**OCEAN ENERGY: A PRIME SOURCE OF RENEWABLE ENERGY**

***V. S. Aitwar1, T. S. Annappaswamy1, M. T. Lakshmipathi1 and Ediga Arun Goud2***

1Department of Aquatic Environment Management, Karnataka Veterinary, Animal and Fisheries Sciences University, College of Fisheries, Mangaluru (Karnataka) - 575 002

2Department of Aquaculture, Dr. Balasaheb Sawant Konkan Krishi Vidhyapeeth, Dapoli, College of Fisheries, Shirgaon, Ratnagiri (Maharashtra)- 415 629

**Corresponding author mail-**[vaijuaitwar99@gmail.com](mailto:vaijuaitwar99@gmail.com)

**Abstract:** Since the beginning of time, Earth has been warning mankind to find safer alternatives to burning fossil fuels, which would emit harmful chemicals into the atmosphere, in order to produce power. The world's energy consumption is projected to increase dramatically in the coming decade. There will be a day when pure air is no longer available if current environmental negligence persists. We are constantly made aware of the enormous threat that conventional energy generation methods bring to the environment. Therefore, producing independent, clean energy is essential. The possibility of using wave energy as a clean energy source to create electricity exists. Despite the fact that this method is still extremely new and very competitive economically, the government and corporations are growing more interested in it. An essential quality of these waves is that they perform better than other renewable energy sources in terms of energy density.

**Keywords:** Wave power, Sustainable energy, Hydropower, Environmental effect.

**Introduction**

In terms of renewable energy sources, ocean waves are one of the potent energy transporters since they exhibit abundant energy reserves throughout the world. According to researchers, 2 Terawatt (TW) of electricity can be produced globally each year by ocean waves. According to theoretical calculations, the annual global wave energy is equivalent to 8 X 106 Terawatt hours (TWh), or around 100 times the plant's entire hydropower capacity (L. Rodrigues, 2008). Fossil fuels would release 2 million tons of carbon dioxide into the atmosphere, if this energy were to be produced. Fossil fuels account for around 80 % of the world's gross primary energy, and the International Energy Agency (IEA) projects that this percentage will remain constant through 2030 despite a 1.6% annual rise in global energy consumption (Salter, 1974).

In accordance with the Kyoto Protocol, wave power can aid in reducing air pollution (L. Rodrigues, 2008). Therefore, it is strongly advised to utilize this technology to the utmost. According to Kempener and Neumann (2014), the world contains 8 x 105 km of coastline that has wave power densities of more than 30 KW/m. Additionally, India has a potential of roughly 14 KW/m on average and 7500 kilometers of coastline. The energy produced might be between 3750 KW and 7500 KW even with just 10% usage. The first investigation into large-scale tidal waves began in 1924 on a number of islands employing powerhouses, ship locks, and electric stations (Karim *et al*., 2015). The methods of wave energy convention development have been ongoing for a long time. Different versions and sizes of created gadgets are available. This frequently results in expensive and time-consuming processes for complex and large devices. However, the cost of building, maintaining, setting up electric lines, building grain storage facilities, purchasing scales, equipment and managing projects is not based on the capacity of the wave energy converter (WEC). Therefore, larger, more energy-efficient gadgets are preferable over smaller ones.

Compared to wind energy, where we can boost energy output by increasing swept area, only a small number of WECs can improve their energy generation. This is because WECs have an optimal size from the beginning of their development, making it challenging to further develop products (Murray, 2013; Holmes, 2009; O'Sullivan *et al*., 2011; Kofoed and Frigaard, 2009; Bjerke *et al*., 2011). As far as we are aware, wave motion is very random. Therefore, a device that could use the erratic input and turn it into a consistent and stable output of electricity is required. An absorber, maybe a buoy, is used to absorb the wave forces. A linear permanent magnet generator can transform the absorbed energy immediately into electricity, or it can be done in stages utilizing hydraulic and mechanical transducers. These converters should be chosen with consideration for variables like life, durability, dependability, efficiency, etc. In order to possibly improve the effectiveness of the entire system, research on the WEC's generating system is still ongoing. A WEC's implementation site must be taken into account when designing it since certain needs and limitations must be met there.

