The Hawaii Wave Energy Opportunity

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Abstract

Surrounded by the Pacific Ocean and experiencing high electric utility rates, the State of Hawaii enjoys a wave energy resource averaging 10-15 kW/m at the 80 m depth contour. Hawaii's legislated renewable portfolio standard (RPS) mandates that 20% of the state's electricity be generated from renewable sources by 2020. Among the challenges to be overcome before wave energy can be a major contributor in Hawaii are the dearth of verifiable performance data from current wave technologies, a complex permitting regime, and competing uses for the state's near-shore waters. Governor Linda Lingle has directed state agencies to streamline the permitting process for renewable energy, specifically including wave power. To facilitate consideration of Hawaii as a location for wave energy projects, the State of Hawaii's Department of Business, Economic Development and Tourism (DBEDT) has published resource assessments, a summary of state permits applicable to ocean energy development, maps and supporting documents which are posted on the department's website. Two wave technologies have been demonstrated in Hawaiian waters and other companies are considering opportunities. Highly experienced naval design, engineering and shipyard companies supporting ocean energy development are established in Hawaii.

Keywords: Hawaii, legislation, policy development.

Introduction

Hawaii's circumstances favor wave energy development. Reliable northeast trade winds create a superior wave energy resource. Long-term data support resource assessments which have concluded that even a minimal withdrawal of wave energy can theoretically provide all the electricity needed for three of the four counties in the state.

Hawaii consists of eight major islands organized into four counties. Each county is served by a different electric utility, and the grids are isolated—there are no interisland grid connections or opportunities to share generating capacity.

Although blessed with a wealth of renewable resources, Hawaii remains 90% dependent on imported oil. A growing percentage—over 25% in 2005—comes from countries in the Middle East. This over-reliance on nonrenewable petroleum leaves Hawaii vulnerable to dislocations in the world oil market caused by natural disasters, military operations, and other events.

As a result of these and additional factors, Hawaii's consumers pay among the highest electricity rates in the USA. As of January 1, 2007, residential rates on Oahu, the most populous island, were approximately US$0.17/kWh, while residential rates on other islands ranged up to US$0.30/kWh. The utility's "avoided cost" on Oahu was approximately US$0.10/kWh for the first quarter of 2007.

The State of Hawaii actively encourages renewable energy development, and presently uses electricity generated from geothermal, biomass, municipal waste, hydroelectric, wind and solar resources. State laws and administrative directives require an increasing emphasis on renewable energy and energy efficiency. Hawaii's Renewable Portfolio Standard mandates that 20% of the state's electricity be generated from renewable resources by 2020.

1 Hawaii's Superior Wave Resource

A wave energy resource assessment conducted in 1992 [1] concluded that the average wave power density along Hawaiian coasts with a northeastern exposure is typically 10-15 kW/m at the 80 m depth contour. The sea floor slopes steeply from the Hawaiian Islands. Because the island shelves are so narrow, the outer shelf depth contour can be sheltered by adjacent headlands or peninsulas. In these protected locations, wave power density along the 80 m depth contour ranges between 7 and 9 kW/m.

Refraction and shoaling significantly reduce wave power densities in shallow water; along the 5 m depth contour, they are roughly 20% lower than along the 80 m contour. Due to the wide variety of coastal orientations and exposures, there is more longshore wave power variability in the shallows than in deep water; it can range from 5-12 kW/m.

There are three primary sources of wave energy in Hawaii: the seas built up by prevailing trade winds, swells generated by storms in the North Pacific, and swells generated by southern hemisphere storms. There are also occasional hazardous high waves generated by tropical storms and Kona winds, but these are relatively rare, occurring no more than a few times a year in Hawaiian waters, and they have a negligible contribution to the state's wave energy resource.

Most of the wave energy available to Hawaii is the result of trade wind-driven swells. The trade winds blow year-round, with monthly average wind speeds ranging from 5-8 m/sec. Trade wind waves commonly arrive out of the northeast, with dominant periods of 6-8 sec and significant heights of 1-2 m.

Extratropical storms northwest of the Hawaiian Islands may develop sustained wind speeds up to 25 m/sec. The resulting waves have dominant periods of 10-14 sec and significant heights of 1.5-2 m, although periods as long as 18 sec and deep-water heights of up to 3 m are not uncommon. These storms are most frequent between November and March and are responsible for the spectacular winter surf on the north shore of Oahu.

Extratropical storms from the southern hemisphere are most frequent from May through September, generating waves with dominant periods of 14-18 sec and significant heights less than 1.5 m.

