COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES

Marine and Hydrokinetic Energy Technology: Finding the Path to Commercialization

Thursday, December 3, 2009
10:00 a.m. - 12:00 p.m.
2318 Rayburn House Office Building

PURPOSE

On Thursday, December 3, the Subcommittee on Energy and Environment will hold a hearing entitled, *"Marine and Hydrokinetic Energy Technology: Finding the Path to Commercialization."* The purpose of the hearing is to explore the role of the Federal government and industry in developing technologies related to marine and hydrokinetic energy generation.

Similar to wind technologies of a few decades ago, interest in marine and hydrokinetic (MHK) technologies is increasing around the world. Also, as with the emergence of wind technologies of the 1970s, MHK technologies of today need a considerable amount of RD&D before commercialization. These technologies include wave, current (tidal, ocean and river), ocean thermal energy generation devices and related environmental monitoring technologies. There are a variety of energy conversion technologies and companies active in this field, and some MHK devices being demonstrated, primarily outside of the United States.

WITNESSES

- **Mr. Jacques Beaudry-Losique,** Deputy Assistant Secretary for Renewable Energy, U.S. Department of Energy

- **Mr. Roger Bedard,** Ocean Energy Leader, Electric Power Research Institute

- **Mr. Jim Dehlsen,** Founder & Chairman, Ecomerit Technologies, LLC

- **Mr. Craig W. Collar, P.E.,** Senior Manager for Energy Resource Development at Snohomish County Public Utility District

- **Ms. Gia Schneider**, Chief Executive Officer of Natel Energy, Inc.

BACKGROUND

The marine and hydrokinetic (MHK) renewable energy industry is relatively new, yet some of its technologies have roots from the growing wind industry. Experts in the industry expect that MHK technologies will follow a similar path as wind turbines. Significant achievement in efficiency enhancements and cost reductions during the past 30 years in the wind industry are transferable to MHK technologies. Similarly, the Electric Power Research Institute (EPRI) predicts that cost reduction forecasts for the MHK industry will follow a similar path as wind technologies, but not without overcoming some significant hurdles.

Studies have estimated that approximately 10 percent of U.S. national electricity demand may be met through river in-stream sites, tidal in-stream sites, and wave generation. This estimate includes approximately 140 TWh/yr from tidal and in-stream river technologies and 260 TWh/yr from wave generated electricity.[1] This does not include ocean thermal energy, ocean currents or other distributed generation in man-made water systems.

MHK generation could be important as it would meet the demand for coastal regions of the U.S. Coastal regions are home to 53 percent of the population of the U.S. despite comprising only 17 percent of the land in the country. 23 of the 25 most populous counties are located in coastal regions and the 10 fastest growing counties are in coastal states - California, Florida, and Texas.[2]

Technologies and Industry Activity

Various MHK technologies can be used to harness energy from three major sources: currents (tidal, ocean and river), waves, and stored ocean thermal energy.

Current (tidal, ocean and river) Energy Technologies

There are several different energy technologies being used to harness the energy found in currents. Ocean currents of the world are untapped reservoirs of energy linked to winds and surface heating processes. The Gulf Stream is an example of an ocean current. Tides, another form of currents, are controlled primarily by the moon. As the tides rise and fall twice each day, they create strong tidal currents in coastal locations with fairly narrow passages. Examples include San Francisco’s Golden Gate, the Tacoma Narrows in Washington’s Puget Sound, and coastal areas of Alaska and Maine. Tidal in-stream energy conversion (TISEC) devices harness the kinetic energy of moving water and do not require a dam or impoundment of any type. Additionally, in-stream river technologies can be used in any kind of free flowing water, such as rivers or man-made canals.

Conversion devices used to harness energy from tidal currents are similar to those used for river currents, the major differences being that river currents are unidirectional and contain fresh water. Different kinds of currents turn turbines- either *horizontal* (axis of rotation is horizontal with respect to the ground, and parallel to the flow of water) or *vertical* (axis of rotation is perpendicular to the flow of water). The kinetic motion of the

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[1] Electric Power Research Institute, “North American Ocean Energy Status.” March, 2007.