**Energy Storage**

Using a proper storage mechanism, the process's energy must be kept in reserve. Depending on the purpose, these storage devices can be either long-term or short-term storage devices. Capacitors, super capacitors, and magnetic energy storage with superconductivity are a few examples of short-term storage devices. Electrolytic capacitors, film capacitors, and ceramic capacitors are a few of the methods that use capacitors for energy storage. Ceramic capacitors age poorly, despite having low equivalent resistance and high-frequency applications. Electrolyte capacitors, which have a comparatively high capacity compared to other capacitors (non- super capacitors), are frequently employed to store huge amounts of power.

In direct current (DC) link programs on power converters, electrolytes are widely employed to maintain bus voltage and control power fluctuations. Due to the high power variances that can be detected when producing wave energy, electrolytes can be employed as electrical energy devices for this purpose. Super Capacitors excel in quick discharge and have the capacity to instantly release all of their stored energy. It should be mentioned that super capacitors are capable of achieving capacitances in the kilo Farad range, but the costs are currently prohibitive. A coil formed of a superconducting material that can super conduct when its temperature is dropped below a certain temperature makes up superconducting magnetic energy storage, a sort of short-time storing device. Due to the current flowing through the coil, the energy is stored in the magnetic field. Energy can be held in reserve indefinitely, and the current won't start to weaken unless the temperature is kept below a certain level. Super conducting magnetic energy storage is more expensive than other energy storage devices and is still in the development stage. It contains significant components, such as a refrigerator, which will make it more susceptible to storms, as well as requiring more room and mechanical upkeep. These factors prevent small and medium-sized businesses from being categorized as ocean-dependent energy applications. A cylinder is utilized with a shaft that revolves in a sturdy housing for flywheel energy storage. The magnet levitates the cylinder to lessen frictional losses. The motor or generator is then connected to this system. In flywheel energy storage, the motor converts the electric energy so that the shaft's rotational speed can be accelerated. Batteries, hydrogen fuel storage, compressed air energy storage, and pumped hydroelectricity are a few examples of long-term storage devices.

A hydrogen-based fuel cell with an electrolyser made of hydrogen gas and kept in high-pressure tanks is the best method for storing extra energy. The fuel cell can then be sent out as needed. Further investigation has been conducted in recent years, and it has been determined that, with the technology currently in use, losses during storage and distribution are too great, and the optimism around the use of hydrogen appears to have decreased. Batteries are another type of long-term storage device that is utilized widely. Over the past few decades, batteries have gained a lot of popularity. At least two electrochemical cells make up an electrochemical battery. Two electrodes plus an electrolyte substance make up a cell. Electric current is produced during the oxidation-reduction process as a result of the chemical reaction occurring at the electrodes (Lerch, 2007). The goal of a compressed air energy storage system is to compress and store air using extra or cheap energy. Smaller plants may be able to store air in tanks, while larger plants typically store it in underground caves. The energy is released when there is a rise in demand or when prices are higher. In order to produce energy, the compressed air is delivered into a combustion turbine generator system.

