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Research Paper

Wave Energy - the renewable energy of the future

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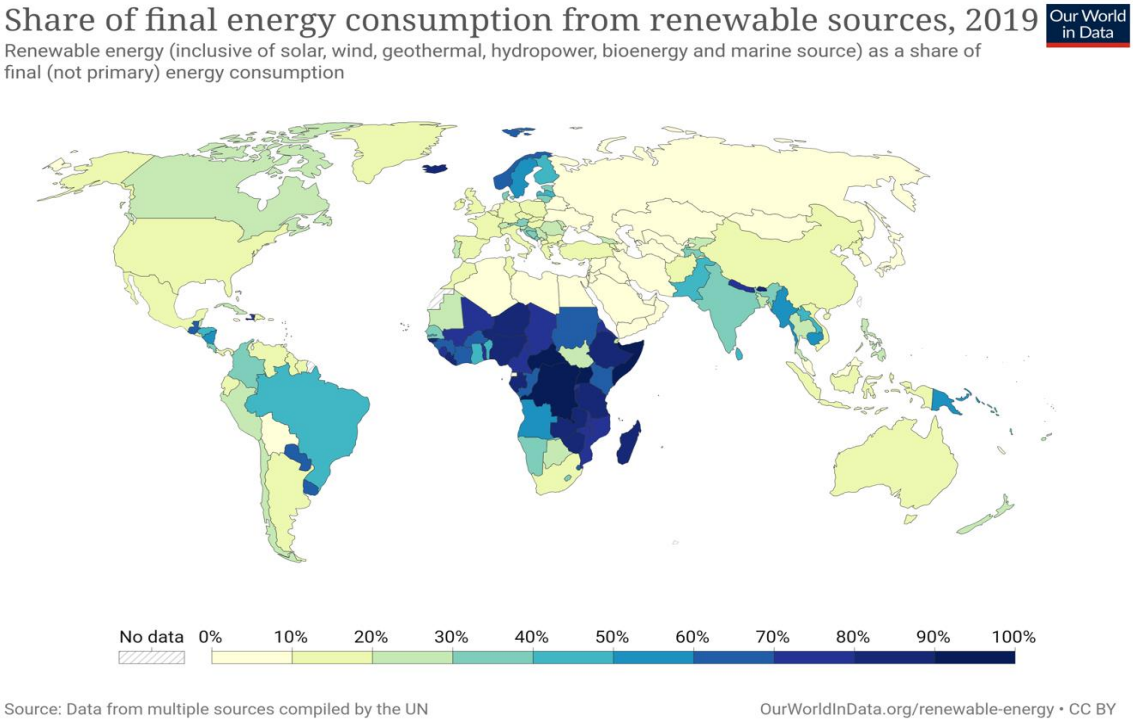
Abstract:
Ever since the Industrial revolution, demand for energy has been growing in the world. As countries around the globe, entered an era of cut-throat competition in the race to becoming more developed than the others taking rising GNP levels as the main indicator of development, production of all goods and services saw a galloping increase. Resources known to human beings witnessed massive and mindless exploitation. All these activities were fuelled by large scale use of power. Here too, the world mercilessly exploited the known sources of power particularly, oil, gas, thermal and nuclear power along with hydropower, wind and solar energy. The growing pressure on non-renewable sources of power and the imminent energy crisis has forced the world to think about alternative sources of power generation to sustain them and their lifestyles. Solar and wind energies were the first to be used and have become quite popular among people, but they are clearly not enough. It was quite natural for humankind to turn their attention to the most abundant resource around them-oceans and seas. Harnessing wave-power is now being seriously discussed as a renewable source of energy. A clean green source of energy, wave energy is a topic of research and experiments, for if humans were to harness this source of power, all its energy woes may come to an end. This paper discusses the ways in which wave energy may be harnessed, its advantages and disadvantages and the possibility of its general use in the near future.
Keywords- *Wave, harness, technology, power, clean*

I. Introduction

As the world is staring at an imminent global energy crisis and fossil fuel reserves are getting depleted rapidly, the compulsion for the use of renewable energy on a massive scale is growing among all nations of the world. Not only are fossil fuel reserves of the earth limited their rates of withdrawal are constantly rising, leading to countries facing an inevitable energy crunch; the large scale use of carbon based fuels have led to rising levels of pollution and growing greenhouse gas emissions causing an almost irreversible damage to the earth. Rising global temperature and climate change has begun showing its adverse impact in various ways, forcing policy makers and international institutions urging countries to take immediate actions to reduce carbon emissions and achieve 'carbon neutrality' as soon as 2030 so that massive catastrophe can be averted. International bodies like the UN have been addressing such issues for some time now. The UN had presented 17 Sustainable Development Goals (SDGs), which included SDG 7 whose mission statement is 'ensuring access to affordable, reliable, sustainable and modern energy to all'. It defined 5 targets and 6 indicators for SDG7. Target 7.2 is' increase global percentage of renewable energy' and it defined this target as 'By 2030 increase substantially the share of renewable energy in the global energy mix.' As of 2019, the share of renewable energy use in the world was as follows-



