HARNESSING OCEAN ENERGY IN INDIA

Introduction

As the Ministry of New and Renewable Energy (MNRE) continues to expand India's renewable energy (RE) portfolio, ocean energy offers a sustainable solution to meet India's growing energy demands while reducing carbon emissions. This article outlines the current state of ocean energy technologies, their potential in India, and the current initiatives undertaken by MNRE to further the development of ocean energy in India.

Technologies in Ocean Energy

Tidal Energy

Tidal energy harnesses the gravitational forces of the moon and the sun, along with Earth's rotation, to generate electricity. Most conventional tidal range schemes utilize bulb turbines, which function similarly to hydropower turbines used in run-of-river plants. Tidal range technology offers three primary methods for power generation:

- **Ebb Tide Generation:** Reservoir fills at high tide; power is generated when water is released during low tide.
- **Flood Tide Generation:** Reservoir is emptied at low tide; power is generated when rising tide flows in through turbines.
- Two-Way Generation: Power is produced during both incoming and outgoing tides using specialized reversible turbines.

Wave Energy

Wave energy can be harnessed through various technologies that convert the energy of ocean waves into electricity. Each technology has its advantages, and the choice depends on factors like wave conditions, location (onshore, nearshore, or offshore), and energy requirements. The primary types include the ones listed below.

- **Attenuators:** These are long, floating structures aligned parallel to the direction of waves. These devices flex as waves pass, and the motion is converted into electricity using hydraulic systems.
- **Point Absorbers:** These are floating devices that move up and down with the waves. The relative motion is used to drive hydraulic pumps or generators. Point absorbers are compact and can be deployed in arrays offshore.
- **Submerged Pressure Differential Devices:** Installed on the seabed, these devices use the pressure difference caused by passing waves to generate energy.
- **Oscillating Wave Surge Converters:** These devices harness the horizontal movement of waves to drive pistons or hydraulic systems for electricity generation. They are usually mounted on the seabed nearshore.
- **Oscillating Water Columns (OWC):** These devices use the movement of waves to compress air in a chamber. The compressed air drives a turbine to generate electricity. OWCs are often installed onshore or nearshore.

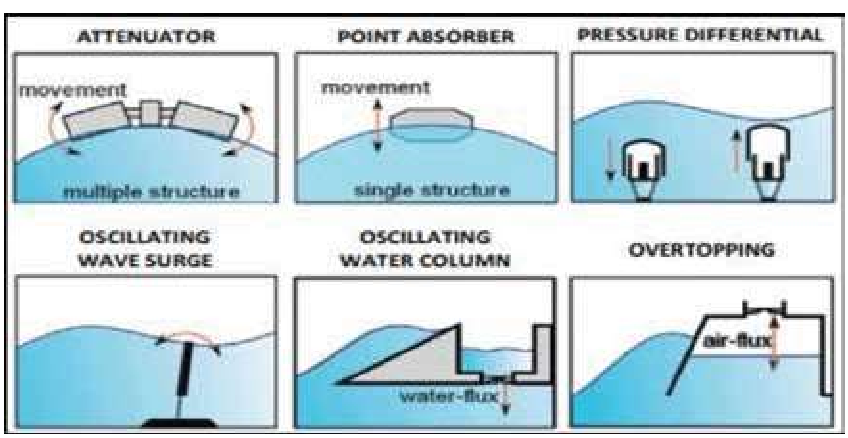

Figure 1. Kinds of wave energy systems (WES)

Source: Memon, S., Lawal, O. M., Tariq, S. A., & Khalid, B. (2020). Wave energy in the UK: Current scope, challenges and prognostications. International Journal of Solar Thermal Vacuum Engineering, 2(1), 59-78.

- **Overtopping Devices:** These structures capture water from waves in a reservoir. The water is then released back to the ocean through turbines, generating electricity.

Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) is a renewable energy technology that harnesses the temperature difference between the warm surface water of the ocean and the cold deep water to generate electricity. There are three main types of OTEC.

- **Open-cycle:** Warmer surface water is introduced through a valve in a low-pressure compartment and flash evaporated. The vapour drives a generator and is condensed by the cold seawater pumped up from below. The condensed water can be collected and because it is fresh water, used for various purposes (Figure 2a). Additionally, the cold seawater pumped up from below, after being used to facilitate condensation, can be introduced in an air-conditioning system. As such, systems can produce power, fresh water and air-conditioning.
- **Closed-cycle:** Surface water, with higher temperatures, is used to provide heat to a working fluid with a low boiling temperature, hence providing higher vapour pressure (Figure 2b). Most commonly ammonia is used as a working fluid, although propylene and refrigerants have also been studied. The vapour drives a generator that produces electricity; the working fluid vapour is then condensed by the cold water from the deep ocean and pumped back in a closed system.
- **Hybrid systems:** Hybrid systems combine both the open and closed cycles where the steam generated by flash evaporation is then used as heat to drive a closed cycle.

