Team 2

Ocean Provided Renewable Energy Alternatives

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Desere't A. Shearer, Justin Bridges, Bonnie Aylor

Table of Contents

ABSTRACT

Our reliance on fossil fuels has led us towards a new era that could be the beginning of a massive depletion of resources, political corruption and foreign dependence. Renewable ocean energy can change this path and become a primary energy source, with the advent of new technologies that will make ocean energy more cost effective. There are a variety of forms of renewable ocean energy; from wind, to water, and even temperature gradient based energy. Barriers to renewable ocean energy include: legislation, cost, public acceptance, as well as transport of the accumulated energy over long distances. As the global community continues to consume vast amounts of energy, alternative forms of energies will become of primary importance. Oils and fossil fuels are ascending in availability and have recently lent themselves to the forefront of global political climates. Renewable energy alternatives that generate themselves from the always-present ocean and its accompanying wind can potentially become an unlimited asset.

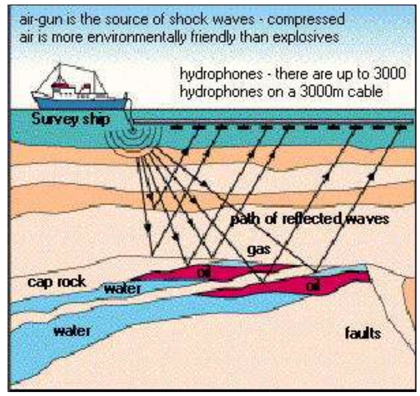
INTRODUCTION

The first oil well drilled for the specific purpose of obtaining oil was drilled in 1859 in the state of Pennsylvania, and since this time the United States electric power industry has generated a majority of its electricity from these fossil fuel sources. In 2011, the United States Energy Information Administration charted the use of petroleum for electricity generation in the US at about 37%, production from natural gas was 25%, and coal was 21%, leaving the total fossil fuel market with an 83% dominance over other sources. At the same time, nuclear energy sat at 9% and renewable energy sources remained at the bottom of the charts, generating a lowly 8% of the electric power production in the US (EIA, 2011). Energy systems aside, oil is used in the manufacturing of a variety of common products, including: gasoline, diesel, heating oil, lubricants, heavy fuel oil, aviation jet fuel, plastics, rubbers, etc. Elimination of oil as a common manufacturing agent is highly unlikely due to the prevalence of oil-based products in both American and global societies (Meyers & MAGGIO, 2012). While the elimination of the use of fossil fuels is unlikely, a reduction in the use of fossil fuels is necessary in order to maintain a suitable supply of it.

OVERVIEW OF THE OIL EXTRACTION PROCESS

The process of finding and accessing oil is expensive, dangerous, and can be environmentally damaging. Ben Dinsmore, captain on a large oil exploration and research vessel [drillship], explains on his Maritime website that an offshore oil well may cost $70,000,000 or more to drill. Once a well has been successfully drilled, an oil company may spend an additional half billion dollars to get the oil back to a refinery. In his explanation, Mr. Dinsmore details the discovery and recovery process. This basic discovery process entails the use of large, expensive equipment, the displacement of a good amount of sand, drilling up to 300-400 ft into the ground, and a high amount of health and safety risk to employees. With the price of machines, manpower, sight selection, and legalization, the process of merely discovering an oil supply can end up as high as $70,000,000 or more. The most interesting part of this process is that, after incurring such high expenditures and disturbing the natural environment, there is always the chance that the discovery test could fail measurement and the investors could decide not to attempt extraction (Maritime).

1Retrieved from: http://www.encapgroup.com/drilling/



Oil drilling and related practices carry an environmental risk due to the very invasive procedures that are used to access the oil, as well as due to the production of air, water and land pollution related to oil consumption. During the process of drilling for oil, streams of drill cuttings and wastewaters are discharged into the ocean. The drilling muds themselves contain a list of hazardous contaminants that otherwise would remain under the ocean bottom soil surface (Scholten, Karman, Huwer, 2000). Another major risk related to offshore oil drilling is the potential for oil spills, which are the unintentional release of oil into the environment from tankers, oil-rigs, and pipe lines. When an oil spill occurs, wildlife can become coated in water repellent oil and lose the ability to trap air and repel water, which reduces their ability to maintain their body heat (Wildlife, 2010). Oil spills also pollute the waterways, shorelines, and seabed; resulting in economic damages and persistent pollution. The US Department of Energy charts annual drainage from accidental oil spills to be around 1.3 million gallons (Live Science, 2010). This serves a larger risk than merely health and welfare disadvantages, but it also serves to slowly dissipate the resource with wasted commodities. As oil depletion occurs and progresses, without new technologies the United States will need to increase its reliance on other nations in order to replenish their supply (Depletion, 2011). Depending on another nation's supply puts restraints on the independence that the US strongly supports for themselves. It also puts power in the hands of the suppliers to dictate certain related rules and regulations as a sort of bartering tool for the obtainment of the resource. Clearly, discovering and using alternatives to fossil fuels is the right decision.

RENEWABLE OCEAN ENERGY

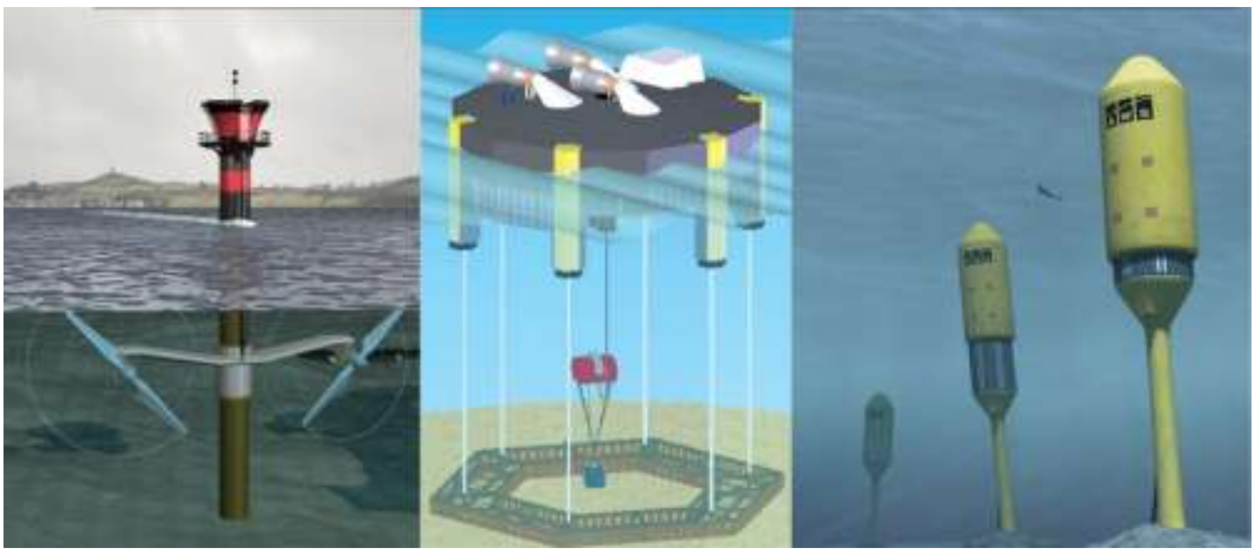
The ocean has long offered great potential for the extraction of renewable energy. The first development of ocean energy occurred more than 100 years ago, in the early 19^{th} century, when the first patents were filed for wave power. However, the use of water for energy dates back to the waterwheel and paddle wheel methods used to power grain grinding activities (Tidal Energy, 2010). According to Griset, there are numerous varieties of resources available in the ocean for harnessing energy. This energy can be harnessed from both ocean winds as well as moving waters. They can be transformed to energy from the oceans natural temperature gradients. These sources are driven by the cycles of the sun and moon. The energy that is contained within the ocean has the potential to provide a greater amount of power than current global energy demands require (Griset, 2011). It is necessary to build a thorough understanding of the technology, the processes and the limitations of ocean and wind energy in order to be capable of transforming the natural supply of energy from the ocean and wind into obtainable energy. This knowledge will allow us as a society to reduce our dependence on, and consumption of, fossil fuels.

