Introduction

Our beautiful ocean and shoreline are our region's most remarkable physical resources. Within that vast expanse of water is energy that could provide a significant part of our county's electricity needs by 2020.

Ocean power technologies are varied, but the primary types are: **wave power** conversion devices, which bob up and down with passing swells; **tidal power** devices, which use strong tidal variations to produce power; **ocean current** devices, which look like wind turbines and are placed below the water surface to take advantage of the power of ocean currents; and **ocean thermal energy conversion devices**, which extract energy from the differences in temperature between the ocean's shallow and deep waters.

The most promising ocean power technology in our region is wave power, as we do not appear to have sufficiently strong tides, ocean currents, or thermal gradients to make other technologies feasible. The good news is that a recent study of California's coastline found enough wave power potential for about six hundred thousand homes in our county and southern San Luis Obispo County.[1] With only about 150,000 households (420,000 people) in the county today, this is obviously far more energy than we need – if the total potential were developed, which is highly unlikely.

As with all energy technologies, the key issues are availability and cost. For the most part, ocean power technologies are very young. The first commercial facilities were installed in 2000 and 2006, in Scotland and Portugal, respectively, but most projects in the water today or slated for the near future are pilot projects. Still, while we can't expect to see the same kind of deployment over the next 10 years that we might for more advanced wind and solar power technologies, we can expect them to begin to come online over the next two decades. With the increasingly strong focus on renewable-energy technologies around the world, we should see medium-scale commercial facilities up to 100 megawatts (MW) by 2010 or 2015, and larger facilities up to 200 MW and more by 2020. However, without existing large-scale wave power facilities to point to, it is difficult to know how much such installations will cost.

Considering the various subsidies available at the state and federal level, wave power technologies could be competitive today – though we will need a track record to establish this as fact. In light of the potentially favorable economics, and with the state's strong support for renewables generally, we project that wave power could supply about 500 MW for our county by 2020, equivalent to about 1,500 gigawatt hours (GWh) a year. This would meet about eight percent of our total energy demand at that time.

As with any technology placed in our oceans, we must fully consider at every step of the way the impacts to fish and other wildlife, as well as to commercial and recreational uses. CEC will work with local stakeholders and policymakers to ensure the utmost sensitivity to any concerns that arise in ocean power development in the future.

Technical Assessment

Of the four ocean power technologies mentioned above, wave power is the most feasible for our county and it will be our focus for the near term. We discuss the remaining three technologies briefly because at some point in the future, technologies and assessments may change to the point where they are feasible in our county.

Wave Power

A number of companies in the U.S., Europe, and elsewhere are developing wave-energy conversion devices (WECs) to capture the energy contained in ocean waves. Some devices, generally known as wave buoys, capture only vertical wave energy — the energy gained from the troughs and crests of waves as they pass by the device. Other devices, such as attenuators, can capture vertical wave energy as well as energy from any other direction.[2]

Pelamis

The most commercially advanced WEC is the Pelamis attenuator, developed by Ocean Power Delivery, Ltd., based in Edinburgh, Scotland (Figure 7-1). The device — a long, tubular structure — floats on the surface of the ocean and converts incoming waves for all directions into electricity. Widely considered the leading WEC technology, the Pelamis has been deployed on a full-scale basis and has endured thousands of hours of testing with no significant design problems. A 2.25 MW pilot project, consisting of three 750 kW devices, will be commissioned in early 2007 in Portugal, with plans to be expanded to 22.5 MW in coming years.[3]

Fig. 7-1. The Pelamis attenuator, developed by Ocean Power Delivery of Scotland.

PowerBuoy and WaveBuoy

Ocean Power Technologies, Inc., based in New Jersey, is not far behind in commercializing its WEC device, the PowerBuoy. This is a buoy connected to a piston system that generates power with each vertical oscillation of the buoy. PowerBuoys were deployed in New Jersey, Hawaii, and Spain in 2005 and 2006, and a larger project is planned for Reedsport, Oregon (see sidebar). While the Hawaii project PowerBuoy's power output is small — 40 kW, compared to the 750 MW Pelamis — the technology has been scaled up to 150 kW for the UK Wave Hub project and will be scaled up 250 kW or more for future projects, and large arrays could be connected to generate hundreds of megawatts. In 2006, hurricane Wilma subjected the New Jersey installation to very rigorous testing. The PowerBuoys survived, and continue to undergo testing in 2007.

