Marine Energy Conversion Devices

Introduction:

The energy industry is in a situation where big advancements must occur in order to support the increased worldwide energy demand. Obviously, sourcing energy from fossil fuels is not the solution over the long term. Climate change, future exhaustion of fossil fuels, and major concerns with nuclear power leads to the necessity for renewable resources. One of the best prospects for renewable energy comes from energy in the ocean in the form of Marine renewable energy [1].

Marine renewable energy totes a promising future if the efficiency of such devices increases. Considering that 70% of Earth's surface is covered in the ocean [2], the resource is readily available. Additionally, the ocean already is critical to life on earth as well as to the atmosphere, weather, and climate. This report will examine the value proposition of using marine renewable energy (MRE's) as well as promoting research and education in the field of renewable resources.

Types of Devices:

The ocean has enormous amounts of energy within it, the only issue is being able to transfer that energy into usable energy. There are other examples of offshore energy sources, including offshore wind farms, solar plants, use of biomass, and compressed air energy storage. However, marine renewable devices utilize the energy in the ocean that is created through waves, ocean currents, and thermal gradients. Different types of devices utilize different aspects of this created energy.

Wave Energy Converters (WEC)

Clearly there are several different ways that energy conversion can occur, and a lot of work is being put into making these styles more efficient as well as coming up with new ways to convert this energy. The most widely used type of wave energy converters (WEC) are point absorbers and attenuators. Point absorbers consist of a floating structure that has a small horizontal dimension when compared to its vertical counterpart. One end of the device is fixed or anchored, usually to the ocean floor, and moves in a vertical direction. The reciprocating action on the floating object caused by waves can then be used to pump a fluid or drive a linear generator, one such device is called the PowerBuoy. The attenuator also floats at or near the water's surface, however the orientation of the device is the opposite of a point absorber. Attenuators, such as the Pelamis device are oriented parallel to the direction of wave travel and rely on the flexing joints between each floating vessel to generate power. The different types of common devices can be classified as shown in figure 1.

There are several factors that affect how much energy a wave or set of waves carries. Some of these factors include wind velocity, direction, and fetch as well as water depth and the topography of the ocean's floor [2]. In more shallow areas, where the wave contacts the ocean floor, a lot of energy will be lost. Therefore, most WEC's need to be in deep water. Since the water off the coast of North Carolina does boast deep sea conditions we are able to create models using buoy data off the North Carolina coast.

