OCEAN RENEWABLE ENERGY COALITION
The Marine and Hydrokinetic Energy Trade Association

U.S. Marine and Hydrokinetic Renewable Energy Roadmap

A National Strategy to Support U.S. Energy Security and Create Jobs through the Commercialization of Marine Renewable Energy Technologies

November 2011

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Kaneohe Bay, Hawaii

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Introduction

The United States has significant untapped energy resources from free-flowing waves, tides and currents which could equal ten percent of today's entire generating portfolio, more than the amount of electricity produced by all conventional hydroelectric dams in the country.

Development of the technologies to capture these Marine and Hydrokinetic (MHK) renewable energy resources can play a significant role in our nation's economic recovery, create manufacturing jobs and increase our energy security.

Leaders in the international MHK industry have established a repertoire of mechanisms aimed at responsibly and efficiently commercializing these nascent technologies. Similar public policy, financing and regulatory support have driven significant progress, and include consistent government funding for research and development (market push), establishment of test center infrastructure, accelerated decision making in permitting and regulation, and reliable incentives for power generation (market pull). However, the most pronounced underlying success factor is the ability to focus resources – commercial, financial, scientific and political – on deploying MHK devices and studying their interactions with the natural environment, increasing technical efficiencies and learning from direct experience. This ability to dedicate and focus resources is the critical path to MHK commercialization.

Structuring programs and competitive funding solicitations to align and focus resources that support deployments and in situ research will require coordination within and among federal, regional and state organizations. The U.S. Department of Energy (DOE) has begun the process in its work with state and federal agencies, national labs, universities and non-governmental organizations like the Ocean Renewable Energy Coalition (OREC). Over the past five years, the U.S. Congress has also demonstrated its support for the industry through increased funding for the DOE Wind and Water Power Program. Sustained federal funding will help create thousands of high paying "green" jobs, hasten deployment of these technologies, give confidence to investors and help attract private capital to drive the industry forward.

The Marine and Hydrokinetic Renewable Energy Roadmap describes the issues, challenges and opportunities facing the U.S. MHK industry and provides a clear, logical path to the commercialization of technologies that contribute to a clean, sustainable and diverse electric generating capability. With the right support, the U.S. MHK renewable energy industry can be competitive internationally. With the right encouragement, MHK renewable energy technologies can help us reduce our reliance on fossil fuels and provide clean energy alternatives to fossil fueled power generating systems. And with the right public awareness, our coastline communities and shipyards can use MHK energy production as a springboard for sustainable economic development.

The Roadmap presents schedules for action on federal investments in technology research and technical information research and development along with public policy reforms necessary to achieve the successful commercialization of U.S. MHK devices by 2030.

Development of the MHK Roadmap

The process of developing an industry Roadmap is a useful technique for organizing research and development partnerships involving the DOE, private companies, the National Laboratories and universities. The process involves a series of meetings attended by industry leaders, technical experts and policy makers to identify future needs.

The National Renewable Energy Laboratory (NREL) initiated development of the U.S. Roadmap, led by NREL Fellow Dr. Robert Thresher, who served as facilitator for a series of stakeholder meetings held from 2009 to 2010. The U.S. Department of Energy (DOE) provided funding for these consultations with representatives of various stakeholder groups[i] to create a U.S. companion to the United Kingdom and Canadian MHK Roadmaps.

The list of participants for the U.S. Roadmap is thorough. It includes numerous stakeholders, technical experts, technology developers, project developers, utilities, consultants, private technology investors, component suppliers, government and university researchers, policy makers, government regulators, community organizations and the public. These stakeholders represent the skilled workforces and supply chains needed to manufacture, install, service and maintain MHK devices and their support facilities. They also represent the communities that will consume electricity generated by the facilities they host in public waters.

The synthesized inputs to the Roadmap embody an unbiased consensus that articulates a vision, offers pathways and sets goals based on the stakeholder meetings. It contains expert testimony on technology development balanced with contributions from industry, NGOs, government agencies and academia. Periodic updates of this Roadmap will be needed to help guide the progress of the MHK industry to responsible commercialization.

Vision Statement

Our vision for the U.S. MHK industry is to achieve the following goals by 2030:

- A commercially viable U.S. MHK renewable energy industry, supported by a robust domestic supply chain, competing on a level playing field with other energy sources, and serving domestic and international marketplaces; and,

- An operational U.S. MHK renewable energy capacity of at least 15 GW deployed in an economically, environmentally and socially responsible manner.

This vision for an emergent U.S. MHK renewable energy industry is aggressive given how few MHK systems, even prototypes, are deployed worldwide. Nevertheless, the stakeholders based these goals on examples of previous technologies that achieved growth and profitability even more rapidly.

Key Factors to MHK Commercialization

There are eight key areas that the Federal Government and stakeholders must work on together to overcome the barriers to commercialization of the U.S. MHK industry by 2030. These issues must be addressed throughout each phase of the commercialization pathway. The eight key areas are:

1. **Technical Research and Development**
    - Perform fundamental and applied research on MHK technologies.
2. **Policy Issues**
    - Develop a policy framework that supports a stable market and informs and educates policymakers.
3. **Siting and Permitting**
    - Assess high potential marine resources and develop siting and permitting guidelines for development.
4. **Environmental Research**
    - Perform in situ studies of effects and benefits of MHK energy generation technologies and establish methods to avoid, minimize and mitigate.
5. **Market Development**
    - Develop a market expansion needs assessment including jobs, ports, ships, materials, community education, standards and approaches for meeting them.
6. **Economic and Financial Issues**
    - Analyze support mechanisms, technology pathways, performance, cost and deployment and develop approaches to address any barriers.
7. **Grid Integration**
    - Support utility integration studies that assess variability, capacity value, interconnection and approaches to overcoming these barriers including the benefits of predictable MHK generation.
8. **Education and Workforce Training**
    - Develop the science, engineering and technician educational programs needed to support the MHK industry.

Renewable Energy Technology Growth Patterns

The U.S. wind industry achieved 40 GW of installed capacity from 1990 – 2010 (Figure 1). Similarly, the cumulative, installed solar photovoltaic power capacity has grown more than 900 percent, from just 1,428 MW in 2000 to 14,730 MW in 2008. By 2020, it is expected to grow another 1,900 percent – reaching 298,415 MW (Appendix D).