**Environmental Impact**

Since wave energy has a positive impact on the environment, fewer hazardous gases must be released to obtain the same quantity of energy as the WEC. Fadaeenejad *et al*. (2014) claim that because offshore islands have a stable development and high-quality environment, using wave energy there has a favourable effect on tourism. The Institute of Electrical Power Engineering added that certain water sports can be performed in WEC's safe water. WECs will therefore have a significant and favourable effect on tourism and recreational activities. Effective agricultural zones won't vanish if wave transmitters are deployed in the sea. According to Bedard's assessment (Bedard, 2007; Boehlert *et al*., 2008), the installation, operation, maintenance, and discharge of these WECs will also have the additional benefit of being the most environmentally friendly technology. The environmental and financial impacts of wave energy, like those of other energy sources, must be considered when designing a new facility. Similar environmental concerns surround maritime wind power projects as they do wave energy. Designing to reduce the environmental impact of wave energy can benefit from learning from offshore oil, wind, and other ocean-based sectors. According to many studies (Boehlert *et al*., 2008; Frid *et al*., 2012; Inger *et al*., 2009; Linley, 2012; Simmonds *et al*., 2010), there are two types of environmental interactions between WECs and the maritime environment. A lot of research has been done on the potential effects on organisms, livestock, fish, habitat, and other things by Frid *et al*. (2012), Inger *et al*.(2009), Linley (2012), and Simmonds *et al*. (2010). To assess the negative effects of such wave farms, they noted the potential for habitat loss or weakening, including for marine vertebrates, marine mammals, and large fish. They also noted the risk of collision with deep noise emissions and electromagnetic fields, as well as the ability to operate as an artificial reef and rebuild the damaged ecosystems (Frid *et al*., 2012; Inger *et al*., 2009). The project's environmental impact varies with its size and is influenced by the area's ecosystems and geography. The life cycle of a transducer is largely determined by the system for monitoring the environment, which must be established through a successful EIA investigation (Solaun *et al*., 2003). In their study by Leeney *et al*. (2014) on various MRI sites (Wave and Tidal) in northern Europe, the authors classified the environmental assessment of the instruments at the various sites into eight environmental categories during the monitoring program, including marine mammals, Benthos, fish and fish habitat, sea birds, marine vertebrates, and other marine organisms at various locations and medium. Due to variations in currents and waves, coastal and near-coast plans may have an impact on coastal erosion. Wave amplitude, water flow, and pulse velocities can all be related to array size. When installing wave energy, this could harm the device. The ocean floor is held in place by many rods, concrete blocks, anchors, and chains. Depending on the sea beds, land preparation may involve washing the seafloor to install electrical cables. The rate of ocean degradation is influenced by the quantity of mounted devices and the anchoring techniques. When producing electricity, wave energy does not release greenhouse gases or other air pollutants, but construction, transportation, and other phases of its life cycle do cause emissions. Additionally, there are consequences when hydraulic rams, power trains, and other objects leak and spill oils, fluids, and bio-fouling paints into the ocean. Local fishing may be impacted, with the exception of the marine installations' region. In addition to limiting access to fishing grounds and to network, cable, and power lines, floating devices can be used to provide priority to certain species of seafood and habitats. Fishing activities, however, might be outside the installation's scope, just as they are in the seas. The flora and fauna of the seabed may be harmed by marine mammals that are vulnerable to floating structures or that operate as seagoing and migratory barriers. Anchor lines can be dangerous for some species, especially large whales because many offshore wind projects are fixed directly to the seabed. Another factor that may inspire mariners to employ structures as temporary rafts is liquid microwave technology. Due to its low profile and potential for complicated visual or radar identification, WEC may present a navigational risk for carriers. In the event that wave energy devices malfunction at night or disintegrate during a storm, this could have an influence on night time traffic. Additionally, increasing ship movement for maintenance and repairs may have an impact on water quality due to the possibility of oil spills. When used in severe environments, the noise from these devices may harm whales and dolphins that hunt using echoes. Operating noise levels for coastal and coast-line equipment contaminate nearby noise on the beach or shore. However, when it is working properly, no noise can be produced because the wind and waves ambient noise acts as a mask. Some swimming and water activities that use floating surfaces may be impacted by offshore waters and neighbouring infrastructure. These facilities offer protection for water sports like water skiing and diving, but surfing and sailing may suffer. Large installations may have a negative aesthetic impact on tourism, and some close devices may require water depths that are several hundred yards from the seashore. The movement of water and sand around the building can be altered by deployment on land and by installations on land, such as platforms, anchors, and cables. Changes in water velocity have an impact on coastal erosion, sediment, stones, and pebbles. Sludge deposition is accelerated by restricted or slow water flow. These environmental issues are nothing more than challenges, and people must create pure energy without harming the environment.