2Retrieved from: http://alaskarenewableenergy.org/alaskas-resources/types-renewable-energy/ocean-wave-and-tidal/

VARYING TECHNOLOGIES

The technology that is chosen for use in converting ocean and wind energy into useable power will depend on the physical properties and characteristics of that the specific environment; such as wind speed, wind stability, temperature and ocean depth. As discussed by T.J. Griset in the Ocean & Coastal Law Journal, projects installed in shallow water, up to 30 meters in depth, extend to and typically rest on the sea floor. These projects typically use monopile designs, consisting of a single pole with a narrow base, and gravity-base designs, consisting of a single pole with a widened base, sometimes as a wall or block, to hold the turbine and its blades in

3Retrieved from: http://www.renewableenergyfocus.com/view/3335/ocean-energy-technology-basics/



flight. Shallow-water projects can rely on modifications of existing land-based turbine technology, which makes shallow-water sites more common due to their cost effective nature. Although shallow water projects, and transitional depth projects, can utilize sea-floor technologies, deepwater projects need to use floating platforms and barrages to maintain stability, since the ocean floor stretches much farther below the surface (Griset, 2011). Another technology, one that's been in use for a long time, employs a barrage or dam to capture water at high tide, which is then forced to flow through turbines where it generates electricity. However, this method has fallen out of favor due to the environmental damage that it creates. Other methods entail the use of wave force to power movement sensitive devices to product electricity into a generator, and temperature fluxes to provide combustion within specified chambers. The ocean-energy field is still in its infancy, but it is slowly growing, propelled by its competition with fossil fuels.

OFFSHORE WIND ENERGY

OVERVIEW

Due to the way that wind is created, wind energy can be considered an indirect form of solar energy. When hot air and cold air run into each other, they circulate and form cyclones of varying levels of pressure and force, growing denser and more diffuse as they mix, resulting in wind formation (Meyer & Maggio, 2012). Another way that wind is generated is through convection; where most of the sun's energy is absorbed by the surface of the earth and then transferred to the air, pushing particles aside as it rushes past the cold layer and then diffuses. Roughly 1-2% of all solar energy is converted to wind energy through uneven heating or through convection (OCE Offshore Wind).

4Retrieved from: http://www.electricauthority.org/going-green/third-generation-green-technologies/

Offshore wind energy has become more prevalent because winds over the ocean typically have a higher rate of speed, which results in greater energy production than wind energy generated on land. Offshore winds are an extremely reliable source of energy in the U.S. because an estimated greater than 50% of the United States population live on or near the coast and offshore winds have a much larger force and consistency than those over land (Griset, 2011). At around four times the current totaled installed power generated in the United States, the wind energy potential of the oceans surrounding the United States grows to around 4,150 gigawatts, according to The Nation Renewable Energy Laboratory (Griset, 2011). The technologies associated with this energy source vary in cost and complexity dependent upon the depth of the water in which it is to be installed. Projects in deeper water cost more and can create more technological challenges because the technology is new and still in the innovation phase of development. However,

5Retrieved from: http://www.habitat.noaa.gov/protection/renewable/technology.html

research and development for new, more cost effective designs continues, unending (Griset, 2011).

Offshore wind energy made its debut in 1990 when Denmark erected the first offshore wind energy farm. Through the process of energy trend flux, offshore wind energy displays periods of popularity and times of abandonment in conjunction. Offshore wind turbines are generally larger than those onshore due to a difference in the scale of the winds. While onshore wind turbines have an average height of 60 to 80 meters, with rotor blades that are 30 to 40 meters long; offshore turbines are greater than 200 feet in height with rotor blades 250 to 350 feet long, creating an average 2 to 4 megawatt capacity (OCE Offshore Wind).

