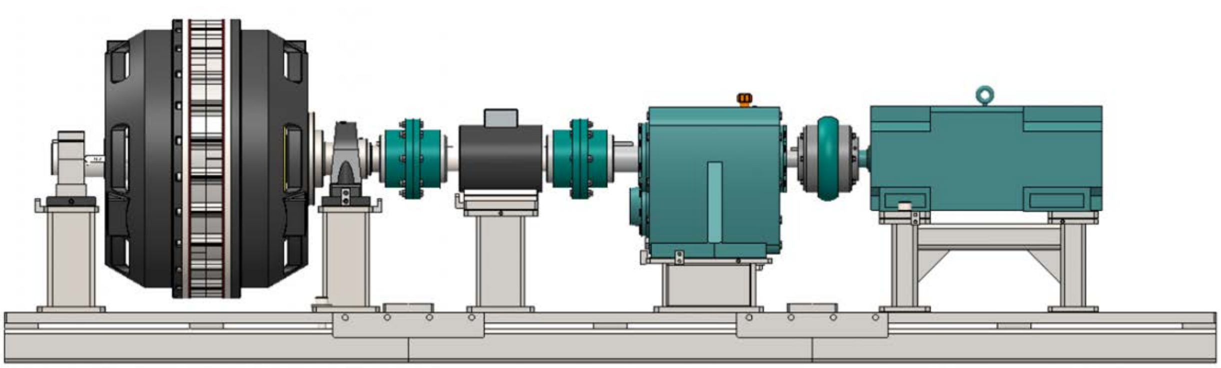
O'ahu, Hawaii: Northwest Energy Innovations (2015-2016)

This 20-kW technology research and testing project, Azura, was the Nation's first 3rd party validated grid-connected, open-ocean wave energy project. Azura demonstrated remarkable reliability, with 98% uptime over 19 months, and survival through hurricanes Ignacio and Lester. The device survived extreme sea conditions, with significant wave height up to 4.5m and individual waves up to 7.5m. The device validated electricity price models while also increasing knowledge of operations and maintenance costs. With testing conducted at the Navy's wave energy test facility off of the Marine Corps Base on Oahu, Hawaii from 2015 to 2016, the project showcased military, industry, agency and university cooperation.

Igiugig, Alaska: The Ocean Renewable Power Company (2015)

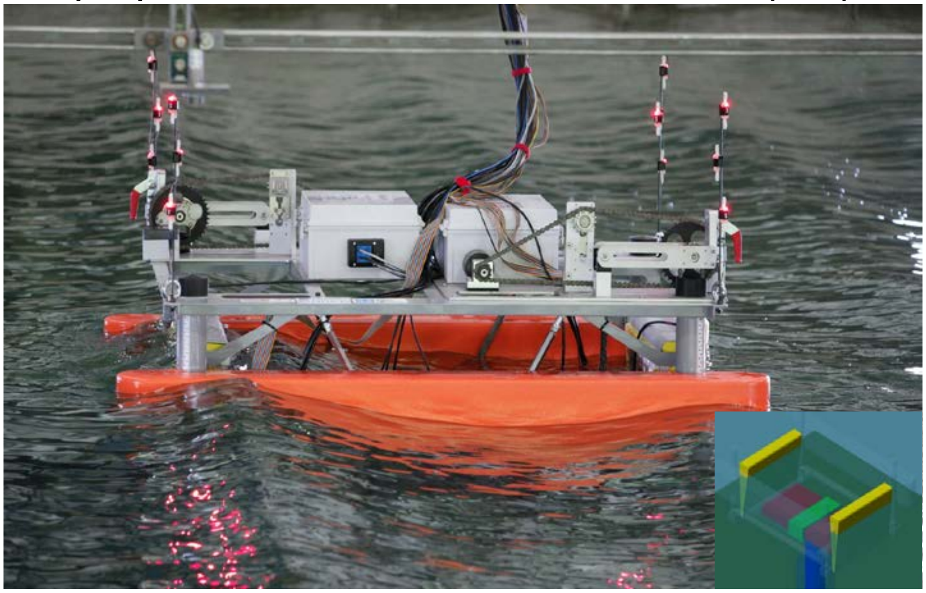
The RivGen river current energy project conducted successful tests and delivered power to a remote fishing village in Alaska while providing information about the reliability of tidal/river energy devices in extreme conditions. The test also demonstrated the viability of a near-term MHK market—remote areas with high electricity costs. Electricity for Igiugig is typically generated with diesel fuel, flown in at a cost of nearly $1/kWh. In addition, environmental monitoring showed no negative impact on fish, which are of great importance to the local economy.

Raleigh, North Carolina: ABB (2016)



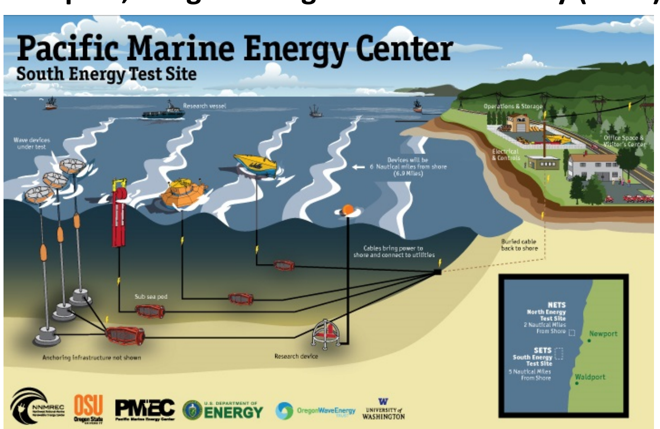
This project successfully built and tested one of the world's largest magnetically geared generators for direct-drive applications. Tests at ABB's corporate research lab in Raleigh indicated the generator could be ideal for low-speed, high-torque applications—which describes the challenging power dynamic wave energy devices encounter at sea—and provide increased reliability. Results showed the technology could possibly be used in other industries, as well, such as wind and tidal energy. ABB partnered with Boston-based device manufacturer Resolute Marine Energy to support the design and potential integration of this next-generation generator into a future wave energy device.