**Beneﬁts**

The following benefits of this technology are listed:

1. In contrast to other renewable energy sources, waves have a high power density.
2. In comparison to other kinds, wave energy is predictable and more regular.
3. Wave energy is the most environmentally friendly form of energy available and has no negative effects on the environment.
4. Waves can cover great distances with little energy loss.
5. Decreased reliance on nonrenewable energy sources.
6. Affordable method of electricity generation.

**Challenges**

The difficulties that could be encountered are:

1. It is challenging to absorb the forces that exist in waves since they are emitted in arbitrary directions.
2. Storms and the ocean's salinity must be withstood by the WEC.
3. A WEC has a high initial cost to construct, and regular maintenance is essential.
4. It is challenging to transform high-force, unpredictable and slow-moving waveaction into continuous output.
5. Electricity transmission from underwater devices to the onshore system has issues.
6. Large WECs might be considered disruptive to marine life.
7. These technologies are still expensive, thus additional development is required.

**Classiﬁcation of WECs**

Wave energy converters can be categorized in a variety of ways. Depending on location the devices are used as WEC.

1. **Shoreline Devices**

These devices are found on the coast. These devices have the benefit of being simple to set up and maintain. To improve power generation, they should be deployed at hotspots. The implementations of these devices are constrained by factors such as coastline geology, tidal range, and coastal landscape preservation.

1. **Nearshore Devices**

Within a kilometer of the beach, these devices are positioned in deep waters of up to 20 meters. Electrical cables are used to transmit the generated power to the shore's grid.

1. **Off Shore Devices**

These devices exist at a depth of more than 40 meters in deep water and are subject to stronger wave regimes. Based on the operating circumstances, the offshore devices are as follows,

1. Floating devices
2. Partially submerged devices
3. Fully submerged devices

**Transducers**

Electrical energy can be produced in a variety of ways. They use mechanical, electrical, and hydraulic transducers in various combinations.

1. **Mechanical Devices**

Gear configurations, Pelton turbines, wells turbines, etc. are some mechanical devices. These have the disadvantages of being big and having low efficiency. Additionally, flywheels are employed to supply a constant rotational output.

1. **Hydraulic Devices**

Since hydraulic devices are more dependable and long-lasting than others, they are used. Pumps, reservoirs, hoses, pipelines, piston configurations, incompressible fluid, etc. make up a typical hydraulic system. Also employed are hydraulic motors. The drawback of hydraulic devices is that they are expensive, big, and take up much more space.

1. **Electromagnetic Devices**

The advantage of using these devices is that they directly transform linear motion into electricity. The linear generator is a well-known electromagnetic apparatus. It has a converter with alternate-polarity permanent magnets attached to it. The iron core and windings of this translator are housed inside a fixed enclosure.

**Future prospectus**

The wave energy appreciation is given to competitors who can create wave conversion devices more effectively. The goal is to develop a system that would cut the cost of using ocean waves for power production in half. Although the creation of new wind turbines has made wind power successful thus far, and the solar industry is aware of what a solar panel looks like, the wave sector lacks similar development opportunities but is always working to convert ocean energy into usable electricity. When you take a look at the emerging wave industries, it makes sense. The development of solar and wind energy over the years has led to most wave energy companies being just a decade old, some being even younger. Around the world, just a few select wave energy companies have been able to exert control over the network, and essentially no one has advanced to the stage where they can provide the promised electricity. It's incredibly challenging to try to gather energy in the ocean since it's not simply salty water, oppression, or major blows. Unlike the wind or sunlight, the water simply does not radiate. The oceans are expanding; their surface, their waves, and their vast variety of patterns show their unexpected nature. One could conclude that the businesses' challenging competition will be entertaining and improve energy efficiency.