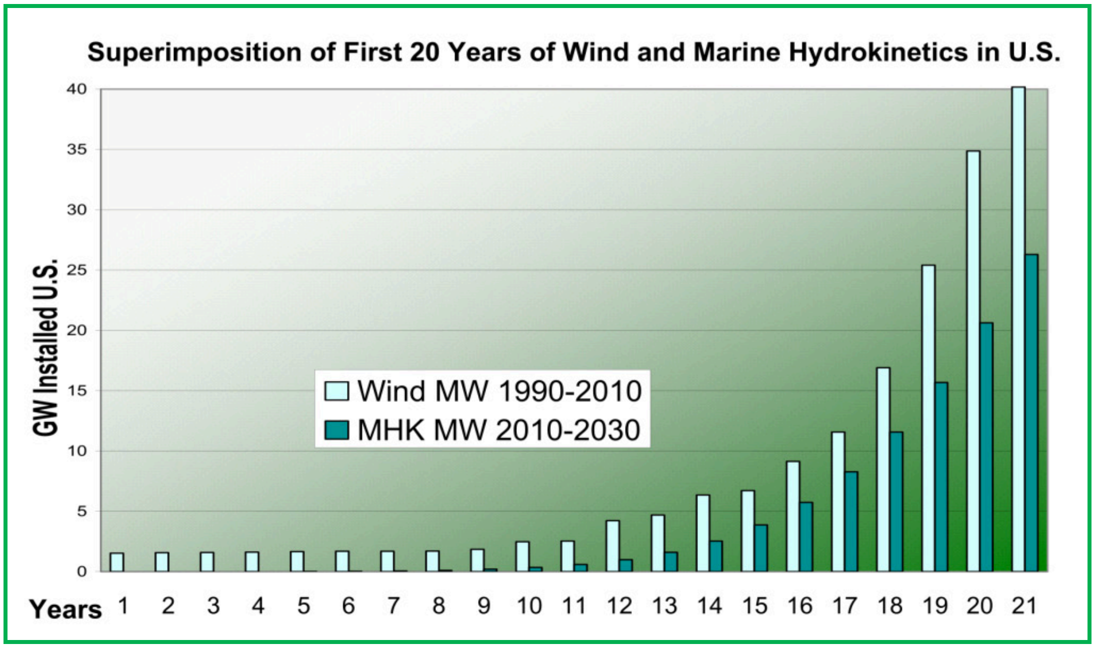

Figure 1 - Comparison of wind industry progress to MHK industry estimates

Potential for Job Creation and Commercial Exports

The MHK industry has significant potential for job creation in the manufacturing and marine services sectors. Using the range of 2.1 to 2.4 job years per MW, the Roadmap participants estimate that our goal of 15 GW installed capacity by 2030 would support the creation of up to 36,000 direct and indirect jobs across the U.S. for fabrication, installation, operations and maintenance of MHK devices.

The Carbon Trust, a U.K. not-for-profit company with the mission to accelerate the move to a low carbon economy, recently predicted that the British marine energy sector could be worth £76 billion to the U.K. economy and support 68,000 jobs by 2050. The Carbon Trust predicted that Britain could capture almost a quarter of the global wave and tidal power market if it builds on its existing technology development leadership position. The majority of the jobs would be a result of the growing export markets into countries that have powerful waves and/or tidal currents. The study, the most in-depth of its kind, found that total marine energy capacity could reach 27.5 GW in the U.K. by 2050, enough to supply more than a fifth of current electricity demand.

The Oregon Wave Energy Trust (OWET) funded ECONorthwest, an economic development consulting company, to make a similar assessment for a 500 MW wave farm off the Oregon Coast. The report concluded that manufacturing, construction and operations of the wave farm would generate 4,553 direct jobs[ii], the majority (4,137) in the construction phase and the remainder (416) in continuing operations.

"Oregon Iron Works has the skilled workforce ready to build what others envision. Ocean renewable energy is a key growth industry that allows us to diversify our business while we continue to grow and create new green jobs right here in the United States."

Chandra Brown, Vice President
Oregon Iron Works, Inc.

Figure 2 - Part of Ocean Power Technologies' Wave PowerBuoy is assembled at Oregon Iron Works.

For small demonstration projects of less than 10 MWs, the jobs impact per MW is likely to be much higher than for a commercial-scale project. Such has been the experience of the offshore wind industry, where average job creation statistics have proven to be relatively stable over many years.

Similar to the U.S., the U.K., Ireland, Portugal, Scotland, Australia and other countries are highly interested in producing emission-free, renewable energy from MHK sources. Scotland, which has had a grid-connected, wave-generating unit in operation since 2001, has a national goal of producing 2 GW by 2020. The U.K. has established a goal to produce 20% of its electricity from ocean renewable technologies by 2020 and Ireland has established a goal of 500 MW by 2020.

The U.K. test programs of commercial scale units has allowed the successful companies producing these devices to secure demonstration project installations in other countries – some of which include direct funding and power purchase agreements. The U.K. has issued leases for deployment of 500 MW of capacity of marine renewables in the Pentland Firth. Moreover, the U.K. recently enacted a Marine and Coastal Bill that consolidates the application process and commits to processing applications within a year's time.[iii] In Canada, the Fundy Ocean Research Center for Energy (FORCE) tidal project in the Bay of Fundy will allow three major commercial tests of tidal technologies to move forward simultaneously, operating while studying environmental issues.

The mechanisms countries have established to demonstrate commercial scale MHK units will boost their position to export successful technologies to regions with marine resources ripe for energy generation. The U.S. has not yet lost its ability to become a net exporter of MHK technology, but must responsibly enact an efficient system to deploy and demonstrate homegrown technology successes as soon as possible in order to secure a significant piece of the growing international industry.

Early Opportunities

Initial deployments in the next few years may benefit from market sectors where the cost of electricity to consumers is high. The opportunity for distributed generation projects in island states and nations, including Hawaii, Guam and Puerto Rico, as well as remote areas like parts of Alaska, provide early and profitable market entries for the MHK industry.

Remote areas and islands are often highly dependent on fossil fuels for electricity and transportation. Many of these areas have very high retail electricity rates – some as high as

$.80 (U.S.)/kW/hr. However, these areas often have abundant renewable resources and small populations. This makes them ideal places to showcase the potential of MHK renewable energy.

In order to capture early revenues in such markets, developers will need to identify approaches that address design and equipment procurement schedules, performance guarantees, availability guarantees and design requirements. A positive sign that the MHK industry is viable is the expressed interest from the maritime and other sectors in providing material, equipment and services. As developers identify supply chain resources with skilled workforces to support manufacturing, deployment and operations, the industry gains credibility and support.

Synergies with Other Offshore Industries

Figure 3 - OREC member Oregon Iron Works serves many industries, from bridge and transit industries to the renewable energy industry, as depicted above.

Working in the marine environment provides synergies with existing industries including ship and boat building, metal and composite fabrication, subsea cables, tourism, ports, fishing, oil and gas, shipping and coastal utilities. Interest in offshore renewables is growing among each of these sectors as witnessed by companies from various sectors joining OREC, the only U.S. national trade association exclusively dedicated to promoting MHK technologies, including Chevron Technology Ventures, Snohomish Public Utility District, Southern Company, Maine Composites Alliance, Ocean Power Technologies, Oregon Iron Works, Renewable Energy Composite Solutions (a division of Christensen Shipyard) and universities from across the U.S. Lessons learned from these sectors include experience with and solutions to a myriad of public policy, regulatory, commercial, technical and environmental issues.

Equally important is the connection between the MHK and offshore wind energy industries. The MHK and offshore wind industries use different methods to extract and convert naturally occurring energy from resources in public waters. Because of variances in the distribution of the different natural resources they will use, they will not necessarily be considered for deployment in the same geographic locations; some devices and technologies will be able to be installed and will work where others will not. Water depth, bathymetry, geographic structures, wave climates, currents and wind regimes will all influence the resources at any site, as well as the efficacy of extracting energy.

Despite these differences, MHK and offshore wind share similar strengths, similar attractiveness and comparable barriers to development in the United States.

MHK and Offshore Wind Technologies
Shared Strengths
• All MHK and offshore wind energy offer improvements to local electrical grids:
• Distributed generation at far reaches of (and beyond) the grid;
• Augmentation of (often petroleum-fired) local generation at microgrid-connected local communities; and
• Peak and intermediate generating capacity incorporating the predictability of waves and tides with broad geographic benefits of wind generation and the potential for base load power from ocean currents.
• Where electricity is presently generated by fuel oil or diesel-fired generators, ocean energy may provide viable and economically attractive opportunities for augmentation of electrical generation and distribution systems within the next five years.
• Useful knowledge and expertise in established industrial sectors, i.e. ship building, subsea cables and marine building materials.
Additional Factors to be Examined
• Technical Commonalities:
• Transmission lines have to be permitted, built, laid, buried, connected and maintained;
• Any components used or deployed in the marine environment must be marinized with little need for maintenance;
• Power Purchase Agreements must be negotiated for the power produced;
• The power produced must be integrated with local electrical grids and regional transmission organizations;
• Education and workforce training must be established; and
• Market development is needed.

