White Paper Submitted to the Western Governors Association Clean and Diversified Energy Advisory Committee:

Ocean Wave Energy Conversion Technology

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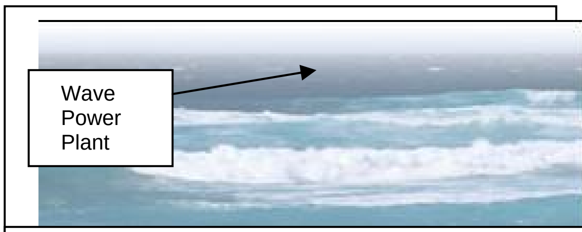
Purpose of This White Paper

To inform the Western Governors Association why wave energy technology should be evaluated as a potential energy supply source to balance and diversify the energy supply portfolio of the Western U.S.



Wave plant not visible from shore

Have you ever watched the swell of an ocean wave surging towards the shore, perhaps carrying a surfer, and pondered its enormous strength? The power of ocean waves is truly awesome. Aside from thrilling surfing enthusiasts and enthralling beachgoers, their destructive potential has long earned the respect of generations of fishermen, boaters, and other mariners who encounter the forces of the sea.

Now consider today's rising fuel prices, at home and at the pump. Think about the all too familiar headlines you read every day about our country's dependence on fossil fuel, including foreign oil, and its implications for the environment and our national security. Wouldn't it be wonderful if the power of ocean waves could somehow be harnessed into useful energy to reduce our dependence on fossil fuel? Instead of burning depleting fossil fuel reserves that pollute the air and water, wouldn't it be wonderful to obtain energy from a resource as clean, pollution free, and abundant as ocean waves? Is this idea the stuff of science fiction? The technology, though young, *exists* to convert the power of ocean waves into electricity.

In a 2004, an Electric Power Research Institute (EPRI) Feasibility Definition Study made a compelling case for investment in offshore wave energy technology for three (3) western states; Hawaii, Oregon and California. Feasibility studies for Alaska, with more than one half of the nations offshore wave energy resource but sparse population, and Washington State, with no transmission from the coast to the inland load centers, were not performed.

The Benefits to Hawaii, Alaska, Washington, Oregon and California

Using wave energy to generate electricity would provide many far-reaching benefits. The construction, operation, and maintenance of wave power plants would create jobs, promote economic development, and improve the energy self-sufficiency of coastal states.

There are other compelling arguments for offshore wave energy technology in these states. First, with proper siting, converting ocean wave energy to electricity is believed to be one of the most environmentally benign ways to generate electricity. Second, offshore wave energy offers a way to minimize the aesthetic issues that plague many energy infrastructure projects, from nuclear to coal and to wind generation. Since wave energy conversion devices have a very low profile and are located at a distance from the shore, they are generally not visible. In addition, wave energy is more predictable than direct solar or wind energy, and therefore can be more easily integrated into the overall electricity grid for providing reliable power. In addition, since a balanced and diversified portfolio of energy sources is the bedrock of a robust electricity system, wave energy is consistent with HI, OR and CA's needs and goals. Wave energy is an important energy source and deserves a fair evaluation of its potential to add to the energy supply mix of HI, OR and CA.

A relatively minor investment today can stimulate a West Coast industry generating billions of dollars of economic output and employing thousands of people while using an abundant and clean natural resource. Surely it is worth taking a serious look at what can be achieved.

Description of Wave Energy Conversion Technology

The Ocean Power Delivery (OPD) Pelamis WEC device, shown below in Figure 1, is one of the most technologically mature device available today. It consists of 4 cylindrical steel sections that are connected by 3 joints. The total length of the device is about 400 ft (120m) and the device diameter is about 15 ft (4.6m). The wave-induced motion of these joints is resisted by hydraulic rams which pump high-pressure oil through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all 3 joints is fed down a single umbilical cable to a junction on the sea bed.

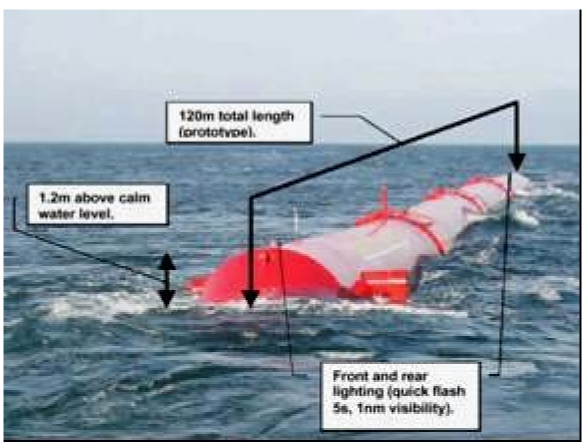


Figure 1. Ocean Power Delivery Pelamis

Other wave energy conversion technologies that are close behind the OPD technology are the overtopping Wave Dragon shown in Figure 2, other point absorbers as represented by the Wave Swing shown in Figure 3, the PowerBuoy in Figure 4 and the AquaBuOY shown in Figure 5. Also close behind are the oscillating water column technology of Energetech shown in Figure 6. In addition, there is several other wave energy extraction devices being developed in the U.S. and around the world.