Thus, there is still a lot of scope for and an urgent need to develop the necessary environment for the shift to renewable energy sources. Of the renewable sources of energy-solar, wind, bioenergy, hydro energy, geothermal and marine energy- solar and wind energy as well as hydropower have been quite popular and have been adopted across the globe. In fact, some countries are performing very well in their efforts to achieve the target of 'net-zero' by using these forms of energy on a large scale. Now the world has started showing growing interest in the ultimate source of renewable energy-Wave Energy. The potential of this source has been accepted by all and efforts are being made to find the best possible way to tap into it. A brief understanding of the concept and methods to tap it are given below.

Wave Energy-

As a source of renewable energy with the highest potential, interest in wave energy is growing considerably. Although this interest is by no means new, attempts to use this energy source can be traced back to a couple of centuries. In the United Kingdom, wave technologies were first reportedly developed during the 1970s. Between 1855 to 1973, some 340 patents were filed in UK alone, for devices to extract energy from ocean waves. Thus, wave energy has always piqued the interest of scientists. In 1989, the World Energy Council said that the potential of wave energy in the world was approximately 2 Terawatts if harnessed fully. This could meet the electricity requirements of the entire world. Together with other renewable resources, wave energy can play an important part in meeting the energy requirements of the world as well as achieving the carbon emission targets.

A wave may be described as a disturbance that travels from one location to another through a medium. When wind blows on the surface of the oceans by effect of both gravity as well as friction, ocean waves are generated. Wave energy is the transmission of energy by ocean- surface waves and the harnessing of that energy to generate power for say, electricity. Since about 71% of the earths' surface is covered oceans, ocean waves offer a tremendous source of renewable energy. The world has an extensive coastline, and therefore a huge potential for tapping into this power source.

Wave power has some distinct advantages over solar and wind power, like:

1) Wave power intensity is higher to both solar and wind power. Just below the sea surface the average wave power level is 10 times denser than wind energy transport 20m above the water and 30-50 times denser than average solar energy intensity.

Average energy intensity-

Solar energy: 100-200 W/m²

Wind energy: 400-600 W/m²

Wave energy: 4-6 kW/m² (just below the sea surface; but less in deeper water)

2) The availability of wave power is much higher at around 90%, whereas wind and solar power availability ranges between 20-30%.
3) Wave power is more predictable than solar and wind power and can therefore be managed better.
4) Wave energy technology contributes little to carbon emission, in the operational stage.
5) Wave power can be integrated with solar, wind and other renewable forms of energy to reduce variability of supply and meet the energy requirements of the regions.

Considering its great potential as a storehouse of energy, governments and private corporate entities are engaged in research and experiments to device ways to use it on a large- scale commercial level to power nations, or at least vast areas thereof.

Harnessing wave energy

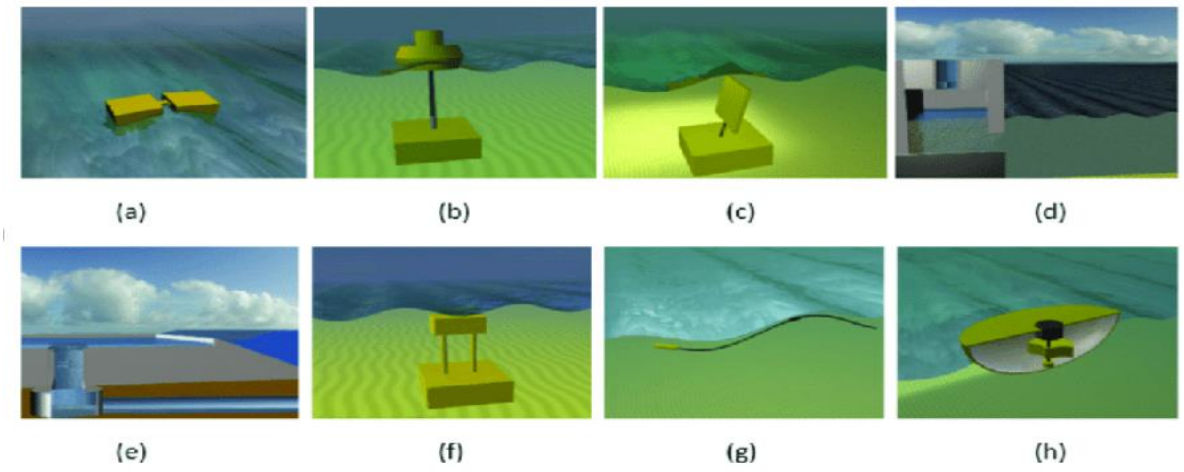
The power stored in waves depends on various factors like the height of the wave, the time taken for a wavelength to pass a fixed position, acceleration due to gravity, water density and length of the wavefront. Machines or devices which are used to exploit wave power and convert it to electrical power are called Wave Energy Convertors (WECs). Wave energy is converted to mechanical energy using a motor or a turbine and then this rotates a generator to produce electrical energy.