Communications

The federal government has and continues to play a critical role in energy technology outreach activities. This role can include funding for industry outreach, hosting and facilitating stakeholder engagements, officially adapting industry recommendations and roadmaps, and participating in state and regional level policy efforts. Finally, coordination and cooperation within the federal agencies on a unified policy plan is critical to support emerging industries, competitive U.S. manufacturing, and a clear, timely and predictable project development process.

At present, MHK stakeholder groups, including federal and state agencies and industry are constrained from active participation in many research and regulatory initiatives and technical exchanges due to limited resources. Funding is required to enlist and encourage more direct communications across industry sectors and among state and federal agencies.

Federal activities related to MHK outreach would provide a focus and a forum for broader participation and more direct feedback to the federal agencies. This would include supporting conferences, workshops and events for public and private stakeholders (International, National, East Coast, West Coast, Gulf, Great Lakes) as well as state and regional level working groups to promote MHK technology and encourage favorable state policies. This support could be modeled on DOE's existing deployment efforts, such as Clean Cities, Wind Powering America, Hawaii/Island Energy Independence.

In addition, this roadmap is intended to be a living document that would require annual updating. Ongoing DOE support for the MHK roadmap would allow the development and acceptance of a more robust roadmap based on modeling, collection and analysis of industry and policy data related to cost of electricity, grid integration, mooring and offshore O&M operations.

Moreover, standardized protocols for communicating cost of energy, system performance, resource assessment, etc. are needed requiring coordination between DOE, NOAA, USACE, FERC, BOEM and BSEE, TC 114, OES-IA, industry and other stakeholder groups. Once developed, standardized terminology can be used in a series of technical and market materials for public consumption and distribution (nature of technology, benefits, top 10 myths, etc).

Federal Government's Role in MHK Development and Commercialization

The Federal Government officially recognized MHK technologies as a source of renewable energy with passage of the Energy Policy Act (EPAct) of 2005. Subsequently, the Energy Independence and Security Act (EISA) of 2007 authorized funding for R&D activities to support MHK technologies. The resulting DOE research and development funding has offered opportunities for developers to leverage government investments and raise private capital that supports industry development. DOE's efforts, coupled with those of the Department of Defense (DOD), which has identified its own ambitious renewable energy requirements and provided funding mechanisms, have demonstrated critical confidence in the nascent MHK industry as it moves toward commercialization. Now is the time to capitalize on these initial investments with a sustained commercialization program.

> *"For every dollar we've received from DOE in grants, we've been able to attract over seven dollars in private capital."*
>
> Chris Sauer, CEO
> Ocean Renewable Power Company

Technology and Technical Information R&D Priorities

The Federal Government has an important role in supporting research and development of MHK technologies that must be implemented to achieve the commercial strategy and mobilize widespread deployment. Federal research investments can facilitate the commercialization efforts of the MHK industry in three important areas, including technology and technical information research and development, national test infrastructure and coordinated resource assessment and characterization of deployment sites. Although discussed separately here, in practice they will be closely intertwined.

Since there are over one hundred different MHK technologies under investigation worldwide, development should concentrate on maturing technologies and issues with broad application. The MHK industry benefits from efforts that focus on critical path issues, areas of common interest, and shared technical challenges, where knowledge gained can be leveraged across multiple implementations. Therefore, the Roadmap concentrates on devices that capture wave energy, tidal energy and current energy from oceans, rivers, and streams. The technologies for these devices are maturing and have broad application. This overall R&D strategy emphasizes the essential roles of enabling technologies, test facilities and resource characterization in realizing MHK commercialization.

Research Focus Areas

During development of the MHK Roadmap, NREL identified six research areas on which to focus in support of MHK commercialization. Each area of basic science and technology is a preexistent, separate and distinct technical discipline that can be directly applied or adapted to solve common problems that have been or will be encountered by MHK developers during the next two decades. Focused efforts to apply existing knowledge gained in other U.S. industries like shipbuilding, sub-sea cable installation and other renewable energy technology development efforts would bring best practices for each of these six areas to bear upon MHK development and contribute to reducing the cost of energy from U.S. MHK.

Figure 4 – Parts to Aquamarine Power's Oyster wave energy device are fabricated.

The following research areas support the pathway to commercialization.

MHK Areas of Research

1. **Seabed Attachments**
    - Foundations, anchors and mooring for floating and bottom-fixed installations.
2. **Engineering Design**
    - Develop design standards and best practices for designs covering structural, mechanical and electrical systems with failure modes analysis.
3. **Materials**
    - Develop environmentally friendly coatings for protection, biodegradable lubricants and oils, advanced structural and foundation materials, and characterize structural and fatigue properties.
4. **Lifecycle and Manufacturing**
    - Manufacturing processes for low cost and high volume, transportation and handling, and rapid low-cost assembly and installation.
5. **Power Takeoff and Control**
    - Develop highly efficient power take-off systems with innovative and adaptive control strategies to maximize energy capture and minimize damaging loads.
6. **Installation, Operations and Maintenance (O&M)**
    - Develop low-cost rapid installation technologies for arrays, and methods to perform O&M during short weather windows.

Wave Energy Device Development
Depending on its complexity, wave device development can take five or more years from concept to ocean prototype testing. Typically, a new concept is simulated with a numerical model to explore its performance and dynamic behavior at low cost. Next, scale models of the devices undergo tank tests to validate and improve the modeling. After satisfactory vetting of the small-scale models, the developer conducts open ocean prototype tests with a device at full, or near full, scale. Building and testing a full-scale prototype is only warranted if there is a high probability of producing a superior device that can be successfully commercialized.

The key research areas for wave devices are device performance and loads, as well as performance in large arrays. For wave energy to reach commercial status and generate significant amounts of energy, the devices must perform well in large arrays. This means that the array layout, spacing and control strategies are critically important. Optimizing the individual performance of a device, while valuable, is not as important as optimizing the entire array energy capture. Systems models are of great importance to estimate system costs accurately and to understand the influence of device scale and array size. Reliability and survival during operations and extreme events will also determine the success of wave technology.

Figure 5 - Ocean Power Technologies' PB150 being deployed in Scotland. This photo is very similar to what will be deployed off the coast of Oregon.

Tidal, Current and Free-Moving Fresh Water Energy Device Development
The development of current devices differs slightly from that of wave devices. This is due to the differences in physical scaling laws of the hydrodynamic forces that each device type seeks to capture. Wave device developers concentrate upon extensive refinement of their designs at smaller, more economical scales. Current turbine system developers place greater emphasis upon accurate modeling that they then combine with rigorous testing of near full-scale prototype devices.

Key research issues for current devices mimic those of wave devices. Both must develop high-energy outputs and prove to perform well in arrays. Although the ways in which wave energy generators and underwater turbines capture energy are very different, some of the same types of numerical modeling tools are used. Models for underwater current devices are thematically the same as for wave devices, yet involve a very physically different energy resource and environment. The most important models for current turbine development examine device performance and dynamics, array dynamics, system scaling and system and component reliability.

Figure 6 - Verdant Power's Free Flow Kinetic Hydropower System Turbines on the shore of their deployment site in New York City's East River.