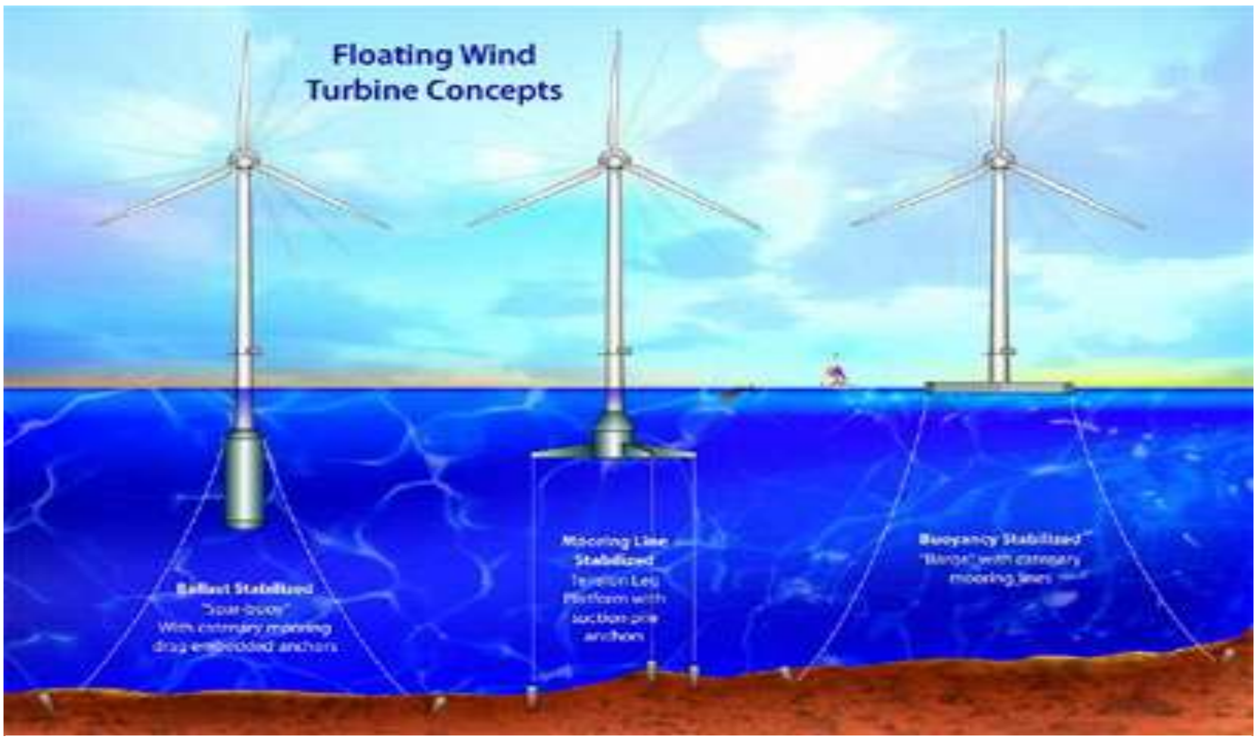
COSTS

When estimating for offshore wind energy systems, it is important to remember that with the increasing price of materials, support, cables and other supplies involved in installation, comes an accompanying increase in price. However, since the offshore systems tend to generate higher amounts of electricity, this increase can balance out according to the level of increased energy production. For offshore wind energy systems, costs are higher than for near shore plants, but less sensitive to planning issues and wind regimes. Wind energy sustains a considerable price drop between 1980 and 1999; from 30 cents per kilowatt hour to 5 cents per kilowatt hour (Pelc & Fujita, 2002). This drastic reduction in cost is due to new technologies and makes wind energy a feasible alternative to fossil fuels. It also provides hope that future designs will afford similar decreased price scales and a larger feasibility as a domestic energy producer.

TECHNOLOGY

While the world average shows that the bulk of offshore wind energy farms are located in shallow water, only about a quarter of United State's wind energy is located in shallow water. Transitional-depth sites represent another 15 percent of the nation's potential offshore wind resources, leaving deepwater sites as the largest segment of the nation's offshore wind potential; accounting for nearly 60 percent (Griset, 2011). The United States has great potential for offshore wind energy, especially in the New England area, off of the Pacific Northwest, the Northern East Coast and over the Great Lakes (Rogers, Manwell, McGowan, 2003). In these suitable locations; piles are fastened into the seabed of the ocean with foundations, a shaft is attached to the pile, and a turbine is mounted on top. The wind turbine contains three rotor blades that rotate as the wind flows, engaging a generator, which then produces electricity. This accumulated electricity is transported from the generators of the wind turbines by undersea collection cables to a transformer. From there, the electricity collected by multiple turbines in the system then transports, by underwater sea cables, to a substation. The substation is connected to an onshore power grid and the electricity is distributed to customers for use.

Offshore farms require more protection from interactions between waves and wind to prevent corrosion and to prevent complications related to interactions with marine vessel navigation. When the turbines are constructed; it is typical for them to be built with corrosion protection,



6Retrieved from: http://www.google.com/imgres?hl=en&client=firefox-a&hs=lJJ&sa=X&rls=org.mozilla:en-US:official&biw=1006&bih=593&tbm=isch&prmd=imvns&tbnid=WBGKfDrZBNftYM:&imgrefurl=http://web.mit.edu/newsoffice/2006/wind.html&docid=cuvr0bxB64TP_M&imgurl=h

internal climate control, high-grade exterior paint and built in service cranes for maintenance. In addition, to reduce the amount of maintenance required, and in a much similar manner to hydraulic oil drilling pipes, these turbines are also created to have automatic greasing, pre-heating, and cooling systems to reduce wear and tear (OCE Offshore Wind). For protection purposes, the wind turbines often have installed lightening protection measures and aerial warning lights for aircraft. Due to the fact that over 90% of offshore wind farms in the United States are in much deeper waters than wind farms in Europe, significant development has been required to strengthen the towers for wind turbines due to the pressure of the deeper waters (OCE Offshore Wind).

EXISTING AND FUTURE WIND ENERGY SITES

As of September 2010, approximately forty-two offshore wind projects had been installed worldwide, primarily in European waters of less than thirty meters depth. The total global offshore wind energy capacity from installed wind energy technologies equals around 2,377 megawatts, estimates the National Renewable Energy Laboratory. The first of these to reach development was the Vindeby project off Denmark, whose eleven turbines mounted in waters of an average depth of four meters have provided five megawatts of capacity since 1991. Denmark is also home to the largest operating offshore wind project; the 91-turbine, 209 megawatt Horns Rev 2 development of 2009. On a global basis, the largest total installed offshore wind capacity currently belongs to the United Kingdom, whose 1,041 megawatts account for nearly 44 percent of the world's total offshore wind capacity(National Renewable Energy Laboratory, ND). Deepwater sites have even begun to step over the design phase and into development; in June 2009, Norwegian developer Statoil Hywind and Siemens Wind Energy collaborated on the installation of the world's first full-scale floating wind turbine. The project utilized a 2.3 megawatt Siemens Turbine, charting up to $70 million in expenses for research, development and construction. Regardless, Statoil predicts that the cost of floating wind turbines could soon fit into competition with other market projects (Griset, 2011). Currently there are twelve proposed offshore wind energy projects for the United States, the first was granted approval for construction in 2010 and will begin construction off of Nantucket Sound, Massachusetts(Griset, 2011).

BENEFITS AND RISKS OF WIND ENERGY

As with any new technology, the benefits and risks associated with wind energy must be carefully considered in order to determine the validity and value of each specific technology. Wind energy generation certainly comes with considerable risks considering the factors involved with the construction of the very tall propelling blades, as well as the accompanying cables and foundation. On a positive note, it's believed that the foundations can become artificial reefs over time, which could result in larger fish populations. While this is positive, larger fish populations could lead to larger bird populations, which could become a hazard. Positively, wind energy is renewable, clean, and has a much lower environmental impact than the use of fossil fuels. Negatively, the turbines and the electromagnetic fields associated with the cables used to transfer the energy onshore could have a critical impact on the fate of migratory birds. Furthermore, underwater noises and vibrations could affect the orientation and navigational abilities of some species. The unpredictability of the wind can result in fluctuations in the amount of energy that could be produced from these turbines. Finally, construction costs for offshore wind farms are expensive and having to transport the energy back to land via the use of underwater transport cable raises the expense of the energy being produced. However, as technology improves, so will pricing.

