Ocean Energy Potential in Sri Lanka

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Abstract: Sri Lanka is an island country in the Indian Ocean with roughly 1,340 km-long coastlines. The nation has considerable potential for ocean energy production due to its geographic location. By analyzing the many forms of ocean energy sources accessible, such as wave, tidal, and ocean current energy, this article seeks to offer an overview of the ocean energy potential in Sri Lanka. According to the report, Sri Lanka has enormous potential for developing ocean energy, notably in wave and tidal energy. High upfront expenditures and the absence of supporting laws and regulatory frameworks, however, provide serious obstacles to the sector's expansion. Nevertheless, the country's commitment to renewable energy and its efforts to establish a conducive policy environment is expected to facilitate ocean energy development in the coming years.

Index Terms: ocean energy, potential, Sri Lanka, wave energy, tidal energy, renewable energy, ocean thermal energy, challenges, opportunities, sustainability.

1. Introduction

Energy is a crucial element for human beings. Yet, a significant portion of the world's electricity is still derived from fossil fuels, which comprise a vast majority of global electricity generation [1]. Due to its potential for enhancing supply security, promoting economic growth, and mitigating CO_2 emissions, there has been growing interest in promoting the development of ocean energy technology and establishing ocean energy markets on a global scale [2]. In 2008, the first generation of commercial ocean energy devices was launched, with SeaGen and Pelamis being the first units installed in the UK and Portugal, respectively [3].

Sri Lanka, an island country in the Indian Ocean, boasts a coastline spanning 1,340 km and territorial waters covering roughly 21,500 km^2 [4]. The contiguous zone extends up to 24 nautical miles from the outer edge of the territorial zone, while the country's exclusive economic zone (EEZ) spans approximately 510,000 km^2 [4] Given this information, Sri Lanka possesses tremendous potential for ocean energy, which can be harnessed using five different technologies: tidal rise and fall (barrages), tidal/ocean currents, waves, temperature gradients, and salinity gradients [1].

2. Tidal ENERGIES

Tidal energy is one of the growing renewable energy techniques; globally, plenty of technologies have been developed to extract energy from the tidal. As an island nation, Sri Lanka has much potential for tidal energy. The tidal occurs due to the centrifugal force and gravitation force of the moon and sun on the earth, and it appears twice daily [5]. It can be said as the rise and fall of the sea level [6]. Due to the distance between the moon and Earth, the gravitational force exerted by the moon is 2.125 times larger than the gravitational force exerted by the sun on Earth [5]. Spring and neap tides are created due to the position of the earth, moon, and sun. Spring tides occur when the moon, sun, and earth are aligned, and Neap tides occur when the moon, earth, and sun are 90 degrees [6]. Fig. 1 illustrates the phenomenon of spring tides, and Fig. 2 illustrates the phenomenon of neap tides. The three main types of tides are diurnal, semi-diurnal, and mixed tides, which vary from place to location on the planet [5].

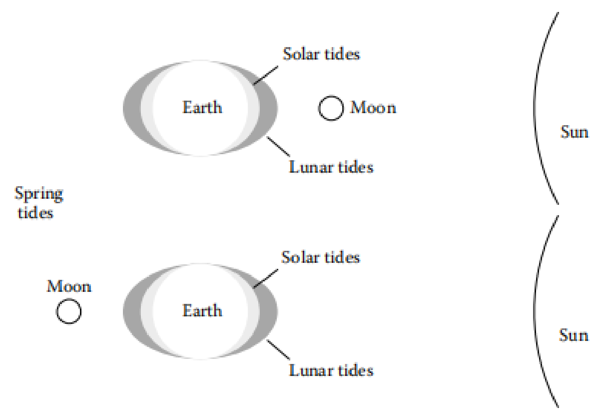

Fig. 1. Spring tides [7]

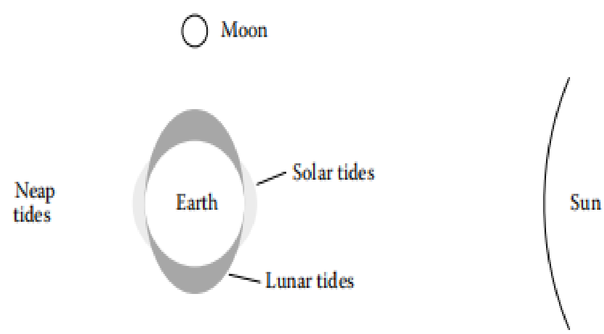

Fig. 2 Neap tides [7]

2.1 TIDAL ENERGY EXTRACTION.

Different technologies are available to extract energy from tides, but two primary methods are mainly used for energy extraction [8].