National Test Infrastructure

The second important federal research role identified by Roadmap stakeholders is support for a national test infrastructure similar to the U.K. commitments for the European Marine Energy Center (EMEC) and WaveHub, and Canadian support of FORCE. We believe that U.S. test centers must be initially government sponsored and funded at levels equivalent to these international examples, and must eventually establish self-sustaining business plans. There are two subthemes to this topic.

The first subtheme is the assignment of mission and capability to each component of the infrastructure. This avoids redundancy beyond that which DOE decides is prudent. The second subtheme is alignment of the infrastructure to the commercialization pathway. The test infrastructure must provide locations that support the commercialization strategy for wave and current devices.

Technology Readiness Levels

The MHK industry depends on test facilities as devices progress through development from concept to models, prototypes and production units. Each stage of technical progress requires a corresponding test capability. To accommodate this requirement, DOE uses Technology Readiness Levels (TRL)[iv] to match devices to test facilities. The DOE TRL guide lists the following stages of development with their corresponding TRLs.

1. Basic Technology Research (TRL 1 & 2)
2. Research to Prove Feasibility (TRL 2 & 3)
3. Technology Development (TRL 4 & 5)
4. Technology Demonstration (TRL 5 & 6)
5. System Commissioning (TRL 7 & 8)
6. System Operations (TRL 9)

Test facilities that support the first three relative levels of technology development (Basic Technology Research, Research to Prove Feasibility, and Technology Development) are plentiful. Academic and private sector research facilities, such as those in the DOE-EERE Hydrodynamic Testing Facilities Database,[v] serve a variety of technologies up through TRL 4 and TRL 5. Further, once device development moves from the laboratory into a relevant environment, the field of candidate test facilities shrinks.

As devices progress to the higher TRL levels for Technology Demonstration, System Commissioning, and System Operations, the dilemma increases. The difficulty is in permitting the relevant environment for use, particularly when there are competing uses for it. The Roadmap participants note that the development of test facilities serving TRL 6 through TRL 8 is hampered by every obstacle and barrier that inhibits MHK development itself. Test facilities for wave and current devices have regulatory and environmental requirements. They need permits and licenses. The construction costs for infrastructure – associated safety systems, undersea cables, and junction boxes – rival those of deployment at equivalent scales. Test facilities are subject to installation and the scarcity or absence of support vessels. Once operational, these test facilities will also need to establish self-sustaining business plans.

Test Facility Development Strategy

U.S. MHK device developers require immediate access to open-water test facilities to demonstrate that prototype and commercial-scale devices achieve good efficiencies, energy capture and reliability. Moreover, there have been initiatives that could provide pre-permitted test facility areas that accommodate categories of technologies that possess the same, or very similar, attributes. To its credit, DOE recognized these challenges and funded the National

Marine Renewable Energy Centers (NMRECs) to create an infrastructure for open water testing of MHK technologies. However, these centers are not yet able to meet the needs of most privately funded technology and device developers, particularly at TRL 7 through TRL 9. Therefore, the Roadmap addresses progress of the national test infrastructure as a serious issue for MHK commercialization efforts.

National testing facilities that support system commissioning and operations require significant build out to be immediately useful to U.S. MHK developers, who must demonstrate efficient and reliable performance in realistic open-water environments before their devices can be financed, insured, and/or bonded. Therefore, the Roadmap recommends that each NMREC develop expandable grid connected test berths to emulate successful U.K. test centers. The capabilities, protocols, sensors, instrumentation and data collection methodologies must be coupled with the receipt of approved permits to support full-scale testing and operation of MHK devices.

After testing facilities are built out to support testing and operation of MHK devices, they must adapt to MHK industry needs for better scale devices, larger arrays and supporting infrastructures. By 2020, U.S. national test facilities should be capable of providing testing programs at remote (industry) sites to address device or site-specific issues. After 2020, DOE should evaluate the conversion of test facilities into operational MHK generation sites and consider their transfer or sale to commercial interests or public utilities.

Resource Assessment and Characterization of Deployment Sites

The third element of federal support for the MHK industry is a coordinated program of resource assessment and characterization of deployment sites.

The Roadmap recommends federal coordination of a national resource database that merges data from public and private sources and distributes it to benefit developers, stakeholders and other sectors. This effort would support DOE's present efforts with OES-IA Annex IV. The Roadmap favors enhanced resource studies at sites with active deployments. This opportunistic strategy adds to national database and model maturity without the cost of independent data collection.

The Roadmap's priority is the resource for wave, tidal and current devices prioritized by developer interest in prime locations. While the Roadmap encourages efforts to refine tools for characterizing MHK resources, it does not endorse them unless associated with a specific deployment or strategy. For example, where there is adequate macro estimates of the MHK resource, detailed assessments should support locations with identifiable, broad interest from developers.

Technical Challenges

Preliminary characterizations of U.S. MHK resources estimated that the nation has vast extractable resources that may be used to produce up to ten percent of the U.S. energy demand. This fueled curiosity in MHK energy, leading to increased interest in more robust resource assessments. Subsequent DOE-funded resource assessments are currently led by Georgia Institute of Technology and the Electric Power Research Institute.

Basic research to understand variances in the marine environment will inform basic marine science and other sectors while also enabling the U.S. to develop robust and well-tuned MHK devices.

Public Policy Reforms for Responsible MHK Commercialization

Federal public policy reforms are necessary to address the permitting and regulatory challenges that are hindering efforts to responsibly commercialize the MHK industry. The Roadmap stakeholders identified three important areas for reform, including positive action on the regulatory framework for pilot and initial stage projects, adopting Adaptive Management and accelerating the decision making process for commercial deployments.

MHK technology and project developers alike must coordinate efforts with the National Oceanic and Atmospheric Administration (NOAA), the Bureau of Ocean Energy Management (BOEM), the Bureau of Safety and Environmental Enforcement (BSEE), the Federal Energy Regulatory Commission (FERC), the Department of Energy (DOE) and several additional federal and state government agencies for permitting projects. This regulatory burden results in a lengthy, arduous and expensive process, even for just testing and demonstration activities. The status quo presents a significant barrier to the responsible commercialization of the MHK industry.

To overcome these challenges, the Roadmap recommends that agencies and stakeholders first approach the deployment of single devices and small arrays as, until proven otherwise, low impact projects with minimal environmental effects. Second, the Roadmap endorses adaptive management as an appropriate solution to confirming initial assessments of low impact and monitoring for long-term impacts that are undiscovered. Third, the Roadmap applauds those agencies already streamlining the permitting process. Other agencies are encouraged to emulate these leadership examples.

Regulatory Framework for Pilot and Initial Stage Projects

The thrust of this section is to promote an approach among regulatory agencies that recognizes the benefits of sustainable energy and balances them against minimal environmental impacts anticipated in small deployments, particularly demonstration or pilot projects.

In 2008, FERC Commissioner Jon Wellinghoff wrote a paper entitled "Facilitating Hydrokinetic Energy Development through Regulatory Innovation" in which he explained that, **"In addition to the further development of hydrokinetic technologies, a key factor in determining whether the country will capture the full potential of this energy source is the regulatory framework in which hydrokinetic systems will operate."**[vi]

In its December 2009 report to the U.S. Congress, the DOE Energy Efficiency and Renewable Energy (EERE) Wind and Water Power Program delivered an exhaustive study that completely addresses all perceived issues related to the deployment of MHK devices. The "Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies" states that **"…a proportional response from regulators is appropriate – small deployments are likely to have small, localized impacts."**[vii] Further, the report notes that **"some aspects of the environmental impacts are unique to the technologies and require operational studies to determine the seriousness of the effects and best mitigation options."**[viii]

New technologies in the process of proving themselves have no history without operational experience. Therefore, demonstration and pilot projects are necessary in the progression from collecting initial data, gaining operational hours, and discovering what environmental effects there are and how to mitigate them. Knowledge gathered in Phase I of the deployment scenario informs planning for later phases that examine the environmental effects of small commercial arrays and large, utility scale MHK arrays. The Roadmap recommends, as the study cited above does, deploying MHK devices in natural waters for operational testing.

