CHAPTER 20
Ocean Power

INTRODUCTION

Ocean power includes technologies that tap the sea's energy, not only that of crashing waves but also the motion of tides and even the heat stored in the oceans, which are the world's largest solar collectors. Ocean power, then, includes three types: wave power, tidal power and thermal energy conversion.

A variety of new ocean power technologies are poised on the threshold of commercial development. In various places around the world, pilot projects are under way or have been completed, and several energy plants are being planned or are under development. Progress in this area has been slow, however, due mainly to the fact that these systems, based on emerging technologies with high research and development and startup costs, have significant engineering hurdles to overcome and are not competitive with current prices of fossil fuels.

With the push toward clean, renewable sources of power and growing concern about climate change, fresh attention is being focused on the enormous power potential of the world's oceans. The potential for ocean power to have an impact in Texas, however, given the state's type of coast, is negligible. The Gulf of Mexico is too shallow and enclosed, for the most part, for its waters to contain sufficient energy to convert to onshore power.

History

Efforts to tap the force of the seas have a long history; tidal mills were used to grind grain in Northern Europe in the Middle Ages, and a Frenchman and his son filed the first patent for a method of using wave power in 1799.[1] More recently, the industry has been engaged in the trials and errors of developing new technologies for using ocean energy, with the errors sometimes bringing setbacks and negative publicity. In 1995, as interest in wave power was building, there was the failure of the Osprey, a large wave device that was destroyed by the very power it was intended to tap, even before its installation on the Scottish coast could be completed. And in 2007, a $2 million wave power buoy sank near the Oregon coast and tidal turbine blades broke in the East River of New York City.[2] Nevertheless, the search for the proper tools continues.

Uses

All forms of ocean power generate electricity by converting water's kinetic or thermal energy into mechanical energy, to drive a turbine or pump. One form of ocean power, ocean thermal energy conversion (OTEC), can be put to secondary uses such as air conditioning, chilled-soil agriculture (which allows plants from temperate zones to grow in the tropics) and aquaculture. And fresh (desalinated) water is a byproduct of some ocean power devices.[3]

OCEAN POWER IN TEXAS

While Texas has a lengthy coastline, offshore conditions make it unlikely that the state will benefit significantly from ocean power technologies. None of the types of ocean power currently on the drawing boards are suited for the Gulf of Mexico, due to that body of water's shallow and semi-enclosed nature. Almost 40 percent of the Gulf is less than 20 meters deep, and the prevailing current of water entering it runs around the tip of the Yucatan Peninsula, far away from the Texas coast.[4] Given present technology, Texas' coasts have none of the characteristics necessary for the cost-effective use of ocean energy.

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Economic Impact

At present, the U.S. has no ocean energy project delivering significant amounts of usable power. States with potential for ocean power include Alaska, Washington, Oregon, California, Hawaii, Maine and Massachusetts.[5]

Production

Wave Energy

The most obvious form of ocean energy is the power of waves. For energy conversion, wave power can be captured on or near shore as well as offshore. Offshore systems use the motion of the waves either to create an electrical charge with a pump and a floating bobber or buoy, or to operate hydraulic pumps within the joints of a floating device resembling a string of sausages. The pressurized fluid from the pumps powers a turbine.[6]

Onshore techniques include the pendulor, the tapchan and the oscillating water column. The *pendulor* uses a flap swung back and forth by waves to power a pump and generator. The *tapchan* is a tapered channel that forces waves higher and thus feeds water into a reservoir above sea level; this water then is used to turn a turbine, as with conventional hydroelectric generation. A related wave device pressurizes seawater to send it to an elevated onshore storage tank for release through a turbine; this device was tested in the Gulf of Mexico before "seeking actual ocean environments" for in-situ testing.[7] And the partially submerged *oscillating water column* channels waves into an opening to compress the air column above the water, forcing it through a turbine; as the wave retreats, the falling water pulls the air through the turbine once again.

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Tidal Energy

To convert tidal power into electricity, a power plant site requires a large volume of fast-moving water. This can be found either in locations with a wide swing in tidal heights or with tidal flows that pass through a narrow channel. The former is often called "traditional" tidal power, while the latter is called "tidal stream" power.[8]

Forty years ago, tidal power plant design took its cue from the established hydroelectric industry. The world's four "traditional" tidal power plants, in France, Russia, Canada and China, use a "barrage" or dam that functions much like an onshore dam but requires a tidal inlet or estuary. The tide comes in and builds up a difference in water height, and then water is released through gates into turbines.[9]

Tidal stream power is featured in two different designs: the tidal fence (underwater turnstiles spanning a channel or narrow strait) and the tidal turbine.