TIDAL, WAVE AND THERMAL ENERGY:

TIDAL ENERGY

OVERVIEW

Ocean currents are the movement of water caused mainly by wind and the heating of ocean waters near the equator through solar radiation. Currents are also slightly affected by the density and salinity variations of the ocean water. Climate and atmospheric sciences make the movement of tides more predictable (US DOE, 2011). Unlike wind energy, tidal energy can be predicted weeks or even years in advance, which allows for better planning to obtain the most energy possible. Though unfortunately, according to the World Offshore Renewable Energy Report 2002-2007, only about 90GW of a total potential of 3,000GW worldwide, is in areas suitable for power generation. According to Griset (2011), of an available global 5,000 gigawatts, the United States only contains about 70 gigawatts of potential energy. Experts say that 35% of the Florida electrical demand could be supplied with merely 1/1000th of the energy contained in the Gulf Stream (OCE Ocean Current). Since the oceans contain such a huge amount of energy, ocean currents provide a secure, relatively clean source of energy production. While in-stream conversion and tidal conversion appear to have great potential, there are also some very substantial barriers to the success of these specific technologies.

7Retrieved from: http://www.care2.com/news/member/467421488/349008

COSTS

Costs are hard to predict for tidal technologies due to the lack of currently available sources of viable tidal power (Department of Interior). Major costs of these systems are caused by the cables used to transport the electricity to the onshore grid, since displacement of these systems into the deep parts of the ocean means that the energy would need to be transported long distances (US DOI, 2006). According to the Department of Energy (2011), it doesn't cost much to operate tidal power plants, but their construction costs are high and lengthen payback periods. As a result, the cost per kilowatt-hour of tidal power cannot compete with conventional fossil fuel power (US DOE, 2011). If construction costs can be lowered, tidal energy can become a more cost effective and viable option of alternative energy.

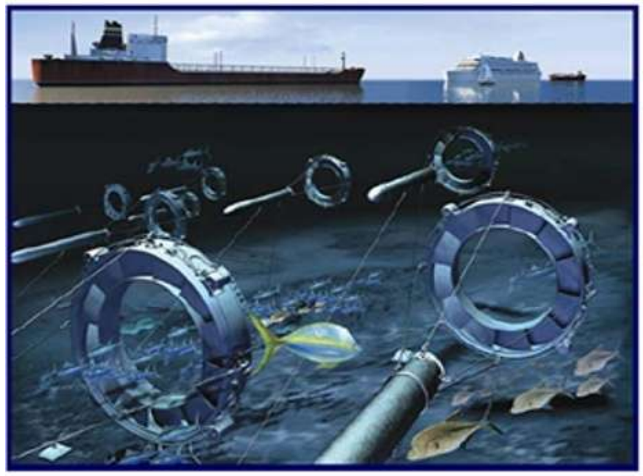
TECHNOLOGY

The process of the production of tidal energy is very similar to that of wind energy. Large

8Figure 1

turbines are installed beneath the surface of the water. The flow of the ocean current then forces the rotation of the blades attached to the turbines, which power a generator to create electricity (Figure 1). The electricity that is created through the production of the generator is then transported to shore through the use of underwater electrical transport cables, and the energy is then passed along to consumers through an electrical grid (OCS Ocean Current).

9Figure 2



Beyond turbines, an additional technological method is that of the barge system moored into the current stream. The barge uses parachutes that move on a cable; as the current pushes against the open parachutes, movement of the cable turns a generator onboard the barge that generates electricity and transports it back to shore (M&M Current, 2012). Another innovation, still in its development phase, involves harnessing the energy through the use of a rim driven turbine. This technology is currently being created by the Florida Hydro Power and Light Company (Figure 2). Companies are using Newtonian and Non-Newtonian process fluid mechanics, applied vortex hydrodynamics and linear implosion technologies to work on developing new, more efficient methods to harness the power of ocean currents (M&M Current, 2012).

EXISTING AND FUTURE TIDAL ENERGY SITES

The first commercial tidal barrage was constructed in the early 1960's on the Brittany coast of northern France. Built at the mouth of the La Rance estuary, the barrage produces 240 megawatts of electricity by utilizing the 2.4 meter tidal height in the estuary (Pelc & Fujita, 2002). Currently there are no tidal power sites in use or constructed in the United States, however the Pacific Northwest and Atlantic Northeast regions, specifically under the Tacoma Narrows Bridge in Washington State, and between Point San Pablo and East Brothers Island in San Francisco Bay are well suited for the development of tidal power in the future (Pelc & Fujita, 2002). In 2003, the world's first commercial grid-connected tidal-current plant opened in Hammerfest, Norway, as a 300-kW plant generating 700 MW hours of power annually (DOI, 2006). There are also roughly 10 smaller noncommercial tidal barrages scattered throughout the world. These sites are used for private power generation or for research purposes only.

Locations where installation of ocean current energy sites would be beneficial in the future require the availability of marine current flows. These currents are generally found in areas of strong, narrow current transport towards a wider, more diffuse water source (M&M Current, 2012). Tidal energy is not suitable for a majority of U.S. waterways due to the fact that a majority of the American ocean flow is too slow and too far from consumers for implementation to be cost effective. The Florida current and the Gulf Stream are the two most economical locations for the United States that could be developed to harness ocean current energy.

BENEFITS AND RISKS OF TIDAL ENERGY

Ocean current energy is beneficial because it is a renewable form of clean energy that is able to produce electricity without the use of fossil fuels. Also, tidal energy is able to produce much more energy than what is produced from wind turbines because water is much denser than air, so tidal currents carry more energy than air. Tides are a much more reliable source of power than air or wind, because the former two types of energy are dependent upon weather conditions to be able to produce power; whereas tidal energy is constant and predictable with two high tides and two low tides daily. Tidal energy plants use virtually no fuel, making them very easy and cheap to maintain and a huge benefit as an energy resource.