Implementing Adaptive Management

Adaptive management is a structured, iterative process of optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time via system monitoring. Adaptive management allows projects to move ahead in the face of uncertainty regarding impacts, so long as projects are closely monitored and operations are changed or even halted if a project causes adverse environmental effects. FERC favors adaptive management, as does the Council on Environmental Quality (CEQ).[ix]

Most resource agencies seek information on the potential impact of marine renewables on the environment. As discussed above, no matter how willing, a developer cannot deliver device data unless it has operational experience. The Roadmap proposes adaptive management techniques that entail less stringent data requirements up-front in exchange for rigorous post-installation monitoring coupled with agreement to mitigate potential or realized harmful effects by removing or altering the deployed devices.

Accelerating the Decision Making Process

U.S. MHK projects are in varying degrees of demonstration stages and are seeking permits to deploy scaled test devices. Using various marine energy test centers in the U.S. and Europe, developers have designed and tested devices for optimal open and protected water testing. Pilot projects currently deployed at fractional scales allow for comprehensive monitoring and testing, but the devices must be in the water to collect the data required for additional permits as projects advance to a commercial stage.

In the past five years, there have been efforts to improve the regulatory processes that MHK developers must follow as they seek to advance the industry. This section reviews these process improvements, assesses their effectiveness and offers feedback for further improvement.

Verdant Exemption: FERC created the "Verdant exemption" in 2007 to allow MHK developers holding a preliminary permit[x] to deploy a test project and connect it to the grid for 18 months without a license. This allows developers to collect the data they need to prepare a license application. However, even with this exemption, developers must still obtain other federal and state permits with their own timelines. The Roadmap recommends that all agencies adopt this exemption.

Pilot License Process: Also in 2007, FERC announced an expedited pilot licensing process for pilot projects, defined as smaller than 5 MW and located outside of environmentally sensitive areas. A pilot license has a term of five years and requires a developer to monitor the project and commit to removal if unacceptable environmental impacts are observed. The quoted schedule for receiving a pilot license process is one year. In practice, it takes much longer largely because of agency requests that developers conduct two-year studies and include the results in the pilot license application. In other words, the processing time is misleading when the imposed prerequisites (consultation and studies) for a pilot license require several years of work and expense. The Roadmap's recommendation for regulatory balance would shorten the aggregate timeline.

Interim Leases: BOEM offers developers the option of a five-year interim (or test) lease to study the effects of pilot projects. The term of the interim lease matches the term of the pilot license. An interim lease will generally require an environmental assessment (EA) rather than a full Environmental Impact Statement (EIS).

Memoranda of Understanding (MOUs): As discussed, one of the challenges to streamlined permitting is the involvement of multiple federal, state and local agencies, which frequently do not coordinate. To improve cooperation, FERC has entered into separate MOUs with Oregon, Washington, California, Maine and Colorado. These MOUs define the roles of each party and commit them to work together for more expeditious licensing of MHK projects. On the federal side, FERC has executed MOUs with BOEMRE and USACE to coordinate licensing.

Categorical Exclusions (CX): On January 3, 2011, the DOE proposed a categorical exclusion for small-scale MHK test and pilot projects. The proposed rule will go into effect November 14, 2011. In support of the proposed CX, DOE prepared a 600-page report comprised of EAs from small array projects in the U.S. and internationally showing that the impacts are minimal. The report included affidavits from six experts agreeing with the conclusions.[xi]

Nationwide Permits (NWP): On February 18, 2011, the USACE proposed a nationwide permit for small MHK projects of up to ten units. A nationwide permit relieves developers of filing a site-specific application, and instead authorizes the activities covered by the permit if the project meets the eligibility requirements. A NWP for MHK projects would expedite the process for obtaining a Verdant exemption or a pilot license. This is a welcome proposal that supports the Roadmap's deployment scenario.

The Pathway to Commercialization

Phase I:	**Demonstration and Pilot Projects (pre-commercial, grid connected)**		
	100 kW	→	5 MW
Phase II:	**Pilot Projects growing into Commercial Project Arrays**		
	5 MW	→	50 MW
Phase III:	**Small Arrays growing into**		**Commercial Utility-Scale Arrays**
	50 MW	→	100 MW

The Roadmap identifies the research, technical and policy issues that will shape commercialization of the MHK industry and explains what factors are common to all types of offshore renewable energy production in the U.S. In addition, as previously discussed, permitting reforms are necessary for this newly emerging industry to allow for the collection of conclusive data on the potential environmental effects of MHK devices. Therefore, the Roadmap proposes a phased deployment approach from demonstration projects to large, commercial, utility scale arrays.

Phased Approach to Responsible Commercialization

The Roadmap offers a phased approach for responsible commercialization of the MHK industry with three critical stages that support increasing project complexity from demonstrations to pilot projects, pilots to small commercial arrays, and commercial arrays to large, utility scale arrays. The goal of each phase is to demonstrate that MHK technology works at the corresponding scale and does not adversely affect the environment. (This assumes that each phase develops and employs effective mitigation methods).

Phase I - Technology Demonstration and Pilot Projects

The first phase of the pathway consists of demonstration and pilot projects from 100 kW to 5 MW. These projects are grid connected with pre-commercial devices at full or subscale.

The U.S. MHK industry is at an early stage of development, with only a handful of pilot demonstration projects operating in U.S. waters. The installation of additional demonstration devices in open-water settings is a critical step to allow developers to gather crucial operational data for projecting device performance, improving designs and establishing baseline costs.

U.S. MHK technology developers are working within this phase now. Easing the ability to get devices into the water will enable U.S. MHK devices to accelerate and mature. In the next few years, the U.S. must enable efficient permitting, so developers can test and improve their technologies. To attract private capital, early-stage companies need to demonstrate a clear path toward "commercial revenues." This requires prototype demonstrations, pilot projects and then commercial-scale projects in the water.

Traditional naval architecture and scientific R&D efforts often make use of tank testing of scaled-down, proof-of-concept designs (and when successful, scaled-down prototypes closer to a final design) in order to gain knowledge of machine responses in increasingly realistic environments. Next, demonstration projects that provide open water experience under real operating conditions (and often include collection of both performance and environmental data) can inform subsequent device development decisions.

These earliest "New Concepts R&D" and "Prototypes Testing" design, development and prototype stages are critical and present the greatest challenges and risks for MHK device developers. Only a handful of U.S. MHK companies have progressed into these stages.[xii] These projects include lab, tank and open water testing of subscale to full-scale prototypes.

Figure 7 – Sound and Sea Technology helps to install Columbia Power Technologies' SeaRay wave energy intermediate scale prototype in Puget Sound in 2011.

Priorities

- Perform fundamental and applied research on MHK technologies;
- Deploy pre-commercial devices in natural waters;
- Monitor and gather data;

- Develop protocols and metrics for measuring effects;
- Identify data gaps;
- Employ adaptive management; and
- Create a funding mechanism that supports public availability of data.

