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# Energy from the Ocean and Scope of its Utilization in India

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**Abstract**

Energy is a basic input to the national economy, both agricultural and industrial, apart from being an instrument for improving the quality of life. Provision of adequate quantities and kind of energy is and will continue to be a challenge to the Governments and the Institutions in the country engaged in various specific tasks relating to energy supply and transport. The primary commercial energy inputs to the Indian economy are from coal, oils, and hydroelectricity and to a limited extent nuclear energy.

Concerns about carbon dioxide and global warming and the security and long term availability of fossil fuel supplies has led to greatly renewed interest in all forms of renewable energy and so the time may have come for ocean renewable energy as well. All ocean energy technologies, except tidal barrages, are conceptual, undergoing R&D, or are in the pre-commercial prototype and demonstration stage. The globally distributed resources and relatively high energy density associated with most ocean energy sources provide ocean energy with the potential to make an important contribution to energy supply in the coming decades, if technical challenges can be overcome and costs thereby reduced. Accordingly, a range of initiatives are being employed to promote and accelerate the development and deployment of ocean energy technologies. In India's perspective, there is tremendous scope for the energy from the ocean as India has a long coastline of about 7500 km and about 336 islands in Bay of Bengal and Arabian Sea. This paper presents a basic review of the technology of each of the major sources including wave conversion, fixed and floating wind turbines, free flowing current turbines and ocean thermal energy, and discusses the magnitudes of each of the resources in India, and the particular technical issues each technology is facing.

**Keywords**: Ocean, energy, turbines, waves, thermal, tidal.

## 1. Introduction

The ocean can produce two types of energy: **thermal energy** from the sun's heat, and **mechanical energy** from the tides and waves. Oceans cover more than 70% of Earth's surface, making them the world's largest solar collectors. The sun's heat warms the surface water a lot more than the deep ocean water, and this temperature difference creates thermal energy. Just a small portion of the heat trapped in the ocean could power the world. Ocean mechanical energy is quite different from ocean thermal energy. Even though the sun affects all ocean activity, tides are driven primarily by the gravitational pull of the moon, and waves are driven primarily by the winds. As a result, tides and waves are intermittent sources of energy, while ocean thermal energy is fairly constant. The ocean also provides, naturally, various mechanisms to collect, concentrate and transform that energy into forms that might be more useful. The oceans are a heat engine that transforms solar energy into the kinetic energy of wind, waves and current. The average solar power flux onto the surface of the ocean at $15^o$ North latitude is about $0.2kW/m^2$, but this is typically converted to trade winds of about 20 knots, which have a power flux of 0.6 $kW/m^2$. Here though, the energy is over a vertical area, perpendicular to the wind. This wind energy subsequently is concentrated into a wave energy flux of 8 $kW/m^2$ [1].These forms of high quality energy are very useful, but often intermittent, require more or less large collectors, and may have environmental issues. On the other hand, wind and wave tend to be stronger in winter, when direct solar energy is lower, so they may provide seasonal leveling in association with land based direct solar systems. Ocean Thermal Energy Conversion eliminates the heat collector, and provides steady power, but has practical issues and tends to be in distant locations.

## 2. Wave Energy

Many wave energy technologies representing a range of operating principles have been conceived, and in many cases demonstrated, to convert energy from waves into a usable form of energy. Major variables include the method of wave interaction with respective motions (heaving, surging, pitching) as well as water depth (deep, intermediate, shallow) and distance from shore (shoreline, near shore, offshore). Efficient operation of floating devices requires large motions, which can be achieved by resonance or by latching, that is, with hold/release of moving parts until potential energy has accumulated. A generic scheme for characterizing ocean wave energy generation devices consists of primary, secondary and tertiary conversion stages [2]. The primary interface subsystem represents fluid-mechanical processes and feeds mechanical power to the next stage. The secondary subsystem can incorporate direct drive or include short-term storage, so that power processing can be facilitated before the electrical machine is operated. The tertiary conversion utilizes electromechanical and electrical processes.

