Water Power Technologies Office (WPTO)

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

WAVE ENERGY PRIZE
U.S. DEPARTMENT OF ENERGY

Request for Information on a Draft Marine and Hydrokinetics (MHK) Program Strategy

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Purpose and Objectives in Developing a Strategy

- Set clear programmatic goals for DOE supported MHK RD&D from now to 2030
- Identify actions that the DOE MHK Program can take to support the development of a self-sustaining / commercially-viable MHK industry in the U.S.
- Help to focus Program activities to create greatest impact on technology and industry advancement
- Clearly communicate the potential benefits and opportunities for MHK to a wide audience
- Collect information and feedback from all stakeholders through public requests for information and meetings

Note: The strategy is intended to guide Water Power Technology Office's (WPTO) MHK Program support of the research, development, and deployment (RD&D) of new MHK technologies and therefore does not focus on challenges, approaches or activities that are outside of the authority or mission of the DOE

The Draft MHK Program Strategy includes the following components:

Vision: A long-term view encapsulating the potential and possibilities of MHK technologies in the U.S.

Mission: The MHK Program's role in helping to realize the Vision

Strategic goals: The Program has identified draft strategic goals for the DOE MHK Program and the industry.

Core challenges: A list of the existing core challenges to meeting the Vision that DOE has a role in helping to address.

Approaches: A list of the approaches to addressing the challenges that DOE has an appropriate role in.

RD&D phases: The Program has identified four RD&D phases to align DOE activities toward meeting strategic goals that could be implemented between now and 2030.

For context, the vision and mission of DOE's EERE are:

EERE Vision: A strong and prosperous America powered by clean, affordable, and secure energy

EERE Mission: To create and sustain American leadership in the transition to a global clean energy economy

MHK Vision

A U.S. Marine and Hydrokinetic industry that expands and diversifies the nation's renewable energy portfolio by responsibly delivering energy from ocean and river resources.

The U.S. has 1250–1850 TWh/yr of technically extractable MHK resource[1] . Extracting 5% of the resource could power to 6-8 million (5%-7%) U.S. homes.

Advantages of MHK energy include:

- Located near load centers
- Predictable and forecastable electricity generation profile that complements other generation sources
- Promising non-electric (e.g. desalination) and off-grid (e.g. remote powered infrastructure/equipment) applications

The MHK Program vision aligns with the EERE vision and goals through

- Powering the Nation with clean, affordable, domestically generated and secure energy
- Supporting the development of a new and robust U.S. industry that can:
  - Revitalize and stimulate the growth of U.S. manufacturing capabilities, infrastructure and technical RD&D expertise
  - Compete in rapidly developing international market opportunities
  - Provide new technical job opportunities with good salaries, for example in Science Technology Engineering and Math (STEM) fields

[1]Quadrennial Technology Review 2015 Chapter 4: Advancing Clean Electric Power Technologies, http://energy.gov/sites/prod/files/2015/10/f27/QTR2015-4N-Marine-and-Hydrokinetic-Power.pdf