[2] National Ocean and Atmospheric Administration, “Population Trends Along the Coastal United States”. September 2004.

water turns the blades of the rotor, which then drives a mechanical generator. The systems used to harness energy from tidal and river currents are similar to those used in wind energy applications. These similarities lead many experts to believe that the development time for TISEC and in-stream river current conversion technologies may be less than other MHK technologies, such as wave energy conversion or ocean thermal energy conversion (OTEC) technologies.

Electricity generated from tidal currents has an estimated cost for a utility and municipal generator ranging from 4 cents/kWh to 12 cents/kWh, depending on power density.[3] Additional cost reductions will be achieved through economies of scale and improved engineering.[4] Despite the similarities between in-stream river devices and in-stream tidal devices, the former has no reliable studies regarding the cost of electricity. Research regarding the cost of electricity for river devices would help to expand the industry.

Companies across the country are developing devices to harness energy from currents. Verdant Power, established in 2000 and based in New York, has three different projects. Its longest running project is the Roosevelt Island Tidal Energy (RITE) Project operated in New York City's East River. In 2005, the Federal Energy Regulatory Commission (FERC) issued a special Declaratory Order allowing Verdant Power to produce and deliver electricity to end users during the testing phase of the RITE Project. The first federally licensed, in-stream hydrokinetic power plant, developed by Hydro Green Energy, was deployed on the Mississippi River in Hastings, Minnesota and began operating commercially on August 20, 2009. This project was approved in December 2008 by FERC. Pre-installation environmental testing has occurred since February 2009. The turbine has a nameplate capacity of 100 kW and its expected output is 35 kW. A second more efficient turbine is scheduled to come online in spring 2010.

Wave Energy Technologies

Wave energy conversion technologies use the motion of waves to generate mechanical energy that can be converted to electricity. There are many different devices in the testing, development, pre-commercial and commercial stages. While all systems operate under the same general concept of generating electricity through wave energy, they differ in design and method of electricity conversion components. Some of the most common technologies include: attenuators or linear absorbers, pitching/surging/heaving/sway (PSHS) devices, oscillating water columns, overtopping terminators, point absorbers, and submerged pressure differentials.

The Electric Power Research Institute (EPRI) states that the cost of electricity for electricity generated through wave energy conversion devices can range from 11.1 cents/kWh in parts of California to 39.1 cents/kWh in Maine. Wave technology is at approximately the same stage of development as wind technology 20 years ago, just starting its emergence as a commercial technology. At the beginning of wind power

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[3] This is the relationship between the density of the seawater (in kilograms per cubic meter) and the instantaneous speed or velocity of the stream (in meters per second).

[4] Electric Power Research Institute. "North America Tidal In-Stream Energy Conversion Technology Feasibility Study". June 11, 2006.

commercialization, the cost of electricity was over 20 cents/kWh. For each doubling of cumulative installed capacity, the cost of electricity from wind energy decreased by roughly18 percent. The cost of electricity is now around 6 cents/kWh (in 2006$). EPRI predicts that many MHK technologies will follow this same path.[5]

Despite the cost of wave energy generation several companies are pursing demonstration projects. Ocean Power Technologies (OPT) founded in 1994 and headquartered in Pennington, NJ has tested and is now deploying its PowerBuoy worldwide. In 2007, PNGC Power signed a funding agreement for OPT to develop a 150 kW PowerBuoy off the coast of Reedsport, Oregon. This project received $2 million in support from DOE in 2008. The first PowerBuoy is expected to be deployed in 2010. Pacific Gas & Electric Company (PG&E) is also looking at wave energy devices. They will be developing a testing center similar to the Wave Hub (discussed below) and has been awarded a cost sharing grant of $1.2 million by DOE for this project. The California Public Utility Commission is also contributing $4.8 million. The proposed WaveConnect project, to be located in Humboldt County, will be able to test up to four wave technologies at one time. PG&E was granted its FERC preliminary permit in March of 2008 and is planning to apply for its pilot plant license with the FERC in spring 2010.[6]