Recent reviews have identified more than 50 wave energy devices at various stages of development [3,4&5]. The dimensional scale constraints of wave devices have not been fully investigated in practice. The dimension of wave devices in the direction of wave propagation is generally limited to lengths below the scale of the dominant wavelengths that characterize the wave power density spectrum at a particular site. Utility-scale electricity generation from wave energy will require device arrays, rather than larger devices and, as with wind turbine generators, devices are likely to be chosen for specific site conditions. Several methods have been proposed to classify wave energy systems. The classification system proposed by Falcao (2009) is based mainly upon the principle of operation.

The energy in a deep water wave of length $\lambda$ and amplitude $\mathbf{a}$ is:

$\mathbf{E} = \frac{1}{2} \rho \, \mathbf{g} \, \lambda \, \mathbf{a}^2$ per unit breadth of crest.

For a random sea of significant height $\mathbf{H_s}$ and zero crossing period $\mathbf{T_z}$, the energy is:

$\mathbf{E} = \frac{1}{2} \mathbf{H_s}^2 \mathbf{T_z}$ kW per meter of crest.

Half of this energy appears as vertical motion, and half as horizontal motion. At least in deep enough water, the wave particle motion reduces exponentially with depth. The main importance of this is that a surface device can exploit the difference in particle motion between it and a deeply submerged object to extract power rather than having to be rigidly connected to the bottom of the ocean.

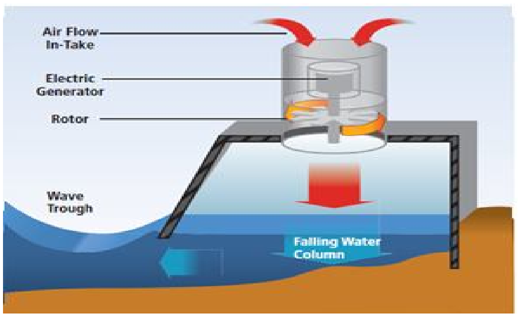


**Fig. 1**: Wave Energy convertor
(Falling water column)

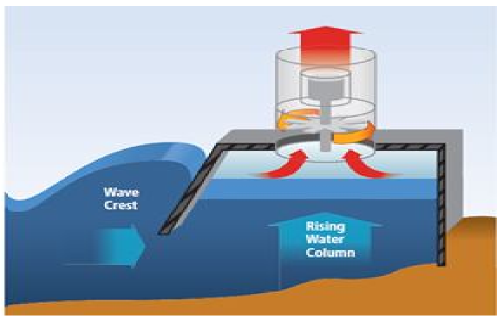


**Fig. 2**: Wave Energy convertor
(Rising water column)

The potential of wave energy would be much greater with an average power on the order of 100 KW per meter of wavefront (100 MW per kilometer) available for extraction. This average value varies widely between winter and monsoon seasons, with the range from calm to stormy waves being on the order of 20 to around 200 KW per meter. In practice, generating of the order of 10 megawatts from a kilometer of wavefront might be feasible. Assuming that 5 % of coastal wavefront were intercepted, the total wave power practically available could not exceed the order of 3750 MW. This limitation might be overcome with floating offshore wave generators, which would in effect increase the length of intercepted wavefront.

India has experimented with a 150-kW wave energy system at Thiruvananthapuram (Kerala) in 1983. The system average output was 25 kW during December–March and 75 kW during April– November in 1983 [6] and Vizhingam wave energy pilot project in Kerala. The wave energy pilot project at Vizhingam, an undertaking of the National Institute of Ocean Technology (NIOT) at IIT-Madras, aims to gather technical data on the oscillating-water column (OWC) concept. The average wave potential along the Indian coast is around 5–10 kW/m. India has a coastline of approximately 7500 km. Even a 10% utilization would mean a resource of 3750– 7500MW [7]. However though prototypes have been built and some operating experience obtained, this is not yet a commercially available technology. A wave energy plant installed by NIOT currently yields 6–7 kW to produce 7000–8000 litres of desalinated water per day [8]. The obstacles to wave power production are mainly technical: a design which will withstand the battering of waves, cost of special materials and techniques for construction and maintenance of equipment and infrastructure in corrosive environment as well as the problems related to efficiency and source variability.