MHK Program Mission and Strategic Goals

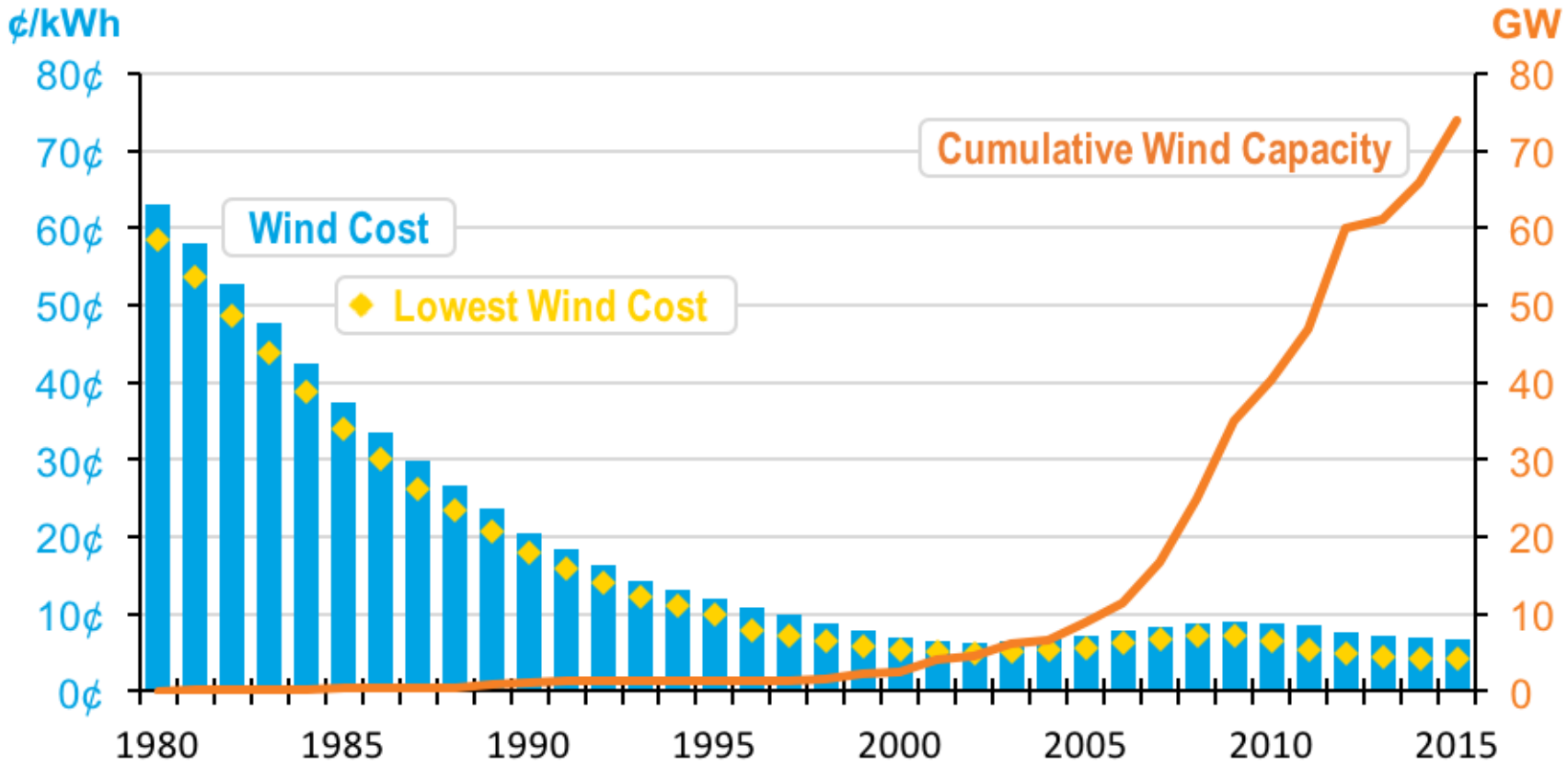
Support the development of safe, reliable, and cost-competitive MHK technologies and reduce deployment barriers

The MHK Program has identified two goals that are critical to accomplishing the mission:

- **Reduce the levelized cost of energy** (LCOE) by 80% compared to the 2015 baseline LCOE values for wave (0.84 $/kW-h[1]) and current (0.58 $/kW-h[1]) technologies by 2030.
- Enable the industry to rapidly increase MHK technology deployments by supporting research and stakeholder outreach activities to reduce deployment barriers and to accelerate project permitting processes.

[1]LCOE 2015 baseline values are for a "first array project", as established by the IEA International Levelized Cost of Energy for Ocean Energy Technologies Report - https://www.ocean-energy-systems.org/library/technical-reports/cost-of-energy/document/international-levelised-cost-of-energy-for-ocean-energy-technologies-2015-/

Experience from other renewable industries suggests how the MHK industry could rapidly penetrate utility scale markets



In the U.S., the first larger-scale wind farms were installed roughly **35 years ago**, though national wind power deployment did not began to surge for another 15-20 years, when wind costs dipped into the cost-competitive range of 5 to 10 cents per kilowatt hour (¢/kWh).

Through DOE support of advanced technology RD&D and activities to reduce deployment barriers, the pace of MHK technology commercialization could possibly be accelerated.

