U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WIND AND WATER POWER TECHNOLOGIES OFFICE

U.S. Department of Energy Wind and Water Power Technologies Office Funding in the United States:

MARINE AND HYDROKINETIC ENERGY PROJECTS

Fiscal Years 2008 - 2012

Marine and Hydrokinetic Research and Development

Introduction

Wind and Water Power Technologies Office

The Wind and Water Power Technologies Office (WWPTO), within the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE), supports the development, deployment, and commercialization of wind and water power technologies. WWPTO works with a variety of stakeholders to identify and support research and development (R&D) efforts that improve technology performance, lower costs, and—ultimately—deploy technologies that efficiently capture the abundant wind and water energy resources in the United States. WWPTO is one office that contains two distinct focus programs: wind and water. The Wind Program and the Water Power Program operate as integrated, but separate entities within WWPTO.

From Fiscal Year (FY) 2008 to FY 2012, WWPTO provided R&D funding across eight broad areas:

1. Conventional Hydropower Projects
2. Marine and Hydrokinetic Projects
3. Offshore Wind Projects
4. Wind Turbine Projects
5. Wind Integration Projects
6. Environmental Impacts of Wind Projects
7. Wind Market Acceptance Projects
8. Wind Workforce Development Projects.

The breakdown of WWPTO funding is presented in a series of reports that showcase the projects funded in each of the eight above mentioned areas.

Marine and Hydrokinetic Technology

The energy from waves, tides, ocean currents, the natural flow of water in rivers, and marine thermal gradients can be captured to generate new sources of clean and renewable electricity. Although the marine and hydrokinetic (MHK) industry is at a relatively early stage of development compared to other renewable energy technologies (such as wind and solar power), the rivers, coasts, and oceans of the United States represent significant potential as a renewable energy resource. The United States uses about 4,000 terawatt hours of electricity per year. DOE estimates that the maximum theoretical electric generation that could be produced from waves, tidal and riverine currents, and ocean thermal energy gradients in U.S. waters is approximately 2,116 terawatt hours per year, more than half of the nation's total annual electricity usage. Although not all of this resource potential can realistically be developed, the nation's enormous MHK energy potential still represents major opportunities for new water power development in the United States.[1]

Photo credit: Alison LaBonte

Verdant Power installs a testing device in the East River of New York City on August 29, 2012. Testing took 2 weeks and looked at new rotors and composite blades.

The Water Power Program helps industry develop and optimize MHK technologies that can harness this renewable, emissions-free resource to generate environmentally sustainable and cost-effective electricity. Through support for public, private, and nonprofit efforts, the Water Power Program promotes MHK technology development and testing in laboratory and open water settings, while gathering the operational, environmental, and market data needed to accelerate the responsible deployment and commercialization of MHK technologies. The Water Power Program works to assess the potential extractable energy from domestic water resources and to reduce the resources required for siting MHK power projects in order to assist industry and government in planning for the nation's energy future. In addition, the Water Power Program recognized a lack of standardized descriptions for the stages of technology development for the wide range of devices and systems within the emerging MHK industry. In FY 2010, the Water Power Program incorporated Technology Readiness Levels (TRLs) into the Funding Opportunity Announcement process to enable consistent and uniform discussions regarding MHK technologies.

From FY 2008 to FY 2012, the Water Power Program announced awards totaling nearly $100 million for 67 projects focused on MHK energy. Table 1 provides a brief description of these projects. There are two sources of funding for MHK projects covered in this report: competitive Funding Opportunity Announcements (funded by Congressional Appropriations) and Congressionally Directed Projects.

Types of Funding Sources

WWPTO R&D projects covered in this report are financed through two primary sources of funding: Congressional Appropriations and Congressionally Directed Projects (CDPs). Congressional Appropriations determine the operating budgets for each EERE office. WWPTO-funded R&D projects are typically awarded to recipients as grants through competitive Funding Opportunity Announcements (FOAs) that are dedicated to specific topic areas. CDPs are also funded by Congress, but are outside of the annual federal budget process. Frequently, there is a cost-share requirement for recipients of both competitive FOA grants and CDPs.

WWPTO also funds research projects at DOE's national laboratories through the laboratories' annual operating plans. This funding is not detailed in this report. However, a national laboratory may be a lead or a partner on a competitively awarded project covered in this report. In these cases, the national laboratory is identified as the lead or partner in the appropriate project descriptions.

The Small Business Innovation Research (SBIR) program in DOE's Office of Science and the Advanced Research Projects Agency-Energy (ARPA-E) provide competitive awards-based funding for domestic small businesses engaging in R&D of innovative technology. SBIR and ARPA-E have funded MHK R&D projects; however, these projects are not covered in this report.

Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Atargis Energy Corporation	Cycloidal Wave Energy Converter	$400,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Colorado
Project Description				
Atargis Energy has designed, constructed and is testing a 1:10 scale model of its Cycloidal Wave Energy Converter (CyCWEC) at the Texas A&M Offshore Technology Research Center. The CycWEC is designed to address storm survival and energy costs—two issues that hamper many wave energy converters currently under development. The DOE-supported work will demonstrate on a kilowatt scale the world's first fully submerged wave energy converter system capable of cancelling deep ocean waves using hydrofoil lift. Laboratory tests and simulations have achieved 99% wave cancellation. System modeling indicates greater than 70% overall wave-to-electric power conversion efficiency and levelized cost of energy below 14 cents per kilowatt hour are attainable.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Bayer MaterialScience, LLC	River Devices to Recover Energy with Advanced Materials (River DREAM)	$240,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Pennsylvania
Project Description				
Bayer MaterialScience is developing a new concept for hydroelectric energy generation from low-head water resources. Bayer has estimated 21,000 megawatts of existing low-head water resources in the United States, but these resources presently lack a technology to effectively harvest energy. The Bayer concept is low profile and largely non-invasive and is expected to leave rivers usable, aesthetically pleasing, and ecologically viable. The successful completion of the project will result in the creation of a model able to fully define the operating parameters and performance capabilities of a generator based on the Galloping Hydroelectric Energy Extraction Device design. The resulting information will be used in the next phase of product development and to create an integrated laboratory scale generator to confirm model predictions. The successful development of this new concept could help advance the MHK industry toward capturing low-head water resources in the United States.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Columbia Power Technologies, Inc.	Direct Drive Wave Energy Buoy	$1,417,990	FY09 Advanced Water Power FOA	Virginia, Washington
Project Description				
Columbia Power Technologies and their project partners completed a year-long deployment of a 7-ton intermediate-scale wave energy converter (WEC) to demonstrate and validate the technology in preparation for a full-scale ocean demonstration. The WEC technology was designed to capture energy through a highly-reliable rotary approach, absorbing up to twice the energy for a given surface area compared to existing technologies. Columbia Power Technologies used data produced during the deployment to optimize its WEC technology and increase its energy capture. Long term, Columbia Power Technologies expects to manufacture the technology in Oregon, estimating the demand for thousands of wave energy devices and hundreds of jobs over the next 10 to 15 years.				

[a] DOE Funding Amounts identified in this table reflect the total DOE funding planned for award to each project for the total period of project performance that may span multiple years. DOE Funding Amounts shown in this table may be subject to change.

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Columbia Power Technologies, Inc.	Benchmark Modeling of the Near-field and Far-field Wave Effects of Wave Energy Arrays	$598,154	FY09 Advanced Water Power FOA	Virginia, Oregon
Project Description				
Columbia Power Technologies and Oregon State University (OSU), through an industry-led partnership, performed benchmarking experiments and numerical modeling on arrays of wave energy converters. The experimental observations helped fill a knowledge gap in the near-field effects of multiple, floating wave energy converters and are critical for estimating the potential far-field environmental effects of wave energy arrays. The experiments have been performed at the Hinsdale Wave Research Laboratory at OSU by subjecting an array of newly developed "Smart Buoys" (lab-scale floating power converters) to conditions expected off the central Oregon coast. The resulting data are an important resource for testing models for wave/buoy interactions, buoy performance, and far-field effects on wave and current patterns due to the presence of arrays.			

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Columbia Power Technologies, Inc.	Direct Drive Wave Energy Buoy	$1,500,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Virginia, Washington
Project Description				
Columbia Power Technologies, through an industry-led partnership, is designing a small-scale wave energy converter with directionionally dependent device weathervanes to face into oncoming waves using a single mooring line. The design uses fore and aft floats that move independently and are attached to seperate drive shafts, each of which is connected to a direct drive, permanent magnet generator. The direct drive design creates a maintenance advantage by removing the need for gearboxes or hydraulics. The asymmetrical fore and aft float geometry design allows for float hard stop capabilties during extreme events and will decrease costs by $400 thousand per unit. The levelized cost of electricity is projected to improve by 60% to 13 cents per kilowatt hour.			

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Concepts ETI, Inc.	Development and Demonstration of a Wave Energy Converter System	$1,195,456	FY08 Advanced Water Power Projects FOA	Vermont, Hawaii
Project Description				
Concepts ETI and Oceanlinx are developing a robust, maintainable, and commercially viable nominal 600 kilowatt wave energy converter (WEC) system to be deployed as part of a $10 million program being undertaken by Oceanlinx. The project focuses on the design and manufacturing of a second-generation variable pitch turbine with improved efficiency and reliability to be deployed offshore for testing and grid connection evaluation in Maui, Hawaii. The project aims to improve overall power recovery efficiency by as much as 50%, using also a pneumatic energy storage technique, compared to the current state-of-the-art WEC systems. The full-scale demonstration will serve to validate the technology design approach, energy recovery efficiency, eliability, and system economics. The successful operation of the system will serve as an important milestone in the commercialization pathway of ocean wave power recovery systems.			

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Dehlsen Associates, LLC	Aquantis C-Plane Ocean Current Turbine Project	$3,900,000	FY10 MHK Technology Readiness Advancement Initiative FOA, FY09 Advanced Water Power FOA	California, Florida, Pennsylvania, Maryland, Virginia
Project Description				
Dehlsen Associates developed the Aquantis Current Plane (C-Plane™) technology, an ocean current turbine designed to extract the kinetic energy from ocean currents. The C-Plane™ is capable of achieving continuous, reliable, and competitively-priced baseload power generation a high capacity factor. The project will conduct: (1) experimental validation of analytical tools/design; (2) a levelized cost of electricity model; (3) certification approvals; (4) a drawing package; and (5) direct drive development. Dehlsen plans to employ a systems integration effort to develop its commercial scale C-Plane™ Multi-Megawatt device. The successful completion of the project is expected to reduce risk in the following areas: energy extraction, dynamic stability, structural optimization, moorings, and attachments. Dehlsen estimates the impact of the C-Plane™ could result in more than 10,000 megawatts of clean, renewable, baseload energy extracted from the Gulf Steam.			