Of the three types of tidal power systems — "traditional," tidal fence and tidal turbine — the tidal turbine is simplest, and the one generating the most research at present. These are essentially underwater wind turbines turned by the tidal currents. Even though ocean currents are slower than wind speeds (currents of 4 to 5.5 mph are optimal for tidal turbines), the density of water is almost 1,000 times that of air, which translates to a higher energy yield. The turbines also have little impact on the environment; the other types can have problems with silt buildup and can interfere with sea life migration because they obstruct a channel.[10]

Ocean Thermal Energy Conversion

Finally, ocean thermal energy conversion (OTEC) is the least accessible form of ocean power, and perhaps the least useful for the U.S. To work, OTEC needs an optimal temperature difference between warm water on the surface and colder water below of about 36°F—a range found only in tropical coastal areas near the equator. In the U.S., OTEC research and testing is taking place in Hawaii. The cold water is brought to the surface by a deeply submerged intake pipe.

Researchers have developed two different types of OTEC and a third that is a hybrid of the other two; all use the thermal energy stored in seawater to power a steam turbine. *Closed-cycle OTEC* uses warm seawater to vaporize a low-boiling point liquid that then drives a turbine to generate electricity. (This approach is similar to the binary cycle method of geothermal generation.) The vaporized liquid then is cooled and condensed back to liquid with cold seawater, and the cycle repeats. *Open-cycle OTEC* gets warm seawater to boil through lowered pressure and uses the resulting steam to drive the turbine. Once again, cold water from the deep converts the steam back to (now desalinated) water.

The *hybrid method* uses the steam from boiled seawater to vaporize a low-boiling point liquid, which then drives the turbine.[11] In concept, these systems are quite simple, but in practice the depths and scale that are required to effectively harness OTEC have been prohibitive.

Transportation and Transmission

Ocean energy does not involve or require fuel transportation or storage. As with other alternative methods of generating electricity, however, ocean energy processes need transmission capacity to make them a viable power source. Electricity generated offshore by OTEC and deep-water wave systems typically would send the power through an underwater cable to the electrical grid onshore. And all transmission lines can involve issues of access, rights of way and property ownership.

Availability

Wave power varies depending on location; more powerful waves are a result of stronger winds blowing over the water's surface. Globally, this occurs primarily in the areas between 30° and 60° latitude, both north and south (**Exhibit 20-1**).[12]

According to the U.S. Department of Energy, traditional (barrage) tidal power requires a difference between high tide and low tide of at least 16 feet. In the U.S., such conditions are limited to the Northeast and Northwest coasts; there are only about 40 such sites worldwide (**Exhibit 20-2**).[13] Tidal stream, on the other hand, simply needs a strong current and, in the case of a tidal fence, a narrow inlet to span.

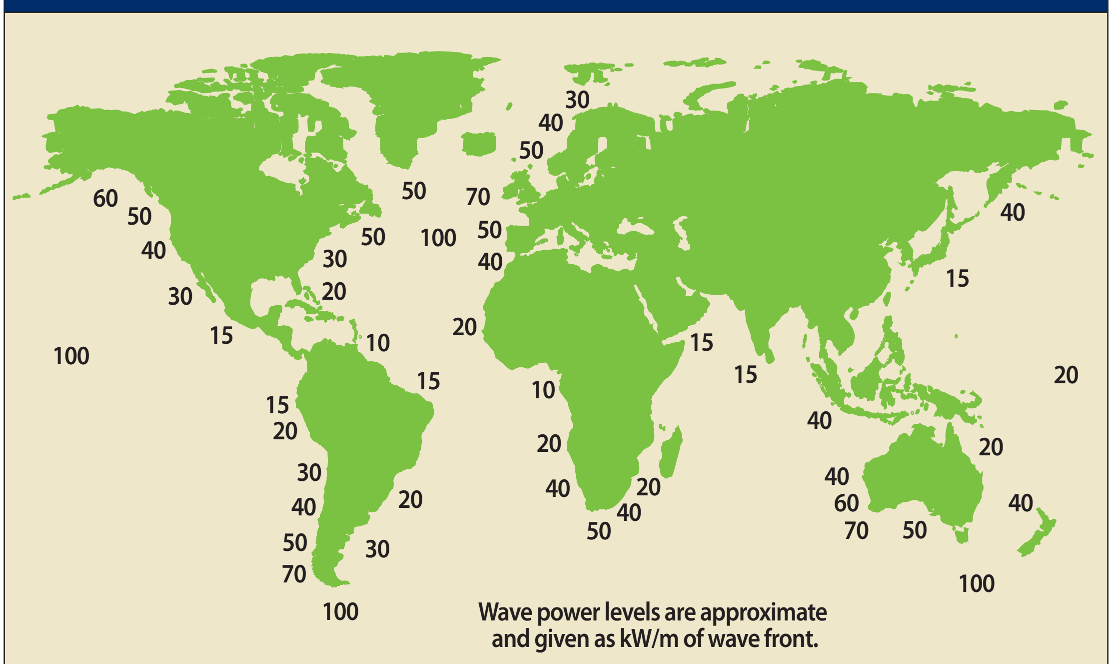
In summary, OTEC requires consistent, substantial temperature differences; tidal power requires large tidal swings or strong tide streams; and even wave power is economically feasible only in certain coastal areas of the world, such as the Northwestern and Northeastern coasts of the U.S.[14]