Reference for historical U.S. Wind Costs and Deployments: DOE Revolution Now Report - http://energy.gov/revolution-now

Areas of RD&D opportunity to accomplish goals

1. **Reducing cost:** Help develop and demonstrate MHK systems for early adopter markets (i.e. high cost, remote, or non-electric) to prove technologies and gain operational experience. Simultaneously, support the development of innovative technologies to achieve cost reductions that are necessary to enter the utility scale electricity markets (i.e. lower cost markets)

2. **Reducing deployment barriers:** Support RD&D projects that proactively address important deployment barriers for the first generation of MHK projects, and over time increasingly focus on addressing barriers for utility-scale electricity markets

Relative timing and effort: Given the currently high costs for early stage MHK technologies, the MHK Program intends to devote the majority of its effort toward supporting technology cost reduction activities from now until 2030. Activities to identify and address deployment barriers (related to manufacturing supply-chain, port and shipping infrastructure, workforce, and siting/permitting issues) are also a critical secondary priority, and efforts focusing on these issues will increase as cost-reduction goals are achieved and deployments rates increase.

Core Challenges

Technology Maturity	Deployment Barriers	Market Development
• **Test infrastructure** for rapid iterative improvements does not exist at all necessary scales in the U.S. • **Installation, operations, and maintenance** costs are high and there have been limited opportunities to improve through experiential learning • Expertise for **optimizing commercial array-scale project layout** for device-device interaction, grid integration and IO&M of **multiple devices** is not yet developed • Understanding of relevant **device-environment interactions and tools** to allow for **optimized device designs** is incomplete leading to higher cost and/or overdesigned systems • **Metrics to evaluate systems** and drive design to cost competitiveness from early stage of development through to commercialization advancement are not established	• Processes for **permitting deployments are expensive and time consuming** due to: 1) extensive requirements for baseline and ongoing environmental monitoring due to perceptions of high environmental risk and lack of transferability of data, and 2) inherently high costs of environmental monitoring offshore • **Stakeholders are not fully utilizing all available sources of accurate and unbiased information** about siting and deployment of MHK technologies, including benefits • **Ocean space** and waterways are already **highly utilized** and are becoming more so due to other emerging uses, increasing the complexity of siting new MHK projects • Deployment infrastructure (e.g. **ports, ships, manufacturing**) that is appropriate/optimized for MHK applications does not yet exist	• Many project development **risks** (e.g. technical, permitting, and financial) are **unquantified** • Market opportunities are unclear due to incomplete **data on resources** and a lack of quantitative information on MHK's value proposition for the electric sector • There is **limited investor and power producer knowledge** of MHK technologies and market opportunities • There are **few incentives and policy measures** available to catalyze the deployment of MHK technologies • The MHK sector has a limited number of **researchers and technical experts available** to address technology and deployment challenges

Approaches

Technology Maturity	Deployment Barriers	Market Development
• Enable systematic technology development by **testing and demonstrating prototypes** at multiple scales • Support the development of approaches for safe and cost efficient **installation, grid integration, operations, maintenance**, and decommissioning of MHK technologies • Drive **innovation** in components, manufacturing, materials, and systems with **R&D** specific to MHK applications • Develop, improve, and validate **tools** and methodologies needed **to optimize device and array performance and reliability** across operational and extreme conditions • Collaboratively develop and apply **quantitative metrics** to identify and advance technologies with high ultimate techno-economic potential for their market applications	• Utilize DOE's convening authority to work with agencies and other groups to identify potential **improvements to regulatory processes and requirements** • Support scientific **research focused on retiring or mitigating environmental risks** and **reducing costs** and complexity of environmental monitoring • Provide accurate, impartial information to **build awareness of MHK technologies** with the general public and specific stakeholder groups • Engage in relevant **coastal and marine planning processes** to ensure that MHK development interests are considered • **Evaluate** current and potential future needs for deployment **infrastructure and possible approaches to bridge gaps**	• Rigorously demonstrate the performance and reliability of MHK technologies through commercial **project demonstrations to reduce risk and build confidence of investors, utilities, and independent power producers** • Assess and **communicate potential MHK market opportunities**, **including** early adopter markets (e.g., high cost markets and **off-grid** electricity demands) and **non-electric** applications (e.g., desalination, offshore aquaculture, shoreline preservation) • Commission analyses to **inform incentives and policy measures** (e.g., RPS, PTC) • Develop, **maintain**, and communicate a **national strategy** • Support development of **standards** for insurance and certification • Support **expansion of the MHK technical and research community**