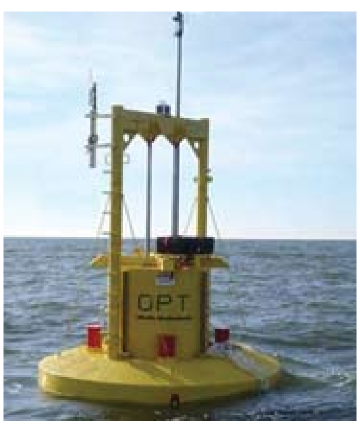


Fig. 7-2. Ocean Power Technologies PowerBuoy, as seen from above water.

Similar to the PowerBuoy is the AquaBuoy by AquaEnergy (now part of Finavera Renewables). In November 2006, AquaEnergy requested a license to build and operate a 1 MW pilot project on the Pacific side of Washington's Olympic Peninsula. AquaEnergy has other projects planned for Oregon, Northern California, Portugal, Vancouver Island, British Columbia, and South Africa, with some projects planned for 100 MW or more.

In July 2006, Ocean Power Technologies, Inc., filed an application — the first on the West Coast — for a commercial wave energy facility off the shore of Reedsport, Oregon. The project will initially consist of 2.5 MW of PowerBuoys about two miles offshore. If all goes well, the project will be expanded to 50 MW over the next few years.

Wave Dragon

The Wave Dragon is a large floating structure that allows water to enter over the sides, then exit the system through a turbine at the bottom. In late 2005, KP Renewables PLC of the United Kingdom entered into a joint contract with Wave Dragon, Inc., to deploy a 7 MW Wave Dragon off the shore of Wales.[4] If the first phase of the project is successful, it has the potential to be expanded to comprise 11 Wave Dragons generating a total of 77 MW.

Fig. 7-3. The Wave Dragon. (Source: © 2005 Wave Dragon)

Wave power potential in our region

A 2005 study funded by the California Energy Commission found 3,357 MW of energy potential at "primary" wave energy sites along 76 miles of southern San Luis Obispo County and Santa Barbara County north of Point Conception.[5] The study also found 3,347 MW of potential at secondary sites outside of the Channel Islands. Beyene projected that a maximum of 20 percent of this potential could be developed, for a total of 1,340 MW. However, our more conservative projection is that 500 MW could be developed in our county by 2020 or a few years later. Two or three large facilities could provide that 500 MW, although it is more likely that we would see a number of smaller projects.

In addition to the sites near shore, our community may also want in the future to explore the region around the Channel Islands, where consistently strong waves offer considerable potential. However, there are many political and environmental issues regarding the development of wave power devices near the islands, similar to the issues with off-shore wind power discussed in Chapter 4.

In particular, the first six nautical miles from the islands comprise the Channel Islands National Marine Sanctuary, and a significant portion of the land comprises the Channel Islands National Park (although 75 percent of Santa Cruz Island is owned by the Nature Conservancy). Ocean power development in this area may be prohibited and would of course raise significant concerns. If offshore wind projects are also developed on or around the islands, it could be feasible and desirable to combine them with wave energy projects, so that both could use the same transmission cables to bring the power back to shore.

The following ocean technologies are not currently feasible in our county, but may become so in the future.

Tidal Power

Unlike wave power conversion devices and current devices, tidal power conversion devices are located near shore. A typical first generation tidal device traps water at high tide, then releases it back to the ocean at low tide through a turbine, which generates electricity. Most first generation tidal power conversion devices are similar to small hydroelectric facilities, which also generate electricity by inducing water to flow over a turbine. A new second generation in-stream tidal power device is being developed, which extracts a portion of the kinetic energy from the moving water stream and it is this second generation that is the focus of interest and application today. Tidal flows are fairly predictable; seawater flows inland for 12 hours of the day, and back out to sea for the remaining 12 hours.

The largest first generation tidal power device in service today is a 240 MW facility at La Rance, France. A 20 MW device has been installed in Canada's Bay of Fundy, which has the highest tides in the world.