Other than a few existing tidal dam plants, only small amounts of electricity are being produced by ocean power in pilot projects and startups worldwide. Estimates of the potential amounts of generating capacity are enormous, however, ranging from 140 to 750 terawatt-hours (TWh) per year for wave power alone. (A terawatt is a trillion watts.)[15] That much power could have supplied 4.9 percent of the world's total electricity consumption in 2004.[16]

Estimates for tidal and OTEC energy potential are similarly impressive; the question is whether these resources can be tapped in a cost-competitive manner, and where.

Exhibit 20-1

Approximate Global Distribution of Wave Power Levels



Source: T.W. Thorpe, "An Overview of Wave Energy Technologies: Status, Performance and Costs."

EXHIBIT 20-2

Areas Appropriate for Traditional Tidal Power

Source: Statkraft Development AS, "Tidal Power: Versatile. Reliable. Renewable."

COSTS AND BENEFITS

The cost of generating electricity from ocean energy mostly involves the research and development of prototypes and, later, the construction or purchase of equipment and facilities. Operations and maintenance carry significant costs as well, due to the often harsh environment of the oceans. Some in the industry hope that the long experience of the offshore oil and gas extraction industry could help them produce durable equipment to survive the harsh conditions in the sea.

The predicted costs of wave power, in particular, have been falling against that of fossil fuels. The World Energy Council estimates that electricity from "arrays of mature devices located in promising wave energy sites" could cost from 5 cents to 10 cents per kilowatt-hour (kWh).[17] In fact, the Limpet, an on-shore oscillating water column device, began commercially generating electricity in Scotland in late 2000. At the time, the expected cost of Limpet's electricity was 7 cents to 8 cents per kWh, already nearly competitive with the non-renewable price of about 5 cents.[18] And according to the Electric Power Research Institute (EPRI), the cost of ocean electricity production will drop significantly as the volume of production increases, as usually happens in the development and commercialization of any new technology.[19]

Environmental Impact

The long-term environmental impacts of commercialized ocean power are as yet unknown. As mentioned earlier, some concerns for potential impacts include interference with sea life migrations, silt buildup and sediment deposits. OTEC also has a potential to affect the temperature of the water near a power plant and, when desalinated water is a byproduct, to require disposal of the removed salts.

Careful site selection along with rigorous monitoring will be necessary to prove boosters' claims of extreme environmental friendliness. Certainly, in the area of air quality, ocean power has less impact than most other forms of electricity generation. Once the devices are in place, they produce electricity without emissions.

Other Risks

Wave power projects can face public resistance to installing large equipment along coastlines. Equipment on the ocean floor can also interfere with sediment flow. Thus far, even wave energy is not yet economically competitive.[20] That situation is likely to change over time, however, as research and testing moves the technology forward.

The early risks of ocean technology are likely to be financial in nature, with venture capital, corporate investment and government subsidies riding on finding the "right" product to access the oceans' energy.

State and Federal Oversight

Ocean power generation falls under the Federal Energy Regulatory Commission's (FERC) jurisdiction. Because the technology is so new, however, applications for pilot projects have been anything but routine, with companies asking for waivers of some licensing requirements. In particular, the applications require some data that cannot be gathered without installing and operating the devices.