Approaches – Crosscutting

Crosscutting Approaches	
Testing and Research Infrastructure	• **Enable access** to world-class **testing facilities** that help **accelerate the pace** of technology development, while reducing demonstration and certification costs
Resource Characterization	• Improve MHK resource assessments and characterizations needed to **optimize technologies, reduce deployment risks, and identify promising markets**
Exchange of Data, Information and Expertise	• Maintain **data sharing** platforms and encourage dissemination, utilization, and open exchange of information • **Leverage experts, technology, data**, methods, and lessons learned from the **international** MHK community as well as **other scientific and industrial sectors** (e.g., offshore wind, oil and gas)

Overview of Major MHK Program RD&D Phases

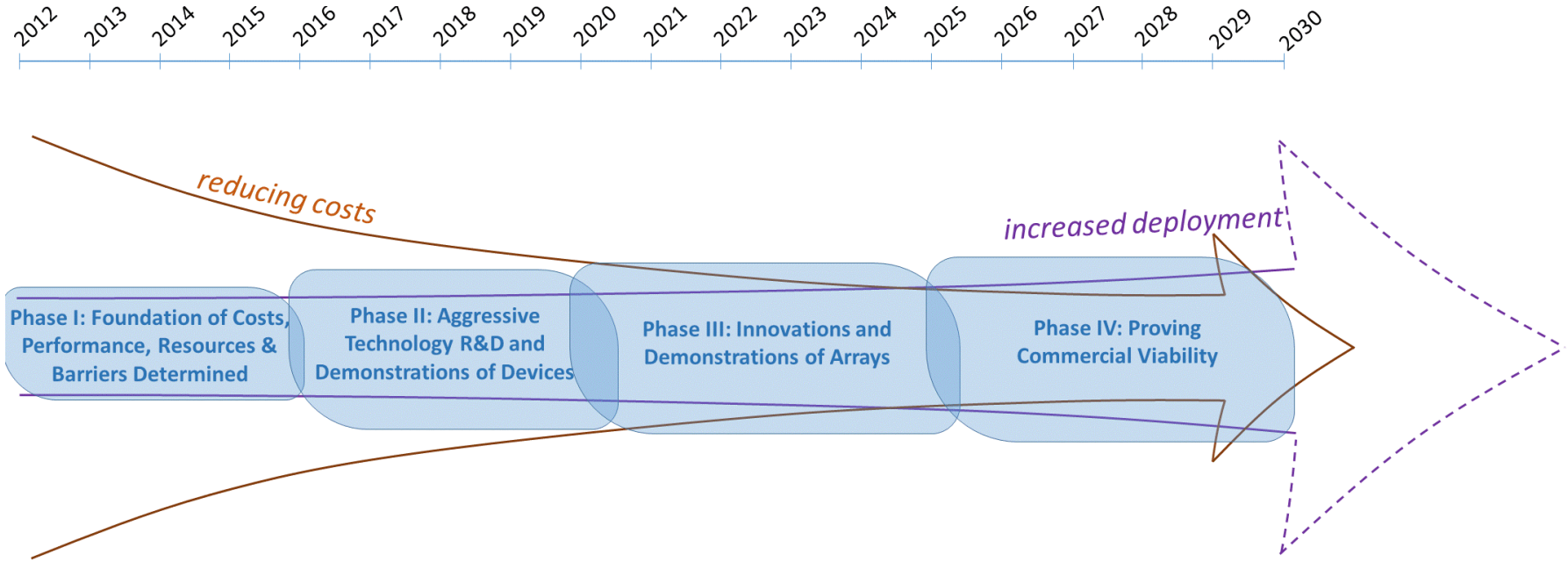
Note: These proposed RD&D phases are intended to summarize major objectives, and do not represent all activities that would be planned/undertaken in these phases

Phase I (~2009-~2015) [COMPLETE]: Complete critical foundational work to determine existing technology costs and performance, R&D needs, resource opportunities and deployment barriers

Phase II (~2015-~2020) [ONGOING]: Aggressive technology innovation and demonstration of Marine and Hydrokinetic systems for multiple resource and market applications

Phase III (~2020-~2025): Implement array-scale innovations and technologies with pilot-scale array demonstration projects

Phase IV (~2025-~2030): Prove the commercial viability of Marine and Hydrokinetic technologies by supporting long-term utility-scale array demonstrations



MHK Program RD&D Phases: Phase I, ~2009-2015 [COMPLETE]