Strategies

- Rely heavily on existing data and literature reviews as a basis for environmental review of pilot projects, with limited site-specific data gathering and study requests narrowly tailored to enable reviewing agencies to comply with their statutory mandates.
- Abide by proportionality principles: data and studies requested must be proportionate to size and duration of small, pilot projects, with focus on impacts of small projects and not future, large scale projects and consistent with agency's statutory mandates.
- Employ adaptive management techniques to shift the focus from extensive pre-siting studies to rigorous post-deployment monitoring with operational changes that minimize adverse effects.
- Support funding for adaptive management which will ensure that results of studies are shared with the public and can be used to advance the industry.
- Invoke existing regulatory tools, such as categorical exclusions and nationwide permits, to accelerate pilot permitting without compromising environmental considerations.
- Develop regulatory procedures for "phased" development to provide MHK developers with flexibility to transition from pilot phase to small array commercial projects at a single site by building out project in phases as additional experience is learned.[xiii]
- Exert strong federal leadership over the pilot permitting process and coordinate multiple agency activity through MOUs and task forces.
- Build on results of first generation pilot projects to identify data gaps, develop protocols and metrics for measuring environmental effects, as well as advanced instrumentation for monitoring and data collection.
- Support federal funding and grants of adaptive management programs and environmental studies, with results shared with all developers, agencies and general public.
- Create government-supported education programs for stakeholders and communities regarding MHK benefits and effects.

Phase II - Pilot Projects Transitioning to Small Commercial Arrays

The second phase of the commercialization pathway consists of pilot projects (5 MW) transitioning to small commercial arrays (50 MW). These projects are grid connected with commercial scale devices.

Phase II will have technology developers, universities and researchers first installing multiple devices into arrays in energetic locations by 2015. The emergent industry will gain knowledge of complex machine responses to the marine environment and between devices, as well as measurable effects of the devices on the marine environment.

Small commercial projects at this stage will have potential to achieve profitability with electrical power sales and government R&D monies, tax incentives and community investment funds. Remote areas presently reliant on high-priced diesel generation will likely become the early beneficiaries of distributed MHK generation. Power purchase agreements with local utilities will prove to be a vital step required to gain confidence of investment communities. Power contracts will ultimately require performance guarantees and an adequate degree of certainty to support project level investments.

From 2011 to 2015, primary activities will consist of testing prototypes and demonstration projects of single machines and then of small arrays. Developers will improve their methods of building, installing, and maintaining MHK devices. Subsequent efforts from 2015 to 2020 will shift towards scaling devices to full commercial scale units, combining them into industrial-size projects and gaining operational experience in the water.

In the time leading up to the year 2020, technologies will mature enough to develop standardized methods to manufacture, deploy, operate, maintain, recover and redeploy cost-efficiently. These efforts will enable the development of larger projects in the 100 MW capacity range.

Priorities

- Perform fundamental and applied research on MHK technologies;
- Reduce permitting costs;
- Further streamline and accelerate the decision making process; and
- Refine protocols.

Strategies

- Share data and experience gained from pilot phase within MHK development community and with stakeholders.
- Build on data generated during the adaptive management phase to transition from pilot projects to small commercial arrays.
- Transfer knowledge gained in Phase I to transition from pilot projects to small commercial arrays.
- Continue participation in international efforts to build a body of knowledge on environmental effects and solutions.
- Begin to fill data gaps based on existing experience.
- Identify types of site-specific data that is necessary for agencies to review projects consistent with their statutory mandates.
- Leverage efforts of offshore wind and potential Atlantic Wind Connection undersea cable to accelerate permitting and reduce costs.
- Build upon and begin to standardize environmental review protocols.
- Evaluate opportunities to engage test centers in ongoing research.
- Support funding for agencies to educate in-house MHK experts familiar with the permitting process who can establish an institutional knowledge base.
- Use data as a basis to inform ongoing coastal and marine spatial planning (CMSP) efforts at the state and federal levels.

Phase III - Small Arrays Transitioning into Utility-Scale Arrays

The third phase consists of small arrays (50 MW) transitioning to large, utility-scale arrays (100 MW). These projects are grid connected with commercial scale devices.

Phase III of the MHK commercialization pathway builds upon the efforts of Phase II and requires that devices be made into reasonably priced, reliable and efficient energy producers with low maintenance costs and negligible impacts on the marine environment. When all of these considerations are met, scaling-up will occur to build profitable commercial ocean renewable energy projects of 100MW or greater in size. Continually advancing technology development will occur gradually over time, and U.S. MHK will eventually compete favorably with conventional energy sources as well as other renewables.

Priorities

- Perform fundamental and applied research on MHK technologies;
- Further reduce costs; and
- Transition to utility scale projects.

Conclusion

Capturing the MHK industry lead will require strategies that establish a system of consistent R&D funding, support for MHK test infrastructure and facilities, accelerated decision making in permitting and regulation and a mix of financial incentives that foster the development of a national and international MHK market. However, the most pronounced underlying success factor is the ability to focus resources – commercial, financial, scientific and political – on deploying MHK devices and studying their interactions with the natural environment, increasing technical efficiencies and learning from direct experience. The ability to dedicate and focus resources is the critical path to MHK commercialization.

The Roadmap sets forth ambitious but attainable goals to establish a commercially viable MHK renewable energy industry by 2030 that competes on a level playing field with other energy sources, promotes a robust domestic supply chain and serves both domestic and international markets. Further, if the commercialization path set forth in the Roadmap is adopted, the U.S. is in a favorable position to achieve at least 15 GW of deployed MHK energy by 2030.

It is clear that the U.S. has taken the initiative to recognize and address many of the issues that serve as barriers not only to its competitive position in the international MHK sector, but to the domestic commercialization of the industry as well. It is apparent that U.S. MHK successes, though welcome, underscore the need for better coordination among U.S. state and federal agencies, the scientific and engineering communities and within the industry itself. As such, it is vital for the U.S. to continue to pursue technical R&D, building national testing infrastructure, refining the MHK policy framework to include guidelines for siting, permitting, adaptive management and phased deployment, leveraging existing workforce and manufacturing experience to develop and strengthen the MHK market, enacting economic and financial incentives to spur growth and private investment and lastly, the continuation of educating the public and employing best practices in the development and eventual commercialization of the industry.

Given the wide recognition and acceptance of a sustainable energy future to achieve U.S. energy independence and increased reliability, the MHK industry is confident that the benefits of past and future investments will result in the timely commercialization of a vibrant MHK industry.

Appendix A – Roadmap Participants

Two seminal documents guided the development of the U.S. MHK Roadmap's commercial and technical strategies. Both documents acknowledge the R&D challenges to the development and deployment of MHK renewable energy and suggest pathways to success. The first is the report from the 2008 workshop of U.S. marine energy stakeholders.[xiv] The second is the technology roadmap for the MHK industry within the United Kingdom.[xv]

The U.S. MHK industry acknowledges the contribution of its international colleagues in developing the Roadmap. Areas of collaboration include the Ocean Energy Systems Implementing Agreement (OES-IA),[xvi] efforts to establish international standards through the American National Standards Institute (ANSI),[xvii] and participation in the International Electrotechnical Committee, IEC TC-114.[xviii]

I. Industry Meeting with OREC Members – Washington, D.C. on 2 December 2009
    1. Larry Armbruster, Sound and Sea Technologies
    2. Roger Bedard, Energy Consultant
    3. John Bonds, Consultant
    4. Phil Dougherty, SMI/Helios
    5. Carolyn Elephant, Ocean Renewable Energy Coalition
    6. Paul Gay, SMI/Helios
    7. Damian Kunko, SMI/Helios
    8. Jarlath MacAtee, Ocean Renewable Power Company
    9. Sean O'Neill, Ocean Renewable Energy Coalition
    10. Derek Robertson, Wavebob
    11. Bill Staby, Resolute Marine Energy
    12. Ron Smith, Verdant Power
    13. Bob Thresher, NREL Facilitator

