JAMIE LEE WISE’S ESSAY EXAMINES THE VARYING SOURCES OF ELECTRICAL ENERGY THAT WE CAN DRAW FROM THE OCEANS. IN HIS WELL-ORGANIZED AND RESEARCHED ESSAY, WISE CAREFULLY EXPLAINS THE SOURCES AND THEN DISCUSSES BOTH THE BENEFITS AND DRAWBACKS OF EACH SOURCE. IN THE END, WISE’S PAPER ARGUES THAT “PUBLIC AWARENESS AND EDUCATION CONCERNING THE BENEFITS OF RENEWABLE ENERGY SOURCES NEED TO BE INCREASED,” AND THAT THE OCEANS CAN BE A VALUABLE RESOURCE “ONLY IF WE TAKE STEPS TO PRESERVE THIS NATURAL WONDER AND USE IT RESPONSIBLY.”

Harnessing the Energy of the Oceans

Introduction

The oceans cover nearly three-quarters of our planet and contain a vast reserve of resources, yet we are only beginning to tap their full potential. The oceans can provide a wide variety of foods, desalinated water, minerals, electricity, transportation, and recreation for the people of our world; however, this discussion will be limited to sources of electrical energy that can be harnessed from the seas.

The world’s energy consumption is currently doubling every 12 years and the consequences of our heavy dependence on fossil fuels are becoming increasingly apparent. Several studies have estimated that our “present reserves of oil and natural gas will be consumed within a few decades, and coal within a few centuries.” In addition, “political instability in the Middle East has demonstrated the economic consequences of oil dependence” (Bregman, Knapp, and Takahashi; 1996). Environmental and political concerns are just two reasons why alternative energy sources, such as ocean energy conversion, need to be considered.

Overview of Ocean Energy Conversion Technologies

Technologies that currently exist for generating electrical power from the oceans can be grouped into six broad categories: thermal energy, tidal power, wave power, ocean currents, ocean winds, and chemical sources. According to Ron Bregman, an Ocean Resource Engineer, the most promising and well-developed of these technologies are thermal energy, tidal power, and wave power (1996).

Thermal Energy

The oceans are the world’s largest solar collectors. Each day the oceans absorb an amount of solar radiation equivalent in heat content to about 250
billion barrels of oil, according to Michael Champ in *Sea Technology* (1995). This solar energy that is absorbed by the oceans as heat can be converted to electricity by a process known as Ocean Thermal Energy Conversion or OTEC. This technology is based on the large temperature differential between the warm tropical surface waters and the near freezing waters of the deep ocean (Vega, 1995).

So far, three varieties of OTEC have been developed and tested to varying degrees. These are known as open-cycle, closed-cycle, and hybrid designs. In an open-cycle plant, large quantities of warm water from the ocean’s surface pour into a chamber where the pressure is reduced to near-vacuum levels, causing the water to turn to steam. The steam is directed through a large, low-pressure turbine, which generates electricity. Once it comes out of the generator, the steam is cooled by another set of pipes containing very cold water from the deep ocean, which condenses it back into desalinated water. A closed-cycle plant operates in much the same way, except that it uses ammonia as the steam-producing fluid. The ammonia is repeatedly circulated throughout the cycle; therefore, this type of plant does not result in the beneficial by-product of desalinated water. However, the closed-cycle design has the advantage of higher efficiencies. A hybrid plant combines both open-cycle and closed-cycle systems to maximize energy efficiency and to gain other advantages specific to each system. OTEC power plants have also been used in conjunction with desalination plants (DiChristina, 1995 and Uehara, Miyara, Ikegami, and Nakaoka; 1996).

**Tidal Power**

Tidal energy conversion uses conventional hydroelectric turbines and related structures in areas where the high-tide and low-tide water levels are sufficiently different to enable the generation of electricity. The amount of power that can be generated by a tidal power system is directly related to this tidal range. An appropriate site needs to include a tidal range of at least 3 meters, an enclosed basin, a stable ocean floor, and a relatively short distance across which the electricity produced must be transmitted (Bregman, Knapp, and Takahashi; 1996).