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Dehlsen Associates, LLC	Siting Study for a Hydrokinetic Energy Project Located Offshore Southeast Florida	$600,000	FY09 Advanced Water Power FOA	California, Florida
Project Description				
Dehlsen Associates is developing a siting study protocol and survey methodology for collecting baseline geophysical and benthic habitat data that can be used by MHK project developers and regulators to make initial project siting decisions that avoid or minimize adverse impacts to sensitive marine benthic habitat on the outer continental shelf off the coast of southeast Florida. The approach will help facilitate the licensing process for hydrokinetic and other ocean renewable energy projects within the study area and will assist in clarifying the baseline environmental data requirements as well as reduce the time, effort, and cost to site and permit future MHK facilities offshore of southeast Florida.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Electric Power Research Institute	Wave Energy Resource Assessment and GIS Database for the U.S.	$499,668	FY08 Advanced Water Power Projects FOA	California
Project Description				
The Electric Power Research Institute (EPRI) has performed an assessment of the total available and technically recoverable ocean wave energy resources for the United States. The final product includes a geospatial database, verified and validated by a third party that displays power densities for specific spatial coordinates. The assessment estimates 1,170 terawatt hours per year is technically recoverable from wave energy resources. The expected users of this product include policymakers, wave energy project developers, wave energy device and technology developers, investors, and universities. The results have been validated and incorporated into the National Renewable Energy Laboratory geospatial renewable energy database. The analysis and development of the geospatial database is expected to accelerate investigation of the nation's wave energy resources.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Electric Power Research Institute	Assessment of the Environmental Effects of Hydrokinetic Turbines on Fish: Desktop and Laboratory Flume Studies	$597,408	FY09 Advanced Water Power FOA	California
Project Description				
The Electric Power Research Institute (EPRI), in partnership with the United States Geological Survey Laboratory, is conducting desktop and flume studies to determine the potential for fish injury and mortality when encountering hydrokinetic turbines of various designs installed in tidal and river environments. Behavioral patterns are also being investigated to assess the potential for disruptions in the upstream and downstream movements of fish. A primary concern of regulatory agencies is how the operation of hydrokinetic turbines will impact local and migratory fish populations. The project aims to accurately and precisely determine the probability of blade strike and injury, and the behavior of fish as they encounter hydrokinetic turbines. The project will provide valuable data and information that can reduce costs and uncertainty for developers and resource and regulatory agencies.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Electric Power Research Institute	A First Assessment of U.S. In-Stream Hydrokinetic Energy Resources since the 1986 NYU Study	$380,978	FY09 Advanced Water Power FOA	California
Project Description				
The Electric Power Research Institute (EPRI) conducted research to assess the total available and the technically recoverable hydrokinetic energy from U.S. rivers. A comprehensive assessment of existing U.S. in-stream hydrokinetic resources did not previously exist and is of critical importance to the acceleration of the market for emerging hydrokinetic technologies. The project comprehensively assessed existing U.S. in-stream hydrokinetic resources and the achievable energy conversion rates possible by future hydrokinetic devices from that resource. The assessment estimates 101 terawatt hours per year, from approximately 20 gigawatts of installed capacity, is technically recoverable from hydrokinetic river energy resources.The final product includes a geospatial database, verified and validated by a third party, which displays power densities for specific spatial coordinates. The expected users of this product include policymakers, project developers, hydrokinetic energy device developers, investors, universities, nongovernmental organizations, environmental groups, DOE, the military, the U.S. Army Corps of Engineers, and the United States Geological Survey. The project is expected to accelerate investigation of the nation's in-stream hydrokinetic energy resources.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Florida Atlantic University	Southeast National Marine Renewable Energy Center	$4,939,375	FY10 CDP, FY09 CDP, FY08 Advanced Water Power Projects FOA	Florida
Project Description				
Florida Atlantic University (FAU) is the home of the Southeast National Marine Renewable Energy Center (SNMREC), a national open-ocean energy laboratory that advances research on the renewable energy resources of open-ocean current systems and ocean thermal energy conversion. SNMREC is building the capability, infrastructure, and strategic partnerships needed for testing hydrokinetic energy generation prototypes and related technologies in the open ocean. In the future, commercial-scale deployments of such systems, with the potential to provide significant base-load power, will depend critically on standardized testing procedures in the real-world operating environment. SNMREC works to identify, develop and test open-ocean current systems to meet this need. SNMREC focuses on: (1) technology testing and resource monitoring; (2) research on technological approaches to detection and mitigation of potential underwater collisions through the use of acoustic and video monitoring, underwater observatory technology, scale-model testing, and other methods, (3) environmental monitoring, demonstration and protocol enhancement; (4) development of an environmental assessment plan; and (5) education and public outreach. Research and development activities support multi-scale field testing of prototype generating systems and bridge the gap between basic science and commercialization of innovative open-ocean current systems that can generate significant amounts of clean, renewable ocean power.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Free Flow Energy, Inc.	Submersible Generator for Hydrokinetics	$160,000	FY10 MHK Technology Readiness Advancement Initiative FOA	New Hampshire
Project Description				
Free Flow Energy is designing a submersible generator as a separate critical subassembly optimized for MHK conditions and designed to couple with different turbine styles. For most existing large electro-mechanical assemblies found in manufacturing, industry, or renewable energy systems (such as wind), the generator is a separate and critical subassembly—not typically designed into the rotating turbine. Free Flow Energy is designing and optimizing a generator for use in a range of MHK systems and turbine styles that can be applied by MHK system designers into a complete system including the turbine, ducting, and supporting structure. The project brings together experienced motor/generator design professionals with leading U.S. academic researchers in the field of motor/generator design and leading U.S. component suppliers to design a generator specifically for the application and acceleration of current and tidal energy.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Free Flow Power Corporation	The Water-To-Wire Project	$1,384,503	FY09 Advanced Water Power FOA	Louisiana
Project Description				
The Free Flow Power (FFP) Water-to-Wire aims to evaluate and optimize the performance, environment, and cost factors of FFP hydrokinetic SmarTurbines™ through design analyses and Mississippi River deployments. Specific objectives are (1) Design, fabrication, and testing of a full-scale prototype turbine—Endpoint: functional generating hardware, (2) In-river deployment and testing of the full-scale prototype turbine—Endpoint: test data demonstrating performance, river environment, and resource potential, and (3) Design and analyses for the commercial scale infrastructure and sites—Endpoint: refined cost and design for complete array systems to provide launch point for next level deployments. The challenges include, (1) A lack of commercially operating hydrokinetic river systems in existence so uncertainty exists about the equipment performance in a relevant environment, (2) Commercial cost of capital and operation and maintenance for practical systems, and (3) The generation from the available resource that is practically achievable. The project results will provide a pathway and supporting data and demonstration results for FFP and all hydrokinetic developers to address the design and cost challenges associated with turbine siting, installation, and maintenance.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Georgia Tech Research Corporation	Assessment of Energy Production Potential from Tidal Streams in the United States	$469,299	FY08 Advanced Water Power Projects FOA	Georgia
Project Description				
Georgia Tech Research Corporation has configured an advanced ocean circulation model for simulations of the tidal flows in multiple computation domains comprising the coast of the United States. The research program advances the state-of-the-art and market penetration in tidal energy resource assessment by modeling the entire U.S. coastline for tidal current variations, developing numerical simulation, and using spatial analysis tools for use in the critical site selection process for energy converters. The completed assessment estimates 250 terawatt hours per year, from approximately 50 gigawatts of installed capacity, is technically recoverable from tidal current energy resources. The assessment has determined that over 90% of the technically recoverable resource is in Alaska. The accuracy of the model results have been validated by DOE's Oak Ridge National Laboratory by comparing the model results with measurements for numerous locations. The data can be viewed at tidalstreampower.gatech.edu.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Georgia Tech Research Corporation	Assessment of Energy Production Potential from Ocean Currents along the United States Coastline	$372,627	FY09 Advanced Water Power FOA	Georgia
Project Description				
Georgia Tech Research Corporation is developing a database on ocean current energy resource potential with participation from a group of experts in ocean circulation observations and modeling. Different sources of ocean current data will be synthesized, such as satellite observations, data assimilation models, in-situ measurements, and high frequency radar. The research project will advance the state-of-the-art and market penetration in ocean current energy resource assessment via contributions on numerous topics, including the synthesis of multiple sources and modalities of ocean current data along the entire U.S. coastline and the development of spatial analysis tools and their use to facilitate the critical site selection process for energy converters. The accuracy of the database will be validated by Oak Ridge National Laboratory by comparing the database with measurements for numerous locations. The velocity and power density probability distributions will be stored in a database, and several spatial analysis tools will be developed for the purpose of disseminating the data to the industry as well as the general public.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Harris Miller Miller & Hanson	Environmental Effects of Sediment Transport Alteration and Impacts of Protected Species: Edgartown Tidal Energy Project	$600,000	FY09 Advanced Water Power FOA	Massachusetts
Project Description				
Harris Miller Miller & Hanson (HMMH), along with Woods Hole Oceanographic Institution and the University of Massachusetts, Dartmouth's School of Marine Science and Technology, is conducting a feasibility study with the Town of Edgartown, Massachusetts on a tidal energy project in the Muskeget Channel. The island towns of Edgartown (on Martha's Vineyard) and Nantucket recognize that they are vulnerable to power supply interruptions due to their position at the end of the power grid, as well as due to potential sea level rise and other consequences of climate change. HMMH is working with both towns and the marine science community to explore the potential for developing sustainable energy resources from the ocean. The objective of the feasibility study is to evaluate the potential environmental impacts associated with sediment transport alteration of two established tidal energy technologies, as well as to collect and analyze information on the occurrence and potential impacts of protected species in the project area. The research will generate information useful to the water power industry on the differences between the two tidal energy technologies' relationship to sediment transport alteration, as well as information of broader public interest on the existence of protected marine species in the project area that will be raised during the permitting process.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Lockheed Martin Corporation	Advanced Composite OTEC Cold Water Pipe Project	$1,195,758	FY08 Advanced Water Power Projects FOA	California
Project Description				
Lockheed Martin is demonstrating an innovative cold water pipe fabrication and deployment approach that is projected to be substantially lower cost and lower risk than previous ocean thermal energy conversion (OTEC) designs. Commercialization of OTEC systems hinges on reducing the capital cost of key components, such as the heat exchangers, cold water pipe, and support platform for floating plants, to enable OTEC to be competitive with other renewable energy systems. Lockheed Martin is using a novel design and materials to form an integrated structure that enables simultaneous in-situ fabrication and deployment of the cold water pipe, thereby reducing manufacturing costs and deployment cost and risk. The project also provides data and experience related to manufacturing methods, labor, and materials costs needed to validate cost projections for the full-scale production of its cold water pipe.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Lockheed Martin Corporation	OTEC Life Cycle Cost Analysis	$499,701	FY09 Advanced Water Power FOA	Virginia
Project Description				
Lockheed Martin is building on other ocean thermal energy conversion (OTEC) projects to conduct economic, cost, and life-cycle analyses of OTEC projects. The sizes and configurations of OTEC plants evaluated under this study are: 100 megawatts, 200 megawatts and 400 megawatts net electrical power output plants where the electricity is cabled to shore via marine power cable, and open ocean grazing 400 megawatt OTEC plants producing anhydrous ammonia as an energy carrier for shipment to selected ports. The project integrates data from previous work, multiple cost models and projected technology and efficiency developments to extrapolate current and future capital, operating and maintenance costs for these OTEC plant configurations. Utilizing the DOE's defined approach, levelized cost of electricity (LCOE) is calculated for each OTEC plant configuration. LCOE provides a figure o f merit that translates the life cycle cost over the performance life of the plant into a single value. Utilizing the LCOE and projected build out plans, energy supply curves are developed for Oahu, Hawaii and the global OTEC resource. The financial analysis resulting from this project will provide decision-makers in government and industry with a reliable means to assess the commercial viability of both nearshore OTEC cabled to local grid projects and grazing OTEC plant projects producing an energy carrier.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Lockheed Martin Corporation	OTEC Pipe-Platform Sub-System Dynamic Interaction Validation	$599,965	FY10 MHK Technology Readiness Advancement Initiative FOA	Virginia
Project Description				
Lockheed Martin Mission System and Sensors, along with a team of leading industry experts, is conducting a project that validates the ability to numerically model the dynamic interaction between a large cold water filled pipe and a floating ocean thermal energy conversion (OTEC) platform excited by meteorological and ocean weather conditions at a state-of-the-art ocean model basin. The OTEC cold water pipe is significantly larger than the marine risers that the conventional offshore industry has validated through scale model tests. The model will be subjected to a properly scaled ocean environment simulated in a deep ocean model basin consisting of waves, swells, current, and wind. In parallel with the test program, numerical modeling will be employed to predict the model performance based on the as-built model characteristics and the environmental conditions simulated in the model basin. The results of the numerical modeling will be compared with the results obtained from the physical testing. Results will also be analyzed to develop best practices for numerical modeling inputs required to accurately predict OTEC scale pipe-platform interactions. These best practices will be documented and distributed to become the standard by which future cold water pipe-platform analysis will be performed.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Lockheed Martin Corporation	Ocean Thermal Extractable Energy Visualization	$375,000	FY09 Advanced Water Power FOA	Virginia
Project Description				
Lockheed Martin, in partnership with DOE's National Renewable Energy Laboratory, has developed a Geographic Information Systems (GIS)-based dataset and software tool, the Ocean Thermal Extractable Energy Visualization (OTEEV) tool. OTEEV is being used to provide a meaningful assessment of maximum practicably extractable energy from the global and domestic ocean thermal resource and identification of regions viable for ocean thermal energy conversion (OTEC) and Cold Seawater Based Air Conditioning. The completed assessment estimates 576 terawatt per hours per year is technically recoverable from ocean thermal resources in U.S. waters, and that much of the technically recoverable resource is in the Pacific Islands region. Through conferences and the publicly accessible web-based GIS tool, the OTEEV team will disseminate the newly available knowledge and insights to policymakers, the energy industry, and the public. A multi-step technical methodology was developed using quality data sets that were synthesized from a wide array of sources to create a complete snapshot of the available energy resource. Using GIS technology, geospatial maps are being developed that include extractable energy, resource magnitude, thermal properties, and supporting information about data coverage and uncertainties. The OTEEV provides a current state-of-the-art resource assessment tool that is applicable to industry for development and commercialization, as well as research and policy agencies.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
M3 Wave Energy Systems, LLC	Delos-Reyes Morrow Pressure Device (DMP): Simple, Scalable, and Submerged	$239,972	FY10 MHK Technology Readiness Advancement Initiative FOA	Oregon
Project Description				