Albuquerque, New Mexico: Sandia National Laboratories (2014)



This project's work to develop open-source computer modeling tools provides foundational research that enables industry to advance MHK technologies. WEC-Sim, which was released in 2014 and updated in 2016, is used by industry—including contestants in the Wave Energy Prize—to efficiently model the power and structural performance of a wave energy converter in different ocean conditions. Accurate and validated modeling tools are necessary for device developers to quickly evaluate design alternatives to improve performance and harness more of the power in waves at a lower cost, advancing the industry.

Newport, Oregon: Oregon State University (2016)



Oregon State University, through a competitive funding process that concluded in 2016, will construct and operate the Pacific Marine Energy Center-South Energy Test Site (PMEC-SETS), a pre-permitted and grid-connected facility to help wave energy device developers bridge a major gap to commercialization—access to economical testing. Testing of wave energy systems is essential to understanding complex device-ocean interactions and improving early-stage designs. Initial operation of this world-class facility is expected beginning summer 2021.

Denver, Colorado: Columbia Power Technologies (CPwr) (2017)

Columbia Power Technologies, a wave energy device developer, in early 2017 began tests of a prototype generator connected to the 5-MW dynamometer at the National Renewable Energy Laboratory's National Wind Technology Center (NWTC). The tests demonstrated cross-over utility for the NWTC's dynamometer, which can simulate ocean-like conditions to economically test generators on land. A successful demonstration of the 6.5m-diameter permanent-magnet generator is expected to confirm industry's ability to further reduce the cost of wave energy through generator air-gap reductions to 2mm or less on future systems.

6. Closing Remarks

While MHK energy is still a nascent market, the Water Power Technologies Office has observed growing interest in the significant potential of MHK energy technologies to power millions of U.S. homes and businesses as well as distributed applications, like forward-operating military bases, remote communities, and maritime communication networks. WPTO drives U.S. leadership in marine energy research and development and has quickly become one of the major players catalyzing MHK technology advancement around the world. More details on specific projects can be found on WPTO's online projects map [https://energy.gov/eere/water/water-power-technologies-office-projects-map] and by consulting the MHK Data Repository found here: https://mhkdr.openei.org/. The office looks forward to continued interest and providing any additional information as requested.

Appendix 1: Expanded List of Partnerships

WPTO provides funding to a wide variety of organization types, who may choose to partner with other organizations to complete a project. Some project partners include:

3U Technologies
48 North Solutions
ABB
AeroCraft
Alaska Hydrokinetic Energy Research Center
Andrews-Cooper
AquaHarmonics
ATA Engineering
Baldor Advanced Technology
BioSonics Inc.
Black & Veatch
California Natural Resources Agency
California Polytechnic State University, San Luis Obispo, Institute for Advanced Technology and Public Policy
CalWave
CH2M
Columbia Power Technologies
Cruz Atcheson
Dehlsen Associates LLC
DNV-GL
Dresser-Rand
Electric Power Research Institute
Energy Hydraulics Ltd.
Ershigs Inc.
Fish4Knowledge
Florida Atlantic University
Fontana Engineering
Glosten
Greenberry
H.T. Harvey & Associates
Harbor Branch Oceanographic Institute
HDR Engineering
HydroGroup
Integral Consulting Inc.
Johns Hopkins Applied Physics Laboratory
JZ Consulting, LLC
Northern Power Systems
Northwest Energy Innovations
Northwest National Marine Renewable Energy Center
Ocean Energy Limited
Ocean Power Technologies
Ocean Renewable Power Company
OceanGybe Environmental
Omega Engineers
Oregon State University
Oregon Wave Energy Trust
Oscilla Power
Pacific Energy Ventures
Pacific Gas & Electric Company
Pacific Northwest National Laboratory
Penn State Applied Research Laboratory
Protean Wave Energy LLC
Ramboll
RCT Systems
Re Vision Consulting
Resolute Marine Energy Inc.
RG Consulting
Rolls-Royce Marine
Sandia National Laboratories
Sea Engineering
Siemens
SMRU Consulting
SpenTech
Stoel Rives
Sustainable Energy Authority of Ireland
Texas A&M University
The Center for Environmental Studies
The Charles E. Schmidt College of Science
The Pennsylvania State University
THK North America Inc.
Tritec Marine USA

Katon
Kearns & West
Kongsberg Underwater Technology, Inc.
Leidos
M3 Wave
Makai Engineering
Marine Energy Council of the National Hydropower Association
McClear Power
Michigan Technical University
National Renewable Energy Laboratory
National Taiwan Ocean University
Naval Surface Warfare Center Carderock Division
NAVFAC
North Carolina State University
UK Wave Hub
University of Alaska Fairbanks
University of California, Davis
University of California, San Diego, Scripps Institute of Oceanography
University of Edinburgh
University of New Hampshire
University of Texas at Austin
University of Washington
Virginia Polytechnic Institute and State University
Wave Venture
Wedge Global
William Lyte
Woods Hole Oceanographic Institute