On the basis of their location, WECs can be categorized as-

(i) On shore: coastal areas where water depth is 10-15 meters and the maximum wave length is 7-8 meters,
(ii) Near shore: shallow water areas where water depth is 15-25 meters and maximum wave height is 15.6 meters,
(iii) Off shore: deep water areas where there is no limitation of water depth and wave height. Water depth is generally more than 50 meters and wave heights may sometimes be more than 30 meters.

On the basis of design and working principles, WECs may be categorized as–

Oscillating Water Column (OWC) devices	Overtopping devices
Point Absorbers	Terminators
Attenuators	Submerged Pressure Differentia
Oscillating Wave Surge Device	Rotating Mass Devices,
Bulge wave device	Sea Carpet, etc.



Types of WECs: a attenuator, b point absorber, c oscillating wave surge converter, d oscillating water column, e overtopping device, f submerged pressure differential, g bulge wave, h rotating mass [8].

The number of devices mentioned above proves that the world is seriously attempting to harness wave energy.

A few 'wave farms' have been set up to tap into this resource, 'Wave farm' is a collection of machines as listed above designed to generate electricity through wave power. The first wave farm began in 2008 in Portugal. But this technology is still in its infancy. There is no fully commercial scale wave farm in operation yet. There are various types of challenges concerning WECs that need to be resolved, such as – (i) It is technically difficult to generate electricity from low frequency oscillating motion and large force. It requires extremely reliable structures and power take-off systems, which need very high capital expenditure, (ii) Operational costs are also very high, since WECs operate in offshore areas requiring high installation, operation and maintenance costs, (iii) WEC concepts and designs are varied and quite disparate simply because wave power resources vary depending on waves- height, direction, frequency, power level, etc.-; locations, weather conditions and seasons.

This has prevented commercialization on a global scale. (iv) Oceans and seas can get extremely rough, therefore technical challenges also include designing and building WECs that can withstand the harsh weather conditions, corrosive effects of saltwater and extreme wave force. The possibility of structural failure and device loss is quite high.

Development of Wave energy in the world

Many countries around the world are developing wave energy technologies, particularly those nations which have vast stretches of coastline and where wave intensities are high. The northern and southern temperate zones are best suited for this purpose. Places with the most potential for generating wave energy include the northern coast of UK, the western seaboard of Europe, the Pacific coastline of North and South America, South Africa, Australia, New Zealand and Japan. Many countries are currently developing wave energy technologies like Australia, China, Denmark, Italy, Korea, Portugal, Spain, Japan, the U.K. and the U.S.

UK, saw its first reported wave technology being developed way back in the 1970s. According to the World Economic Forum, there are many ongoing wave energy projects in Scotland, England and Wales. Wave Energy Scotland has invested more than $52m (£40m) in almost 100 projects since its establishment in 2014, to tap into this resource.

Australia approved a national Offshore Electricity Infrastructure bill in 2021 to build a framework to create the necessary infrastructure for offshore energy projects. In 2022, a wave energy converter successfully generated energy from ocean waves to power homes.

The European Union is also taking steps to harness this energy. It is expected to use its numerous islands for this purpose as part of the Offshore Renewable Energy Strategy. It is the leading investor in ocean energy research, development and innovation. It has set a target of deploying 100 megawatts of wave and tidal energy by 2050. It had around 17 ongoing projects by 2021.

Spain is taking leaps in this effort. The famous Spanish town of Mutriku has a wave energy plant officially commissioned by the Spanish utility firm Ente Vasco de la Energia (EVE). In July 2011. This plant currently generates about 296kW of output.