Verdant Power, a Virginia-based company, has installed the first two of six water turbines planned for New York's East River.[6] This is a tidal power application because the flow in the East River adjacent to Roosevelt Island is a two way tidal flow. The Roosevelt Island Tidal Energy project began installation in December, 2006. In its first 35 days of operation, it had delivered over 9,450 kWh of tidal electricity to a supermarket on Roosevelt Island.[7]

The kinetic energy in tidal water is about 5 kilowatts per square meter at places like the Bay of Fundy, and 2 to 3 kilowatts per square meter in San Francisco's and Seattle's faster tidal regions.[8] Tides in our county do not appear to be high enough in kinetic power density to make existing tidal energy devices economically feasible. While San Francisco is considering a tidal power device for the waters below the Golden Gate Bridge, the land formations conducive to this technology that are found in that inlet are not present in our county.

Current Power

Current power devices also rely on the directional flow of water but do not require high tides for operation. Instead, they can use constant ocean currents or river flows. The energy from currents is highest in the U.S. in the Gulf Stream off the coast of Florida, which moves at about 1.5 meters per second.[9] Our coastal current, the California Current, moves much more slowly, from 0.03 to 0.07 meters per second,[10] and is periodically disrupted by the El Niño phenomenon.

Aquantis, LLC, a company based in Carpinteria, California, and associated with Clipper Windpower, LLC, is developing a current turbine for deployment in the Gulf Stream and other strong currents. At 2.5 MW, the "C Plane" would be the largest device of all the current power prototypes being developed. While current power technology could generate a significant amount of energy in such places as Florida (whose coast is very near the Gulf Stream) and areas with strong river currents, Santa Barbara County doesn't appear to have sufficiently strong ocean or river currents to make this technology viable.

Ocean Thermal Energy Conversion

Ocean thermal energy conversion (OTEC) devices are usable only in waters with a large thermal gradient — in other words, a large difference in temperature between warmer and cooler waters. The most common OTEC process exploits this gradient to generate electrical energy by using the ocean's warmer surface water to turn liquid ammonia into a gas, which then turns a turbine to generate electricity. The deeper, cooler water is then used to cool and condense the gas back into a liquid.

This technology received substantial support from the Ocean Thermal Energy Conversion Act of 1980, and a number of pilot facilities were built around the U.S. As energy prices dipped in the 1980s, however, governmental support waned for this and other renewable energy technologies. Today, only a few OTEC devices exist around the world, with one relatively large device continuing to operate on the Big Island of Hawaii, at the Natural Energy Laboratory near Kona.

Unfortunately, the temperature gradient must generally be 20º C (36° F) or higher for OTEC to work.[11] Gradients in our region are not large enough to be useful for this technology.

Overcoming Barriers

The barriers to ocean power development in our region include potential environmental effects, a complex and difficult regulatory process, and a current lack of government support for development.

As outlined above, we will focus only on the wave-energy conversion devices, as these are the only technologies with real potential in our region in the foreseeable future. Because wave-energy conversion devices use the motion of the waves to generate energy, these technologies primarily float on the surface of the water, but are moored to the ocean floor. Such facilities would require transmission lines to shore and on-shore support facilities. The following discussion briefly describes some of the issues surrounding the development of such devices in our coastal waters.

Environmental Impacts

Development of wave-energy conversion facilities can entail a number of potential complex environmental effects:

- ***Interactions with marine life (fish and mammals)***
- ***Atmospheric and ocean emissions***
- ***Visual impacts***
- ***Conflicts with other uses of the sea space (fishng, boating, shipping, diving, etc.)***
- ***Impacts from installation and decommissioning***

An environmental review under the California Environmental Quality Act (CEQA) will be required before any wave power projects, pilot or permanent, are installed in our county's coastal waters. Similarly, a review under the National Environmental Policy Act (NEPA) will be required for any devices in federal waters (more than three miles from shore) or projects involving federal funding. Connecting to on-shore transmission lines would require approval by the California Coastal Commission and other local, state and federal permitting agencies . Potential environmental effects and policy conflicts will have to be studied, mitigation measures identified and implemented, and alternatives considered prior to final permitting.

In weighing the pros and cons of these technologies, we hope that the debate will include a discussion of how traditional fossil fuel energy sources -- coal, natural gas and nuclear power -- all have a significant impact on the environment. The marine environment is particularly affected, both directly through emissions, and indirectly by raising the temperature of our oceans through global warming.