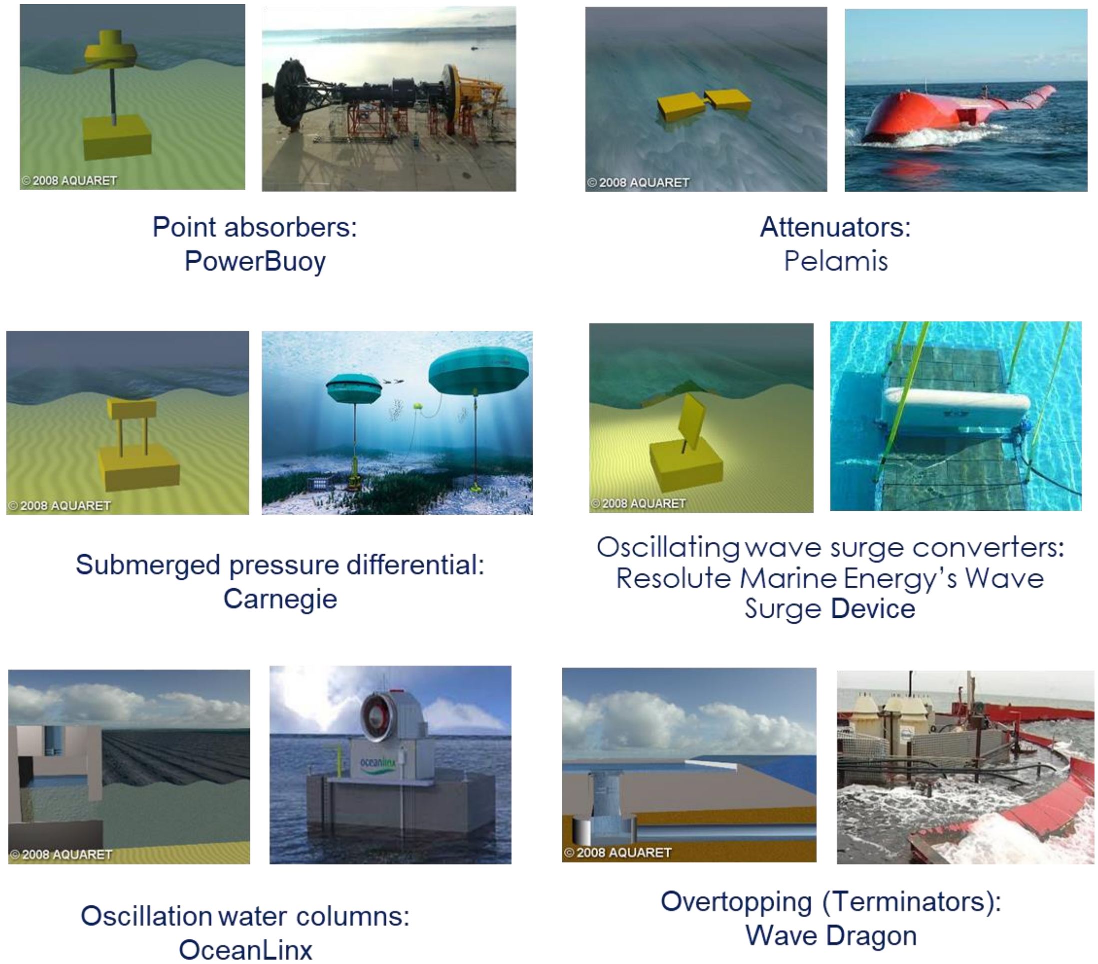


Fig 1: WEC Devices

Ocean Current Energy Converters (OCEC)

The second medium for energy to be exerted through are the ocean currents. The factors that influence the speed and direction of a current include wind, tides, water density (or salinity), rotation of the earth, and the topography of the ocean floor. There are two different classifications of ocean currents: surface or deep ocean currents. Surface currents cover the top 10% of the ocean's depth. Gyres, or rotating ocean currents occur due to the Coriolis effect, which means the current moves as a curve and not a straight line. The ocean current comes from the rotation of earth as well as wind patterns, and the current helps redistribute warmth all around the globe. Deep-ocean currents make up the remaining 90% of the ocean and are primarily caused by density which is related to the temperature and salinity of the water.

There are different device types of current energy devices including underwater turbines, reciprocating hydrofoils, and venturi effect devices (as shown in figure 2). Underwater turbines are utilized at the ocean floor where the current energy rotates the turbine blades. These turbines then convert this energy into usable electricity, and the turbines can be placed vertically, horizontally, or floating. An example of this is the Atlantis AK1000 axial-flow turbine. Another example of current energy converters is the reciprocating hydrofoil. This style utilizes an arm with a hydrofoil on the end that is lifted by the ocean current, and the linear energy from the arm is converted to electrical energy. An example of this device is the bioSTREAM oscillatory-hydrofoil turbine. Next, the venturi effect device also known as a ducted turbine funnels the water through a duct, which increases the water's velocity. The resultant flow then drives a turbine and creates electrical energy. An example of these devices is the Atlantis Solon-K ducted turbine.