Figure 2. Wave Dragon

Figure 3. TeamWork Wave Swing deployment

Figure 4 and 5. Ocean Power Technology PowerBuoy and AquaEnergy AquaBuOY

Figure 6. Energetech oscillating water column

Oregon State University (OSU) Contribution

The state of Oregon has a university that is one of the leading universities in the nation in wave energy conversion research and is now proposing to develop a national-scale research, development and demonstration test center off the coast of Oregon. A research center may be one option for attracting a wave energy project to Oregon. OSU has a track record of successful wave energy technology research. They have developed three direct drive prototype buoys designed to be anchored 1-2 miles offshore, in typical water depths of greater than 100 feet, where the buoys will experience gradual, repetitive waves. OSU's Permanent Magnet Linear Generator Buoy prototype is shown in Figure 7 along with the research team that developed the technology. OSU's research team continues to pursue optimum wave energy topologies and have also developed a Permanent Magnet Rack and Pinion Generator Buoy; and a Contact-less Force Transmission Generator Buoy. OSU's goal is to expand its wave energy program and play an intricate part in developing a wave park in Oregon.

Figure 7. OSU Linear Generator Buoy and Team

The long term vision of OSU is depicted in the following figure depicting an array or park of direct drive buoy modules.

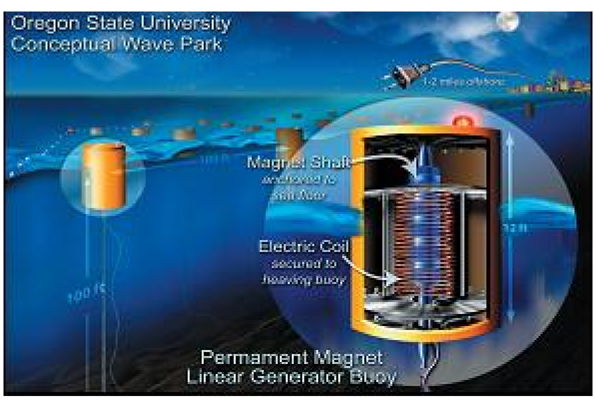


Figure 9. OSU Conceptual Wave Park

EPRI Feasibility Study

In 2004, EPRI conducted a feasibility definition study which resulted in a compelling case for investment in offshore wave energy conversion technology for the western states of Hawaii, Oregon and California.

Sites and wave energy conversion devices were identified and assessed. Based on specific sites and devices selected by state electricity stakeholders, pilot and commercial scale plants were designed, their performance and cost was estimated and their economics assessed.

Supply and cost curves

It is an established fact that learning through production experience reduces costs – a phenomenon that follows a logarithmic relationship such that for every doubling of the cumulative production volume, there is a specific percentage drop in production costs. The specific percentage used in this study was 82%, which is consistent with documented experience in the wind energy, photovoltaic, shipbuilding, and offshore oil and gas industries.

The industry-documented wind energy learning curve is shown as the top line in Figure 10. The cost of electricity is about 4 cents/kWh in 2004 U.S. dollars based on 40,000 MW of worldwide installed capacity (at the end of 2004) and a good wind site. The lower and higher bound cost estimates of wave energy in Oregon are also shown in Figure 10. The 82% learning curve is applied to the wave power plant installed cost but not to the operation and maintenance part of the cost of electricity (hence the reason that the three lines are not parallel).

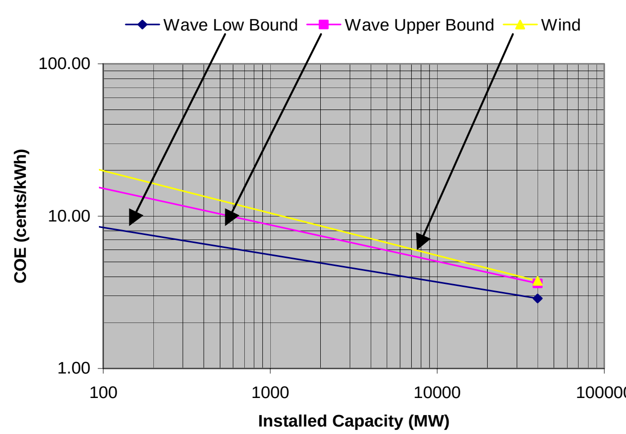


Figure 10. Wind and Wave Energy COE as a Function of Cumulative Installed Capacity

The cost of electricity for the first 100 MW commercial scale plant in Oregon (and Hawaii and California are about the same) is between 8 and 16 cents/kWhr which is substantially less than the entry point for wind technology when it reached a capacity of 100 MW back in the early 1980s.