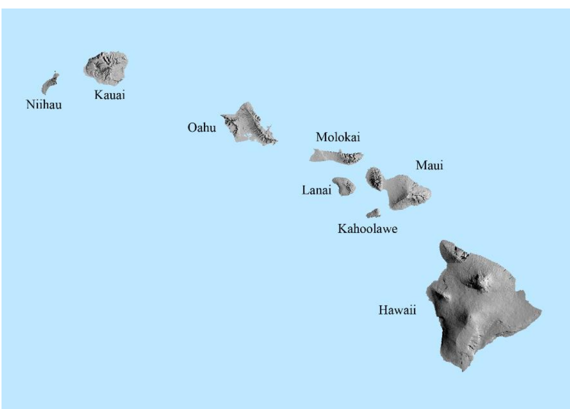

Figure 1: Major Hawaiian islands.

In theory, recovering only 5-10% of the wave energy available in outer shelf waters off the northern coastlines of the islands of Kauai, Maui and Hawaii could meet the total annual electricity demand of those islands. Less than 0.5% of Molokai's wave energy resource could meet the electricity demands of that island. Except for Oahu, where electricity demand is comparable to two-thirds of the available resource, wave energy can be withdrawn at very low levels and still make a substantial contribution to island energy supply.

2 State Policies Promote Renewables

Hawaii's energy objectives are codified in state law [2] and call for increasing the degree of self-sufficiency by using indigenous energy resources. The state government promotes commercialization of Hawaii's sustainable energy resources to reduce its high dependence on imported oil, increase local economic development, and reduce the potential negative economic impacts of oil price fluctuations.

The Renewable Portfolio Standards (RPS) law [3] mandates that electric utilities in Hawaii provide 10% of their electricity from renewable resources and energy efficiency by 2010, 15% by 2015, and 20% by 2020. In 2005, the equivalent of 7.6% of the electricity used in Hawaii was generated from renewable resources, although the percentage is higher on some individual islands. For instance, renewables provided 23% of the electricity on the island of Hawaii in 2006.

To meet RPS requirements, the utilities serving the City and County of Honolulu (i.e., the island of Oahu), the County of Hawaii (the island of Hawaii) and the County of Maui (the islands of Maui, Molokai and Lanai), may aggregate their renewable portfolios. The Hawaii Electric Light Company (HELCO), which serves the County of Hawaii, and the Maui Electric Company (MECO), which serves the County of Maui, are subsidiaries of the Hawaiian Electric Company (HECO). HECO provides service to the City and County of Honolulu.

The County of Kauai is served by a separate entity, the Kauai Island Utility Cooperative.

In January 2006, Governor Linda Lingle issued Administrative Directive 06-01 to all executive agencies. AD 06-01 emphasized the need for energy and resource efficiency within the state government, and for renewable energy development. Among the injunctions listed was the following:

> All affected agencies and programs are directed to review internal policies, rules, and practices regarding permitting requirements affecting renewable energy development. To the extent possible, permitting policies and practices should be streamlined to expedite implementation of renewable energy projects.

This Directive demonstrates the Lingle Administration's commitment to leading by example, and highlights the critical role that obtaining permits plays in the establishment of renewable energy facilities. A 1991 analysis [4] found that the "complex system of permits and approvals can require up to seven years for a single project." While the permitting system has been somewhat simplified since then, it remains a barrier to the timely development of renewable energy.

In order to better understand permitting requirements for ocean energy devices, the State Department of Business, Economic Development and Tourism (DBEDT), which manages the administration's energy programs, prepared a summary table of pertinent state permits. Along with an accompanying description of the state's permitting process, this summary is posted on DBEDT's energy website at http://www.hawaii.gov/dbedt/info/energy/renewable/wave.

Permits for wave energy facilities are required from the state as well as the county and federal governments. Regulatory responsibilities in some instances overlap or are shared among various agencies. One example of shared responsibilities is the Hawaii Coastal Zone Management

(CZM) Program. The counties administer a permit system for some types of development within designated Special Management Areas (SMA) along the shoreline, which the state must monitor to ensure compliance with statewide CZM objectives and policies. Shore-based facilities, such as transmission equipment, will trigger the SMA rules.

An environmental review will be required of any ocean energy activity since state waters and submerged lands will be used. Hawaii's environmental review process is explained in a detailed guidebook available online at www.state.hi.us/health/oeqc/publications/guidebook.pdf.

Hawaii's land use system designates broad purposes—such as agriculture, conservation or urban—for lands and waters throughout the state. Submerged lands and state ocean waters are in the Conservation District.