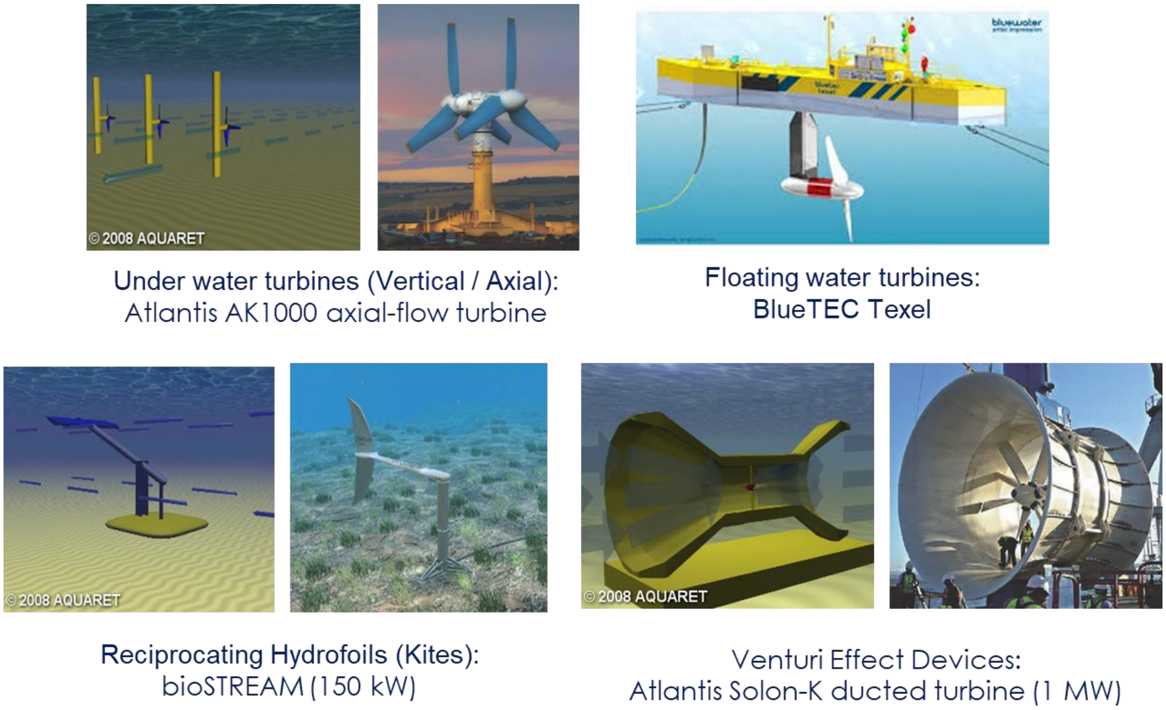
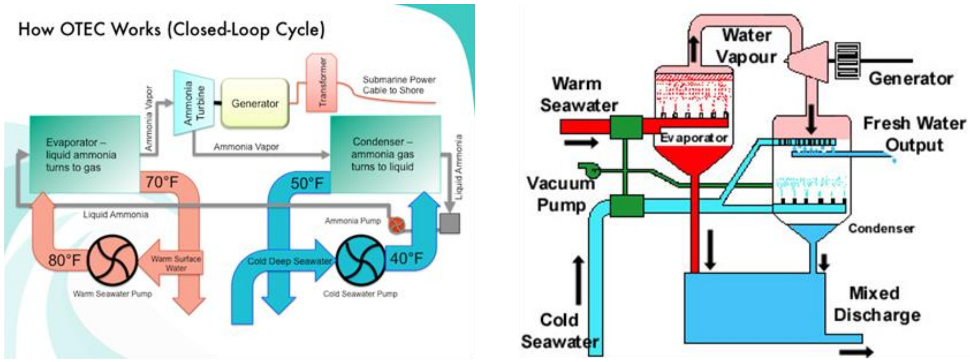


Fig 2: OCEC Devices

Ocean Thermal Energy Converters (OTEC)

The third type of energy is the thermal gradients within the oceans. 70% of solar radiation is absorbed by the ocean's surface. This heat and energy, as well as the difference in temperature between cool deep water and the warm surface water causes thermal gradients, which should ideally be around 20°C [4].

The different types of devices include open, closed, or hybrid loop structures to convert the thermal energy to electrical energy. The closed loop OTEC devices use warm seawater to heat a working fluid with a low boiling point, like ammonia [5]. The working fluids keep heating up and become a vapor which drives the turbines. The vapors are then condensed by cold water and cycled back. The open loop OTEC devices place warm seawater in a low-pressure container which causes the water to boil. The expanding steam then drives a low-pressure turbine which is attached to an electric generator. The environmental impacts of these devices are more pressing when compared to the other devices we have discussed. If toxic chemicals, like ammonia that are used in these devices were to be released into the ocean the impact could be detrimental to the environment, additionally intake of small organisms is the deadliest issue these devices face. Over a long period of these devices being run a slight increase to water temperature has been noticed, which can greatly affect successful egg hatching, and high mortality rates among coral and fish. Below are images of both a closed and open loop system, these images were created by Earth Science Australia [5].



Close-Loop OTEC Open-Loop OTEC

Fig 3: OTEC Devices

References:

1. Borthwick, Alistair GL. "Marine renewable energy seascape." Engineering 2, no. 1 (2016): 69-78
2. Dhanak, Manhar R., and Nikolaos I. Xiros, eds. Springer handbook of ocean engineering. Springer, 2016.
3. He, Ruoying, John Bane, Mike Muglia, Sara Haines, Caroline Lowcher, Yanlin Gong, and Patterson Taylor. "Gulf stream marine hydrokinetic energy resource characterization off Cape Hatteras, North Carolina USA." In OCEANS 2016-Shanghai, pp. 1-4. IEEE, 2016
4. Pelc, Robin, and Rod M. Fujita. "Renewable energy from the ocean." Marine Policy 26, no. 6 (2002): 471-479.
5. Straatman, Paul JT, and Wilfried GJHM Van Sark. "A new hybrid ocean thermal energy conversion–Offshore solar pond (OTEC–OSP) design: A cost optimization approach." Solar Energy 82, no. 6 (2008): 520-527