Tidal power plants can be classified as ebb-generation, flood-generation, or a combination of the two. An ebb-generation tidal plant produces electricity by allowing seawater to rise into a basin, such as an estuary or bay, by opening the sluice gates during the flood stage of the tide. Once the basin is full, the gates are closed until the sea level ebbs below the level in the basin. The gates are then opened to allow a controlled water flow through the turbines, thereby generating electricity. Flood-generation, in which energy is produced by the incoming tide, is also utilized; however, the electricity that can be generated
from this stage is much less than for the ebb stage. Typically a combination of both ebb-generation and flood-generation is used. The result is two periods per day, approximately five hours each, during which electricity can be produced. (Clark, 1995).

Another type of tidal power plant, designed by a Spanish inventor, works by using a floating platform connected to an underwater tank. Water flows through turbines into the tank and produces electricity. Tidal energy is then used to pump the water out of the container, so the cycle can begin again. This system has the advantage of being largely underwater so as to avoid damage from storms, has a lesser impact on the coastal environment than traditional tidal plants, and is expected to cost about half as much to build and maintain (Luke, 1994).

Wave Power

Wave energy has two components, potential energy and kinetic energy, both of which can be harnessed by changing it into another form, such as mechanical motion or fluid pressure. Many varieties of wave energy conversion devices currently exist, including oscillating water columns, surge devices, heaving floats, pitching devices, heaving and pitching floats, and heave and surge devices. These devices may be designed to float on the surface or be moored to the ocean floor and can be located in either shallow or deep water (Bregman, Knapp, and Takahashi; 1996).

The most promising of these devices is the oscillating water column which works by allowing waves to flow into a container containing several air-driven turbines with propellers at the top of the column. As the water enters and exits the container with each wave, air is forced through the turbine propellers, enabling the generators to produce electricity. Specially designed turbines, which rotate in the same direction regardless of the direction of airflow, are often used (Miyazaki, 1987).

Surge devices utilize the forward horizontal force of waves flowing through a turbine into and out of a reservoir. The turbines turn during both water entry and exit, generating twice the amount of electricity from each wave. A heave and pitch float is a device that is fixed to the sea floor consisting of a piston connected via an arm to a buoy that floats on the water's surface. As waves pass by and cause the attached buoy to rise and fall, the piston moves back and forth—a motion that can be used to generate electricity. Pitching devices utilize the pitching moment of rotary pumps. Heaving floats utilize the vertical motion of buoys floating on the surface. Heave and surge devices use both the heaving and surging motions (Hagerman, 1995).
Other Energy Sources

Other potential sources of ocean energy are not as well-developed as OTEC, tidal power plants, and wave devices; however, they may hold greater potential in the future as our traditional energy sources become increasingly scarce and relatively more expensive (Champ, McLain, and Vadus; 1995). Ocean currents can be used to create electrical power in a way similar to waves and tides. Steady blowing ocean winds could be employed as a source of power generation in much the same fashion as windmills on land. Several possibilities also exist to harness chemical energy from the ocean, which could then be used as fuel to generate electrical energy. One example is hydrogen production. In addition to generating electricity, OTEC power plants could produce hydrogen from seawater by utilizing an electrolytic process (DiChristina, 1995).

FEASIBILITY OF CURRENT TECHNOLOGIES

Current barriers to widespread use of ocean energy conversion technologies include a reluctance to invest in a largely untested technology, higher capital costs associated with initial plant construction, competition from other forms of energy, and the geographic limitations associated with each type of energy conversion device (Tanner, 1994).

Technical Issues

Because it relies on large temperature gradients, ocean thermal energy conversion is generally limited to tropical regions. Due to a temperature differential between the surface and deep ocean waters of only 15 to 26 degrees Celsius, OTEC has efficiencies of only 2 to 4 percent (Uehara, Miyara, Ikegami, and Nakaoka; 1996). Therefore, the plant must move very large amounts of water through the plant using anywhere from 20 to 40 percent of the electricity it generates to do so (DiChristina, 1995). Another drawback is that a small OTEC power plant can currently only produce about 100 kilowatts of electricity, which is a miniscule amount relative to a traditional power plant’s generation capacity.