II. Regulatory Agency Meeting – Washington, D.C. on 9 December 2009
    1. Ben Baron-Taltre, NOAA Fisheries
    2. Stephen Bowler, FERC
    3. Kellie Foster, NOAA Fisheries
    4. Wright Frank, MMS/BOEMRE
    5. Jennifer Hill, FERC
    6. Tim Konnert, FERC
    7. Emily Lindow, NOAA
    8. Ralph Lopez, NOAA Fisheries
    9. Ann Miles, FERC
    10. Michelle Morin, MMS/BOEMRE
    11. David Turner, FERC
    12. Bob Thresher, NREL Facilitator

II. Sandia National Laboratories Meeting – Albuquerque, NM on 21 December 2009

1. Matt Barone, SNL
2. Al LiVecchi, NREL
3. Josh Paquett, SNL
4. Jose Zayas, SNL
5. Bob Thresher, NREL Facilitator

II. Oregon Wave Energy Trust – Portland, Oregon on 25 January 2010

1. Jason Busch, Oregon Wave Energy Trust
2. Justin Klure, Pacific Energy Ventures
3. Al LiVecchi, NREL
4. Rick Williams, SAIC
5. Bob Thresher, NREL Facilitator

III. Oregon State University NNMRE – Corvallis, OR on 26 January 2010

1. Meleah Ashford, OSU
2. George Boehlert, OSU
3. Ted Brekken, OSU
4. Kaety Hildenbrand, OSU Sea Grant
5. Annette von Jouanne, OSU
6. Al LiVecchi, NREL
7. Bob Paasch, OSU
8. Ken Rhinefrank, Columbia Power Technologies
9. Jed Smith, Advanced Research Corporation
10. Bob Thresher, NREL Facilitator

IV. Pacific Northwest National Laboratory – Seattle, WA on 1 February 2010

1. Andrea Copping, PNNL
2. Al LiVecchi, NREL
3. Marshall Richmond, PNNL
4. Bob Thresher, NREL Facilitator

V. University of Washington NNMRC – Seattle, WA on 2 February 2010

1. Alberto Aliseda, UW-NNMREC
2. Larry Armbruster, Sound and Sea technology
3. Rich Chwaszczewski, SAIC
4. Craig Collar, SnoPUD
5. Andrea Copping, PNNL
6. Layna Goodman, NAVFAC NW
7. Al LiVecchi, NREL
8. Phil Malte, UW-NNMREC
9. Brian Polagye, UW-NNMREC
10. Marshall Richmond, PNNL

11. Jim Thomson, UW-NNMREC
12. Bob Thresher, NREL Facilitator

VI. Draft Roadmap Presentation for Industry Feedback at the Global Marine Renewable Energy Conference, Seattle WA on 13 April 2010.

1. Approximate head count of 50 attendees for the presentation by R. Thresher
2. Session feedback discussion facilitated by Henry Jeffry of the University of Edinburgh

VII. Follow-up Telephone Inputs to the Roadmap

1. Roger Bedard, EPRI
2. Dennis Cooper, Lockheed-Martin

VIII. OREC Webcast

Appendix B – U.S. MHK Roadmap Team

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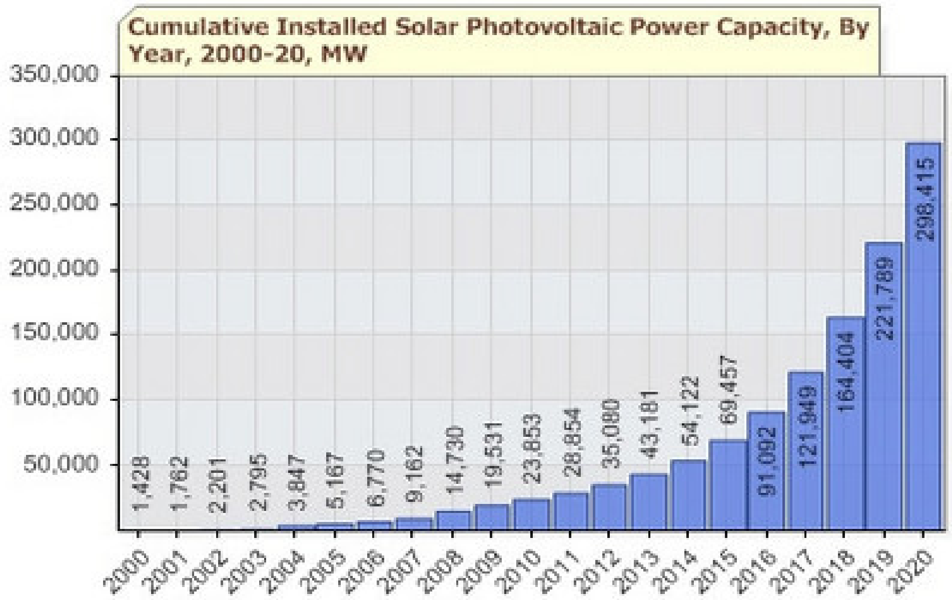
Meegan Kelly

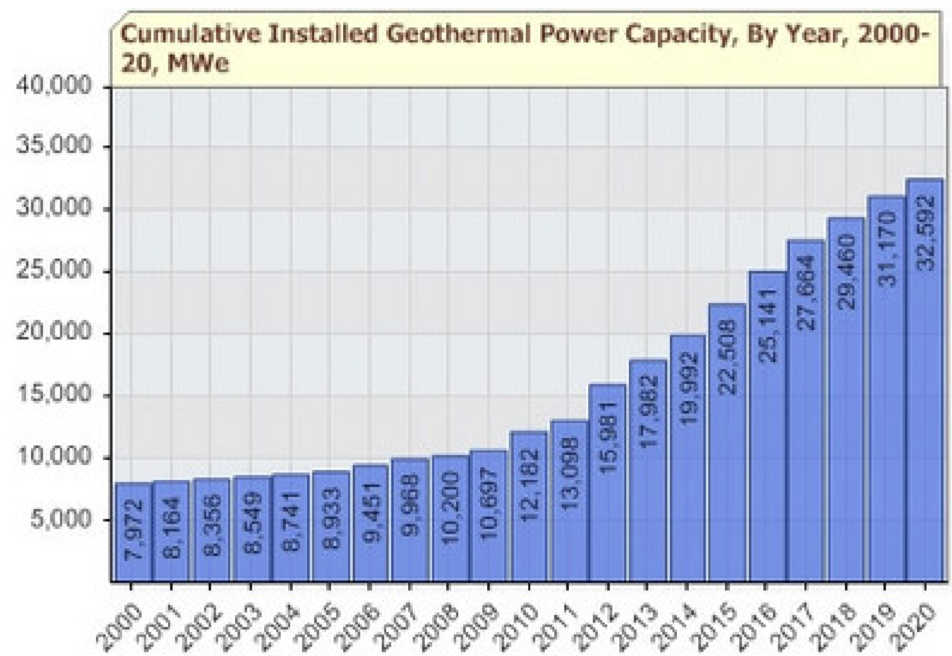
Appendix C – Acronyms

BOEM	Bureau of Ocean Energy Management, Regulation, and Enforcement
BSEE	Bureau of Safety and Environmental Enforcement
CEQ	Council on Environmental Quality
CMSP	Coastal and Marine Spatial Planning
CX	categorical exclusion
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EA	Environmental Assessment
EERE	Energy, Environment and Renewable Energy
EIS	Environmental Impact Statement
EMEC	European Marine Energy Center
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EU	European Union
FERC	Federal Energy Regulatory Commission
FONSI	Finding of No Significant Impact
FORCE	Fundy Ocean Research Center for Energy
GW	gigawatts
kW	kilowatt
kWh	kilowatt-hour
MHK	marine and hydrokinetic
MMS	Minerals Management Service
MOU	memorandum of understanding
MW	megawatt
NGOs	Nongovernmental Organizations
NMREC	National Marine Renewable Energy Center
NREL	National Renewable Energy Laboratory
NOAA	National Oceanic and Atmospheric Administration
NWP	nationwide permit
O&M	Operations and Maintenance
OES-IA	Ocean Energy Systems Implementing Agreement
OWET	Oregon Wave Energy Trust
R&D	Research and Development
TRB	Transportation Research Board
TRL	Technology Readiness Level
USACE	U.S. Army Corps of Engineers