Ocean Thermal Energy Conversion Technologies

Ocean thermal energy conversion (OTEC) is an energy technology that converts solar radiation in the ocean to electric power. OTEC systems use the ocean's natural thermal gradient—the ocean's layers of water have different temperatures—to drive a power-producing cycle. More than 70 percent of the Earth's surface is covered with oceans. This makes them the world's largest solar energy collector and energy storage system. On an average day, 60 million square kilometers (23 million square miles) of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil. A fraction of this stored energy can be converted to electricity with OTEC technologies.

The three types of systems used for OTEC are closed-cycle, open-cycle, and hybrid, which employ features from both closed and open-cycle systems. *Closed-cycle* utilizes a fluid with a low boiling point that is vaporized by warm surface seawater in a heat exchanger. The vapor turns a turbo-generator, and is then run though a second heat exchanger containing cold deep-seawater. This condenses the vapor back to the liquid form and it is then recycled through the system. *Open-cycle* technologies use warm seawater that boils when placed in a low-pressure container. The steam from the boiling water drives a low-pressure turbine that is attached to a generator. It is then condensed back to a liquid. *Hybrid* systems involve warm seawater which enters a vacuum chamber where it is flash-evaporated into steam, similar to the open-cycle evaporation process. The steam vaporizes a low-boiling-point fluid (in a closed-cycle loop) that drives a turbine to produce electricity.

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[5] Electric Power Research Institute. "North American Ocean Energy Status". March 2007.

[6] Electric Power Research Institute. "Offshore Ocean Wave Energy: A Summer 2009 Technology and Market Assessment Update," July 21, 2009.

Even though OTEC systems have no fuel costs, the high initial cost of building a facility makes OTEC generated electricity more expensive than conventional alternatives. Existing OTEC systems have a low overall efficiency, but there is reason to believe that subsequent technology advances and an expanded body of research based on off-shore oil and gas industry can make OTEC technologies cost-effective. Lockheed Martin Corporation reports that one of the key challenges facing OTEC is creating an economically viable plant. This situation is due to the non-linear scale-up of major OTEC subsystems—increasing the output power by a factor of ten increases the plant capital costs by factor three. The resulting cost of electricity from the first 100 MW commercial facility is calculated to be approximately 21 to 25 cents/kWh. These rates are competitive today in such locations as Hawaii and Guam. However, this number does not take into account several factors such as production and investment credits and decreased costs of future plants which further lower the cost.

OTEC systems currently are restricted to experimental and demonstration units. Island communities which currently rely on expensive, imported fossil fuels for electrical generation are the most promising market for OTEC. DOE originally funded research in OTEC in 1980 and has recently awarded two grants to Lockheed Martin Corporation totaling $1,000,000. The funding will help develop and describe designs, performance, and life-cycle costs for both the near shore and offshore OTEC baseline cost figures. Additionally, funding will go towards the development of a GIS-based dataset and software tool to assess the maximum extractable energy potential globally using OTEC technologies. The U.S. Navy has expressed considerable interest in OTEC. In September of this year the U.S. Naval Facilities Engineering Command (NAVFAC) recently awarded Lockheed Martin an $8.12 million contract to further the OTEC technology development.

International Activities

Many countries are developing MHK energy technologies. Brazil, Canada, the Netherlands, Italy, China, Sweden, Mexico, Germany, Australia, Portugal, India, Ireland, Japan, Denmark, Greece, New Zealand and many others are all operating MHK energy devices at the various scales of testing and commercialization. For example, South Korea deployed their first commercial tidal power plant in May of this year. It is estimated that this device will power approximately 430 households annually, and by 2013 it will have up to 90,000 kW of capacity and supply electricity to 46,000 houses. South Korea is also developing an additional 254 kW tidal power plant in Sihwa, which is scheduled to be completed by the end of next year.