M3 Wave Energy Systems (M3) is conducting a 12-month project to explore the commercial viability of the submerged Delos-Reyes Morrow Pressure Device (DMP) — a new method of converting ocean wave energy into electricity. The key result is an estimate of the power output and cost of electricity for a full-scale system. This project will advance the technology from concept definition/feasibility through analytical proof of concept and small scale experimental testing. The Northwest National Marine Renewable Energy Center at Oregon State University will provide M3 with an analysis of nearshore wave conditions. These wave models will be used to conduct realistic, scaled wave tank testing and computer modeling to estimate the full-scale power output of a DMP device. Pacific Energy Ventures and M3 will work with industry experts to estimate full-scale system and operating costs. The cost estimate and full-scale power output will be used to determine a first pass cost of electricity.This project will further the technology around the DMP wave energy converter and aid in developing new tools and techniques that will be beneficial to all nearshore wave energy devices.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Makai Ocean Engineering, Inc.	Modeling the Physical and Biochemical Influence of Ocean Thermal Energy Conversion Plant Discharges into their Adjacent Waters	$240,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Hawaii
Project Description				
Makai Ocean Engineering is working to critically enhance a numerical model to quantify the relationships between ocean thermal energy conversion (OTEC) discharge component design, OTEC performance, and environmental changes that may result from the OTEC discharge plume. This modeling capability will be essential for designing the discharge components to minimize OTEC's environmental impact and optimize cost, and for discussion with OTEC regulators and permitting agencies. Specifically, this work will use collected oceanographic data to calibrate modeled ocean circulation, analyze the OTEC discharge plumes using these validated realistic ocean conditions, and provide biogeochemical model predictions in order to design OTEC plants to minimize environmental impacts and prevent algal blooms. The results of this project and model are relevant to both a 5 megawatt pilot-scale OTEC plant planned by Naval Facilities Engineering Command for Hawaii and the National Oceanic and Atmospheric Administration.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Missouri University of Science and Technology	Remote Monitoring of the Structural Health of Hydrokinetic Composite Turbine Blades	$159,972	FY10 MHK Technology Readiness Advancement Initiative FOA	Missouri
Project Description				
Missouri University of Science and Technology is developing a composite turbine blade for hydrokinetic energy systems that is capable of acquiring and transmitting its own structural health information. Developing technologies that allow hydrokinetic technologies to be remotely monitored and unattended for long periods of time is important for accelerating the deployment of these technologies, which operate in remote, harsh environments. These harsh conditions result in operation and maintenance costs expected to be 70–95% of the total investment cost of the system. The project will fabricate a prototype composite turbine blade, demonstrate underwater transmission of strain data, and develop a plan to advance the concept to a prototype demonstration phase. The expected results of developing a component to remotely monitor turbine blade structural health are: (1) the reduction of operation and maintenance costs, (2) the ability to alert monitors of the need for a replacement blade, (3) notification of a transient event causing damage, (4) accelerated deployment of hydrokinetic systems due to enhanced operational lifetime by operating at reduced capacity to reduce structural load, and (5) in the long-term, a benefit to consumers through savings on operation and maintenance costs that lower the cost of electricity.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Multnomah County, Oregon	Bridge Hydro-Turbine Study	$150,000	FY10 CDP	Oregon
Project Description				
Multnomah County in Oregon is conducting a feasibility study on attaching mini-turbines to the face of bridge piers on the Willamette River in order to generate renewable and economically-stable electricity. Since Multnomah County has limited geothermal, solar, and wind renewable energy, hydrokinetic resources on the Willamette River may be the most viable option for providing renewable and reliable electricity generation. Attaching miniturbines to seven county-owned piers could provide hydrokinetic electricity generation to the county or local grid without building a dam or diversion, while also providing some protection from shipping, fish, and wildlife. The feasibility study is expected to help determine whether generating electricity via these mini-turbines attached to bridge piers is economically and logistically feasible; the optimal size, number, and placement of turbines and resultant electrical power generated; the compliance issues associated with the project; and whether the county, local utility, or third-party developer would be the best entity to undertake such a hydrokinetic energy production project.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Northwest Energy Innovations	WET-NZ Multi-Mode Wave Energy Converter Advancement Project	$1,818,519	FY10 MHK Technology Readiness Advancement Initiative FOA	Oregon
Project Description				
Northwest Energy Innovations (NWEI), in partnership with other industry leaders, has verified the ocean wavelength functionality of the Wave Energy Technology-New Zealand (WET-NZ) device through wave tank testing and controlled open sea deployment of a 1:2 scale device. The project built on previous testing in controlled nearshore wave environments by implementing a range of identified design improvements. Through the new round of wave tank testing and controlled sea deployment, this project gained energy capture performance data for improved cost of electricity calculations and new understanding of the wave impedance matching ability of the WET-NZ design. WET-NZ is at an advanced stage of development and positioned for deployment of a full-scale pre-commercial prototype device. The WET-NZ technology is positioned for implementation of a commercialization strategy in the United States.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Northwest Energy Innovations	WET-NZ Multi-Mode Wave Energy Converter Advancement Project	$500,00	FY12 In-Water Wave Energy Conversion Device Testing Support	Hawaii
Project Description				
NWEI's Wave Energy Technology-New Zealand will be deployed at the U.S. Navy's Wave Energy Test Site in Hawaii to conduct open-ocean grid connected testing for a period of 12 months. The primary objectives of this project are to utilize data collected during the deployment to optimize energy capture, validate existing levelized cost of electricity and performance models, and further refine the models.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Engineering and Energy Systems International, Inc.	The Potential Impacts of OTEC Intakes on Aquatic Organisms at an OTEC Site Currently Under Development	$594,961	FY09 Advanced Water Power FOA	Hawaii
Project Description				
Ocean Engineering and Energy Systems International and industry partners are conducting a project to evaluate the potential impacts of an ocean thermal energy conversion (OTEC) facility's intakes on the island of Kauai, Hawaii. Such work will be required for licensing of OTEC facilities under the OTEC Act of 1980 (administered by the National Oceanic and Atmospheric Administration). The site-specific data generated during the project will be valuable to the industry for designing OTEC facilities with minimal impact to aquatic organisms. Further, the data generated for this site should be readily transferable to other OTEC sites under development, thus facilitating the development and deployment of future OTEC facilities in an effective and environmentally responsible manner.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Power Technologies, Inc.	Reedsport PB150 Deployment and Ocean Test Project	$4,377,293	FY10 MHK Technology Readiness Advancement Initiative FOA, FY08 CDP	Oregon
Project Description				
Ocean Power Technologies is conducting the Reedsport PB150 Deployment and Ocean Test Project, which will deploy a full-scale PB150 PowerBuoy system in a relevant ocean testing demonstration site in the Oregon territorial waters in the spring of 2013. The project will collect detailed operating characteristics during two years of operations. The data will be used to validate market opportunities for the PB150 PowerBuoy, which can produce up to 150 kilowatts of power, and be economically viable in markets where the fundamental cost of electricity is high and/or targets such as Renewable Portfolio Standards have been adopted to encourage renewable deployment. The project will produce performance and reliability data directly applicable to the development of manufacturing methodologies to maximize production and minimize cost for deployment in future buoy farms.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Power Technologies, Inc	PB500 Utility-Scale Wave Energy Converter Development	$3,900,000	FY10 MHK Technology Readiness Advancement Initiative FOA, FY09 Advance Water Power FOA	Oregon
Project Description				
Ocean Power Technologies is building on its existing PowerBuoy technology to complete the major components for constructing a fully integrated design of the PB500 PowerBuoy. The components will be assembled to create a full-scale modular power take-off test bed device. The PB500 will have the ability to produce up to 500 kilowatts of power at a levelized cost of electricity that could compete with land-based fossil fuel generation systems in the global market for energy generation.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Renewable Power Company Alaska, LLC	Acoustic Monitoring of Beluga Whale Interactions with Cook Inlet Tidal Energy Project	$600,000	FY09 Advanced Water Power FOA	Alaska
Project Description				
Ocean Renewable Power Company (ORPC) Alaska is conducting a two-year study on the effects of tidal turbines on beluga whales in Cook Inlet, Alaska. Cook Inlet is home to some of the greatest tidal energy potential in the United States, as well as an endangered population of beluga whales. Successful permitting and operation of a tidal power project in Cook Inlet will require a rigorous biological assessment of the potential and realized effects of the tidal turbines on the Inlet beluga whales. This project will collect baseline data to characterize pre-deployment patterns of marine mammal distribution, relative abundance, and behavior in ORPC Alaska's proposed deployment areas near Fire Island and near East Foreland at the initial pilot project site. This project will attempt to adapt the use of passive hydroacoustic devices (previously utilized with Bowhead whales in the Beaufort Sea) to determine both relative abundance and location of beluga whale vocalizations within the proposed deployment areas. Hydroacoustic data collected during this effort will also be used to characterize the ambient acoustic environment of the proposed project sites pre-deployment as required by project licensing. The project will compare this method with other passive hydrophone technologies and visual observation techniques performed simultaneously and recommend a best practice for future data collection based on the results.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Renewable Power Company Alaska, LLC	Abrasion Testing of Critical Components of Hydrokinetic Devices	$240,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Alaska
Project Description				
Ocean Renewable Power Company (ORPC) Alaska is working with the University of Alaska Anchorage (UAA) to convert tidal and river currents into emission-free electricity. The project tests the performance of core ORPC Alaska device components in a laboratory setting that replicates environmental conditions encountered in Alaskan deployments. The project specifically focuses on understanding wear caused by high suspended sediment concentrations at tidal and river energy sites common in Alaska. One area of concern is the effect of sediments from the marine environment on device bearings and seals, since failures of these components could lead to both loss of efficiency and catastrophic system failures. The project performs laboratory testing of various combinations of bearings and seals to determine the relationships between bearing wear rates and seal failures due to suspended sediment abrasion. ORPC's proprietary turbine-generator unit is being tested in Cobscook Bay, Maine, which is a lower suspended sediment concentration environment. The UAA research will provide ORPC Alaska with an ability to test and adapt its technology to new and diverse conditions. The lessons learned will be applicable in future hydrokinetic projects worldwide.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Renewable Power Company, LLC	OCGen™ Module Mooring Project	$1,034,534	FY09 Advanced Water Power FOA	Maine
Project Description				
Ocean Renewable Power Company's (ORPC) OCGen™ Module Mooring Project is investigating the design of a standard mooring system for hydrokinetic devices that will be moored below the ocean's surface and above the sea floor in reversing tidal environments. Anchoring in fast water is not commonly performed, and standard anchoring systems for these conditions do not yet exist. The project includes hydrodynamic modeling of a buoyant OCGen™ module and subsequent development of a robust, effective, environmentally-friendly anchoring system for the module. The project includes the analytical models for a design of a mooring system for an OCGen™ Power System, verification of these analytical models using scale model testing; design, construction and deployment of an experimental version of the mooring system in the field; and monitoring of the performance and environmental effects of this deployed mooring system for a period of two months. The project enables ORPC to prove the technical and economic viability of a mooring system for fast water applications, and moved the OCGen™ Power System along the path from pre-commercial phase to an initial commercial production model that can be deployed in tidal streams to produce and deliver emissions-free, predictable, schedulable, and renewable electrical energy.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Ocean Renewable Power Company, LLC	TidGen™ Power System Commercialization Project	$10,000,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Maine
Project Description				
Ocean Renewable Power Company (ORPC) is conducting the TidGen™ Power System Commercialization Project in Cobscook Bay off Eastport and Lubec, Maine. Over three years and two phases, ORPC will build, install, operate, and monitor a commercial-scale array of three grid-connected TidGen™ devices. During the project's first phase, ORPC has built, installed, and is now operating the first TidGen™ device, interconnected with the Bangor Hydro Electric Company distribution grid with a 20-year power purchase agreement. ORPC is performing detailed testing and monitoring of the local environment, as well as all system components and subsystems. During the second phase, ORPC will build, install and integrate two additional TidGen™ devices. Together these three devices will form an integrated underwater array of three within a commercial-scale TidGen™ Power System, which will then continue to be operated, tested, monitored, inspected, and maintained for a period of one year after integration. The ORPC TidGen™ Power System Commercialization Project is expected to ultimately result in accelerated distribution of a commercial tidal-current based hydrokinetic system for reliable and cost-competitive delivery of utility-scale electricity with technology developed, manufactured, and deployed by a U.S. company in domestic waters.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Oregon State University	Northwest National Marine Renewable Energy Center	$13,021,170	FY10 CDP, FY09 CDP, FY08 Advanced Water Power Projects FOA	Oregon, Washington
Project Description				
Oregon State University and the University of Washington have partnered to develop the Northwest National Marine Renewable Energy Center (NNMREC) with a full range of capabilities to support wave and tidal energy development for the United States. NNMREC activities are structured to facilitate device commercialization, inform regulatory and policy decisions, and close key gaps in understanding. NNMREC focuses on topic areas that address: (1) development of facilities to serve as an integrated, standardized test center for the United States and international developers of wave and tidal energy; (2) evaluation of potential environmental and ecosystem impacts; (3) device and array optimization for effective deployment of wave and tidal energy technologies; (4) improved forecasting of the wave energy resource; and (5) increased reliability and survivability of marine energy systems. The results of key NNMREC findings and research programs will be disseminated to all stakeholders and interested parties through workshops, conferences, publications, and an online portal.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Pacific Energy Ventures, LLC	Siting Protocol for Marine and Hydrokinetic Energy Projects	$919,803	FY08 Advanced Water Power Projects FOA	Oregon
Project Description				
Pacific Energy Ventures (PEV) developed siting protocols that facilitate market penetration of the emerging MHK industry by increasing consistency, predictability, and efficiency in project siting. The multi-disciplinary team engaged public and private sector stakeholders in an iterative, collaborative process to analyze and identify protocols for MHK siting. PEV captured the findings and results of this effort in a framework that explains and outlines permitting processes, synthesizes environmental information, and identifies key data gaps and options to address them (www.advancedh2opower.com/framework). The project findings have also been shared in formal reports, workshops and conference presentations. In addition to providing clarity and guidance for project siting, the development of these protocols has helped foster collaboration and consensus building among MHK stakeholders at large.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Pacific Energy Ventures, LLC	Active Acoustic Deterrence of Migratory Whales	$593,846	FY09 Advanced Water Power FOA	Oregon
Project Description				
Pacific Energy Ventures is evaluating the effectiveness of an active acoustic deterrence system. Every year more than 20,000 gray whales migrate from Baja, Mexico, to the Bering Sea off the coast of Alaska. Oregon State University's Marine Mammal Institute recently completed Phase I of an Oregon Wave Energy Trust (OWET) action plan to evaluate the impacts of wave energy development on gray whales. The study concluded that the migration paths of some gray whales occur at distances and depths similar to those proposed for offshore wave energy developments; thus, there is a possibility of collision, entanglement, or displacement for whales from wave energy structures. As part of the OWET funded study, a group of acoustic and whale experts recommended the testing of a limited range acoustic deterrent system to discourage gray whales from entering wave energy parks. This project is testing the effectiveness of an acoustic pinger that emits a one second long pulse once every minute. Trained observers are tracking the whales' paths through the test area and will be able to determine the effectiveness of the deterrence system. The project is being conducted directly west of Yaquina Head near Newport, Oregon, where the Phase I baseline data was collected. The project site is in vicinity of the Northwest National Marine Renewable Energy Center's wave energy test site and results are expected to provide west coast wave energy developers with a mitigation measure to prevent gray whales from entering the project area or becoming entangled in mooring lines, if required.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Pacific Gas and Electric Company	WaveConnect Wave Energy In-Water Testing and Development	$1,200,000	FY08 Advanced Water Power Projects FOA	California