Permitting Issues

Because of resource sensitivity and public perception issues regarding ocean energy facilities in our coastal waters, new project permitting will in all likelihood involve a detailed and complex review by a number of Federal, State and local agencies. These will most likely include, among others:

- ***California Coastal Commission***
- ***Department of Fish and Game***
- ***State Lands Commission***

- ***Public Utilities Commission***
- ***Santa Barbara County***
- ***Santa Barbara County Air Pollution Control District***
- ***Federal Energy Regulatory Commission***
- ***United States Department of the Interior***
- ***United States Department of Energy***
- ***United States Environmental Protection Agency***
- ***National Oceanic and Atmospheric Administration***
- ***United States Coast Guard***

While the California Coastal Act provides policy direction for the development of coastal-dependent industrial facilities, including new thermal electric generating plants, new technologies such as those considered in this chapter are not specifically addressed or provided for in this law. Given the history of public opposition to energy-related industrial development in the off-shore environment, wave power facilities will be highly scrutinized by the public and by permitting agencies.

In addition to a difficult regulatory process, the Electric Power Research Institute has concluded that the primary barriers to wave energy technology are not technical but political:

- ***Uncertainty in the regulatory system***
- ***An un-level playing field for ocean power due to more favorable subsidies for fossil fuels***

These factors will affect the timing and viability of ocean power development in our region.

Cost

With wave energy technologies still relatively young, we have limited price data available and must rely on a few case studies and assessments. In Scotland, a shore-based wave power device known as the Limpet (operated by Wavegen) sold power to the Scottish grid at 7 cents per kilowatt hour in 2005 – a fairly competitive price when we consider that new wind power projects sell power at a wholesale price of about 6 cents per kilowatt hour in California, with a 1.9 cents/kWh federal subsidy. In Washington State, AquaEnergy has contracted with the local utility to sell power from its pilot facility at 4.5 cents per kilowatt hour.[12] However, it is too early to judge whether this reflects an accurate price for actual production costs.

A rigorous assessment of the Pelamis device and the Energetech Wave Dragon in California found projected real "cost of electricity" to be 11.2 cents and 9.2 cents per kilowatt hour, respectively. Conducted by the Electric Power Research Institute, the assessment took into account some of the available state and federal tax incentives (10 percent federal investment tax credit and California's six percent investment tax credit).[13] These costs are higher than projected costs for new natural gas (about 9 cents/kWh), wind (about 6 cents/kWh), or geothermal plants (about 6 cents/kWh).

However, the federal Renewable Energy Productive Incentive (REPI) provides a 1.5 cents per kWh (in 1993 dollars) incentive to local governments, tribes and other non-tax paying entities.[14] This figure is adjusted for inflation annually, so is 1.9 cents per kWh in 2007.[15] This incentive could make wave power projects competitive with new fossil generation – particularly with the Wave Dragon device, though local governments developing wave power facilities could not take advantage of investment tax credits because they don't pay taxes.

Additionally, the state's Renewable Portfolio Standard (SB 1078) provides "supplemental energy payments"[16] for eligible renewables that cost more than the market cost for new natural gas plants in California. Essentially, this subsidy pays investor-owned utilities the additional cost above approximately 9 cents/kWh that it would pay to purchase the power from the wave power facility. There are limits to what the supplemental payments can provide and, as of early 2007, no renewable energy contract had qualified for supplemental energy payments, so we cannot say how effective this subsidy has been or will be.

It is still unclear, accordingly, whether all these cost estimates and subsidies will allow commercial-scale facilities to be built at competitive costs in California – or whether commercial-scale facilities could even be permitted.

For better or worse, the cost barrier will be resolved over the next decade. As small commercial projects come online around the world, we will gain a better understanding of their actual costs. Spain and Portugal, where commercial facilities are being built currently, provide large subsidies for wave power production, in the form of a guaranteed price per kWh (known as a "feed in tariff"). Although state energy agencies are not currently very friendly to ocean power technologies because of entrenched opposition to any type of ocean development in California, this situation may well change quickly given the state's commitment to mitigating climate change. In particular, AB 32 requires that California's greenhouse gas emissions be reduced back to 1990 levels by 2020. Renewable energy of all types will be key to achieving this goal.