1. The potential energy of the seawater, which is captured due to the range of tides, is used to generate electricity [8-9].
2. The kinetic energy of the tidal stream, which is the energy of flowing water in tidal currents, is used to generate electricity [8-9].

Devices used to generate electricity from tides can be mainly categorized into two types [6].

Tidal Barrage

A tidal barrage is a system that uses tidal range for energy extraction from tides. A tidal range system takes advantage of the difference between high and low tides. A tidal barrage is a dam-like structure similar to a hydropower plant built across the estuary [9]. The tidal range of the estuary must be more than 5m [10].

The sluice gates allow seawater to flow into the basin during high tidal and hold the water by closing sluice gates until low tidal. During low tidal, sluice gates are opened and release the water back into the ocean. The turbines at the sluice gates generate power when water flows into or out of the basin. Flood generation, ebb generation, ebb and flood generation, two basin schemes, and pumping are the other methods that use the same principle for energy extraction [9].Tidal lagoons are similar to tidal barrages, except they are built to cover a large coastal area [5].

Calculations

The total energy of the tidal barrage varies due to the potential energy of the water which is stored in the tidal barrage. The potential energy can be calculated by using equation (1) [11].

$$E = \frac{1}{2} A\rho g h^2 \tag{1}$$

Where,

A = The horizontal area of the tidal barrage basing.

ρ = The density of water. (1025kg/m^2)

g = The acceleration due to the Earth's gravity. (9.81m/s^2)

h = The vertical tidal range.

Tidal Stream

In this method, energy is extracted with the help of the kinetic energy of the tidal current. Tidal stream technology is similar to wind power because both technologies use flowing fluid to generate electricity [8]. Mainly Horizontal axis and Vertical axis turbines are used for energy extraction [10].

Calculations

The power output of most turbines varies due to the efficiency “Ɛ” of the turbine. The energy of the tidal stream can be calculated using equation (2) [11].

$$P = \frac{\varepsilon \rho A V^3}{2} \tag{2}$$

Where,

V = The velocity of the flow.

Ɛ = The turbine efficiency.

ρ = The density of water. (1025kg/m^2)

A = The swept area of the turbine. (m^2)

P = The power generated. (watts)

2.2 TIDAL ENERGY POTENTIAL IN SRI LANKA.

Sri Lanka is an island nation located in the Indian Ocean. Sri Lanka has a 1,340 km long coastline, and territorial waters cover an area of about 21,500 km^2 [4]. The contiguous zone extends up to 24 nautical miles from the outer edge of the territorial zone. The exclusive economic zone (EEZ) of Sri Lanka covers an area of about 510,000 km^2 [4]. As an island nation, Sri Lanka has much potential for tidal energy. Sri Lanka is a country that experiences semi-diurnal tides [12]. Two low and two high tides diurnal occur every 12 hours and 25 minutes. Along the Sri Lankan coastline, a total of 85 tidal inlets are identified. In the tidal inlet, sea waters meet ocean waters. The tidal range of the Sri Lankan coastline varies between 0.45m to 0.65m. During the spring tidal, the total tidal energy potential of all 85 tidal inlets is 52512967.08 MW [13]. Fig. 3 shows Tidal inlets along the Sri Lankan coast.

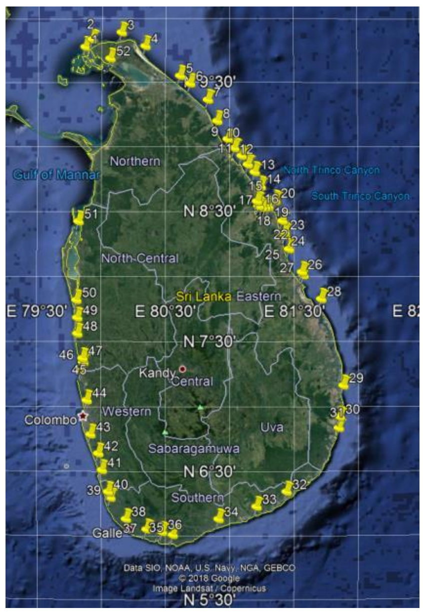

Fig. 3. Tidal inlets along the Sri Lankan coast [13]

3. OCEAN THERMAL ENERGY

Ocean thermal energy is a renewable energy source that results from the temperature contrast between warm water at the ocean's surface and cold water in the ocean's depths. Despite its potential as a clean energy alternative, it has yet to be widely adopted due to financial and technological obstacles [14] The International Energy Agency (IEA) has calculated that ocean thermal energy has a total global potential of about 10,000 terawatt-hours (TWh) per year, more than double the world's current yearly electricity usage. Nevertheless, only a tiny portion of this potential can be cost-effectively harnessed using existing technology.