Project Description

The Pacific Gas and Electric Company (PG&E) WaveConnect project was intended to demonstrate the technical and economic viability of wave power in the open ocean adjacent to PG&E's service territory. WaveConnect was conceived as a multi-stage process leading to long-term megawatt-scale wave power production. The program was halted near the end of the first stage for the following:

- Permitting issues were much more challenging than originally anticipated.
- The cost of developing a pilot project at was much greater than the $15 - $20 million originally estimated.

Significant additional investment in design, testing and demonstration will be needed to improve designs and reduce costs. PG&E estimated a cost of electricity which is not competitive with current or near-term renewable alternatives such as wind or solar photovoltaics. As wave energy converter technologies mature, and regulatory and permitting agencies grow more familiar with their environmental impacts, PG&E believes that wave power will merit further evaluation, demonstration and deployment.

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
PCCI, Inc.	Marine and Hydrokinetic Renewable Energy Technologies: Identification of Potential Navigational Impacts and Mitigation Measures	$165,290	FY08 Advanced Water Power Projects FOA	Virginia

Project Description

PCCI is developing a technical manual to assist developers and regulators in obtaining the information needed for the permit application process relating to navigational impacts and mitigation measures. A key issue when siting renewable energy technologies in navigable waters is the impact of a proposed facility on traditional waterway uses. PCCI and its team are coordinating with the U.S. Coast Guard to advance the industry's knowledge of potential navigational impacts and provide information to assist project developers to avoid or mitigate those impacts. The PCCI team is also coordinating with two other project teams funded by DOE to develop a variety of tools and resources for use by stakeholders. The project and technical manual is expected to streamline and accelerate the deployment of MHK renewable energy installations by providing developers, regulators, and industry stakeholders with information and coordination guidance on navigational impacts, mitigation, and related permitting requirements.

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Princeton Power Systems, Inc.	Marine High-Voltage Power Conditioning and Transmission System with Integrated Energy Storage	$599,799	FY10 MHK Technology Readiness Advancement Initiative FOA	New Jersey

Project Description

Princeton Power Systems is demonstrating its Marine Power Conditioner with Storage, which combines three innovative technologies, including a high voltage direct current power terminal, ultra capacitor energy storage, and a circuit architecture that allows for sophisticated sharing, control, and communications among three power terminals. Most MHK energy sources are variable and physically distant from load centers, requiring power conditioning systems that both buffer the power generation and transmit it to shore at high voltage. Currently available energy storage and transmission systems are expensive and poorly suited for these applications, and new technologies could provide substantial benefits. Tests have resulted in achieving a production cost under 50 cents per watt for a marine-rugged 500 kilowatt system. The results of the project will add to improved integration of wave/tidal power generators with load needs, leading to an increase in the number of wave/tidal power installations and, subsequently, a greater percentage of energy generated from non-polluting, renewable energy sources. In addition, the project will help establish the United States as a global technological leader in advanced marine power conversion systems.