The amount of power that can be generated from tidal plants is much greater than for OTEC, ranging anywhere from 50 to 240 megawatts per site. The LaRance Tidal Power Station in southern France is the world’s largest ocean energy conversion plant, with the ability to produce up to 240 megawatts of electricity (Frau, 1993). The downside of tidal power is that an efficient plant requires large variations in tides, between 3 and 16 meters, which occur in relatively few areas. In some areas of the world, the neap tidal
range can be only half that of the spring tidal range (Clark, 1995). Suitable sites with consistent tidal ranges generally occur only in areas between latitudes of 50 to 60-degrees north and south of the equator (Bregman, Knapp, and Takahashi; 1996). Another drawback to tidal power is that the ebb and flood tidal stages can vary from day to day, making the hours during which electricity is produced vary also. These hours may not coincide with the peak demand for electricity, which can diminish the value of such a system (Bregman, Knapp, and Takahashi; 1996).

Wave energy is more widely applicable with potential along most coastal areas. Coastal wave power plants are estimated to have the potential to produce approximately 48 megawatts of electricity per kilometer of coastline. The wave power available at deep ocean sites is three to eight times that available at the adjacent coastal site; however, the cost of electricity transmission from these sites is prohibitory (Blankesteijn, 1996).

Other engineering issues that all of these emerging technologies must solve are the corrosiveness of seawater and the damaging effects that strong winds and high waves may have on the power plant equipment. Algae growth on the submerged portions of the equipment can also be a problem. Corrosion resistance can be prevented to a great degree by a cathodic protection system, and antifouling paints applied to the metal surfaces may provide some protection against the algae (Clark, 1995).

Cost Issues

Perhaps the greatest obstacle to the widespread acceptance of ocean-powered generation is the higher capital cost associated with the construction of such a plant when compared with construction of a traditional fossil-fuel plant. The life expectancy of the components used in any ocean power plant can also be limited due to the corrosiveness of saltwater and possible damage by hurricanes and other severe storms, which can factor into the overall cost.

The energy cost of OTEC per kilowatt-hour has been calculated to be about twice that of coal or oil fired plants, assuming the cost of oil at around $20 per barrel (Tanner, 1994). The technology used to build a tidal power plant is quite expensive, even when compared to other ocean-powered generation devices. What is not often considered is that the useful life span of a tidal plant is about three times longer than a fossil-fuel powered plant and the cost of the tide does not increase with inflation as do coal and oil (Bernshtein, 1995). The costs of constructing and operating a wave power plant can be very difficult to calculate because they are highly dependent on the exact coastal location of the plant. However, the costs are still quite high when compared to traditional power plant construction (Hagerman, 1995). Ultimately,
the greatest feasibility and most competitive costs for ocean energy conversion technologies may be on small islands and in isolated communities where the primary source of electricity is from diesel-driven generators (Miyazaki).

**Environmental Issues**

All of the renewable energy sources discussed above have a distinct environmental advantage over traditional fossil-based fuels and nuclear power sources in that they do not produce harmful by-products such as air pollution or toxic waste. In fact, the major by-product of OTEC is thousands of gallons per day of potable desalinated water! However, there are also changes in the temperature and salinity of the water discharged from an OTEC plant. These changes could have adverse affects on the surrounding marine ecosystem (DiChristina, 1995). Tidal power plants can produce accelerated environmental changes to the coastal area surrounding it. For example, the altered water level in the basin would decrease the natural tidal zone of the area, possibly having a negative effect on the local ecology (Clark, 1995). Wave power stations may disrupt the natural flow of water and the transport of sand along coastal areas, possibly resulting in exacerbated beach erosion problems (Hagerman, 1995).

**Conclusion**

Many research and development goals remain to be accomplished if these types of ocean energy sources are to be feasible. Cost reductions are imperative to make renewable energy an attractive alternative to fossil-based fuels. The reliability and efficiency of the associated technologies must be improved. Suitable sites need to be identified. Navigational hazards created by offshore devices need to be considered, as well as the impact on scenic views from the shorelines (California Energy Commission, 1992). According to the Pacific Gas & Electric Company (1991), interconnection with the existing utility power grid must also be addressed.

Public awareness and education concerning the benefits of renewable energy sources need to be increased. The global political climate must also change, placing greater emphasis on long-term benefits and costs rather than focusing on the short-term. Perhaps most importantly, a better understanding of the impacts of these technologies on marine life and on our shorelines must be gained. The oceans can continue to be a valuable resource for our planet, but only if we take steps to preserve this natural wonder and use it responsibly.
REFERENCES