A Conservation District Use Permit will be required from the State Board of Land and Natural Resources for an ocean energy installation. A Conservation District Use Application (CDUA) specific to marine activities is available online at www.hawaii.gov/dlnr/occl/forms/CDUA-marine.pdf. Ocean energy development companies will work directly with the staff at the Department of Land and Natural Resources (DLNR) to complete the application. Applications must also contain a completed environmental review and must be in compliance with county Special Management Area rules and regulations.

In addition, ocean and submerged land leases must be obtained from DLNR for long-term projects. Alternatively, a revocable permit or right-of-entry might be more appropriate for brief activities, such as short-term research.

While most land and ocean leases must be obtained through public auction, ocean energy operations that qualify as renewable energy producers under Hawaii Revised Statutes (HRS) §171-95 may be entitled to favorable treatment and obtain leases, revocable permits, licenses and easements through direct negotiation with DLNR. Because ocean energy projects will incorporate unique, innovative technologies, a customized lease document tailored to the project's requirements will be prepared, subject to approval by the Attorney General.

Also, to comply with the federal Clean Water Act, a Water Qualify Certification will need to be obtained from the State Department of Health for any device within 4.8 km (3 miles) of the shoreline.

Interest in supporting wave energy development by Hawaii's elected officials remains high. In the most recently concluded session of the Hawaii State Legislature, bills to require priority handling and processing of all state and county permits required for renewable energy projects were considered. Other legislative proposals sought to direct DBEDT to work with wave energy developers and the electric utility companies to develop a facility for the generation of wave energy similar to the Wave Hub proposed off the coast of Cornwall, UK.

Siting any ocean energy facility requires knowledge of bathymetry, hazards, and competing uses of the surface and subsurface waters. To facilitate developer consideration of suitable wave energy sites, DBEDT has prepared sample maps identifying features such as natural and artificial reefs, body surfing sites, ocean recreation areas and fisheries management areas. Explanations of two types of zones—marine management areas and zones of military concern—provide additional detail. These maps and supplemental papers are also posted at DBEDT's energy website, mentioned previously.

Furthermore, an interactive feature at DBEDT's Office of Planning website allows users to compile their own customized maps using publicly-available GIS layers. The URL is http://www.hawaii.gov/dbedt/gis.

Investment incentives are also offered by the state government to support advanced technology development. A tax credit for high-technology businesses is available to overcome a critical shortage of seed and venture capital. HRS §235-110.9 allows a nonrefundable business investment tax credit of up to US$2 million over five years for investments in a qualified high technology business. A business is "qualified" if it conducts more than 50% of its activities in qualified research and if it conducts more than 75% of its qualified research in the state. Non-fossil fuel energy related technology is specifically listed as "qualified research."

In an effort to further promote wave energy development, the State of Hawaii has been pleased to facilitate visits to the islands by both Ocean Power Delivery Ltd and Energetech Australia Pty Ltd, now Oceanlinx.

3 Commercial Activity Supporting Wave Power

Hawaii currently hosts two demonstrations of wave energy technology. Ocean Power Technologies (OPT) has deployed a 20 kW PowerBuoy at sea off Oahu. The location is the Marine Corps Base Hawaii in Kaneohe and

Figure 2: PowerBuoy deployed off New Jersey.

the demonstration is under the direction of the U.S. Office of Naval Research. First deployed in 2004, the buoy was in the ocean for a total of 11 months, having been removed, reworked and redeployed in 2005, and then removed again in 2006. Electricity was generated for four of the months it spent at sea and was burned off as heat in onshore resistors.

A second, 40 kW PowerBuoy is expected to be deployed in the same location in 2007. This buoy reflects improvements demonstrated in a similar device which was tested for more than a year off New Jersey.

The second technology demonstrated in Hawaii is a patent-pending device invented by Navatek Ltd., a Honolulu high-technology firm best known for its advanced ship designs. A small-scale, 2.4 m (8 ft) demonstration Wave Energy Conversion (WEC) device was deployed in Hawaiian waters in late 2006 to test the concept. Several weeks' preliminary testing confirmed that the WEC could generate power. Tank tests scheduled to begin in March 2007 will determine the device's sensitivity to wave amplitude, period and heading, as well as other factors. Discussions with potential investors are expected to lead to further development and commercialization of the device, which features a power take-off using a clutch and belt system.

Figure 3: Navatek's prototype WEC.

There are a number of highly experienced naval design, engineering and shipyard companies in Hawaii which are supporting ocean energy development.