9Retrieved from: http://www.vattenfall.com/en/ocean-energy.htm

Despite the benefits of tidal energy, there are risks as well. The costs of constructing a new tidal energy power plant are extremely high, serving as a huge deterrent of investment and construction. Also, the limited availability of suitable locations, forty existing locations throughout the world that are capable of producing enough electricity to make tidal energy practical, creates a big hindrance to the availability of power generated as a result of tidal energy. According to the World Energy Council Ocean Current Report, the total amount of electricity available from tidal power is about 450 gigawatts of installed capacity. The amount of power capable of being produced from tidal energy would only account for an estimated 6% of global energy demands annually (Tidal Energy, 2010). Tidal energy plants that produce electricity with the assistance of dams or barrages can result in environmental concerns similar to those of common dams; such as interference with fish migration routes, and an accumulation of silt at the base of the dams. Tidal energy production also involves finding solutions to issues such as avoiding bubble formations, marine growth buildup and corrosion, as well as interference with shipping routes and marine recreation. Lastly, the interference with the natural flow of water can have a significant impact on the hydrology and salinity of the estuaries, causing harm to the natural processes that occur in estuaries, which act as nurseries for marine organisms (Pelc & Fujita, 2002).

WAVE ENERGY

OVERVIEW

"The oceans cover a little more than 70 percent of the Earth's surface. This makes them the world's largest solar energy collector and energy storage system. According to the World Energy Council, the global energy available from wave energy conversion is 2000 TWh/yr. Tapping just 0.2 percent of this energy would satisfy the current global demand for electricity." (Anthony T. Jones, Ph.D.)

10Retrieved from: http://www.techthefuture.com/energy/loopwing-yields-energy-from-ocean/

If what Mr. Jones said is correct, humanity has the perfect energy source that is just waiting to be realized. The idea of harnessing energy from the motion of waves has long existed. In 1799 Monsieur Girard and his son filed a patent in Paris, France proposing the use of waves for powering mechanical methods to drive pumps, mills, saws and other types of machinery (OCS Wave Energy). Between 1799 and 1973 there were 340 patents filed relating to ocean wave energy production (OCS Wave Energy). This interest in the amount of energy created by waves and the ocean has not waned, and with the right political and financial climate, this source could protect the globe from the damages of years of the use of fossil fuels. With the oil embargo in 1972, an energy crisis was created and governments began to look for alternative energy sources so that they were not so reliant on a resource that was limited and politically impacted. These factors made the use of wave energy important enough to create international wave energy symposiums and the building of the first commercial energy power facility, which was constructed in 2000 (Power, 2002).

Waves are created by and get their energy as a result of wind, which is created as a byproduct of solar radiation. Energy from wind is transferred into the ocean where it is able to be stored, built-up and transmitted thousands of miles by waves, with little or no loss of the energy. The amount of energy that waves contain is a form of energy that is constant and will be continually replenished as long as solar radiation of the sun exists. What this says is that wave energy will be around for as long as humanity is, and that it is an excellent source of clean, renewable energy (OCE Wave Energy).

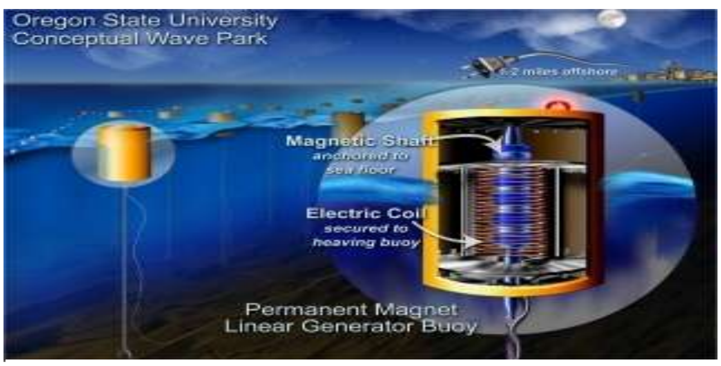
COSTS

According to the Ocean Energy Council, the best wave generator technology in place is in the United Kingdom and is producing energy at an average projected/assessed cost of 7.5 cents kWh. In comparison, electricity generated by large scale coal burning power plants costs about 2.6 cents per kilowatt-hour. Combined-cycle natural gas turbine technology, the primary source of new electric power capacity, is about 3 cents per kilowatt hour or higher. It is not unusual to average costs of 5 cents per kilowatt-hour and up for municipal utilities districts (OCE Wave Energy). Clearly wave generated energy costs more at the present time, which is the norm for new technologies. It's expected that improving technology and economies of scale will allow wave generators to produce electricity at a cost comparable to wind-driven turbines, which produce energy at about 4.5 cents kWh. This is positive news in that, with newer technology, costs for wave generated energy will be comparable to that of fossil fuels (OCE Wave Energy) (Pelc & Fujita, 2002).

TECHNOLOGY

Wave energy is only feasible in areas with consistent wave motions due to high winds; such as the western coast of Scotland, Southern Africa, Northern Canada, Australia, and the northeast and west coasts of the United States (Energy Savers, 2011). Kinetic energy in waves is created through the movement of the ocean and changes in ocean swells of both height and speed. Wave energy is a source of irregular, oscillating low-caliber energy that can be harnessed at a 60-hertz frequency and processed to an electrical grid. The average wave, measuring at four–foot from crest to surface with ten second durations, can exert more than 35,000 horsepower per mile of coast when it strikes (Ocean Energy Council, 2012). There are primarily three types of wave energy technology available today: float or buoy systems, oscillating water columns, and tapered channel systems.

Float or buoy systems attached to the sea floor utilize the upward and downward motions of ocean swells to power hydraulic pumps (Figure 4). As the floats rise and fall with the waves, they power the hydraulic pumps that power an electrical generator. The power that is created from this process is then transported to shore through a series of underwater electrical transport cables. Oscillating water columns use the wave's in and out motion as water enters the column and forces air into a turbine. The columns fill with water as the swell rises and falls, and then the column empties out for the next swell increase. The air inside the column is compressed as the water enters, which creates heat. The process, in turn, creates energy in a manner similar to that of a piston. Once the energy is created, it is transported to land through underwater electrical transport cables. Lastly, a structure that is mounted on the shore channels and concentrates the waves and drives them into an elevated reservoir through a tapered channel system. Then the system releases water, creating energy by powering a turbine similar to the processes of a dam. This type of energy harnessing is called the hydropower method (Energy Savers, 2011).



10Figure 4

EXISTING AND FUTURE SITES

As of 2007, there were 12 proposed ocean wave energy projects along the pacific coast of the United States (Oregon State University, 2007). One such project, a plant designed by Ocean Powers Technologies, consists of a 50 megawatt wave park that could take 10-15 years to complete. A proposal was filed with the Federal Energy Regulatory Commission that detailed plans to place a 15 kilowatt buoy into place at this energy park in Gardiner, Oregon in the spring of 2008, and 13 more by the fall of 2008. An ocean-wave energy park such as this one can power 60,000 households when operating at full capacity (Oregon State University, 2007).