According to the U.S. Energy Information Administration, waves around its coasts could meet 66% of the country's' electricity needs. The U.S. had only one active wave energy project of more than 1 megawatt capacity. It was launched in 2020, at the U.S. Navy Wave Energy Test Site near Kaneohe, Hawaii. The Department of Energy awarded $25 million in 2022 to eight such projects which will make up the first round of open water testing at an Oregon State University facility called PacWave, off the Oregon coast.

Wave energy company CorPower says it has built the largest wave energy test rig at its base in Stockholm in Sweden.

Japan is working on various ways of harnessing energy from sea including tidal and wave power and on ocean thermal energy conversion (OTEC).

Recently India too has shown interest in harnessing this source along its coastline in Tamil Nadu and Maharashtra.

Wave energy and India

India has a vast coastline of approximately 7517 kms, and therefore has potential to utilize wave power as a source of energy, particularly on its western coast. As interest in this renewable energy source has grown in the world, India too has started exploring its potential. According to the IIT-Madras CRISIL Report, 2014, India has a potential wave power of 40 GW and its potential tidal wave power is 12 GW. Researchers of IIT-Madras have developed and deployed a system to generate electricity from seawaves. This has been named Sindhuja-I and has been deployed about six kilometers off the coast of Tuticorin in Tamil Nadu where the sea has a depth of about 20meters. It can currently produce 100 watts of energy. It will be scaled up to produce 1 megawatt of energy over another two years. But researchers admit that any attempt to produce enough electricity to power up even one city like Madras is going to be too expensive.

Ocean Wave Energy Generation: The wave energy device developed by IIT Madras researchers. (Image credit: IIT Madras)

Similarly, the oscillating water column device technology has been tried at Vizhijam, along the Kerala coast near Thiruvananthapuram by the National Institute of Ocean Technology, Chennai. A 65Kw ocean thermal energy conversion plant in Lakshadweep has been planned to tap into the potential of ocean waves in the Indian ocean.

The Maharashtra Energy Development Agency (MEDA) had sponsored a study by the Centre for Earth Science Studies, Thiruvananthapuram, to assess the wave energy potential along the coast of Maharashtra. The study revealed that Maharashtra coast had an annual wave potential of 4-8kW per meter of the length of the wave crest. During monsoons the potential rose to 12-20Kw/m. Efforts are being made to set up demonstration power development projects.

The prohibitive costs of implementing such projects is a big limiting factor in a country like ours.

Wave energy- a mixed blessing?

Although wave power is going to become significant in the future, as of now there are both advantages and disadvantages of launching these projects.

Benefits-

1) The biggest advantage of wave energy is no doubt its quality of being a clean, green energy source. Unlike fossil fuels, it does not produce harmful GHGs and has a relatively low environmental impact. Also, unlike fossil fuel sites, it does not require the use of land, which is becoming a scarce resource in many parts of the world.

2) The production of wave energy is almost pollution free, compared to fossil fuel-based energy production.

3) Unlike the stock of fossil fuels which are finite, waves are an unlimited and sustainable energy source that are constantly replenished.

4) This source of energy lends itself to better planning and management as wave patterns are quite predictable making it a consistent source of energy.

5) Since most of the earths' surface is covered by oceans, and ocean waves are present along coastlines all over the globe, therefore, it presents the most opportunity to derive energy to meet the growing demand in the world. With a worldwide potential of 2 terawatts, wave energy is set make major contributions to the energy-mix in the future.

6) Since ocean waves are driven by gravitational pull of the moon and by winds, which follow a regular pattern, therefore wave energy can be predicted and forecasted.

7) A major advantage of wave energy is its high energy density. The energy density of waves along the shoreline is estimated to be around 30-40kW/m of wave, and further out into the ocean, waves can generate almost 100kW/m of power. This makes it a very cost-effective source of energy.

8) Once the initial infrastructure and technology has been put in place (though this is extremely expensive), the operating costs of these projects is low. As technology improves, the costs of setting up of the projects may decline.

9) The generation of wave energy does not require any fuel. Unlike fossil fuel-based projects, wave energy projects do not require fuel use for extraction or operation, making it cost effective as well as a clean source of energy.

10) Wave energy production sights do not spoil the aesthetics of their surroundings. Wave energy devices are placed mostly or wholly submerged under the water, and are usually located far out into the ocean or sea, it does not in any way diminish the natural beauty of the place or beach.

