RESEARCH ARTICLE

Global Ocean Energy Technologies and Potential Applicability in Sri Lanka

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Abstract: The ocean represents one of the largest untapped sources of renewable energy, offering diverse opportunities through waves, tidal, ocean thermal, and salinity gradient systems. Globally, these technologies have demonstrated significant potential, with case studies highlighting their technical feasibility and contributions to sustainable energy portfolios. For Sri Lanka, an island nation with strong grid connectivity but high reliance on fossil fuels, marine energy offers a promising pathway to enhance energy security, diversify supply, and mitigate environmental impacts. This review synthesizes international advancements in ocean energy technologies and critically evaluates their applicability in the Sri Lankan context. Findings indicate that wave energy along the island's west to south-east coastlines is particularly promising, with consistent swollen waves enabling large- and medium-scale projects. Ocean Thermal Energy Conversion (OTEC) also shows strong feasibility, supported by year-round thermal gradients, with an estimated capacity exceeding 4,000 MW. Conversely, Sri Lanka's low tidal ranges limit the viability of conventional tidal barrages, although micro-tidal and in-stream systems may offer localized solutions. Salinity gradient energy, especially through Pressure Retarded Osmosis (PRO), presents additional opportunities, with selected river basins capable of generating up to 251 MW under optimized flow scenarios. Collectively, these resources could significantly contribute to Sri Lanka's renewable energy mix if supported by targeted research, site-specific assessments, and infrastructure integration. The study emphasizes the need for technological adaptation, investment, and policy support to harness Sri Lanka's marine energy potential, positioning it as viable complement to existing renewable strategies.

Keywords: Ocean Energy, Renewable Energy, Wave Energy, OTEC, Tidal Energy

INTRODUCTION

Renewable energy is vital in addressing global climate change due to its infinite supply and lower environmental impact compared to finite fossil fuels, which emit harmful greenhouse gases [1]. Fossil fuel combustion drives global warming, sea level rise, and extreme weather events [1], [2]. As the global energy transition shifts toward lower-carbon systems, renewable energy is expected to dominate future primary energy growth. Hydropower remains the most widely adopted source, but wind and solar have expanded rapidly over the last decade. The combined share of renewables including wind, solar, geothermal, and biomass rose from 5% in 2018 to over 40% in rapid transition scenarios and nearly 60% in net-zero scenarios by 2050, reducing the contribution of hydrocarbons from 85% to roughly 40% and 20%, respectively [3]. Transitioning to renewables can stabilize energy prices, create employment, enhance energy security, and minimize health risks from air pollution [1], [2].

1.1 Ocean-Based Renewables for Energy Security

Oceans provide abundant alternatives to fossil fuels, offering energy in thermal, kinetic, chemical, and biological forms [3]. Estimates of global potential highlight significant contributions from various sources: tidal energy could produce around 800 TWh, wave energy about 2,000 TWh, osmotic energy between 8,000 and 80,000 TWh, and thermal difference energy from 10,000 to 87,600 TWh [4].

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Other forecasts indicate a potential of 4–18 million tons of oil equivalent [5], 32 TW of electricity globally [6], and deployment of ocean power converters generating 337 GW, yielding 885 TWh per year [7]. Incorporating ocean energy into the global renewable mix can substantially enhance energy security, reduce reliance on fossil fuels, and support climate change mitigation efforts.

1.2 Sri Lanka's Energy Profile and Renewable Distribution

Sri Lanka has achieved an impressive 98% grid connectivity, reflecting strong access to electricity by South Asian standards. The country's total installed power generation capacity is approximately 4,050 MW, comprising 900 MW from coal, 1,335 MW from oil-fired thermal plants, 1,375 MW from hydro power, and 442 MW from non-conventional renewable sources, including wind, mini hydro, biomass, and solar [8]. The annual electricity demand is about 10,500 GWh, with 38% consumed domestically, 39% by industries, 20% by commercial enterprises, and the remainder by other sectors such as religious institutions and street lighting [8].

The cumulative installed capacity of non-conventional renewables in 2020 was 1,114 MW, comprising small biomass (153 MW), mini hydro (873 MW), small solar (161 MW), and small wind projects (401 MW). Despite this, renewable energy still contributes a relatively small share compared to fossil fuel-based generation, showing a heavy reliance on conventional sources [8].