Islay, Scotland serves as home to the first commercial constructs, a technology known as the Limpet 500. The limpet 500 has been contributing power to the UK power grid since November 2000, and was designed to generate 0.5 megawatts of electricity annually. The plant utilizes an oscillating water column designed for sitting on-shore (Pelc & Fujita, 2002). The most suitable locations for harnessing wave energy are in extreme latitudes and along western coastlines due to the high winds, resulting in large wave distributions, commonly associated with these areas (Ocean Energy Council, 2012).

Since August of 1990, Demi-Tek Corp has been operating a hybrid technology, called the Monitor, which utilizes both wave and wind energy harvesting off of the shores of Asbery Park, New Jersey. The Monitor produces enough electricity to light the city's boardwalk and convention hall. Originally, the Monitor was deployed to help reduce wave action and protect beaches from erosion. It is anchored to the ocean floor by cables similar to those used for offshore oil drilling, and electricity is brought to shore by an undersea cable (Pelc & Fujita, 2002).

BENEFITS AND RISKS OF WAVE ENERGY

11Retrieved from: http://blogs.reuters.com/environment/2009/12/12/california-looks-to-catch-a-wave-of-energy/

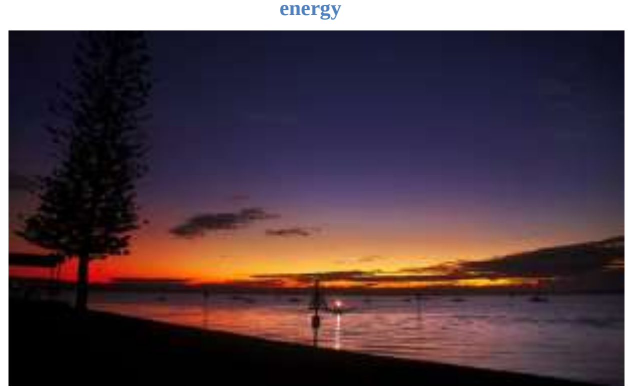
A benefit of wave energy is that wave power is readily available roughly 90 percent of the time at a given site, while wind and solar power is only available up to 20-30 percent of the time (Pelc & Fujita, 2002). Wave power facilities have the potential to act as a wave breaker system, reducing waves in the ocean and resulting in calmer seas, which would be beneficial in harbors. However, this same system could also negatively impact the mixing of the upper layers of the sea and cause harm to marine life and fisheries (Pelc & Fujita, 2002). According to the Ocean Energy Council, a positive factor of wave energy is that it contains roughly 1000 times the kinetic energy of wind, allowing much smaller and less conspicuous devices to produce the same amount of power in a fraction of the space (Ocean Energy Council, 2012). Estimating the resource potential of wave energy is much easier than with wind, which is a very important factor in obtaining funding sources. Another large benefit to wave energy is that wave energy needs only 1/200th the land area of wind and requires no access roads, therefore decreasing the cost of infrastructure. Wave energy devices are quieter and much less visually obtrusive than wind devices, which typically run 40-60 meters in height and usually require occupancy in remote locations with attendant high transmission costs. Since there is no need to use fuels in powering these systems, wave energy facilities produce virtually free energy (Ocean Energy Council, 2012).

Equipment used for wave energy production can result in navigational problems for marine transportation. Equipment that is near or onshore can result in visual impacts to the surrounding environment, which can cause public outcry. As a result of disturbance of the sea floor during installation, silt build up around the equipment, new hardware being present and other associated habitat difficulties; wave energy production equipment can interfere with marine recreation for individuals and equipment can have a negative impact on marine life. A major impediment to gains in investment on this technology is that construction of equipment tends to incur a large expense, resulting in higher energy costs than the more traditional fossil fuels (OCS, N.D.).

OCEAN THERMAL ENERGY CONVERSION

OVERVIEW

12Rtrieved from: http://www.campaignsthatmatter.com/articles/27-clean-ocean-energy



Ocean Thermal Energy Conversion (OTEC) technology made its debut when first proposed by a French physicist, by the name of Jacques Arsene d'Arsonval, in 1881. However, it was a student of d'Arsonval's named Georges Claude, who actually built the first ocean thermal energy conversion station in Cuba in 1930. The system that Claude constructed in Cuba was able to produce 22 kilowatts of electricity through the use of a low-pressure turbine. Claude constructed a second OTEC system on board a cargo vessel in 1935 near Brazil. Both of Claude's systems were destroyed due to weather related impacts before they were able to become net energy generators (Energy Savers, 2011). The United States began its own research into OTEC in 1974 with the National Energy Laboratory of Hawaii Authority (Energy Savers, 2011). OTEC technology uses the temperature differential between the deep cold and relatively warmer surface waters of the ocean to generate electricity. The technology is potentially viable in tropical areas where the year-round temperature differential between the deep cold and warm surface waters is greater than 20 degrees Celsius [36 degrees Fahrenheit] (National Renewable Energy Laboratory, N.D.).

In the United States, the Office of Ocean and Coastal Resource Management, which is a division of the National Oceanic and Atmospheric Administration, is the responsible agency for granting licenses for ocean thermal energy conversion projects. As of 1996, NOAA had not yet received any applications for permits to build a commercial ocean thermal energy conversion system. Due to the lack of permit applications, NOAA suspended its permitting program for these systems; only to restart the program in 2008 after a spike in oil prices generated renewed interest in ocean thermal energy conversion technologies (National Oceanic and Atmospheric Administration, 2011). Starting in the 1970's, governments have been able to work with private companies to create ocean thermal energy technologies off of continental coastlines, producing anywhere from 18 to 103 to 120 kilowatts of energy, enough to power a school and other small buildings in a condensed area (Fujita et'al, 2012).