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Principle Power, Inc.	WindWaveFloat	$1,359,000	FY09 Advanced Water Power FOA	California
Project Description				
Principle Power is conducting an engineering and cost study for the WindWaveFloat, an innovative wave energy concept with the potential to reduce the levelized cost of electricity and environmental impact of electricity generation. Most wave energy converters can only achieve a nameplate capacity of less than 1 megawatt due to physical limitations driven by metocean conditions. This leads to high structural costs and low power production, with mooring and installation encompassing 25–40% of the device's capital cost. The project assessed combination of a number of wave and wind energy power take-off mechanisms in an innovative floating support structure, the WindFloat, thus amortizing the mooring and installation costs over higher power output. The use of a floating support structure leads to a number of additional benefits, like reduced environmental impacts and more flexible siting in deep waters. The project consists of engineering studies, numerical and physical models development, wave tank validation and testing, performance verification, cost/benefit analysis, and optimization studies to increase energy production. The WindWaveFloat project will provide results in of an integrated system with a combined power generation capacity of greater than 5 megawatts with reduced environmental impact, optimized use of space, and shared infrastructure that may results in the lowest levelized cost of electricity possible.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
RE Vision Consulting, LLC	Marine and Hydrokinetic Renewable Energy Technologies: Identification of Potential Navigational Impacts and Mitigation Measures	$350,000	FY08 Advanced Water Power Projects FOA	California
Project Description				
RE Vision Consulting is working to accelerate the adoption of MHK energy technologies by studying siting issues and developing materials to help the industry site projects more efficiently. One of the key issues that project proponents face as they engage stakeholders is that many conflicting uses and environmental issues are not well-understood. Much of this lack of understanding comes from a limited understanding of the technologies themselves and their lifecycle impacts. A scenario-based approach was used to provide a solid understanding of the impacts these technologies will have in respect to navigation and environmental effects. The final product consists of three reports: (1) A wave energy deployment scenario report, (2) A tidal deployment scenario report, and (3) An environmental assessment framework report. The frameworks and representative scenarios developed provide an objective and transparent tool for stakeholders, regulators and developers to assist in the decision-making process for siting wave and tidal energy plants, and meet the goal of improving understanding between all stakeholders.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
RE Vision Consulting, LLC	Assessment of projected life-cycle costs for wave, tidal, ocean current, and in-stream hydrokinetic power in the United States over time	$374,991	FY09 Advanced Water Power FOA	California
Project Description				
RE Vision Consulting conducted an assessment of projected lifecycle costs for emerging MHK generation technologies with a final report delivered in September 2012. Unlike more mature renewable energy sectors, historical cost data available in this sector has been limited to a few pilot and demonstration projects worldwide. MHK technology represents its unique challenges in the evaluation of lifecycle cost profiles and relies heavily on predictive cost models and techno-economic assessments. Over the past six years, RE Vision has developed a suite of parametrically driven techno-economic models that were used in a wide range of siting and economic studies. The study addresses three major questions: (1) What is the present cost of MHK technologies, (2) How much energy can be extracted from these MHK resources at what cost, and (3) At which cost levels will the technology see significant deployment in the United States. To address these questions, RE Vision Consulting engaged in three sequential efforts: (1) Establishment of present-day cost profiles for MHK technologies, (2) Compilation of existing resource assessments to develop supply curves, and (3) Development of deployment scenarios to evaluate how much present-day costs would need to be reduced to allow for significant technology deployment in the United States. The project's results support a more accurate understanding of the present and future lifecycle cost for emerging MHK generation technologies. This knowledge will serve the technology development process, help determine critical decisions on policy mechanisms that support the sector, and provide input to future capacity planning models.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Resolute Marine Energy, Inc.	Wave Actuated Power Take-Off Device for Electricity Generation	$159,998	FY10 MHK Technology Readiness Advancement Initiative FOA	Massachusetts
Project Description				
Resolute Marine Energy is developing a cost-effective power take-off system for the Surge Device, a wave energy converter already under development by the company. In addition, the project is assessing the cost-to-manufacture power take-off systems at various scales, ranging from multi-kilowatt individual units for early-stage deployments in off-grid applications to sub-megawatt units for multi-megawatt, grid-connected arrays. The project will develop a fully packaged embodiment of Resolute Marine Energy's power take-off concept at a 1 kilowatt scale to enable more realistic and comprehensive ocean testing of the Surge Device. The successful development of the power take-off concept is expected to reduce the levelized cost of electricity when incorporated in the Surge Device and advance the integrated system's commercial readiness.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Science Applications International Corporation	International Standards Development for Marine and Hydrokinetic Renewable Energy	$593,000	FY08 Advanced Water Power Projects FOA	California
Project Description				
Science Applications International Corporation (SAIC) is working with a group of industry stakeholders to develop a set of relevant industry standards, as well as a consistent method and process for developing standards for the MHK renewable energy industry. The project will use the well-established and proven International Electrotechnical Commission (IEC) development process as a foundation, and will include qualified U.S. industry technical experts to populate the standards development working groups. Standardization will enable marine renewable energy technologies to become marketable by providing a foundation for certification systems, promoting international trade of uniform high-quality products, and supporting transfer of expertise from traditional energy systems. SAIC will convene multiple standards development working groups with participation of key U.S. industry technical experts; support the international project teams; develop a report on existing IEC standards and processes; and disseminate a semi-annual newsletter to the marine renewable energy community to educate industry members and stakeholders about the processes, progress, and description of these standards.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Scientific Solutions, Inc.	Underwater Active Acoustic Monitoring Network for Marine and Hydrokinetic Energy Projects	$600,000	FY10 MHK Technology Readiness Advancement Initiative FOA	New Hampshire
Project Description				
Scientific Solutions (SSI) is conducting a joint effort with Ocean Renewable Power Company (ORPC) to fully develop, integrate, test, and operate a full-scale active acoustic detection system for MHK technology and other offshore renewable energy projects. This system will be deployed and integrated with ORPC's TidGen™ tidal energy device in Cobscook Bay near Eastport and Lubec, Maine. MHK energy projects may not be viable without real-time monitoring of the surrounding underwater environment. There are unknown risks associated with harm to marine life and risks associated with floating debris interacting with moving parts. A viable solution for this problem is active acoustics or active sonar, which may provide detection of an underwater object. However, there are no sonar systems on the market that provide a comprehensive solution. SSI has developed a technology used in the Swimmer Detection Sonar Network (SDSN) with a concept ideally suited for the MHK industry. The project combines SDSN with ORPC's advanced stage tidal turbine development and demonstration project. The expected results are to complete an acoustic monitoring system design which includes the deployment of the prototype integrated with an MHK system; and, to make the system available to the MHK and offshore renewable power industry through a commercialization effort. The successful completion of this project will enable the offshore renewable energy industry to conduct real-time monitoring of the surrounding underwater environment and reduce risks associated with marine life and floating debris.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Semprus Biosciences	Environmentally Benign and Permanent Modifications to Prevent Biofouling on Marine and Hydrokinetic Devices	$160,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Massachusetts
Project Description				
Semprus Biosciences is developing environmentally benign and permanent modifications to prevent biofouling on MHK devices. Biofouling, including growth on external surfaces by bacteria, algae, barnacles, mussels, and other marine organisms, may accumulate quickly on MHK devices, causing mechanical wear and changes in performance. Biofouling on crucial components of hydrokinetic devices, such as rotors, generators, and turbines, imposes substantial mass and hydrodynamic loading with associated efficiency loss and maintenance costs. Most antifouling coatings leach toxic ingredients, such as copper and tributyltin, through an eroding process, but increasingly stringent regulation of biocides has led to interest in the development of non-biocidal technologies to control fouling. Semprus Biosciences' research team is developing permanent modifications to prevent fouling from a broad spectrum of organisms on devices of all shapes, sizes, and materials for the life of the product. These modifications are expected to out-perform currently used nontoxic underwater coatings in biofouling resistance and be ready for the next stage of development with demonstration in MHK systems.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Shift Power Solutions Inc.	Protective, Modular Wave Power Generation System	$240,000	FY10 MHK Technology Readiness Advancement Initiative FOA	California
Project Description				
Shift Power Solutions is working to capture the energy from waves before they impact breakwaters, groynes , and other marine structures. Waves have high power densities. While this makes them good candidates for electrical energy conversion, their energy is often a destructive force that acts on natural and manmade coastal structures. Shift Power Solutions is working to develop a system to harvest wave energy that is scalable, modular, adaptable, costeffective, and reduces degradation to coasts and marine installations. There are a wide variety of coastal situations in which this type of energy harvesting may be useful, but manufacturing location-specific components is expensive. Therefore, the project is focusing on development of a modular system to allow installations to be adapted for specific locations without the cost of tailored manufacturing. The benefits to the coastal communities are twofold: stabilization of the coastline and the local production of persistent renewable-based electricity. The project seeks to establish the technical feasibility of the concept by analyzing, building, and testing a prototype capable of generating up to a kilowatt of electricity. If feasible, subsequent development may ultimately result in systems containing thousands of modules, capable of generating megawatts of baseline power.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Snohomish County Public Utility District #1	Puget Sound Tidal Energy In-Water Testing and Development Project	$1,200,000	FY08 Advanced Water Power Projects FOA	Washington
Project Description				
Snohomish County Public Utility District #1 (District) in Washington state conducted in-water testing of tidal flow technology with the Admiralty Inlet Pilot Tidal Project, a first step toward potential construction of a commercial-scale tidal turbine array. In this phase of the project, the District completed the engineering design and obtained construction approvals for a Puget Sound tidal pilot demonstration plant in the Admiralty Inlet region of the Sound. The project executed site studies necessary to support plant siting and design, complete plant design and construction planning, and conduct environmental studies and other activities required to complete all federal, state, and local permit applications for a pilot tidal plant. There is potential to generate clean, renewable, environmentally benign, and cost-effective electricity from tidal flows at selected sites in the Puget Sound, as well as at other U.S. sites. Successful tidal energy demonstration in the Sound is expected to facilitate technical advancement and commercial development of the tidal energy industry, providing benefits for both the region and the country. As a result of this project, the District is fully prepared to construct a pilot demonstration tidal energy plant with the potential to advance to utility-scale tidal energy development. As the second largest public utility in Washington, the District is well positioned to share key learning among other regional and national stakeholders.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Snohomish County Public Utility District #1	Study of the Acoustic Effects of Hydrokinetic Tidal Turbines in Admiralty Inlet, Puget Sound	$522,550	FY09 Advanced Water Power FOA	Washington
Project Description				
Snohomish County Public Utility District #1 (District) and its partners determined the acoustic impacts of hydrokinetic turbines operating in Admiralty Inlet, Washington. This is the site selected for the District's pilot project, Puget Sound Tidal Energy Demonstration Project, in which two OpenHydro Group Ltd. turbines will be installed off Admiralty Head for a period of up to five years. The pilot project is intended to provide both operational experience with the devices and the opportunity to monitor the site for any effects on the marine environment. To study acoustic impacts, this project employed complementary long-term measurements to characterize how aquatic species use Admiralty Inlet and deployed both in-water testing and laboratory studies to investigate how noise from a turbine could affect aquatic species. The study's results will provide regulatory agencies, tribes, and public stakeholders with continuous longterm monitoring of aquatic species within the project area and a new understanding of how species could be affected by the operation of the District's pilot project. In addition to assessing acoustic effects, the collected and interpreted information about aquatic species will help to establish a baseline for assessing other possible project impacts—for example, interference with migration. As such, the methodologies developed under this project will be broadly applicable to hydrokinetic energy projects across the United States and worldwide.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Snohomish County Public Utility District #1	Puget Sound Pilot Tidal Energy Project	$475,750	FY09 CDP	Washington
Project Description				
Snohomish County Public Utility District #1 (District) is continuing work on the Admiralty Inlet Pilot Tidal Project in Washington. This phase of the project is partnering with the Northwest National Marine Renewable Energy Center (NNMREC) to develop and verify monitoring capabilities necessary for post-installation environmental monitoring of the pilot project. The primary focus is on development of near-turbine monitoring capabilities to observe aquatic species interactions in the immediate vicinity of turbine rotors and address concerns about the risk of post-installation blade strike. Additionally, equipment suitable for post-installation passive acoustic monitoring will be tested, and the potential for cross-talk between different active acoustic instruments will be evaluated. Overall, the project is conducting: (1) Near-field monitoring of blade strike and species-specific aggregation or avoidance; (2) Passive acoustic monitoring; (3) Current velocity monitoring; component packaging; and (4) Cost evaluation for each type of monitoring. Both the monitoring equipment purchased and the lessons learned through monitoring will contribute to the District's Puget Sound Tidal Energy Demonstration Project and potential construction of a commercial scale power plant.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Snohomish County Public Utility District #1	Puget Sound Pilot Tidal Energy Project	$10,000,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Washington
Project Description				
Snohomish County Public Utility District #1 (District) is building upon its efforts to study and develop the Puget Sound Tidal Energy Demonstration Project in the Admiralty Inlet, a site that has been identified as one of the largest tidal hydrokinetic resources in the United States. This phase of the project involves the deployment, operation, monitoring, and evaluation of two 6-meter diameter Open-Centre Turbines developed and manufactured by OpenHydro Group Ltd. with a capacity of 250 kilowatts each. While the turbines will be connected to the grid and produce a modest amount of energy, the primary purpose of the project is to gather data to advance the viability of commercial tidal energy generation from technical, economic, social, and environmental standpoints. The evaluation covers a three-year operational period and provides data that is critical to the responsible advancement of commercial scale tidal energy in the United States. Successful tidal energy demonstration at Admiralty Inlet may enable significant commercial development of hydrokinetic energy elsewhere in Puget Sound and in other regions of the United States, resulting in important benefits for both the Northwest region and the country as a whole.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Sound & Sea Technology, Inc.	Advanced Anchoring Technology	$239,899	FY10 MHK Technology Readiness Advancement Initiative FOA	Washington, British Columbia
Project Description				
Sound & Sea Technology is working on an alternative and novel solution for an anchor system. Anchoring and mooring systems for MHK energy systems constitute a portion of the overall cost of an installed MHK system. Improvements in anchoring can provide a significant reduction in the cost per installed kilowatt of MHK systems. Sound & Sea Technology's solution uses grouted pile anchor technology, which is commonly used in terrestrial construction projects. The project expects to prove the new anchoring concept, improve the technology required to remotely attach MHK anchoring systems, and develop a quality control and certification procedure to validate deep underwater grouted pile anchor installations. Development of this techology is expected to reduce the capital and installation costs of MHK systems by providing a more flexible anchoring technology suitable for varying water and sea bottom conditions.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Sunlight Photonics, Inc.	Tidal Energy System for On-shore Power Generation	$399,990	FY10 MHK Technology Readiness Advancement Initiative FOA	New Jersey
Project Description				
Sunlight Photonics is demonstrating the proof of concept for a new, efficient, and robust Hydraulic Energy Transfer (HET) system that eliminates the primary technology problems of sub-sea electronics corrosion and high-ratio gear failure that has plagued MHK electric generation to date. The HET concept, originally proposed and published by Sunlight Photonics' partner, the National Aeronautics and Space Administration Jet Propulsion Laboratory (JPL), is an extension of work by JPL on ocean energy submersibles currently being tested for the U.S. Navy. A systems and cost analysis by JPL has shown that this hydraulic energy transfer system is more efficient and less costly than comparable conventional tidal energy systems. Building on this work, Sunlight Photonics, JPL, and other partners will demonstrate a 15 kilowatt system and define a clear path for scale-up and commercialization. The project model will validate design predictions and system level functionality. The critical subsystems have been integrated and are currently under test at the Mechanical Engineering Department at Rutgers University, including immersion tank tests. The proposed system is expected to be efficient, low-maintenance, and inexpensive, while also being applicable to tidal, current, river and wave energy, as well as adaptable for offshore wind energy. In addition, the HET systems are expected to provide an attractive option for energy storage issues found in smart grid development.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Turner Hunt Ocean Renewable, LLC	Turner Hunt Ocean Renewable's (THOR's) Power Method for Hydrokinetic Devices	$400,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Ohio
Project Description				
Turner Hunt Ocean Renewable (THOR) is demonstrating and testing a power control protocol method that maximizes, modulates, and controls the electrical power output from a hydrokinetic device. Other operational control methods will also be tested and evaluated using a fully functional scale model operating in THOR's unique open channel recirculating water flume. THOR's Power Method was previously shown to provide dramatic increases to the energy yield of the hydrokinetic device. This project will implement THOR's Power Method via a fully functional automatic control system resident in the scale model that will be exposed to the full range of free stream current flow regimes expected to be encountered under actual conditions. THOR's Power Method for Hydrokinetic Devices will test and validate a power regulation scheme that can provide dramatic increases to the energy yield of hydrokinetic devices.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of California, Davis	Active Flow Control on Bidirectional Rotors for Tidal MHK Applications	$158,336	FY10 MHK Technology Readiness Advancement Initiative FOA	California
Project Description				
The University of California, Davis has combined two existing technologies to develop an innovative, reliable, cost-effective rotor for tidal MHK applications. The project improves upon bidirectional rotor tidal turbines (BRTT) with the addition of microtabs to improve blade hydrodynamic and rotor performance while still permitting bidirectional rotor operation. Although BRTTs are already undergoing commercial development, there are some disadvantages to the design, such as efficiency losses. The University of California, Davis has optimized the rotor design to recapture some of the performance shortfalls of the BRTT, while also alleviating cyclic loads and extending turbine life. The successful development of an optimized BRTT rotor with microtabs is expected to offer a new rotor technology that can (1) Reduce costs and improve reliability and yield; provide a lower cost of electricity than existing MHK configurations; (2) Offer a component technology that can be applied to all tidal current sites; (3) Address load alleviation at any current-driven MHK site; and (4) Provide a subcomponent technology that synergistically benefits parallel work in wind power.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of Hawaii	National Renewable Marine Energy Center in Hawaii	$7,999,647	FY08 Advanced Water Power Projects FOA	Hawaii
Project Description				
University of Hawaii (UH) established the Hawaii National Marine Renewable Energy Center (HINMREC), led by the Hawaii Natural Energy Institute, to facilitate commercialization of wave energy converters (WEC) and to accelerate development and testing of ocean thermal energy conversion (OTEC) technologies in Hawaii and elsewhere in the world. WEC and OTEC were selected since Hawaii has ample resources, significant expertise in these areas, and ongoing or planned commercialization and demonstration projects in the state. HINMREC is a collaborative effort between academia, industry and government. HINMREC is structured to provide open access to its facilities and expertise, and broad dissemination of non-proprietary information through the internet (http://hinmrec.hnei.hawaii.edu/), for all credible wave power system developers and other stakeholders. In addition to supporting tasks that address specific near-term needs of the industry partners, the UH faculty participants pursue independent research on critical technical issues related to resource assessment, device performance, and environmental impacts. These efforts, while technologies independent are also designed to provide maximum value to potential developers. HINMREC is collaborating closely with the U.S. Navy to implement a wave-energy-test-site (WETS) in Kaneohe Marine Corps Base Hawaii. The concept is to expand existing facilities to provide multiple-berthing for devices in the 100 to 1000 kilowatt range. WETS will allow for testing in water depths ranging from 30 meters to 70 meters. The vision for HINMREC consists of a fully operational WETS and continuing providing services required to evaluate WEC and OTEC designs.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of Maine	Maine Tidal Power Initiative	$1,951,500	FY10 CDP, FY09 CDP	Maine
Project Description				
University of Maine has established the Maine Tidal Power Initiative to develop resource and environmental protocols while industry partners deploy a Tidal In-Stream Energy Conversion device. These protocols can then be used throughout the United States to evaluate tidal energy resources and better understand the potential impact of tidal energy development on the environment. The project includes: (1) A resource assessment; (2) Development of the initial array design parameters using scale model tests; (3) Baseline environmental studies and monitoring; and (4) In-situ measurement and monitoring of the beta pre-commercial Turbine Generator Unit (TGU) developed by Ocean Renewable Power Company (ORPC) and (5) A study of the human dimensions of this work. Site-specific work is focused on the Cobscook Bay/Western Passage area near Eastport, Maine, which is potentially the most viable commercial tidal energy site in the United States and became the first grid-connected, commerical-scale tidal energy site in the country with ORPC's TGU deployment in 2012. The protocols and methods developed at this site have been used to perform initial scoping reviews of smaller tidal sites in Taunton Bay, Castine and Wiscasset, Maine. Upon successful completion, the project is expected to advance both research and education. The research component, linked with the testing of ORPC's TGU in the Cobscook Bay/Western Passage site will result in baseline resource and environmental data for the site, as well as the initial evaluation of the suitability of the approach for at least two other tidal development sites in Maine. The educational component involves graduate and undergraduate students at the University of Maine and the Maine Maritime Academy, providing training for a new generation of skilled work force to support future ocean renewable energy industries.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of Massachusetts Dartmouth	New England Marine Renewable Energy Center	$1,701,500	FY10 CDP, FY09 CDP	Maine
Project Description				
The University of Massachusetts, Dartmouth established the New England Marine Renewable Energy Center (NEMREC) in 2009 to promote the development of ocean energy—including wave, tidal, and offshore wind energy—through academic research; development of test sites; and stakeholder engagement with government, industry, academia, and the public. NEMREC has expanded its work to provide pre-permitted and closely monitored test sites in the National Offshore Renewable Energy Innovation Zone for marine renewable devices, maintain its University Research Consortium (URC), provide small grants for research at coalition universities, and initiate feasibility studies for ocean test sites. NEMREC's URC hosts an annual technical conference, as well as other technology sharing activities. In addition, NEMREC will conduct public outreach via meetings with stakeholders, including governmental agencies, public interest groups, and the general public.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of New Hampshire	Center for Ocean Renewable Energy (CORE) Infrastructure Enhancements	$750,000	FY10 CDP	New Hampshire
Project Description				
The University of New Hampshire is enhancing three principal components of the University's Center for Ocean Renewable Energy (CORE) research, development, and evaluation infrastructure, including Chase Ocean Engineering Laboratory (Chase Lab), the General Sullivan Bridge (GSB) tidal energy site, and the Offshore Wave and Wind (OWW) energy site, to serve the needs of ocean renewable developers. At the Chase Lab, upgrades were completed to the tank facility ensuring that the wave/tow tank is improved to meet the required needs for model stage testing of ocean renewable energy devices. The water quality system has been improved to maintain water clarity for detailed visual and optical observations of turbine blade water interactions. Upgrades to the tow carriage can accommodate more and varied turbine designs and provide the measurement data required for engineering evaluation of the turbine. The wave generating system is being carefully evaluated, and needed enhancements will be made. At the GSB site, a new testing platform has been designed and fabricated for deploying large scale devices, complete with all the instrumentation needed to evaluate the tidal flow upstream and downstream of the device under test. Additional capabilities include measurement systems capable of evaluating in-situ loads on the mooring system, fluid flow measurements, and mechanical and electrical outputs of the device under test. At the OWW energy site, the environmental assessment buoy has been enhanced and upgraded to have wave measurement capability and a conductivity temperature depth for water property assessment deployed on the subsurface component of the buoy system. The above surface structure has a weather station for measuring wind speed and direction and atmospheric temperature. The significant infrastructure upgrades to CORE's three sites are providing significant benefits to the ocean energy industry's research, development, and evaluation capabilities.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
University of Washington	Northwest National Marine Renewable Energy Center - Tidal Energy Research	$440,000	FY10 CDP	Washington
Project Description				
The University of Washington (UW) is advancing research and development of tidal in-stream energy conversion at the Northwest National Marine Renewable Energy Center (NNMREC). Numerical modeling and laboratory flume experiments of flow around turbines and in their wakes are performed. The numerical modeling allows UW to investigate optimization for energy extraction as well as potential ecosystem effects. This includes tidal estuary and channel modeling. Comparison of the reduced-scale turbines in the flume improves the accuracy and dependability of numerical simulations and helps fill the gaps between the design and optimization stages of reduced-scale turbines and full scale testing. Additionally, field work is conducted in Puget Sound, a very good controlled field site for studying tidal energy. The UW goal is to develop instrumentation methodology for field measurements that include tidal current velocity, ambient noise, biological activity, and water properties. Analysis and interpretation of the data are focused on quantification of natural variability in the tidal flow, as well as forecasting of power generation potential.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
US Synthetic Corporation	The Development of Open, Water Lubricated Polycrystalline Diamond Thrust Bearings for use in Marine Hydrokinetic (MHK) Energy Machines	$146,984	FY10 MHK Technology Readiness Advancement Initiative FOA	Utah
Project Description				
US Synthetic Corporation is providing a new bearing technology to MHK machines to reduce operating costs, improve reliability, and reduce power loss. Polycrystalline Diamond (PCD) thrust bearings have been successfully used in oil and gas devices for many years. PCD advantages are the ability to operate in the open, without seals using abrasive liquids (e.g. such as drilling fluid) as a lubricant. In addition, they can withstand the rigors of severe load variation and lubricant contamination. A hydrokinetic energy machine with water-lubricated PCD bearings would reduce maintenance costs and improve reliability over equivalent machines using conventional bearings. In addition, PCD bearings without lubricants other than the water itself reduce the danger of polluting a marine environment. The project will use advanced analytical tools for the initial design of thrust bearings for use in a conceptual water turbine; build and test the bearings in the US synthetic bearing test facility; and compare the measured bearing performance with the design predictions. Finally, design protocols based on both experimental results and analytical models will be developed that permit the design of a thrust bearing for any desirable size and length of time. At the conclusion of this project, two sets of sample test bearings will be made available to qualified MHK developers free of charge.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Verdant Power, Inc.	Improved Structure and Fabrication of Large, High-Power Kinetic Hydropower System (KHPS) Rotors	$1,120,830	FY08 Advanced Water Power Projects FOA	New York
Project Description				
Verdant Power is designing and developing an improved blade structure and concomitant blade design for manufacture, fabrication and testing. The improved design allows for larger, higher-power and more cost-effective Kinetic Hydropower Systems (KHPS) rotors. Verdant Power has already proven the performance of the entire KHPS from water to wire at the Roosevelt Island Tidal Energy Project in New York City's East River. The most critical subsystem of the KHPS is the rotor itself and, while the current rotor is highly successful at a 5 meter diameter, broad commercialization requires rotors to capture energy from higher water velocities and deeper resources that can accommodate larger rotor diameters. The current project supports scale-up of the rotor with improvements to handle the loads imposed by larger rotor sizes and higher water flow speeds while maintaining the present high performance of the rotor. This new design cycle requires a multidisciplinary collaboration of hydrodynamic and structural modeling, blade design and analysis, and design for manufacture and fabrication technique development. A 5 meter diameter prototype has been fabricated, and undergone extensive strength and fatigue testing in laboratory conditions, and full-scale in-water hydrodynamic testing. The project is expected to advance larger, more robust, and more cost-effective devices that will significantly hasten the commercial development of kinetic hydropower resources.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Verdant Power, Inc.	Component Reliability Testing and Manufacturing Optimization to Advance the Kinetic Hydropower System (KHPS) to DOE TRL 7/8	$1,500,000	FY10 MHK Technology Readiness Advancement Initiative FOA	New York
Project Description				
Verdant Power aims to advance key components and deployment requirements of its Kinetic Hydropower System (KHPS) towards a DOE Technology Readiness Level of 7/8. Verdant Power will be conducting critical component testing and analysis to progressively validate longevity and reliability parameters for the KHPS and U.S. MHK devices overall, and will continue compliance work on approved operational environmental monitoring plans in anticipation of KHPS turbine installation. The project scope will include: evaluation of four Generation 5 KHPS turbine critical components (blades, seals, brake, and gearbox) for longevity and reliability; evaluation of components as part of a cost-effective operation and maintenance projection for MHK devices; and continued compliance work and implementation of instrumentation that builds the case for MHK devices as environmentally compatible. Beyond this project, Verdant's goal is to successfully deploy a KHPS system at the Roosevelt Island Tidal Energy project site in New York.				