Figure 10 also shows that the cost of wave-generated electricity is less than wind-generated electricity at any equal cumulative production volume under all cost estimating assumptions for the wave plant. The lower capital cost of a wave machine (compared to a wind machine) more than compensates for the higher O&M cost for the remotely located offshore wave machine. A challenge to the wave energy industry is to drive down O&M costs to offer even more economic favorability and to delay the crossover point shown at greater than 40,000 MW.

***A megawatt recommendation and* a timeline for technology and policy implementation**

As of September 1, 2005, there is 2.29 MW worldwide offshore installed wave energy capacity. The total installed in the U.S. is 0.04 MW.

- 0.75 MW OPD Pelamis at European Marine Energy Centre (EMEC), Orkney, Scotland
- MW WaveSwing at Lexious, Portugal
- 0.5 MW Energetech at Port Kembla, Australia
- 0.04 MW Ocean Power Technology, Hawaii

EPRI predicts, assuming that the U.S. or the HI, OR or CA state governments decide on policy and measures to stimulate wave energy technology electricity generation in the latter half of the first decade of the 21st century, that the capacity installed in the U.S. in the following years will be:

2006 = 0 MW
2007 = 1 MW
2008 = 4 MW
2009 = 8 MW
2010 = 120 MW

Barriers for the technology and proposed solutions

The primary barriers to the above capacity being installed in the US and a commercialization of wave energy technology in general are as follows:

1. Lack of U.S. Federal Government support. The U.S. government is and has supported the development and demonstration of all electricity technologies except for ocean wave energy. A current example is the clean coal technology development and the $1 billion for a Future Generation clean coal demonstration program.
2. Lack of U.S. Federal Government production subsidies. The entry cost of an emerging technology is high relative to established technologies. For those technologies deemed to be in the public benefit, the Federal Government has in the past subsidized early production of the emerging technology. A current example is the renewable production tax credits, which does not include renewable wave energy.
3. U.S. Federal, State and Local Government regulatory uncertainty. Given the uncertainties of permitting an offshore project, the private investment communities will chose to invest its capital in projects with less risk.

Policy Recommendations to the Western Governors

The eight recommendations listed below were made in March of 2004 and documented in the EPRI Wave Energy Project Final Summary report which is available on our public website (see www.epri/oceanenergy/)). One of the eight, #4 has come to pass. The U.S. has joined the IEA Ocean Energy Systems for the years of 2005 and 2006. Others may be appropriate for individual state action. And such action may influence other state and federal efforts.

The development of ocean energy technology and the deployment of this clean renewable energy technology would be greatly accelerated if the Federal Government were supporting the development. Appropriate roles for the Federal Government in ocean energy development could include some, or all, of the following:

1. Providing leadership for the development of an ocean energy RD&D program to fill known R&D gaps identified in this report, and to accelerate technology development and prototype system deployment
2. Operating a national offshore wave test center to test the performance and reliability of prototype ocean energy systems under real conditions
3. Development of design and testing standards for ocean energy devices
4. Joining the International Energy Agency Ocean Energy Systems Implementing Agreement to collaborate RD&D activities, and

appropriate ocean energy policies with other governments and organizations
5. Leading activities to streamline the process for licensing, leasing, and permitting renewable energy facilities in U.S. waters
6. Studying provision of production tax credits, renewable energy credits, and other incentives to spur private investment in ocean energy technologies and projects, and implementing appropriate incentives to accelerate ocean wave energy deployment
7. Ensuring that the public receives a fair return from the use of ocean energy resources
8. Ensuring that development rights are allocated through a transparent process that takes into account state, local, and public concerns.

Examples of Successful Support Mechanisms

Portugal

In 2004 the Portuguese Government set ambitious renewable energy targets of 39% and chose to effectively "import" a wave energy industry to help them achieve it. To attract technology developers they offered a dedicated marine energy tariff (some 24€cents currently and indexed linked) per kilowatt hour delivered for the first 20MW of connected capacity. The capacity figure is expected to be raised to 50MW as more projects apply for permits etc. There are a number of competing projects currently underway and OPD's, phased wave farm development will be the first project installed under this initiative.