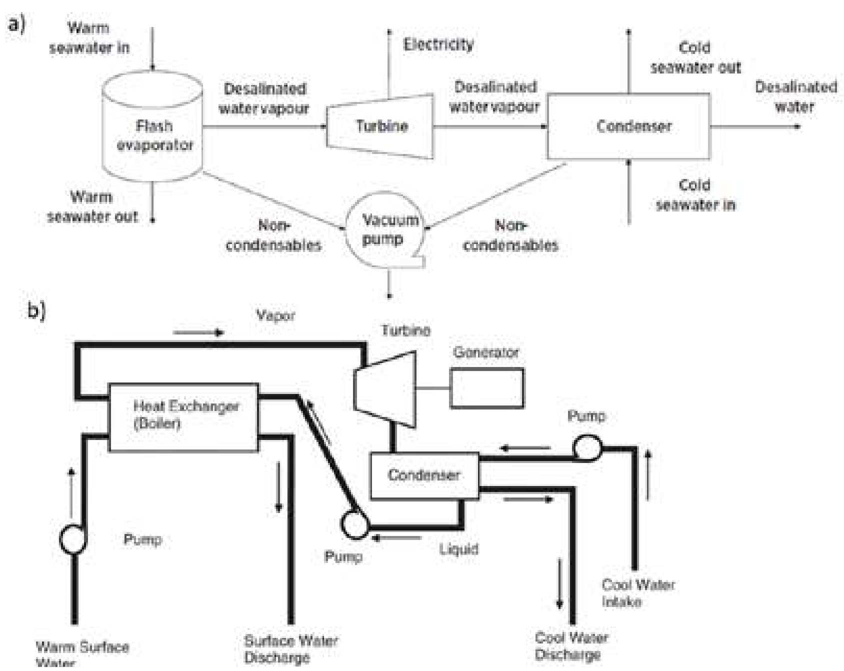

Figure 2. (a) Open cycle OTEC, (b) Closed cycle OTEC

Source (Fig. 2b): *Ocean thermal energy conversion technology brief, June 2014.*

Potential and Opportunities in India

Resource Assessment

The global installed capacity of ocean energy remains small compared to other renewables but is growing. The International Renewable Energy Agency (IRENA) estimates around 550 MW of tidal energy and 16 MW of wave energy projects globally.

India has significant potential for harnessing tidal energy due to its long coastline, particularly in regions like the Gulf of Khambhat, Gulf of Kutch, and the Sundarbans in West Bengal. As per the report from IREDA, India's theoretical potential for tidal power is estimated at 12,455 MW, with the highest concentrations in Gujarat and West Bengal. The Gulf of Khambhat alone accounts for 7000 MW, followed by 1200 MW in the Gulf of Kutch and approximately 100 MW in the Sundarbans region.

The country's wave power potential is estimated at 41.3 GW, according to CRISIL, making it a promising addition to India's renewable energy portfolio. India's southern coasts, particularly Tamil Nadu, Kerala, and Karnataka, are identified as suitable regions for harnessing wave energy.

Ocean Thermal Energy Conversion (OTEC) in India holds significant potential due to the country's tropical coastline, where the temperature difference between warm surface water and cold deep water is ideal for this technology. The National Institute of Ocean Technology (NIOT) has been at the forefront of OTEC development in India. A notable initiative includes a 1 MW demonstration plant planned near Kavaratti in the Lakshadweep Islands to harness this renewable energy source.

Technology	Total Potential	Location	Project/Regional Potential
Tidal Energy	12,455 MW	Gulf of Khambhat	7000 MW
		Gulf of Kutch	1200 MW
		Sundarbans	100 MW
Wave Energy	41.3 GW	Southern Coast (Tamil Nadu, Kerala, Karnataka)	41.3 GW
OTEC	1 MW	Lakshadweep Islands (Kavaratti)	1 MW (Demonstration Plant)

Geographical Advantages

- **Extensive Coastline**
- 7,500 km of coastline providing diverse marine energy opportunities
- Strategic location in the Indian Ocean with consistent wave patterns
- Numerous islands and coastal regions suitable for various ocean energy technologies
- **Favourable Ocean Conditions**
- Strong tidal ranges in specific regions (Gulf of Khambhat, Gulf of Kutch)
- Consistent wave activity along the southern coastline
- Suitable temperature gradients for OTEC in tropical waters

Technical and Infrastructure Support

- **Research and Development**
- Established institutions like NIOT focusing on ocean energy technologies
- Existing marine research infrastructure and expertise
- Growing experience in offshore engineering and marine operations
- **Supporting Infrastructure**
- Well-developed coastal infrastructure including ports
- Existing power grid connections near coastal areas
- Maritime facilities supporting offshore operations

Policy and Economic Framework

- **Regulatory Support**
- Ocean energy classified as renewable energy by Ministry of New and Renewable Energy
- Policy framework supporting renewable energy development
- Government initiatives promoting clean energy technologies
- **Economic Potential**
- Large coastal population creating local demand
- Potential for integrated applications (power generation, desalination)
- Opportunities for industrial and economic development in coastal regions

Environmental and Social Benefits

- Environmental Impact
- Contribution to renewable energy goals
- Reduced carbon emissions
- Sustainable coastal development
- **Social Development**
- Employment generation in coastal communities
- Energy security for remote coastal and inland areas
- Development of skilled workforce in marine technology sector

Strategic Advantages

India offers unique strategic advantages for harnessing ocean energy. The following advantages position India favourably for developing ocean energy as a significant component of its renewable energy portfolio.

MNRE's Current Initiatives

MNRE's strategic initiatives in RE development align with India's Nationally Determined Contributions (NDCs) under the Paris Agreement, supporting both emissions reduction and clean energy transition goals. Through targeted research investments, technology demonstrations, and collaborative partnerships, the Ministry is working to establish RE as a reliable component of India's sustainable energy future.

The Ministry is implementing the Renewable Energy Research and Technology Development (RE-RTD) Programme, which aims at scaling up the R&D effort for promoting indigenous technology development for widespread deployment of new and renewable energy in an efficient and cost-effective manner across the country. MNRE has included ocean energy development under the RE-RTD Programme.

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