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Table 1: FY 2008 – FY 2012 Marine and Hydrokinetic Project Descriptions[a]

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Vortex Hydro Energy, LLC	Advanced Integration of Power Take-Off in Vortex Induced Vibration Aquatic Clean Energy (VIVACE)	$999,955	FY10 MHK Technology Readiness Advancement Initiative FOA	Michigan
Project Description				
Vortex Hydro Energy is commercializing the Vortex Induced Vibration Aquatic Clean Energy (VIVACE) converter, which is a University of Michigan patented MHK device designed for slow-moving currents. Unlike water turbines, VIVACE does not use propeller blades. Rather, river or ocean currents flow around cylinders, causing them to move up and down. The kinetic energy of the cylinder is then converted to electricity. In addition to being simpler in design and more cost-effective than a water turbine, the VIVACE converter is a transformational technology designed for water currents as slow as 2 to 4 knots. The majority of river and ocean currents in the United States are slower than 3 knots, but conventional turbine technology targets rivers with water currents greater than 4 knots. The VIVACE converter thus taps into a new source of clean and renewable energy. The project focuses on improving the energy conversion efficiency of the VIVACE converter in a laboratory setting and open water testing of the improved system in the Saint Clair River at Port Huron, Michigan.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Wavebob, LLC	Wavebob Advanced Wave Energy Conversion Project	$2,400,000	FY10 MHK Technology Readiness Advancement Initiative FOA	Maryland
Project Description				
Wavebob is conducting an evaluation of its Wavebob Energy Conversion System (WEC-1) in order to better understand power generation and efficiency. WEC-1 converts wave energy to electricity on a commercial scale to promote use in large utility serviced markets and smaller discrete markets. After 10 years of research, WEC-1 has matured to the point of transitioning to pre-commercial demonstration. The study is advancing Wavebob's plans to insert WEC-1 into a commercial-scale demonstration project planned for U.S. waters in 2013. The Wavebob Advanced Wave Energy Conversion Project reduces key risk factors related to an improved design that replaces its hydraulic based power take-off. This project supports the design, fabrication, and testing of Wavebob's device both offshore and in a wave tank. Technical documentation and economic data generated during this project are providing the basis for the commercial-scale sea trials. The project offers the opportunity to improve WEC-1 power generation efficiency and, at the same time, reduce system capital and operating costs. Successful completion of this project is expected to accelerate WEC-1 entry into the market and accelerate the deployment of technologies to provide a domestic source of clean, affordable and environmentally responsible energy.				