Appendix D – Maps and Figures



Growth Projections for Solar Photovoltaic Power



Growth Projections for Geothermal Power

Appendix E – The Importance of MHK Energy

Ocean Energy Resources and Demographics

- Seventy percent of the Earth's surface is covered by water. Most of this water moves, some of it moves with considerable energy.
- Water is 816 times denser than air and has correspondingly greater power density.
- Ocean renewable energy resources are more predictable than other renewable energy sources:
- Ocean waves can be reliably predicted by 3 days.
- River currents can be predicted for weeks.
- Tidal and ocean currents can be predicted for hundreds of years.
- Some MHK resources are near densely populated coastal areas on coasts and major rivers.
- The number of people living within 60 miles of coastlines will increase by 35% (from 1995) to include 2.75 billion people there by 2025.

Marine Hydrokinetic Energy Production

- Marine Hydrokinetic devices extract a portion of the energy in moving water and convert it to electricity or pressurized water.
- Ocean renewable energy is more predictable than that produced from other renewable sources.
- A diversity of energy sources is the foundation of any reliable electrical system.
- Marine Hydrokinetics can readily provide distributed generation at the far reaches of (and beyond) the electrical grid.
- The total market for tidal and wave renewable energy in a high scenario is worth up to $746.6 billion (cumulative undiscounted) in the period 2010-2050 with the market reaching up to $64.9 billion per annum by 2050.[xix]

Marine Hydrokinetic Advantages

- Not just CO2 free but emission free (for electric generation, not manufacturing, construction, etc.).
- No waste or wastewater discharge.
- No mining, drilling, fuel transport, processing or refining of fuel (and associated emissions).
- Electricity generation near load.
- Limited catastrophic consequences of failure.
- No depletion of finite resources.
- The equivalent of a fixed rate mortgage as opposed to the variable rates driven by fossil fuel prices for traditional generation.
- Support in efforts to decrease GHG emissions and slow down ocean acidification.
- Limited demand on roadways or rail.
- No competition for precious land resources or biomass stocks.

- Predictability supports and enhances grid integration with other renewables.
- No fresh water use.
- Potential for producing desalinated water.
- Potential for producing hydrogen.
- Potential for export of technology.
- Jobs and economic development.
- Support U.S. Energy Security and reduce reliance on foreign oil.
- Support for a healthier America and clean air.

Endnotes

[i] Five meetings were held in 2010 with small stakeholder groups consisting of 10 to 20 participants from different sectors of the industry. A first draft of this Roadmap was presented at an open meeting held prior to the Global Marine Energy Conference in Seattle, Washington, April 2010. This draft Roadmap was also presented in the Marine Energy Technology Advancement Partnership webinar sponsored by the Clean Energy States Alliance in May and at the HydroVision Conference in Charlotte, North Carolina in July 2010. All of these events were well attended by industry members, nongovernment organizations, and state and federal agencies with an interest in and responsibilities for MHK technology development. Feedback and comments on the Roadmap were gathered at each of these events and were used to develop this final draft Roadmap. (See Appendix A – Roadmap Participants and Appendix B – Contact Information)

[ii] ECONorthwest, Economic Impacts of Wave Energy to Oregon's Economy, A Report to Oregon Wave Energy Trust, Final Report September 7, 2009, http://www.oregonwave.org/wp-content/uploads/Economic-Impact-Study-FINAL-mod.pdf

[iii] DECC, December 8, 2010, "Renewables Obligation Banding Review 2013 – Acceleration of Review Timetable," http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/renew_obs.aspx

[iv] USDOE Technology Readiness Assessment Guide, DOE G 413.3-4, October 12, 2009

[v] Hydrodynamic Testing Facilities Database, http://www1.eere.energy.gov/windandhydro/hydrodynamic/

[vi] Wellinghoff, Jon, Pederson, James, and Morenoff, David L., "Facilitating Hydrokinetic Energy Development Through Regulatory Innovation," Environmental Law Journal, Vol. 29:397:2008. Available online: http://www.felj.org/docs/elj292/397_-_hydrokinetics-clean_final_print_11-3-08.pdf

[vii] U.S. DOE, EERE, Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies, December 2009, p.65. Online: http://www1.eere.energy.gov/windandhydro/pdfs/doe_eisa_633b.pdf.

[viii] Ibid, p. 66.

[ix] (73 FR 61291-61323, October 15, 2008, and 73 FR 43084-43099, July 24, 2008, respectively).

[x] Issued for a three-year period, the preliminary permit gives developers an opportunity to study a site and gather data to prepare a license application, while maintaining priority over other competitors to file the application at the site. A preliminary permit does not authorize developers to construct or operate a project.

[xi] Matthew Dunne, Acting Chief Counsel, ARPA-E Memo to: Carol Borgstrom, Director, Office of NEPA Policy and Compliance entitled: Proposed NEPA Categorical Exclusion B5.25 November 18, 2010, Available online: http://nepa.energy.gov/documents/ARPAETechSupportMemo.pdf

[xii] Verdant Power, Ocean Renewable Power Company, Columbia Power Technologies, and Ocean Power Technologies have deployed tidal and wave devices in U.S. waters.

[xiii] Under FERC's existing regulatory practices, a developer must complete development of a licensed project within four years, and does not have the ability, for example, to build the project out over a period of ten years based on knowledge and experience gleaned from the initial phases of operation.

[xiv] Bedard, Roger, 2008, Prioritized Research, Development, Deployment and Demonstration Needs: Marine and Other Hydrokinetic Renewable Energy, Electric Power Research Institute, Palo Alto, CA. Available at: http://oceanenergy.epri.com/attachments/ocean/reports/Final_MHK_Prioritized_RDD_Needs_Report_123108.pdf.

[xv] Special thanks to Henry Jeffrey at the University of Edinburgh, Scotland for sharing his work on the UKERC Roadmap and for extensive consultations on all stages of development of the U.S. roadmap. Mueller, M., and Jeffrey, H., 2008, UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap, University of Edinburgh, Edinburgh, UK, online at UKERC website: http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf.

[xvi] Ocean Energy Systems Implementing Agreement, available at http://www.iea-oceans.org/

[xvii] American National Standards Institute, http://www.ansi.org

[xviii] USNC TC-114, http://www.tc114.us/

[xix] "Carbon Trust: Marine Renewables Green Growth Paper," March 2011. Available at: http://www.carbontrust.co.uk/news/news/press-centre/2011/Documents/110503-marine-green-growth.pdf.