Pacific Shipyards International LLC (PSI) provides world class ship repair and conversion with experience in steel and aluminum fabrication, welding, machining and other services. PSI constructed the OPT PowerBuoy initially deployed at Kaneohe Bay—it was the first shipyard to build a buoy that large—and also built Navatek's WEC model. Navatek itself utilizes advanced hydrodynamics expertise and supercomputer tools for the work it does on defense research projects for the Office of Naval Research, the Defense Advanced Research Projects Agency and the Center of Excellence for Research in Ocean Sciences.

PSI, located at Pier 42 in Honolulu, operates two floating drydocks with lift capacities of 2,034 MT (2,000 LT) and 6,096 MT (6,000 LT).

A graving drydock owned by the U.S. Navy and located at the Pearl Harbor Naval Shipyard is large enough to handle aircraft carriers and cruise ships, and is commercially available.

Marisco, Ltd., based at Barbers Point Harbor on Oahu, also has a floating drydock with a certified lift capacity of 3,500 MT (3,445 LT). Marisco is one of the largest marine and industrial service companies in Hawaii. It offers a wide spectrum of services including drydocking, machining, welding, pipefitting, machinery troubleshooting and repairs. Marisco operates the largest industrial machine shop in the state.

A host of ocean engineering expertise is also available in Hawaii. Among the firms with experience of interest to ocean energy companies are: Makai Ocean Engineering, Inc., a world leader in the design and installation of large deep-water pipelines; Oceanit, a diversified science and engineering company; and Sea Engineering, Inc., which installed and serviced the OPT demonstration in Kaneohe Bay.

The construction and deployment of OPT's PowerBuoy demonstrates local capabilities. Construction of the PowerBuoy system was performed primarily by Hawaii fabricators. Its deployment was supported entirely by local diver and workboat subcontractors. This included towing the PowerBuoy to the deployment site and connecting the system to its anchor on the sea bottom [5].

The University of Hawaii (UH) also offers ocean science expertise. Its Hawaii Undersea Research Laboratory has used submersibles to investigate submarine volcanoes, among other purposes. The UH Hawaii Mapping Research Group has developed seafloor mapping systems which simultaneously acquire true sidescan sonar imagery, phase difference bathymetry, and multibeam subbottom data. The UH Department of Oceanography has gathered a wide variety of data on physical and biogeochemical processes in the open sea. The Ocean and Resources Engineering Department aims to benefit ocean, wind and coastal engineering communities with research in fluid dynamics and fluid-structure interactions. The University's research fleet includes a twin-hull vessel designed to perform general purpose oceanographic research in coastal and deep ocean areas, including survey tasks.

4 Challenges for Wave Energy

Hawaii's electric utilities are likely to consider wave energy technologies as pre-commercial until there has been sufficient demonstration of full-scale prototypes to provide data on actual technical performance, the cost of generation, availability, survivability in extreme conditions, and overall reliability of the power plant. At-sea demonstrations will also help address expected public questions regarding the impacts of wave energy devices on current ocean uses, including recreation and shipping.

Hawaii is well situated to provide opportunities for research, development and demonstration which will overcome these barriers.

Hawaii's residents and visitors have understandably strong ties to the sea. Visual beauty is important, and minimizing the visual impact of wave devices will be one criterion for their widespread acceptance.

The ocean is also widely used for recreation. The maps developed by DBEDT indicate ocean recreation areas which should be avoided as sites for wave energy development. These areas, however, are generally located in calm, nearshore waters generally unsuitable for wave power. Boating, jetskiing, parasailing, kayaking, diving and snorkeling are among the activities enjoyed in these areas.

Marine life conservation districts are also inappropriate for wave power development. As with ocean recreation areas, though, these districts are generally in nearshore waters which would not normally be considered for energy production.

Surfing is widespread and culturally important, and any development which is perceived as impacting surfing sites will generate public concern. Offshore wave power plants may, however, be able to be spaced far enough apart that the impact on wave heights at shore is minimal. It is estimated that a 5-10% withdrawal of wave energy offshore would correspond roughly to a 3-5% reduction in wave heights at the coast [1, 6].

It is possible that wave installations can serve as fish aggregation devices, contributing to the population of fish species. They may therefore be compatible with the bottomfish restricted areas shown in the previously-discussed maps developed by DBEDT because fishing is already restricted in these zones to conserve spawning populations. Bottomfish restricted areas, however, tend to be in deeper waters which pose technical challenges for wave plant mooring systems.

These challenges are, of course, similar to those faced by wave energy developers throughout the world. Balancing them are a strong track record in support of renewable energy, a wealth of wave energy resources, extensive expertise in marine science and technology, a mandated RPS goal and a proactive government, all of which highlight the outstanding opportunities for wave energy research, development, demonstration and deployment in Hawaii.

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