

# Oceanic perspectives on renewable energy conversion: A comprehensive review in the Indian context

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## ABSTRACT

The demand for energy exploitation by natural means has currently become popular, which poses several issues related to global warming. The extraction of the abundance of energy from the marine environment that can cope with the ever-increasing demand is exciting and challenging for its sustainable aspects. The prominent forms of energy available in the sea are due to waves, tides, wind, and thermal gradients. Several existing research has focused on these challenging tasks for renewable energy conversion. This paper discusses the modern, innovative, renewable hybrid marine energy converters that are proposed and attempted globally, and also illustrates the relevance of these technologies in the Indian context. Further, the projects that have been explored on the Indian coast and the future potential that could be explored are also discussed.

**Keywords:** Energy, Global warming, Sustainability, Renewable energy, Hybrid marine energy converters

## INTRODUCTION

It is widely accepted that there is an increase in the demand for electricity consumption globally. EIA (2013) has predicted that an increase in global consumption will reach about 40% by 2020 to 2040. This is due to technological advancement and population. Many developed and developing countries focus on excess power generation to meet every individual's demand for the present and future.

India is the world's second-largest coal producer to the tune of 762 million tons, with its consumption to the extent of about 967 million tons as per Ahmed et al. (2023). India's annual electricity use crossed 1300 billion kWh in 2022, a nearly 70% jump over 2012. Industrial and domestic fields hold the maximum total energy consumption for the year 2012-2022, which is likely to increase exponentially over the next decade. India is the third-largest country in the world in terms of electricity generation, as per the findings of the Energy Information Administration (EIA) in 2023. The thermal power plants supply over 65% of the electricity consumed, followed by hydroelectric power plants (22%), nuclear power plants (3%), and other energy sources (10%) like solar and biomass. Thermal power plants are, therefore, the primary source. However, this emits an excess amount of CO<sub>2</sub>, which is a significant factor in global warming. The contribution of renewable sources for power generation is very low in India. This paper focused on electricity energy conversion using marine renewable energy. Among several other sources of renewable energy, marine energy is a clean and renewable source of energy. Since the sea waves always exist, wave power is more consistent and available for electricity generation compared to other renewable energy sources like wind, tide, and solar. They can be a good source of energy generation for off-grid coastal areas and islands.

According to IRENA (International Renewable Energy Agency), India has the potential to generate more than 4500

MW of electricity by 2022 through renewable hydropower. Moreover, they have brought out a comparison of renewable energy jobs by different technologies for India (Figure 1), showing that the employment and technology for marine renewable energy are still under development.

The availability of energy from the marine environment is huge, and its extraction for energy conversion worldwide is still in progress. Several developed countries have demonstrated successful techniques and employment opportunities for converting energy from the ocean to electricity. Hence, introducing this technology in India not only produces clean energy, but also enhances employment and economic growth. China is expected to contribute significantly to the global increase in renewable electricity, followed by the United States, the European Union, and India. Norway, known for hydroelectric power, consumed hydro energy equivalent to 45% of its total energy supply in 2021.

Gielen et al. (2019) reported that, according to the International Renewable Energy Agency (IRENA), renewable energy's contribution to the global energy mix must increase sixfold in order to reduce the rise in average world temperatures below 2.0 °C over pre-industrial levels. The goal by 2040 is for renewable energy to match coal and natural gas electricity generation globally, aiming for zero CO<sub>2</sub> emissions. Some jurisdictions, including Denmark, Germany, South Australia, and certain US states, have achieved high integration of variable renewables. Examples include Denmark, where wind power met 42% of electricity demand in 2015, and Portugal and Uruguay, with significant contributions from wind power as well.

Interconnectors play a crucial role in balancing electricity systems by facilitating the import and export of renewable energy. Innovative hybrid systems have emerged between countries and regions to optimize the use of renewable resources. Considering the geographical location of the Indian