Even though ocean thermal energy has much promise, there are still specific difficulties. Although the technology is still in its infancy, OTEC systems demand a significant infrastructure investment [15]. Additionally, there are worries regarding potential disruptions to ocean currents and marine life because the environmental impact of OTEC systems on marine ecosystems is not yet fully known.

A country with an island in the Indian Ocean, Sri Lanka boasts a 1,300-kilometer-long coastline. Due to its location in the tropics, the nation has tremendous potential for ocean thermal energy conversion (OTEC).

The potential for OTEC in Sri Lanka is thought to be over 4,000 megawatts (MW), which is comparable to around 40% of the nation's current power demand, according to research done by the National Institute of

Oceanography and Marine Geology in Sri Lanka [16]. According to the report, Sri Lanka's western and southern beaches offer the best prospects for OTEC growth.

Despite these initiatives, OTEC development in Sri Lanka is still in its infancy and faces several obstacles. These include the high OTEC system initial investment costs and the technical and environmental problems associated with the maritime deployment of these systems.

4. Ocean wave energy

The world is facing a critical juncture where it must address the ever-increasing global energy demand while also considering the severe environmental implications associated with non-green energy sources. In light of this, exploring renewable energy sources has become crucial. Among these sources, ocean wave energy has emerged as a promising option due to its high energy density and minimal environmental impact. Sri Lanka, located in the northern Indian Ocean between 5°-10°N latitude and 79°-82°E longitude, is surrounded by a narrow continental shelf that drops sharply to a depth of over 1000m beyond its edge. The country's coastline is diverse, consisting of long sandy beaches, rocky headlands, semi-enclosed bays and lagoons, river inlets, and coastal wetlands. Long-distance swell waves characterize the ocean wave climate in the southwest to the southeast coastline, modulated seasonally by tropical monsoon systems operating in the Indian Ocean. That monsoon wind pattern is shown in Fig. 4 and 5 [18].

Sri Lanka's south and west coasts from May to September during the southwest monsoon season. Meanwhile, the north and east coasts experience energetic seas from October to December during the northeast monsoon season. Because of this consistent wave activity and the energetic seas generated by local wind waves, Sri Lanka is an excellent place for harvesting wave energy [19].

Fig. 4. Northeast monsoon wind pattern [19]

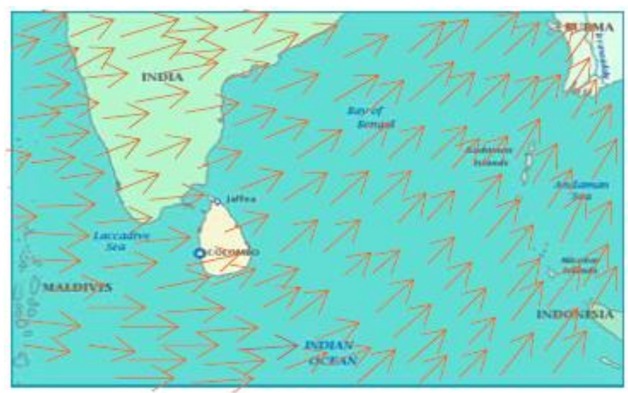

Fig. 5. Southwest monsoon wind pattern [19]

Additionally, a new identifier has been introduced to specify areas with the higher stability of wave power, with the southwestern to south-eastern coastal areas of Sri Lanka showing high energy potential and stability in both the short and long term [17].

The potential of ocean wave energy as a green energy source has attracted increasing attention globally, owing to its high energy density and low environmental impact. A recent study identified the southwestern to southeastern coastal areas of Sri Lanka as having a high energy potential and stability for both short and long-term wave power generation. A feasibility study on the south coast of Sri Lanka using numerically simulated waves from the WAVEWATCHIII model also suggests that installing small-scale wave energy devices can be feasible. With the ever-increasing global energy demand and the environmental implications associated with energy production using non-green sources, ocean wave energy presents an attractive option that can provide clean and sustainable energy without the need for land use [17].