COSTS

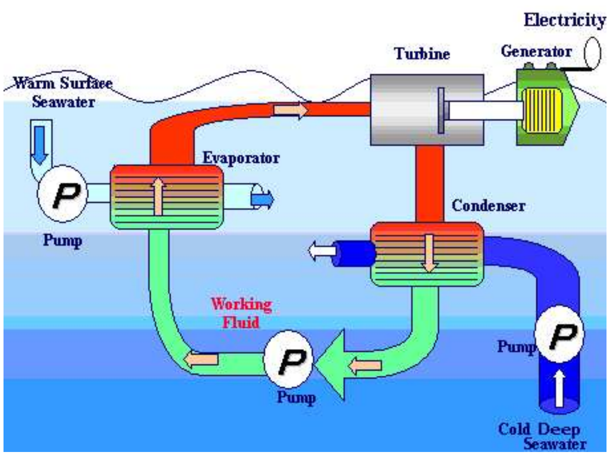
Currently ocean thermal energy is unable to compete with fossil fuels on the subject of economics because the cost of construction and maintenance for these facilities is considerably high. Competition is further complicated by the use of energy transport cables that supply energy back to land. These cables are not only expensive to install, but they also run the risk of damage from tropical storms and rough seas. Difficulty in relation to the discovery of a large enough space in proximity to a part of the ocean exhibiting proper energy differences creates a dependence on the extensive use of undersea cables, significantly raising investment costs. Land based ocean thermal conversion facilities where deep water access is available is typically the most cost efficient type of facility due to the fact that deep sea construction is not required. Even so, cost efficiency improvements are under examination to address the development and testing of cheaper, lighter, and more durable materials for seawater pipes and more efficient placement measures (Fujita, et al, 2012).

TECHNOLOGY

Ocean Thermal Energy Conversion, or OTEC, involves the use of warm surface water to vaporize a working fluid with a low boiling point, such as ammonia, and then the vapor is used to drive a turbine and generator. Cold water pumped from the deep ocean is then used to re-condense the working fluid. The temperature differential must be greater than approximately 20 degrees Celsius for net power generation. Such differentials exist in the tropical zones of the Caribbean and the Pacific however the expanse of viable locations is limited (National Renewable Energy Laboratory, N.D.).

13Figure 5:

Retrieve from: http://japantechniche.com/2008/09/28/power-generation-based-on-ocean-thermal-energy-conversion/



The actual distribution of feasible sites for OTEC will depend on other factors as well; such as proximity to shore and the potential to increase the temperature gradient by means of applying waste heat from other industrial facilities. With ocean's covering more than 70 % of the earth's surface, they are the biggest collector of solar radiation and the biggest storage center of this energy. On the average day, 23 million square miles of Tropical Ocean are able to absorb enough solar radiation to be equal in heat context to 250 billion barrels of oil. Ocean thermal energy harnessing just 1/10th the amount of solar energy available in tropical zones could supply an amount of electricity that is 20 times greater than the total average United States energy consumption daily (National Renewable Energy Laboratory, N.D.).

According to the Department of Energy, there are three different types of OTEC systems that are able to produce electricity: the closed cycle system, open cycle system and the hybrid system. The closed cycle OTEC systems vaporize liquids at a low chemical boiling point to power a turbine that generates electricity. The warmer upper level surface water of the ocean is pumped through a heat exchanger, which is where the liquids with the low boiling points are vaporized.

When the low boiling point liquids, such as ammonia, are vaporized, the expanding gas rotates the turbine to power the electricity generator. Cold water pumped from deeper levels of the ocean are pumped through a second heat exchanger in the system, which transforms the heated vapor back into liquid form where it will be recycled back into the system for reuse, as shown in Figure 5 (DOC, 2011).

In an open cycle OTEC system; warmer water from the upper layer of the ocean is pumped into low-pressure containers, which cause the water to boil. The steam that is created from the boiling ocean water expands to turn a low pressure turbine, powering an energy producing electrical generator. As the water turns to steam in the low-pressure containers, only salt is left behind, indicating that the steam is pure water. The steam is then turned back into liquid form when it is cooled down by exposure to the cooler temperatures of the deeper level ocean water (DOC, 2011).

The hybrid OTEC system uses a combination of technology from both the closed cycle systems and the open cycle systems. In these systems, warmer, upper level ocean water is pumped into vacuum sealed chambers where the water is instantly flash boiled into steam similar to how the process is done in open cycle systems. The steam is then used to boil liquids with a low boiling point into a vapor similar to the closed cycle system. The vapor produced from the liquid with the low boiling point is then used to rotate a turbine which creates electricity (Fujita, et. al., 2012).

EXISTING AND FUTURE SITES

Areas that are located within the tropical zone that could have a use for OTEC technology include parts of the United States and Australia, as well as 29 territories and 66 developing countries. All of these would be capable of utilizing ocean thermal energy conversion to be able to supply parts of the energy needs for their own individual locations (National Renewable Energy Laboratory, N.D.). Commercial OTEC power sites could be developed as either a platform which is attached to the shelf, or a mooring or free floating facility in deep water. Land based and near shore facilities are the most preferred method of OTEC because they do not require the expensive mooring, long transport power cables and intensive maintenance that is required for open ocean platforms. These facilities are able to be built on land or close to land, which can provide the facility with protection against tropical storms or rough surf zones. This protection is expanded when the technologies are constructed at 10 to 30 meters from shore, providing desalinated water and air conditioning for nearby industrial facilities (National Renewable Energy Laboratory, N.D.).

Shelf mounted facilities are OTEC facilities mounted in the ocean onto the continental shelf at up to 100 meters in water depth. This provides closer access to cold lower layers of water and helps the facility avoid turbulence often associated with surf zones (National Renewable Energy Laboratory, N.D.). Stress caused by open ocean conditions, and providing costly transport cables to transport the energy produced long distances back to land, often causes problems in regards to the management of these facilities (National Renewable Energy Laboratory, N.D.). Floating facilities are designed to operate offshore, in deep waters, as large capacity generators of electricity. These facilities result in greater difficulties because of the complications involved in facility stabilization practices and the transport of energy to land. Platforms are built as self-propelled drifting devices, or constructed on ships as a means of reducing such difficulties. The power that these moveable platforms will generate can be used to produce energy intensive products such as hydrogen, ammonia or methanol (National Renewable Energy Laboratory, N.D.).

BENEFITS AND RISKS OF THERMAL ENERGY CONVERSION

Of the ocean-generated energy options that are currently available, ocean thermal energy conversion seems the most multi-productive. OTEC is able to help produce fuels like ammonia, hydrogen, and methanol. The technology also produces desalinated water that can be used for agricultural, industrial and residential uses. Theoretically, an OTEC plant that generates 2-MW of net electricity could produce about 4,300 cubic meters (14,118.3 cubic feet) of desalinated water each day (National Renewable Energy Laboratory, N.D.). As a byproduct of creating electricity, ocean thermal energy conversion is also able to produce air conditioning by use of the ocean-cooled waters, reducing the need for extra electricity. Effluents of OTEC plants can support production of several kinds of valuable aquaculture crops; including lobsters, abalone, and micro- algae, improving OTEC's economic feasibility (Energy Savers, 2012).