In 2005, FERC granted limited licensing exceptions for pilot projects, particularly one in New York, and preliminary permits for the study of potential sites off the Florida coast. The commission also began to streamline its process for permitting ocean power projects.[21] State regulations for such facilities are similarly immature and are likely to be drawn from existing laws governing conventional power plants and electricity transmission.

Subsidies and Taxes

To date, ocean energy projects have received little assistance in the form of incentives or subsidies from the state or federal governments. EPRI considers the lack of government support to be the foremost obstacle to the development of this energy resource. According to EPRI, the "U.S. government…has supported the development and demonstration of all electricity technologies except ocean wave energy."[22]

There is one recent, minor exception to that statement: the U.S. Navy is funding a wave power plant built by Ocean Power Technologies at a base in Hawaii. This installation eventually will have a capacity greater than 1 MW; its first wave power device was installed in 2004.[23] Nevertheless, this emerging technology has received little promotion in the U.S. The current federal renewable energy tax credits do not cover ocean energy, although Florida has included it in a state tax incentive for commercial electricity production.[24]

The U.S. Congress, however, appears to be giving ocean energy some new attention. In June 2007, the House Committee on Science and Technology approved the "Marine Renewable Energy Research and Development Act" that would provide $50 million a year for the next four years to promote ocean energy research and projects.[25]

While many states are supporting research in renewable energy, only Maine, which is considered to have a high potential for tidal energy, includes any support for research into ocean (tidal) power in its eligible renewable technologies.[26] Hawaii includes both wave energy and ocean thermal conversion in its generous 100 percent tax credit for investment in "high tech business."[27] The state of Texas offers no subsidies or incentives for ocean power.

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There are no state or federal taxes or fees specific to ocean power, although ocean power companies would have to receive permits from FERC for power plants tied into multi-state electrical grids.

More information on subsidies for ocean energy can be found in Chapter 28.

Other States and Countries

In the U.S., Hawaii was an early location for experiments with ocean power, particularly ocean thermal conversion, and now interest is growing in the Northwest and the Northeast. Tidal pilot projects are being considered in San Francisco Bay and New York City. Wave energy is being investigated in states such as Oregon, Washington, Maine, Rhode Island and Florida. FERC has given approval for wave energy projects in Washington and Oregon to proceed, granting a preliminary permit for a demonstration of a device at Reedsport, Oregon and accepting a commercial license application for a project in Makah Bay, Washington.[28]

Other nations, however, have led the way on ocean energy, particularly wave power, primarily because they are situated near valuable ocean energy assets (e.g., good tide differentials or wave intensity). Various ocean power technologies are planned, in place or being tested in the United Kingdom, Portugal, Spain, Australia and Japan, and new sites and designs are being pursued in these nations and others. In Portugal, a wave power project already has begun delivering electricity to homes, due in large part to government assistance.[29]

A glance at wave power levels across the world (**Exhibit 20-1**) makes it clear why the United Kingdom, in particular, has been the site for the most aggressive development of electricity generated by the sea. In 2004, Scotland opened the European Marine Energy Centre in the Orkney Islands to act as a proving ground for wave energy devices; the facility is expanding to include tidal devices. The partners in the research center, including the Scottish government and the Carbon Trust, have invested nearly $30 million in the endeavor.[30]

Outlook for Texas

There has been some speculation recently about the possibility of tapping the "Loop Current," the stream of ocean water running from the Caribbean into the Gulf of Mexico through the Yucatan Strait, but this would be very difficult to accomplish.[31] The Loop Current is highly variable, making its U-turn back towards the tip of Florida at different points on its northward path within the Gulf. No matter how far north it travels before turning, however, the loop never goes very far westward; the only parts of the Loop Current that approach the Texas coast are eddies that are "pinched" off of the loop and spin into the western half of the Gulf.[32]

Therefore, while the Loop Current may someday be used for power generation, it would probably be tapped at the locations where it is most energetic — in the Yucatan Strait (the entrance) or the Florida Strait (the exit). As with the other forms of ocean power conversion, this is unlikely to have a place in Texas' renewable energy portfolio.

In all, ocean power is an unlikely choice for Texas. Despite our hundreds of miles of coastline, and the energy industry's many years of experience in Gulf waters, the state lacks the conditions needed to bring inventors and investors to our shores.

Endnotes

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