The United Kingdom (UK) has made efforts to develop MHK energy technology. It has established specific funding streams and centers for development and testing of MHK technologies. The UK’s marine energy goal is to have 2 GW of installed capacity by 2020. The Government is also developing a Marine Action Plan that is expected to be published by spring 2010. The Marine Renewables Proving Fund was established by the UK Government to provide up to $32.8 million in grants for the testing and demonstration of pre-commercial wave and tidal stream technologies. They also have established the Marine Renewables Deployment Fund, which will support technologies as they move from development to deployment. Additionally, three device testing centers have been established with a combined funding of up to $56.6 million from the UK Government. They are:

- *New and Renewable Energy Centre (NaREC):* The UK Government appropriated $14.5 million to build on and utilize existing infrastructure to provide an open access facility for marine developers to test and prove designs/components onshore. This facility includes complete in-house prototype development facilities for wave technology, including a wave tank, mechanical and electrical design engineering and procurement, electrical engineering consultancy and support for power conversion and drive train development, complete system testing from marine environment to grid connection, resource and feasibility assessment and consultancy, market analysis and research, and project management, funding, and investment coordination.

- *European Marine Energy Centre (EMEC):* EMEC was established following a recommendation by the House of Commons Committee on Science and Technology in 2002. The UK will provide $11.9 million as part of a renewable energy strategy for their in-sea stage testing facilities-- the only multi-berth, purpose-built, open-sea testing facilities in the world. The Edinburgh-based Pelamis Wave Power technology has generated electricity to the national grid from its deep water floating device at EMEC's wave test site. After being tested, the Pelamis was deployed and connected to the Portuguese grid in the fall of 2008, but is currently not in operation. Verdant Power, Ocean Power Technologies and Columbia Power Technologies, as well as other MHK energy developers based in the United States have tested their technologies or interacted with EMEC's testing facilities and staff. EMEC is linked with a range of different developers and devices, as well as academic institutions and regulatory bodies. EMEC aims to ensure that different devices are monitored in a consistent way, using the best available methods. Furthermore, the dissemination of monitoring information can be carried out throughout the industry, regulatory bodies and their advisors, as appropriate.

- The *Wave Hub:* Due to be built in 2010, the Wave Hub is a $62 million project in which a collection of wave energy conversion devices will be connected to the national grid through high voltage sub-sea cables. It will be the UK's first offshore facility for the demonstration of wave energy generation devices.

Barriers to Generation in the United States

Despite the fact that the U.S. has significant MHK resources and several companies interested in the technology, more investment and greater attention has been paid to these technologies in Europe. The U.S. MHK industry is behind Europe and this could be because of a variety of interconnected financial, regulatory, and environmental barriers.

While cost remains one of the largest barriers, it is estimated that with appropriate pilot and commercial scale demonstration of MHK technologies, the cost of MHK generated electricity will quickly decrease over time. Getting from pilot to commercial scale requires investment in small-scale systems which are not yet proven technologies. It is already difficult to finance new renewable projects with the existing state and federal incentives. MHK projects have an additional set of unique environmental and regulatory barriers which add to the cost of installation and project uncertainty which investors find risky. As a result, developers are put in the position of needing to push for large commercial technologies to drive costs down, but will not do so until a technology is demonstrated and proven commercially viable.

Project finances are heavily dependent upon the pace of the regulatory permitting process. This regulatory permitting process can be costly, lengthy, and complex, and is a very significant barrier to MHK development in the United States (not the focus of this hearing). This process includes activities such as lease and revenue negotiations, submittal of plans and operations concerning the demonstration site assessment, construction and operations requirements, environmental and safety monitoring and inspections. Generally, many of these qualifications have not changed for over a half century and were developed for traditional hydropower plants or for oil and gas projects, not for demonstration MHK activities. Although earlier this year the FERC and Mineral Management Service (MMS) established a less complex permitting, licensing, leasing framework, and pilot project approval process, there are still upwards of 20 other federal, state, and local regulatory agencies which oversee MHK projects.