Project Recipient	Project Title	DOE Funding Amount	Funding Source	Project Location
Whitestone Power and Communications (operated by the Whitestone Community Association)	Whitestone Poncelet River In-Stream Energy Conversion (RISEC) Project	$142,050	FY10 MHK Technology Readiness Advancement Initiative FOA	Alaska
Project Description				
Whitestone Power and Communications (WPC), in partnership with Hasz Consulting Company, has entered the first phase for design and permitting of the Whitestone Poncelet River In-Stream Energy Conversion (RISEC) Project. The project uses renewable river current hydrokinetic energy from the Tanana River in Alaska. The goal of this project is to conduct in-water testing and evaluation of RISEC technology that is representative of what could be expected for a commercial-scale hydrokinetic power plant. The design is expected to overcome the unique challenges presented by the Alaskan river environment including high density of aquatic life, high debris and sediment loads, and severe weather. As developed, the concept proposes solutions to materials, transmission, and power generation obstacles encountered by traditional waterwheels, resulting in unprecedented efficiency, longevity, and cost effectiveness. This low-impact design provides a carbon-neutral and cost-effective solution with global potential to harness renewable marine resources for the production of electricity. Upon successful completion of this project, the RISEC technology will move from the design phase to the complete manufacture of a full-scale prototype. WPC anticipates the proposed system being widely used in river applications throughout Alaska, the United States, and globally in shallow, swift water applications where large-diameter submersible turbines cannot be used. WPC also expects the design to significantly diminish the cost of electricity, which is potentially a significant challenge for remote and rural communities throughout Alaska.				

Marine and Hydrokinetic Funding Distribution

DOE funded 67 Marine and Hydrokinetic projects through the Water Power Program from FY 2008 to FY 2012. These projects are categorized in the following sections by activity area, topic area, geographic region and division, state, recipient type, and funding source.

Funding by Activity Area and Topic Area

The Water Power Program's R&D efforts between FY 2008 and FY 2012 fall under two activity areas: Technology Development and Market Acceleration and Deployment. The Water Power Program's Technology Development projects are aimed at reducing the technical barriers to MHK device development, improving device reliability and performance, and enhancing the understanding and evaluation of various technology types. The Water Power Program's Market Acceleration and Deployment projects are aimed at reducing the time and costs associated with siting water power projects; better quantifying the potential magnitude, costs, and benefits of water power generation; and identifying and addressing other barriers to deployment. When total DOE funding for MHK from FY 2008 to FY 2012 is categorized by activity area,

MHK renewable energy is an emerging industry actively working to research, develop, and demonstrate technology designs. To support the development and deployment of MHK devices, nearly 90% of WWPTO's MHK funding from FY 2008 to FY 2012 was directed toward technology development.

Technology Development activities received nearly 90% of the funding while Market Acceleration and Deployment activities received the remaining 10%.

Within the Technology Development and Market Acceleration and Deployment activity areas, the Water Power Program funds particular topics in priority areas. The Technology Development activity area is mostly divided among Ocean/ River/Tidal/Current Energy Systems, Testing Facilities, and Wave Energy Systems. Environmental Impacts and Siting projects represented the largest topic area funded under the Market Acceleration and Deployment activity area. Table 2 provides details on the MHK funding for each topic area within the Technology Development and Market Acceleration and Deployment activity areas.

Photo credit: Oregon State University

The Northwest National Marine Renewable Energy Center's first open water testing platform, the Ocean Sentinel, was deployed August 17th, 2012, and the first test at the new platform was held a week later by WWPTO-funded Northwest Energy Innovations.

Table 2: FY 2008 – FY 2012 Marine and Hydrokinetic Funding Distribution by Topic Area

Topic Area	Total Funding	Percent of Total
Technology Development Subtotal	**$88,475,937**	**89.7%**
Ocean/River/Tidal Current Energy Systems	$31,846,883	32.3%
Test Facility Support and Construction	$28,851,692	29.2%
Wave Energy Systems	$20,654,910	20.9%
Component Design and Development	$2,419,037	2.5%
Ocean Thermal Energy Conversion Systems	$2,035,723	2.1%
Technology Assessment	$1,467,692	1.5%
Instrumentation, Testing and Evaluation	$1,200,000	1.2%
Market Acceleration and Deployment Subtotal	**$10,191,330**	**10.3%**
Environmental Impacts and Siting	$8,093,512	8.2%
Resource Assessments	$2,097,572	2.1%
Total	**$98,667,021**	

Funding by Geographic Region & Division

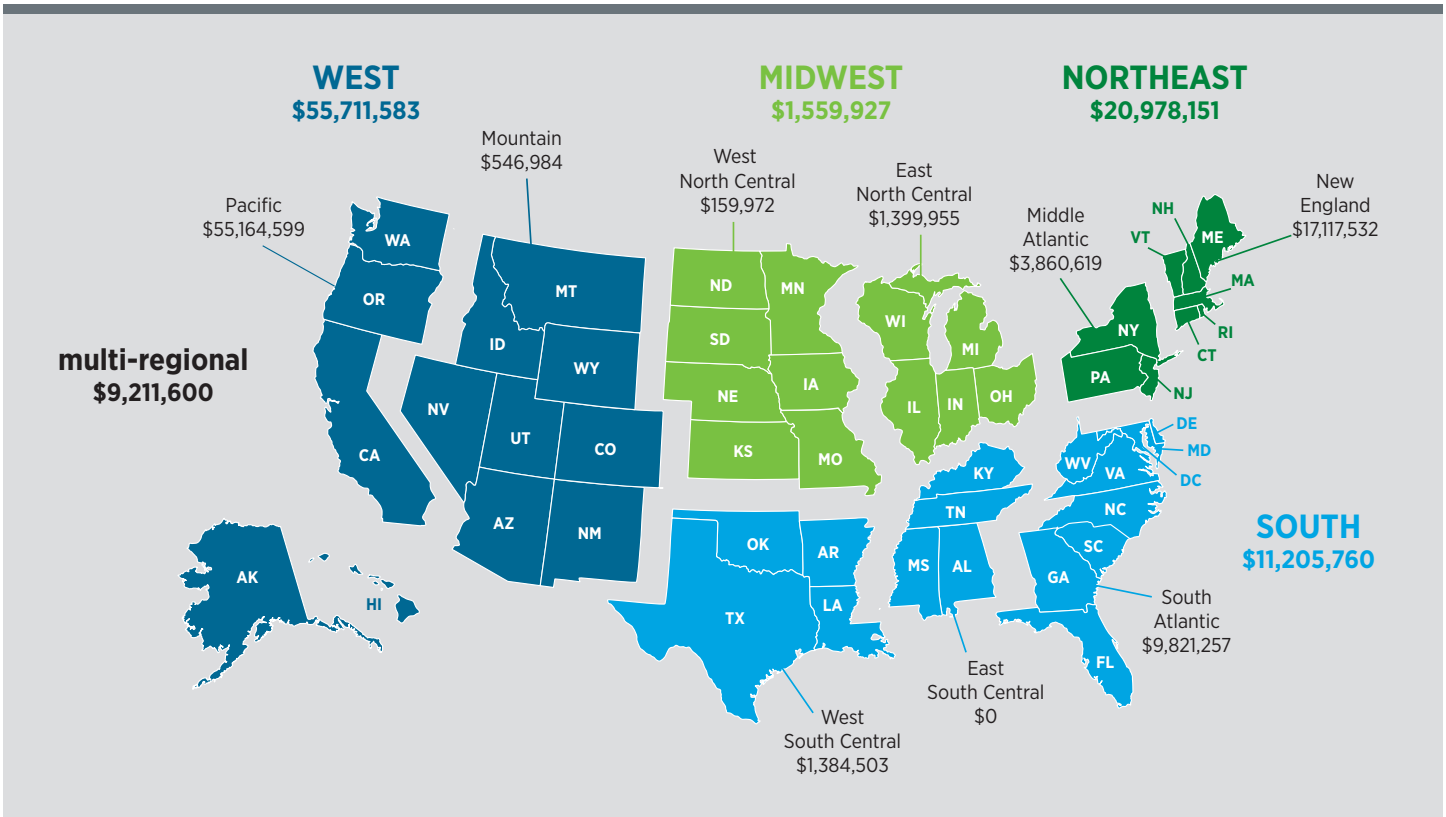
MHK projects were awarded in each of the nation's four geographic regions. Table 3 provides details on how the Water Power Program's funding was distributed within regions and divisions. The geographic regions and divisions used to present the distribution of WWPTO's funding are based on the U.S. Census Regions and Divisions.[2] Six projects spanned several regions and divisions and are thus categorized as multi-regional.[b]

Exhibit 1 provides a map that shows how the Water Power Program's MHK project funding was distributed throughout the United States.

Table 3: FY 2008 – FY 2012 Marine and Hydrokinetic Funding by Geographic Region & Division

Region	Region Total Funding	Division	Division Total Funding
West	$55,711,583	Pacific	$55,164,599
		Mountain	$546,984
South	$11,205,760	South Atlantic	$9,821,257
		West South Central	$1,384,503
		East South Central	$0
Northeast	$20,978,151	New England	$17,117,532
		Middle Atlantic	$3,860,619
Midwest	$1,559,927	East North Central	$1,399,955
		West North Central	$159,972
multi-regional[b]	$9,211,600	national	$9,211,600
		Total	**$98,667,021**

Exhibit 1: FY 2008 – FY 2012 Marine and Hydrokinetic Funding by Geographic Region & Division



[b] The multi-regional category is not used in the U.S. Census regions and divisions. The multi-regional category reflects WWPTO funding awarded to projects occurring across multiple divisions and regions.

Funding by State

Projects in 22 states have received funding for MHK projects through the Water Power Program. Funding awarded to seven projects is disbursed across many states (including Vermont, which is not listed in Table 4), and is categorized as multi-state.[c] Table 4 outlines funding by state.

Combined, Maine, Oregon, and Washington received nearly 40% of total funding for MHK projects. All three states had projects aimed at improving, testing and demonstrating various MHK technologies that are nearing commercialization, and some of the strongest wave and tidal resource potential in the continental U.S. also resides off the coasts of these states.

Table 4: FY 2008 – FY 2012 Marine and Hydrokinetic Funding Distribution by State

State	Total Funding
Alaska	$982,050
California	$6,949,139
Colorado	$400,000
Florida	$4,939,375
Georgia	$841,926
Hawaii	$8,834,608
Louisiana	$1,384,503
Maine	$12,986,034
Maryland	$2,400,000
Massachusetts	$2,621,498
Michigan	$999,955
Missouri	$159,972
New Hampshire	$1,510,000
New Jersey	$999,789
New York	$2,620,830
Ohio	$400,000
Oregon	$12,499,433
Pennsylvania	$240,000
Utah	$146,984
Virginia	$1,639,956
Washington	$12,878,199
multi-state[c]	$22,232,770
Total	**$98,667,021**

[c] The multi-state category reflects WWPTO funding awarded to projects occurring across multiple states.