11) Wave energy can lead to electricity price stability. This is so because unlike fossil fuels, there is little or no supply variation of the source of energy.
12) Wave energy farms or projects can be tailor made to meet electricity requirements of regions of varying sizes.
13) Wave energy technology development and production and distribution processes can lead to the generation of a lot of employment opportunities.
14) There are numerous miscellaneous benefits of harnessing energy from waves. Some the major ones are- (i) Wave power plants can be used to power desalination plants and convert salt water to freshwater, the supply of which is scarce in several countries and regions, this can be especially useful for remote islands where wave energy plants may be used to provide electricity supply and freshwater supply (ii) Wave plants can be used for the production of hydrogen which can be further used as a clean fuel; (iii) Wave power may be used to fuel shipping vessels, reducing their dependence on fossil fuels; (iv) Wave energy may be used to run pumps for irrigation for agriculture, etc.
As we can see, the benefits of wave power are many, but it has its own challenges too.
Challenges-
1) As of now the establishment costs of wave energy projects are prohibitive. This makes it very difficult to raise adequate funds for them. The comparative costs of other sources particularly fossil fuels seem far less. But there is hope that as technology advances, future costs may decline.
2) Several technical difficulties are foreseen in the processes of production and distribution of this energy. Since wave intensities and direction keep changing, it may be difficult to continue to generate a constant amount of energy. Also, integrating wave energy into the electricity grid will be very difficult due to several factors including variations of weather.
3) Since wave energy plants are offshore, equipment is exposed to severe weather conditions and to corrosive salt water. The intensity and height of waves are influenced by wind patterns. In times of storms and typhoons, the possibilities of damage are very high, requiring regular upkeep and maintenance, further raising costs. Wind directions and water level fluctuations may reduce the efficiency of the WECs. Similarly, large underwater disturbances such as earthquakes and volcanic eruptions can damage machinery.
4) One major drawback of the development of wave energy projects is their potential to harm marine life. The underwater use of equipment such as turbines, cables etc. will disturb the habitats of various forms of marine life and harm them. The electromagnetic fields and underwater noise may actually alter the behavioral patterns of marine creature like fish and other marine forms as also that of seabirds. There is also the fear of entanglement of sea and ocean creatures in the equipment and cables and collision with them, leading to large scale deaths of marine animals. Mooring systems can affect benthic organisms adversely. There will be potential risks to roosting and nesting sites. These impacts are a matter of grave concern.
5) Noise pollution is another way wave energy equipment can harm marine life. Though individual WECs may produce negligible disturbance, but care must be taken when setting up wave parks or farms. For collectively, the noise produced may cause a problem for dolphins, fish and other animals that rely on sound to find food and communicate.
6) Wave energy systems can be successful only in coastal regions with required wave intensities. This limits its use over a wide area especially in remote inland areas.
7) Since waves are not constant, therefore electricity supply from them will be intermittent.
8) Another significant difficulty is related to transmission of this energy from the place of production- which is offshore -to the place of consumption. Challenges encountered may be in the form of distance, regularity, quality of supply, grid integration and costs
9) The sites of these projects may potentially reduce the access of fishing vessels and ships to these areas. They may also displace commercial and recreational fishermen and affect livelihoods.
10) Progress of wave energy production and use has been extremely slow due to the factors mentioned above. Only a few large-scale projects are operating presently. More research is needed along with funds to expedite the work in this area.
Wave power capturing and distributing technology is still in an experimental stage, and the high costs and risks involved have slowed down its development process.

II. Conclusion

With the increasing demand and need in the world for reducing carbon and greenhouse emissions, ending the use of coal, keeping global warming from precipitating while at the same time meeting the needs of the growing population including its energy requirements, it is necessary to explore all forms of renewable energy sources. The use of solar and wind energy has no doubt a lot of potential and is currently being used on a large scale as an alternative to thermal energy, but in order to meet the ever growing demand for energy for various reasons, it is imperative to explore and tap other forms of renewable sources of energy. Wave energy is

well poised to supplement and complement these popular forms of renewable energy technologies to provide the world a diverse energy-mix to use for sustainable development. But given the slow rate of development of this technology, it still has a long way to go before it can become commercially viable. The IEA says in its Ocean Power tracking report that 'ocean power is not currently on track to play its part in helping the world reach carbon neutrality by 2050. To achieve this goal ocean power generation needs to grow at an average of 33% a year between 2020-2030'. This said, there is no doubt that the most abundant potential energy source-oceans – will in the near future become the most reliable source of clean green renewable source of energy too.

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