As wave power technologies are commercialized around the world and economies of scale bring costs down, we will be able to better assess the true costs for these technologies. It's key, however, that we build pilot projects and small commercial projects as a means of achieving economies of scale.

The Action Plan

Because ocean energy is a relatively new technology, it is not available to homeowners or most businesses. Individuals can, of course, contact their state and local elected officials to urge them to support ocean power and to urge the development of a pilot project or commercial project. Our action plan for this chapter focuses, however, on local governments and what CEC can do to work with companies outside our region to develop wave power in our county.

What can local governments do?

At this point, wave power is the only type of ocean power likely to be feasible in our region. Over the next few years, any wave energy projects will necessarily be pilot projects of a few megawatts or less.

CEC is investigating an opportunity with the Electric Power Research Institute (EPRI) to site a pilot wave power project at one of the oil platforms offshore from Vandenberg Air Force Base. The plan calls for using one of the platforms that is scheduled to be decommissioned as a mooring point for a number of different wave energy devices. It's possible, however, that a working platform could be suitable for a pilot wave power project. Essentially, the project would be a testing ground for the various manufacturers of wave power technologies, which would allow us to determine which technologies work best for our region.

In addition to the California Coastal Commission and various State and Federal agencies, the City of Lompoc would probably have to approve this project because the electricity substation that would be required to supply electricity to the grid is located near the city. Accordingly, the City of Lompoc and the county government could do much to make this pilot project a reality by offering public support, holding hearings to debate its merits, and/or offering financial support.

Once a pilot project is installed, one or two years of evaluation will be required. On completion of testing, the best site(s) could be developed with commercial size projects. As discussed above, a 50 MW project is planned for Reedsport, Oregon. Projects of similar size could be developed along our county's shoreline over the next decade.

What will CEC do?

1. Support the development of a pilot wave power project.

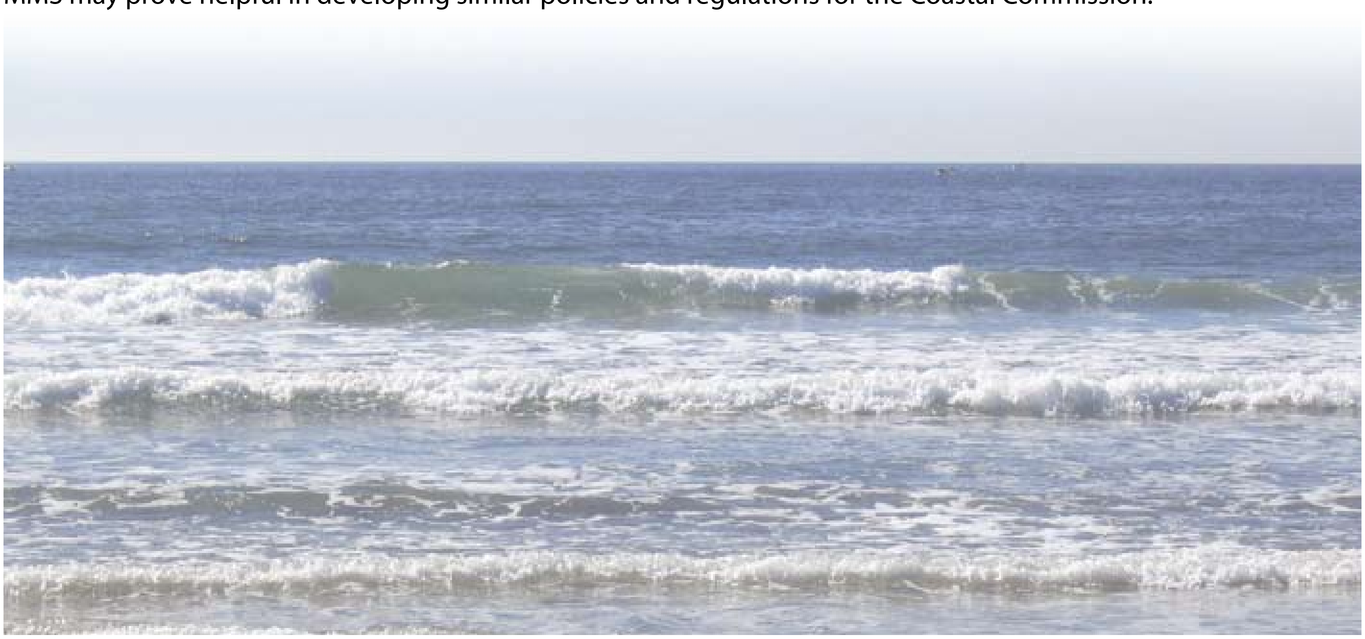
During 2007, CEC will work with EPRI and local governments to develop a pilot wave power project. Such a project will not be uncontroversial, but we hope that, with the public's growing awareness of the many problems stemming from our use of energy derived from fossil fuels, residents who might normally be opposed to such ideas will see the merit in our proposal. We will convene town hall meetings to discuss any proposals that are developed, and work with local policymakers throughout the process. We will also work with other non-profits with a stake in ocean protection and coastal protection to ensure that concerns are ameliorated.