SCOPE AND PURPOSE

This review aims to consolidate existing knowledge on ocean energy technologies and assess their potential applicability in Sri Lanka, an island nation that has yet to initiate large-scale ocean energy projects. While prior studies have provided valuable insights through small-scale experiments and localized assessments, the available data remains fragmented and insufficient to guide comprehensive planning.

The scope of this review is twofold: first, to evaluate global ocean energy technologies such as wave, tidal, ocean thermal, and salinity gradient systems and second, to examine their feasibility within Sri Lanka's coastal and climatic context. The analysis emphasizes technical and environmental considerations while offering a broad national-level perspective rather than detailed sectoral assessments. By synthesizing global advances with local conditions, the review seeks to provide a foundation for researchers, policymakers, and industry stakeholders to identify opportunities, address challenges, and shape future initiatives in ocean energy development for Sri Lanka.

METHODOLOGY

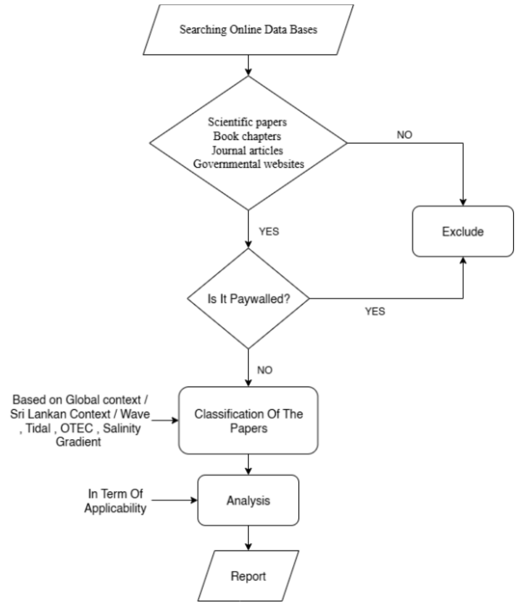

Figure 1: Review Methodology

This critical review was conducted through a structured and selective literature search process, focusing on freely available and reliable sources. Online databases, scientific journals, book chapters, and governmental websites were screened to identify relevant studies on ocean-based renewable energy technologies, including wave, tidal, ocean thermal energy conversion (OTEC), and salinity gradient systems. Paywalled articles were excluded to ensure accessibility, with priority given to open-access research and institutional reports. The selected studies were then classified according to their global or Sri Lankan context, with emphasis on both technological and contextual insights. Case studies were incorporated after the identification of technologies to provide practical examples of application and performance. Finally, the classified literature was critically analyzed in terms of applicability, strengths, limitations, and contextual relevance, forming the basis of the findings presented in this review.

TYPES AND METHODS OF OCEAN ENERGY GENERATION

4.1 Technologies And Methods

Table 1: Technologies and Features of Ocean Energy Technologies

Category	Main Types	Working Principle	Key Features/Applications	Reference
Wave Energy	Oscillating Water Column (OWC)	Waves compress and decompress trapped air in a chamber, creating bidirectional airflow that drives an air turbine-generator.	Simple and robust with an annual harvesting potential of 15–25 kW/m. High commercialization opportunity.	[9] [10] [11]
	Overtopping Converters	Waves over top a ramp into a reservoir and stored water released through turbines.	Stable power output and simple.	[9] [12]
	Point Absorbers	Floating or submerged buoy oscillates (heave/sway/pitch); PTO converts to power.	Compact, omni-directional design; can be deployed in arrays offshore for scalable energy generation.	[9] [13]
	Oscillating Body Converters (OBCs)	Floating/submerged bodies move with waves. Hydraulic/PTO systems generate power.	Advanced designs, small size, versatile and consistent power generation.	[9] [14]
	Wave-Activated Bodies (WABs)	Articulated or hinged floating segments flex as waves pass; the relative motion drives hydraulic pistons linked to generators.	Straightforward design, efficiency typically ranges from 10–35%.	[9] [15] [16] [17]
Tidal Energy	Tidal Barrage	Barrages impound tidal waters in estuaries or bays; turbines harvest energy from the difference in water levels between high and low tide.	Predictable, provides large-scale generation and predictable output, but causes ecological and sedimentation impacts.	[9] [18] [19] [20]
	Tidal Stream Turbines	Underwater horizontal/vertical axis turbines harness kinetic energy of tidal currents.	Categorized into horizontal axis tidal current turbines (HATCTs), crossflow or vertical axis tidal current turbines (VATCTs), and other non-turbine devices. HATCTs account for 76% of all turbines with higher energy efficiency (over 35%). VATCTs account for 12% of turbines; preferably under weaker current conditions due to higher torque generation at lower current velocity and tip speed ratio.	[1] [21] [22] [23] [24] [25]
Ocean Thermal Energy Converter (OTEC)	Closed-Cycle OTEC	Heat transfer from warm saltwater evaporates fluid with low boiling point in the evaporator. The vapor expands through a turbo generator to produce energy.	Compact turbines, sustainable energy generation from ocean thermal gradients.	[26] [27] [28]