Part of the complex net of regulatory barriers for MHK devices are the environmental impact requirements needed for permits and licenses. Baseline data collections and significant monitoring of individual sites are needed to fully understand the impacts of MHK devices on the environment. Although environmental issues are expected to be minor for small numbers of units, one factor to be considered is whether large numbers of units will have more significant impacts on the environment. Techniques or models are needed to predict the cumulative effects of multiple units in order to guide deployment and monitoring.[7] A system of management practices, known as "adaptive management," is being used to identify potential environmental impacts, monitor these impacts, and compare them against quantified environmental performance goals. Adaptive management is particularly valuable in the early stages of technology development. In addition to site-specific research, collaborative research that is shared across industry groups and federal agencies is being discussed as a way to meet environmental requirements. Participants in a workshop convened by the DOE agreed that a facility, like the UK's EMEC, would be useful in carrying out environmental studies and making results publicly available.

Department of Energy Marine and Hydrokinetic Activities

The U.S. became involved in marine renewable energy research in 1974 when the Hawaii State Legislature established the Natural Energy Laboratory of Hawaii Authority. The Laboratory became one of the world's leading test facilities for OTEC technologies, but work there was discontinued in 2000. In 1980, two laws were enacted to promote the

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[7] Fisheries. Volume 32 Number 4. "Potential Impacts of Hydrokinetic and Wave Energy Conversion Technologies on Aquatic Environments". April 2007.

commercial development of OTEC technology: the Ocean Thermal Energy Conversion Act, (P.L. 96-320), later modified by P.L. 98-623, and the Ocean Thermal Energy Conversion Research, Development, and Demonstration Act, P.L. 96-310.

The Congress did not act on MHK technologies again until the Energy Policy Act of 2005 (P.L. 109-58). Included in section 931(a)(2)(E) was a broad authorization for research, development, demonstration, and commercial application programs for ocean energy, including wave energy. That authorization contained no further instructions on how to structure a MHK program and expires after FY 2010. Then as part of the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) the Marine Renewable Energy Research and Development Act of 2007 was authorized. This directed the DOE to support RD&D and commercial application programs for MHK renewable energy technologies, including tidal flow and ocean thermal energy conversion technologies, and authorized DOE to provide grants to higher education institutions for establishment of national centers for marine renewable energy research, development, and demonstration. This research received an authorization of appropriations for $50,000,000 annually from 2008 to 2012. Additionally, DOE is required to submit a report in June of 2009 to Congress that addresses the potential environmental impacts of MHK technologies - the report has not been submitted as of yet.

Since the 2007 EISA authorization DOE has established a portfolio of RD&D activities within the Wind and Hydropower program in the Office of Energy Efficiency and Renewable Energy. The DOE has received $10, $40 and $50 million over the last three years for all of the programs water activities, this includes traditional hydropower. The MHK activities have received a small amount of funding and the program has issued a variety of small awards to fulfill its statutory obligations. The two national centers were awarded $1.25 million each for up to 5 years: Northwest National Marine Renewable Energy Center, a partnership between Oregon State University and the University of Washington; and the National Marine Renewable Energy Center of Hawaii. DOE's program priorities for their solicitations include systems deployment, testing and validation; cost reduction and system performance/reliability; understanding environmental effects; resource modeling; and development evaluation and performance standards.

Although DOE has made significant efforts to conduct MHK RD&D, it is not clear if DOE is able to meet the needs of the industry under the current structure of the program. This hearing seeks to address the following questions: 1) Should MHK activities be removed from the larger Wind and Hydropower program and become its own technology program? 2) How could test facilities or specific grants help deploy more MHK devices into the actual demonstrate sites? and 3) How can the DOE, working with other federal agencies, help overcome environmental and regulatory barriers through better practices and improved technologies?