2. Work with developers on commercial size wave power projects.

As mentioned above, the California Energy Commission consultant's report identified several good wave energy sites along the coast of Santa Barbara County and southern San Luis Obispo County, with a total potential for 3,357 MW. We are working with the report's author to provide detail on the exact locations , and will then work with wave power developers to determine which would be the most feasible sites in our region. We will also work with the environmental community to address potential concerns stemming from a commercial-scale project. With the recent designation of parts of our North County coastline as Marine Protected Areas, it will be necessary to be especially sensitive to marine impacts from any future wave energy development.

3. Work with California Coastal Commission and other state agencies to develop regulations for ocean power development

California Coastal Commission regulations don't currently include consideration of ocean power technologies. This is not surprising as these technologies are very new. It will be crucial as we move forward for the Coastal Commission to develop such regulations and we plan to work with the Commission, and other relevant state agencies, to do so. We are currently involved with the federal Minerals Management Service in developing similar regulations for renewable and alternative energy development in federal waters. Our experience with MMS may prove helpful in developing similar policies and regulations for the Coastal Commission.



Endnotes

[1] California Energy Commission, "California Small Hydropower and Ocean Wave Power Potential," April, 2005.

[2] Much of our information on wave power comes from reports completed by the Electric Power Research Institute in Palo Alto, California. EPRI's final report assessing wave power technologies for North American can be found online at: http://www.epri.com/oceanenergy/attachments/wave/reports/009_Final_Report_RB_Rev_2_092205.pdf.

[3] For more information on the Pelamis by Ocean Power Delivery, visit: www.oceanpd.com.

[4] More information can be found at Wave Dragon's website: http://www.wavedragon.net/index.php.

[5] California Energy Commission, "California Small Hydropower and Ocean Wave Power Potential," April, 2005.

[6] Verdant Power website: http://www.verdantpower.com/initiatives/currentinit.html.

[7] Email correspondence with Roger Bedard, EPRI's Ocean Power Program director, Feb. 14, 2007.

[8] Electric Power Research Institute, presentation to International Energy Agency, November 2005. Online: http://www.epri.com/oceanenergy/attachments/ocean/briefing/IEABriefingRB111705.pdf.

[9] Coble, Charles R., Elaine G. Murray, and Dale R. Rice. Earth Science, 3rd ed. Englewood Cliffs, NJ: Prentice Hall, 1987: 256–257.

[10] Elert, Glenn, ed. The Physics Factbook. Online: http://hypertextbook.com/facts/2002/EugeneStatnikov.shtml.

[11] National Renewable Energy Laboratory, OTEC program. Online: http://www.nrel.gov/otec/design_location.html.

[12] Catching the Wave: Renewable Power from the Sea (2004). Online at: http://depts.washington.edu/poeweb/gradprograms/envmgt/2004symposium/wavetext.pdf.

[13] EPRI Final Summary Report, Offshore Wave Power Feasibility Demonstration Project (2005). Online at: http://www.epri.com/oceanenergy/attachments/wave/reports/009_Final_Report_RB_Rev_2_092205.pdf.

[14] 42 USC § 13317, http://www.dsireusa.org/documents/Incentives/US33F3.pdf.

[15] DSIRE database: http://www.dsireusa.org/library/includes/incentivesearch.cfm?Incentive_Code=US33F&Search=Technology&techno=OceanThermal&currentpageid=2&EE=0&RE=1.

[16] California Public Utilities Code section 399.15.