United Kingdom

The UK has a longer history of support for the Marine Energy Industry. Over recent years the Government has:
• Established the "European Marine Energy Centre" in Orkney, Scotland. EMEC enables machine developers a "plug in" facility where they can have their wave or tidal prototype devices independently tested and outputs verified.
• Launched the "Carbon Trust, Marine Energy Challenge" an initiative whereby device developers could get access to high level engineering design and verification through partnering with renowned engineering consultancies
• Through the Department of Trade and Industry (DTI), awarded over £25 M to support the ongoing development of marine energy devices.
• Launched a £50M support fund which earmarks £8M direct funding for EMEC and the Wave Hub initiative with the remaining £42M available to support demonstration projects. Project funding comprises both capital and revenue funding.

Wave Hub, will offer a "plug in" facility with all the necessary permits etc to allow "next generation" multi device demonstration projects to negate the cost of grid connection.

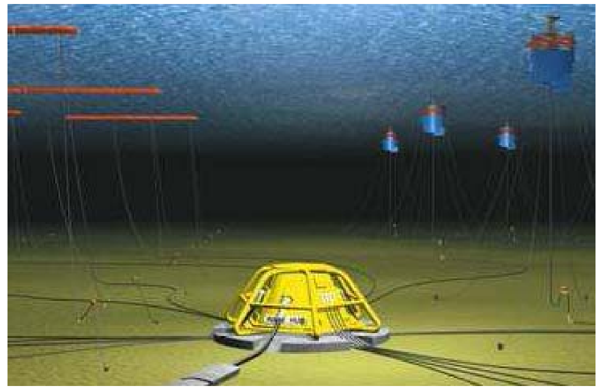


Figure 11. Wave Hub Concept

Such initiatives have fostered a vibrant industry and enticed other overseas device developers to either relocate entirely to or open subsidiary companies in the UK.

Frequently Asked Questions

What is wave energy?

Waves are the movement of water near the surface of the sea. Waves are formed by winds blowing over the water surface which make the water particles adopt a circular motion. The energy of this circular motion is determined by the speed and duration of the wind, the length of sea it blows over, the water depth and the sea bed conditions. The characteristic of wave energy that makes it especially attractive for electricity generation is its high power density compared to the power density of solar and wind energy.

Will these devices survive storms and the hostile marine environment?

Yes. Today's wave energy conversion technology is the result of many years of testing, modeling and development many developer organizations. Full scale prototype have been continuously operating and providing electricity into the since the summer of 2004. The core theme of the current design concepts is survivability.

Will these devices affect the environment?

Given proper care in site planning, offshore wave power promises to be one of the most environmentally benign electrical generation technologies. We recommend that early demonstration and commercial offshore wave power plants include rigorous monitoring of the environmental effects of the plant and similarly rigorous monitoring of a nearby undeveloped site in its natural state (before and after controlled impact studies). With proper siting, offshore wave energy power plants should not cause any permanent damage to the environment.

Will the regulatory authorities grant a permit for this offshore wave power plant?

The novelty of the technology at the federal and state level will likely trigger conservative evaluations and extensive approval processes. The difficulty of obtaining a permit for a wave power plant presents a significant barrier to the development of WEC technology because:

- There is a wide variety of regulations and agencies involved with no clear jurisdictional responsibilities.
- No specific "fast-track" regulations have been developed for short-term marine renewable demonstration projects.

Permitting early wave energy plants will be a challenge since there is no precedence in the US for regulatory authorities to base an approval decision. Nevertheless, we believe that, with strong public support and the positive experiences in the UK and other countries, the Federal Energy Regulatory Agency Commission (FERC) and other federal, state and local agencies will allow this emerging technology power plant project to go forward.

Will offshore WEC technology provide reliable and cost-effective electricity?

Yes. Once WEC technology is a commercial technology, it will provide a cost of electricity equivalent or lower than that produced by existing power plant technology today.

EPRI Perspective

EPRI believes that a diversified and balanced portfolio of energy sources is the foundation of a robust and reliable electrical system and that offshore wave energy technology needs to be evaluated for its role in contributing to our national portfolio of energy supply technologies.

The Electric Power Research Institute (EPRI) was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together member organizations, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power.

For more information, please contact:

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References: (references are available at www.epri.com/oceanenergy/)

(1) EPRI Report WP-003-OR, Oregon Site Study
(2) EPRI Report WP-006-OR, Pilot and Commercial System Level Design Study
(3) EPRI WP-009-US, Final Summary Report