CHALLENGES AND BARRIERS

There are currently some challenges and barriers that make full acceptance and implementation of ocean energy technologies difficult to accomplish. Politics, project costs, possible project-caused environmental damages, public acceptance of the technology, and transport of the accumulated energy are each issues that must be addressed in order for renewable energies to become cost effective and feasible. One of the largest problems that ocean energy faces is the difficulty in competing with what are effectively subsidized fossil fuel energy sectors. In order to progress, it is imperative that the ocean energy industry is given assistance from governments in its early stages of development so that the necessary technologies can be developed that would allow this alternative energy source to be fully explored. Research carried out at the United Nations University Institute for Advanced Studies expects ocean energy to become financially viable in the early 2020s. In the meantime, development and construction of wave power facilities are eligible for subsidization via feed-in-tariffs, which have been greatly responsible for the rapid development of the renewable industry in several European countries (Our World 2.0).

14Rtrieved from: http://www.ecofriend.com/entry/seadog-pump-wave-energy-technology-to-tap-ocean-for-renewable-power/

EXAMPLES OF APPLICABLE ENVIRONMENTAL REGULATIONS

Many environmental regulations apply to any project that involves alternative ocean energy sources. With the passage of the Energy Policy Act of 2005 [EPAct], Public Law 109-58 [H.R. 6], the Minerals Management Service [MMS], a bureau of the U.S. Department of the Interior, was given jurisdiction over Renewable Energy and Alternate Use Program projects. These projects include: wind, wave, ocean current, solar energy, hydrogen generation, and projects that make alternative use of existing oil and natural gas platforms in Federal waters. To apply the requirements of the National Environmental Policy Act [NEPA] in the establishment of national offshore alternate energy development policy and a national alternate-energy-related use program with associated rules, MMS plans to prepare a programmatic environmental impact statement [Programmatic EIS] (DOI, 2006).

According to the Congressional Research Service, many different Federal Agencies may be involved in the review and permitting process for renewable energies depending upon the location and type of the project. An example of one agency's, The Army Corps of Engineers, duties for regulating such projects are as follows:

- permitting for a number of activities in waterways and offshore areas;
- under section §10 of the Rivers and Harbors Act; regulating and permitting for work and structure that may affect navigable waters;
- under section §404 of the Clean Water Act; issue permits for the discharge of dredge and fill materials into navigable waters; and
- under section §401 of the Clean Water Act; involvement in water quality certification.

The Clean Water Act Section §401 applies to projects that will be located within three miles of the coast of the United States. Any individual that applies for a federal license to participate in an activity that discharges a pollutant, including water with pollutants and temperature changes, must secure a water quality certificate from the state where the project will be located. Section §404 applies to locations within three nautical miles of the coast of the United States and requires the applicant to obtain a permit for any process that would discharge dredge or fill materials into United States waters. The Federal Power Act, under section 16 U.S.C. §817 (1) gives the authority to the Federal Energy Regulatory Commission to license any non-federal hydroelectric project. The endangered Species Act, 16 U.S.C. §1531, protects any plants or animals that have been designated as threatened or endangered by the Fish and Wildlife Services and the National Marine Fisheries Service. Once a plant or animal is listed as threatened or endangered, no project may be funded or conducted by a federal agency until the Fish and Wildlife Service or the National Marine Fisheries Service determine that the project will not adversely harm the habitat of the endangered or threatened species.

The Fish and Wildlife Coordination Act, 16 U.S.C. §661, authorizes the Fish and Wildlife Services and National Marine Fisheries Service the power to determine possible impacts to fish and wildlife from proposed water resource project development. Any federal agency that conducts, licenses, or permits these types of projects must first consult with the federal and state fish and wildlife agencies regarding the possible impacts of the project and what would need to be done to mitigate the effects. The Marine Mammal Protection Act, 16 U.S.C. §1361-1407, prohibits the harassment, hunting or capture of any marine mammal. This act comes into effect if it is determined that a proposed project may harass marine mammals, and is based on construction, location and the performance of the project. There are many other environmental regulations that apply to these technologies, but that is outside the scope of this paper.

FUTURE OUTLOOK

In spite of efforts on the part of a number of U.S. scientists and engineers, little federal or state funding of wave energy development has been forthcoming. In the last few years, the Navy, through its Office of Naval Research SBIR program, has provided some research funds, but the SBIR funding level is not adequate for demonstration projects (A Brief History of Wave Energy Development, 2002),. In the United States, research on renewable energy has lagged in part because it is difficult for any new technology to compete economically with cheap and established fossil fuel plants. Renewable's often pay off in the long term, because the ‘‘fuel’’—sunlight, wind, ocean waves, etc.—tends to be free and limitless. In the short term, renewable energy plants are sometimes prohibitively capital intensive. However, proper accounting for externalized costs of energy production puts renewable energy in a more favorable light. Advances in technology and economies of scale can cause the costs of such technologies to drop considerably over time. For example, wind power cost 30 cents/ kWh in the 1980s, much too high to be economically feasible; by 1999 that cost had dropped to 5 cents/kWh, making wind power cost competitive with fossil fuels, even without accounting for the costs of pollution and other adverse impacts associated with fossil fuels (Pelc & Fujita, 2002).

CONCLUSION

In conclusion, it has been determined that, although there is a vast need for the many products that can be delivered through the use of petroleum, it is necessary to find an alternative to fossil fuels for the delivery of energy needs. Fossil fuels consume 83% of the energy grid, yet they are a depleting resource. Aside from depletion factors, the resource is risky in terms of economics, health and environmental welfare. Renewable energy technologies are a good alternative to fossil fuels, ocean energy technology being one of those. Ocean energy technology displays its value in the large availability of its resource derivative, the natural systems of the ocean. There are four main types of ocean energy technology; wind, tidal, wave, and temperature systems. Of these four, analysis and feasibility studies narrow OTEC technologies as a most viable choice. This technology, early in its stages of development and not without its drawbacks, is quickly reaching values closer and closer to the cost effectiveness of fossil fuels. OTEC has barriers in relation to its effect on the marine environment as well as its effect on marine transportation vessels, in some locations. However, the technology can be situated in regions that minimize these barriers. The technology also supplies useful byproducts such as marine wildlife beneficial effluents and desalinated water. Furthermore, the technology can power air conditioning systems at its facilities, virtually bypassing the need for other energy forms. The natural resource that it uses is the temperature differentials of ocean waters. This resource is constant and barely changes from one decade to another. This makes the resource virtually unending. The technologies will soon be as affordable for energy consumers as fossil fuels and proves to be an essential choice for implementation as an energy alternative.

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Figure 1 and 2

http://www.oceanenergycouncil.com/index.php/Ocean-Currents/What-devices-are-used-in-current-energy-conversion.html

Figure 3

http://ocsenergy.anl.gov/documents/docs/OCS_EIS_WhitePaper_Current.pdf

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