Phase I: Complete critical foundational work to determine existing technology costs and performance, R&D needs, resource opportunities and deployment barriers

Phase I Objectives:

- **Conduct national assessments** for all major MHK resources and have results objectively evaluated and compared, enabling DOE to align research program priorities to areas of greatest opportunity and give industry better information for device design and project siting
- **Quantify a baseline for levelized cost of energy** for marine energy conversion technologies to identify key cost elements of systems[2] and promising cost reduction opportunities[3] to focus research and development (R&D) investments (e.g. controls, power take off, structure components, and system capture efficiency)
- **Perform an assessment and evaluation of existing deployment barriers** by evaluating the first generation of U.S. MHK system deployments and collecting relevant data from other countries to target the highest priority issues and set long-term goals for reducing deployment barriers

[2] DOE Reference Model Project, http://energy.sandia.gov/rmp, 2014

[3] MHK Cost Reduction Pathway White Papers, Sandia National Laboratories, http://prod.sandia.gov/sand_doc/2013/137203.pdf; http://prod.sandia.gov/sand_doc/2013/137204.pdf; http://prod.sandia.gov/sand_doc/2013/137207.pdf; http://prod.sandia.gov/sand_doc/2013/137205.pdf, 2013

MHK Program RD&D Phases: Phase II, ~2015-2020 [ONGOING]

Phase II: Aggressive technology innovation and demonstration of MHK systems for multiple resource and market applications

Phase II Objectives:

- Support the open water **demonstration of today's most promising high technology readiness level MHK systems** that integrate advanced components and technologies specifically designed for MHK applications. This work will demonstrate cost reductions from technology integration, and begin to build the sectors' installation, operation, and maintenance experience.
- Complete construction and commissioning of a **high energy open water wave energy test facility**, establishing a comprehensive suite of wave energy test capabilities in the U.S.
- Support the **development and demonstration of next-generation high technology performance level wave energy systems** in an open water environment. This work will demonstrate the techno-economically viability of wave energy in utility scale electricity markets and justify future investments to advance technology readiness.
- Conduct **targeted market analyses** for wave and current technologies (including non-electric applications) to identify early-adopter markets for near-term, commercial deployments.

MHK Program RD&D Phases: Phase III, ~2020-2025

Phase III: Implement array-scale innovations and technologies with pilot-scale array demonstration projects

Phase III Objectives:

- **Demonstrate array-scale pilot projects using the most promising high technology readiness level MHK technologies**. Three or more projects with a capacity of at least 1 MW per project will be supported. In order to demonstrate reliability and commercial readiness, these projects will be required to establish power offtake agreements (e.g. power purchase agreements) and operate for 2 or more years in a privately developed site. Lessons learned during these demonstration projects will help identify promising R&D that enables further technology cost and deployment barrier reductions, thus benefiting the entire MHK sector.
- **Support array-scale tests of next-generation high technology performance level wave energy technologies**. Two or more grid-connected projects with a capacity of at least 1 MW per project will be supported. The intent is for demonstrations to be performed at a fully energetic wave energy test site with an operational period of at least 1 year. This task will de-risk technology, enabling future commercial demonstrations of array-scale projects in utility markets.
- **Demonstrate reductions in deployment barriers and improved permitting efficiencies** by having array-scale pilot projects (with a capacity of at least 1 MW) licensed in less than 24 months.

MHK Program RD&D Phases: Phase IV, ~2025-2030

Phase IV: Prove the commercial viability of Marine and Hydrokinetic technologies by supporting long-term utility-scale array demonstrations

Phase IV Objectives:

- **Complete permitting, construction and commissioning of 4 to 5 array scale demonstrations in utility markets** (nominally rated at 10-20MW each) in fully energetic resources and collect the first year of operational data to prove commercial viability of technologies and demonstrate that 2030 cost-reduction goals have been achieved

- **Demonstrate reductions in deployment barriers and improved permitting efficiencies** by having larger, commercial array-scale projects (nominally less than 20MW or 40 devices) licensed in less than 36 months, to increase confidence and reduce financing uncertainty necessary for significant deployments to occur after 2030

- **Complete industry-wide MHK market studies** over multiple years to document the growth in investments, projects, infrastructure, suppliers and workforce in the U.S., to provide necessary information for potential future investors and to demonstrate growth occurring in the U.S. MHK industry