**Fig. 3**: Low temperature desalination plant.

## 3. Tidal Energy

Tidal energy could only meet a small portion of India's energy needs due to limited potential sites. The potential sites are the Gulf of Kutch (estimated potential of 1200 MW), Gulf of Cambay (7000 MW) and the Durgaduani Creek in the Sundarbans Delta (100 MW) [9]. The first Indian plant of 3.65MW capacity is being installed in the

Durgaduani creek in Sunderbans (tidal range 3 m). Most recently, India joined the tidal power wave with the approval of a commercial-scale tidal power plant in the Gulf of Kutch. The 50 Mw plant will be developed by the London-based company Atlantis Resources Corporation in partnership with Gujarat Power Corporation, and construction will start this year. The plant will be the first of its kind in Asia.

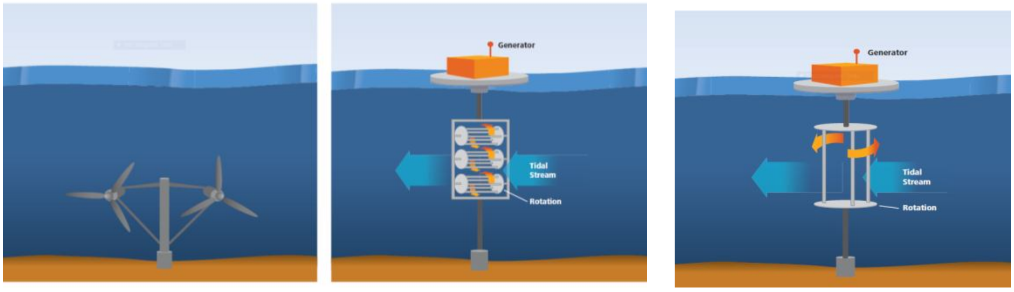


**Fig. 4**: Tidal current Energy converters: Twine turbine horizontal axis device (left), cross-flow device (middle) and vertical axis device (right). Design by NREL.

## 4. Ocean Thermal Energy

Ocean Thermal Energy Conversion (OTEC) extracts solar energy through a heat engine operating across the temperature difference between warm surface water and cold deep water. In the tropics, surface waters are above 80$^{o}$F, but at ocean depths of about 1,000 meters, water temperatures are just above freezing everywhere in the ocean. This provides a 45 to 50 $^{o}$F temperature differential that can be used to extract energy from the surface waters[10]. The most optimistic expectations for OTEC predict a cost on the order of ten times greater than for conventional fossil sources. If OTEC can ever be made cost effective, India is ideally situated to use it, with its large length of coastline adjacent to the deep off-shore water of the Indian ocean.

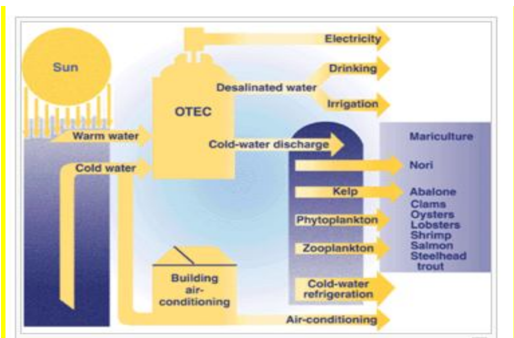


**Fig. 5**: OTEC Technology and applications.

**Fig. 6**: Rankine Cycle based OTEC power plant.

The India OTEC program started in 1980 to install a 20 MW plant off the Tami Nadu coast and in 1982, an OTEC cell was formed in National Institute of Ocean Technology (NIOT). A preliminary design was also completed in 1984 for a 1 MW closed Rankine cycle floating plant with ammonia as working fluid. In 1997, Government of India proposed to establish a 1 MW gross OTEC plant. To develop this project, India researchers have been exploring the participation of international expertise for a joint research and development. Based on the temperature and bathymetric profiles, the optimization of the closed loop system was done with the help of Saga University in 1998.

## 5. Conclusion

Ocean energy represents a significant opportunity to address the growing need for energy and the problems associated with traditional fossil fuels. There is significant room for innovation and for more routine engineering development in energy harvesting and conversion devices and in all of the infrastructure required to support the construction, installation, maintenance and decommissioning of these systems.The excitement about alternative energy suggests that ocean energy oriented projects might be a similar opportunity, though perhaps on a smaller scale. The technology may take decade to mature but ocean energy is an option worth pursuing.

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