**References**

Bedard, R., 2007. Economic and social benefits from wave energy conversion marine technology. *Marine Technology Society Journal*, *41*(3), pp.44-50.

Bjerke, I., Hjetland, E., Tjensvoll, G. and Sjolte, J., 2011. Experiences from field testing with the bolt wave energy converter. In *Proceedings of the 9th European Wave and Tidal Energy Conference (EWTEC11), Southampton, UK* (Vol. 59).

Boehlert, G.W., McMurray, G.R. and Tortorici, C.E., 2008. Ecological effects of wave energy development in the Pacific Northwest: a scientific workshop. pp. 11-12.

Fadaeenejad, M., Shamsipour, R., Rokni, S.D. and Gomes, C., 2014. New approaches in harnessing wave energy: With special attention to small islands. *Renewable and Sustainable Energy Reviews*, *29*, pp.345-354.

Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I. and Kenchington, E., 2012. The environmental interactions of tidal and wave energy generation devices. *Environmental Impact Assessment Review*, *32*(1), pp.133-139.

Holmes, B., 2009. *Tank testing of wave energy conversion systems: marine renewable energy guides*. European Marine Energy Centre. pp. 1-88.

Inger, R., Attrill, M.J., Bearhop, S., Broderick, A.C., James Grecian, W., Hodgson, D.J., Mills, C., Sheehan, E., Votier, S.C., Witt, M.J. and Godley, B.J., 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. *Journal of applied ecology*, *46*(6), pp.1145-1153.

Karim, A.Z., Rahman, M.M. and Karmoker, S., 2015, September. Electricity generation by using amplitude of Ocean wave. In *2015 3rd International Conference on Green Energy and Technology (ICGET)* pp. 1-7.

Kempener, R. and Newmann, F., 2014. Tidal Energy Technology Brief, International Renewable Energy Agency (IRENA). *Abu Dhabi*. pp. 1-36.

Kofoed, J.P. and Frigaard, P., 2009. Development of wave energy devices: The Danish case/the dragon of nissum bredning. *Journal of Ocean Technology*, *4*(4), pp.83-96.

Leeney, R.H., Greaves, D., Conley, D. and O'Hagan, A.M., 2014. Environmental Impact Assessments for wave energy developments–Learning from existing activities and informing future research priorities. *Ocean & Coastal Management*, *99*, pp.14-22.

Lerch, E., 2007, September. Storage of fluctuating wind energy. In *2007 European Conference on Power Electronics and Applications* (pp. 1-8). IEEE.

Linley, A., 2012. Environmental interactions with marine renewable energy. *Mar. Sci., 22e25*.

Murray, D.B., 2013. *Energy storage systems for wave energy converters and microgrids* (Doctoral dissertation, University College Cork).pp. 1-267.

O’Sullivan, D.L. and Lewis, A.W., 2011. Generator selection and comparative performance in offshore oscillating water column ocean wave energy converters. *IEEE transactions on energy conversion*, *26*(2), pp.603-614.

Rodrigues, L., 2008. Wave power conversion systems for electrical energy production. *RE&PQJ*, *1*(6).

Salter, S.H., 1974. Wave power. *Nature*, *249*(5459), pp.720-724.

Simmonds, M.P., Brown, V.C., Eisfeld, S. and Lott, R., 2010. Marine Renewable Energy Developments: benefits versus concerns. *Chippenham, UK: Paper SC/62/E8 presented to the IWC Scientific Committee (unpublished)*.

Solaun, O., Borja, Á. and Bald, J., 2003. *Protocolo para la realización de los estudios de impacto ambiental en el medio marino*. AZTI. pp. 1-79.