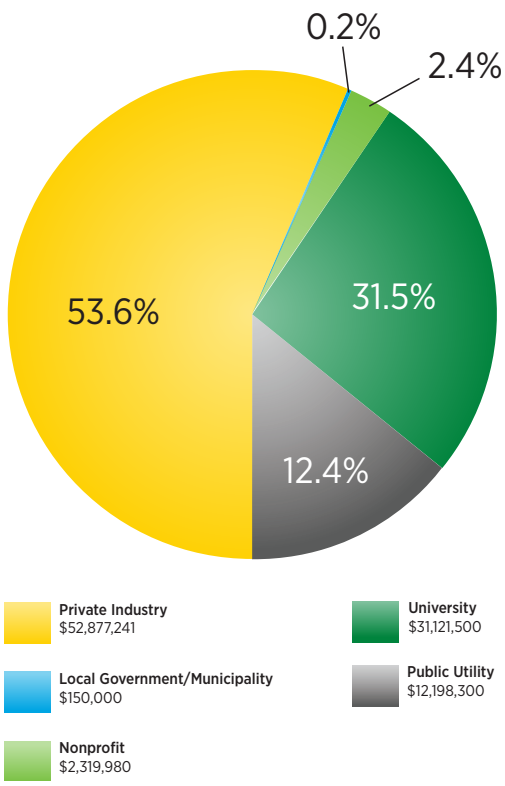
Funding by Recipient Type

DOE funds a variety of recipient types, including private industry, nonprofit organizations, universities and community colleges, investor-owned utilities and public utilities, local and state governments, as well as DOE national laboratories, federal agencies, and interstate government agencies.

More than half of the total MHK funding from FY 2008 to FY 2012 was awarded to private industry, and nearly a third went to universities or colleges. Combined, the three university-run National Marine Renewable Energy Centers in the Pacific Northwest, Hawaii, and Florida represented 85% of university funding and 27% of all MHK funding from FY 2008 to FY 2012.

The remaining funds were awarded to public utilities, nonprofit organizations, and local or municipal governments. Exhibit 2 provides these details by recipient type.

Exhibit 2: FY 2008 – FY 2012 Marine and Hydrokinetic Funding Distribution by Recipient Type



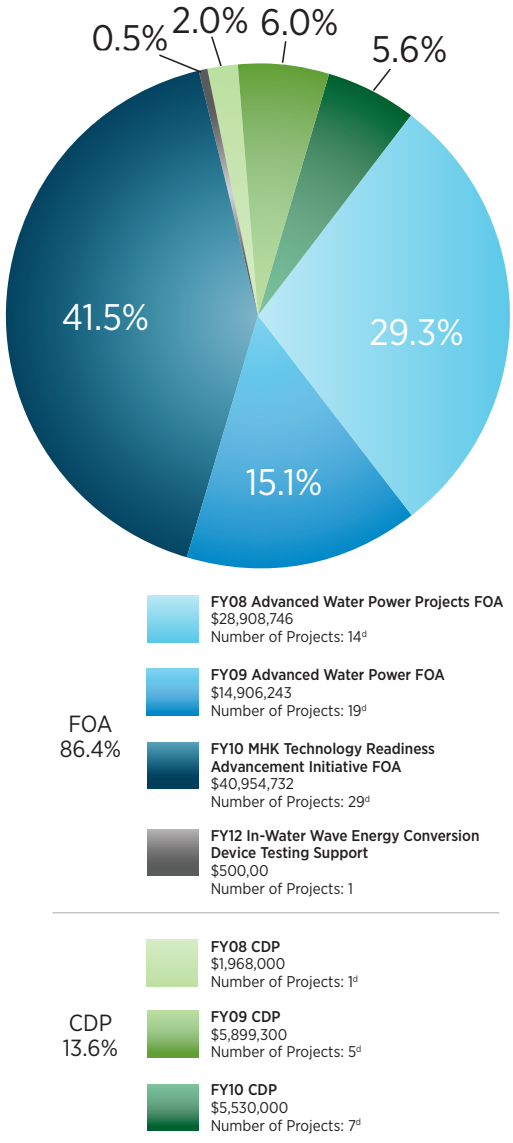
Total funding: $98,667,021

Industry projects awarded to private-sector companies dominate the Water Power Program's MHK investment portfolio, representing more than 50%— or $52.9 million of total funding.

Funding Sources

From FY 2008 to FY 2012, the Water Power Program issued four competitive FOAs focused on MHK. These FOAs provided more than $85 million in announced awards for 63 unique MHK projects. An additional $13 million was awarded to 13 unique MHK projects through congressionally directed funds. Although the unique number of awards made by the Program is 76, some projects, where bodies of work overlapped significantly, were combined in Table 1 resulting in an operational total of 67 projects. Exhibit 3 provides details on the funding sources for the Water Power Program's 76 unique MHK projects.

Exhibit 3: FY 2008 – FY 2012 Funding Sources for Marine and Hydrokinetic R&D Projects



Total funding: $98,667,021

[d] The total number of unique MHK projects awarded was 76; however, 16 projects, where bodies of work overlapped significantly, were combined into 7 projects, resulting in the 67 reported. See Table 1 for more details.

Accomplishments

The Water Power Program provided nearly $100 million in funding for MHK projects from FY 2008 to FY 2012, with numerous projects operating over multiple years. The Water Power Program has already realized significant returns on the federal investment to date and anticipates significant key accomplishments in the years to come. A few of the Water Power Program's project accomplishments include the following:

- In 2012, the Water Power Program completed four **assessments of U.S. MHK resources**: wave, tidal, river hydrokinetic, and ocean thermal energy. The wave assessment, completed by the Electric Power Research Institute (EPRI), found that 1,170 terawatt hours per year are recoverable, with the West Coast (including Alaska and Hawaii) containing high potential for wave energy development. The tidal assessment, completed by Georgia Tech Research Corporation, found that 249 terawatt hours per year are recoverable, with locations with high kinetic power density scattered along both the Atlantic and Pacific coasts, and especially off the coast of Alaska. The river hydrokinetic assessment, also completed by EPRI, found that 120 terawatt hours per year are recoverable, with the Mississippi River containing nearly half of U.S. potential. The ocean thermal energy assessment, completed by Lockheed Martin, found that 576 terawatt hours per year are recoverable in U.S. waters. Additionally, Georgia Tech Research Corporation is updating an assessment of U.S. ocean current resources that will be finished in 2013. The maps of each completed resource assessment are available at: *water.energy.gov/water/resource_assessment_characterization.html*.
- **Ocean Renewable Power Company** (ORPC) has successfully deployed the first U.S. commercial tidal project in the United States using its TidGen™ Power System. In September of 2012, Bangor Hydro Electric Company verified that electricity was flowing from ORPC's Cobscook Bay Tidal Project in Maine, marking the first time in U.S. history that such a project has been connected to the electric power grid. Due to its success, ORPC was named Emerging Company of the Year in November 2012 by the New England Clean Energy Council. The project is not done however, with ORPC planning to install two additional 150 kilowatt tidal energy devices at the site starting in 2013.
- **Verdant Power** received a 10-year Federal Energy Regulatory Commission (FERC) Hydrokinetic Pilot License for its Roosevelt Island Tidal Energy (RITE) Project on January 23, 2012, making it the first licensed tidal power project in the United States. On September 7, 2012 Verdant successfully completed an in-water dynamometry test, with the new rotor performing very well. This project in New York City builds upon an initial DOE investment in 2008 to improve Verdant Power's

turbine blade design. The project is being developed in a phased approach to eventually include up to 30 turbines providing 1 megawatt of power.

- In 2012, FERC granted **Ocean Power Technologies** (OPT) a commercial license for the full build-out of a 1.5 megawatt, grid-connected wave park in the waters off Reedsport, Oregon. This is the first commercial license issued for a wave power project in the United States and provides approval for the deployment of up to ten grid-connected OPT devices for 35-years. The Water Power Program has provided more than $8 million over the years to support the eventual deployment of OPT's 150 and 500 kilowatt devices (PB150 and PB500 respectively). The PB150 should be deployed spring of 2013, while the PB500 will be lab and tank testing in 2013. The issuance of a commercial wave license is a critical milestone and emphasizes the Water Power Program's investments in safe, environmentally sustainable and cost-effective electricity from the nation's water resources.
- In 2012, **Northwest Energy Innovations** (NWEI), in partnership with other industry leaders from New Zealand, verified the ocean wavelength functionality of the WET-NZ device through wave tank testing and a controlled open sea deployment of their 1:2 scale device. The WET-NZ was deployed on August 22, 2012 at the Northwest National Marine Renewable Energy Center (NNMREC) off the coast of Oregon. The first developer to test at the Northwest National Marine Renewable Energy Center's offshore mobile ocean test berth, NWEI obtained six weeks of power performance data, in addition to installation experience. Next the device will be tested for one year at the U.S. Navy's Wave Energy Test Site on Kaneohe Bay in Oahu, Hawaii.
- On March 1, 2012, the **Snohomish County Public Utility District #1** of Washington State filed a final license application with FERC for the Admiralty Inlet Pilot Tidal Project. This DOE-funded project represents approximately $10 million of federal investment and will deploy two grid-connected 6 meter diameter turbines in Admiralty Inlet in 2013. The open-center turbines are ducted, horizontal axis tidal devices. Field measurements in this location are ongoing, making this the best characterized tidal site in the United States.
- **Harris Miller, Miller & Hanson, Inc.** (HMMH) completed a project in the spring of 2012 aimed at providing siting information to the Edgartown Tidal Energy Project. HMMH developed a model to predict changes in hydrodynamics and sediment transport due to energy extraction by tidal devices in Muskeget Channel, Massachusetts and used model results to assess potential changes to benthic habitat. The project also determined the occurrence of protected species in the area to inform monitoring efforts at the proposed project location. These data have been used specifically to inform the Edgartown Tidal Energy Project Draft License application, but the methodology could be used to help other tidal energy projects secure a license.

Photo credit: Ocean Power Technologies

Ocean Power Technologies' (OPT) second utility-scale 150 kilowatt PowerBuoy, the PB150, was fabricated in Portland, Oregon, and is planned for deployment off the coast of Reedsport, Oregon spring 2013. Pictured is the first deployment of the PB150 off the Eastern coast of Scotland.

- In 2012, **Dehlsen Associates, LLC** completed a study that identifies regulatory requirements for avoiding sensitive benthic habitat off the coast of southeastern Florida to inform siting of ocean current technologies. Geophysical and benthic habitat surveys were then conducted within areas selected by the Bureau of Ocean Energy Management to inform MHK siting development and to create ocean energy benthic survey methodologies.
- In September of 2012, **Vortex Hydro Energy** tested the Vortex Induced Vibration Aquatic Clean Energy (VIVACE) converter in Michigan's St. Clair River. The VIVACE converter is a novel device that generates power on a river bottom by creating vortices as the water flows through it that makes the device bob up and down (*vortexhydroenergy.com/technology/*). The VIVACE converter is designed for water currents as slow as 2 to 4 knots, a flow range not targeted by conventional turbine technologies.
- In October of 2011, **EPRI** published two reports on the risk of fish injury and mortality as a result of turbine blade strike. EPRI, in conjunction with researchers at Alden and Conte laboratories, demonstrated that fish survival rates were high, regardless of size, species, or flow rate as they were largely able to avoid the hydrokinetic turbines. The researchers also concluded

that many of the mechanisms that can cause injury at conventional hydropower dams are likely to be absent or much less severe in hydrokinetic projects. A third report detailing the research done at the Conte labs is forthcoming. The reports are available at: *mhk.pnnl.gov/wiki/index.php/Evaluation_of_Fish_Injury_and_Mortality_Associated_with_Hydrokinetic_Turbines*, and *mhk.pnnl.gov/wiki/index.php/Fish_Passage_Through_Turbines_EPRI*.

- In March of 2011, **Columbia Power Technologies'** "SeaRay" wave energy converter was deployed in Puget Sound, Washington. This 1:7 scale wave energy converter device was successfully tested over the course of one full year, being remotely controlled and operated from Corvallis, Oregon. This unique point absorber technology directly couples the motion of waves to the electrical generator via a direct drive, rotary power take-off. Capture of critical, in-water performance data will help inform the future designs of wave energy converters.

Ocean Renewable Power Company's TidGen in Eastport, Maine before deployment August 14, 2012. A few weeks later it became the first tidal power system to deliver power to the U.S. electric grid.

End Notes

[1] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind and Water Power Program, *Water Power for a Clean Future*, DOE/GO-102011-3287. June 2011. http://water.energy.gov/pdfs/51315.pdf

[2] Energy Information Administration, U.S. Census Regions and Divisions. June 14, 2000. http://www.eia.doe.gov/emeu/reps/maps/us_census.html

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