The west to the southeast coast of Sri Lanka experiences the highest average wave power due to the combination of distant swell waves from the southern Indian Ocean and local monsoonal sea waves. According to the computational wave model results, the average power along the continental shelf margin ranged from 12-16 kW/m. In contrast, the north and east coasts of Sri Lanka had significantly lower wave power, with an average of 2-4 kW/m. As consistent swell waves are considered ideal for wave energy harvesting, many studies focused on analyzing and discussing the coast stretching from the northwest to the southeast. [19]
"In this study, data from a 25-year simulation period was used to identify ten offshore locations along the southeast to northwest coastal offshore areas named M1 to M10. Fig. 6 shows how to locate these locations and Table 1 explains each location's annual wave energy behavior."

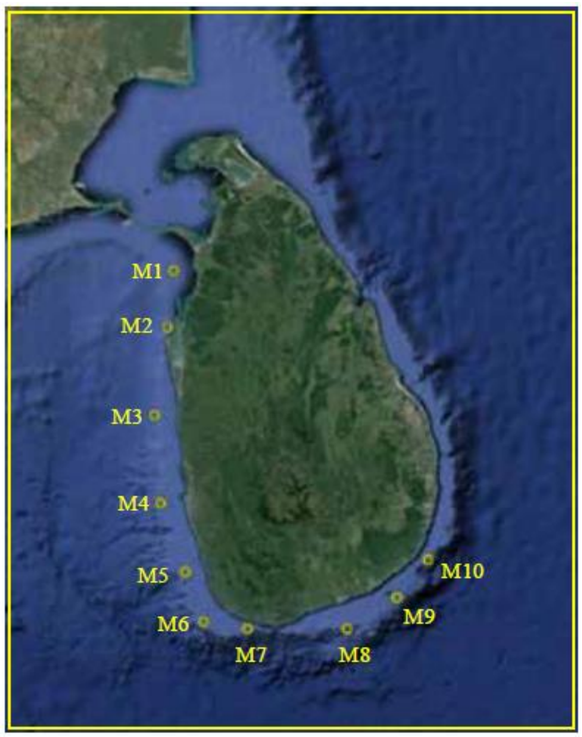

Fig. 6. Locations (M1 to M10) used for a Detailed Analysis of Wave Power around the North-West to South-East Coast of Sri Lanka [19]

Table 1. Geo-Coordinates and the Water Depth of the Locations M1 to M10 Around the Coastline of Sri Lanka from North-West to South-East. [19]

Location (Figure 4)	**Geo-coordinates**	**Water depth (m)**	**Annual Average Wave Power for 25 years(KW/m)**
M1	8°45'N 79°45'E	18	2.5
M2	8°18'N 79°42'E	30	2.5
M3	7°36'N 79°36'E	100	6
M4	6°54'N 79°39'E	45	11
M5	6°21'N 79°51'E	63	13.5
M6	5°57'N 80°00'E	73	18
M7	5°54'N 80°21'E	58	14.5
M8	5°54'N 81°09'E	60	17.5
M9	6°09'N 81°33'E	58	13.5
M10	6°27'N 81°48'E	48	10.5

5. CONCLUSION

Finally, Sri Lanka has considerable potential for generating ocean energy, mainly through wave and tidal energy. By using this data, the most suitable place for setting up an ocean wave energy plant can be easily identified. According to the data, there is a high potential for this in the South Sea. The reason is that both M8 and M6 locations are located on the south coast, with wave energy higher than 15KW/m. In addition, the depth of the beach at those locations is normal, so it is also suitable for setting up ocean wave energy power plants. The country's geographic location offers the best conditions for the utilization of maritime energy sources, which have the potential to increase the country's mix of renewable energy sources significantly. However, several obstacles must be overcome for the industry to expand, including expensive start-up costs, a lack of encouraging policies, and weak regulatory frameworks. Despite these obstacles, Sri Lanka has demonstrated a commitment to renewable energy. Actions are being taken to create an environment where ocean energy may develop in a supportive political framework. Ocean energy development in Sri Lanka seems promising in the years to come, given its enormous potential and commitment to a sustainable energy future. With the right policies and incentives in place, ocean energy could provide a sustainable and reliable source of electricity for Sri Lanka, contributing to the country's energy security and sustainability goals.

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