	Open-cycle OTEC	Warm seawater is flash evaporated under a partial vacuum (1% to 3% of atmospheric pressure). The steam expands through a turbine generating power, then condenses.	Direct seawater uses and produces freshwater. Surface condenser is costly but yields potable water.	[9] [28]
	Kalina Cycle OTEC	Uses water-ammonia blend as working fluid enhancing conversion efficiency.	Improves efficiency by reducing heat transfer-related irreversibility but higher cost and complexity.	[27] [29]
	Hybrid System	Combines closed and open cycles. Uses warm seawater to generate vapor and produce desalinated water.	Simultaneous power and freshwater generation. Both water and electricity production can be modified independently.	[27] [30] [31]
Salinity Gradient Energy	Pressure Retarded Osmosis (PRO)	Freshwater flows through semi-permeable membrane into seawater, creating pressure that drives a turbine.	Can utilize river water and seawater, or high-saline solutions like Dead Sea water with seawater. Limited adoption.	[9] [32] [33]
	Reverse Electrodialysis (RED)	Alternating ion-exchange membranes allow ions to move between seawater and freshwater, generating voltage.	Limited adoption due to unpredictable compositions and contaminants in water bodies.	[32] [33] [34]

4.2 Case Studies

4.2.1 Tidal Energy Case Studies

The La Rance Tidal Power Plant in France (1966) was the first large-scale tidal station, producing 240 MW and 480 GWh/year with 24 bulb turbines and six sluice gates across a 720 m embankment, impounding a 22 km² basin with a 9–14 m tidal range [35], [36]. The Sihwa Lake Plant in South Korea (2011) is the largest globally, with 254 MW and 552 GWh/year, operating on flood-only generation using 10 turbines across a 42.4 km² basin with a 7.8 m spring tide range [35], [37]. In China, the Jiangxia Plant (1980) generates 4.1 MW with six reversible turbines and two-way pumping from a 1.5 km² basin (5.08 m tidal range), while the Haishan Plant (1975), a unique 150 kW linked-basin scheme, operates up to 22 h/day with pumping and a 4.87 m range [35], [38]. Russia's Kislaya Guba Plant (1968), the only Arctic tidal facility, began at 400 kW (later 1.7 MW), using two-way turbines in a 1.1 km² basin (2.5 m range) and is notable for being built by women engineers [35], [39]. In Canada, the Annapolis Royal Station (1984–2019) operated a 20 MW Straflo turbine on ebb generation but was shut down due to high fish mortality [35], [40].

4.2.2 Wave Energy Case Studies

Wave Energy Converters include several types with notable projects worldwide. Oscillating Water Columns (OWCs) use trapped water columns to drive air turbines, examples being Mutriku (Spain, 296 kW), REWEC3 (Italy, 20 kW), King Island (Australia, 200 kW), Yongsoo (Korea, 500 kW), MARMOK-A-5 (Spain, 30 kW), Ocean Energy Buoy (Ireland, 500 kW), and Islay Limpet (UK, 0.5 MW) [9], [12], [41]. Oscillating Body Converters (OBCs) harness body motion from waves, such as PB3 PowerBuoy (USA, 3 kW), CET06 (Australia, 1000 kW), Atmocean (USA, 10 kW), Seabased (Sweden, 30 kW), Wavepiston (Denmark, 100–200 kW), and WaveRoller (Finland, 350 kW) [9], [12], [42]-[48]. Point Absorbers, floating or submerged bodies that oscillate for energy, include Ada Foah Wave Farm (Ghana, 0.4 MW), Agucadoura Wave Farm (Portugal, 2.25 MW), and Sotenäs Station (Sweden, 3 MW). Overtopping Converters, which store wave water in reservoirs, include the SDE Sea Waves Plant (Israel, 0.04 MW) [9], [49], [50], [51].

4.2.3 OTEC case studies

KRISO (Korean Research Institute of Ships and Ocean Engineering) has extensively researched Ocean Thermal Energy Conversion (OTEC), developing and testing several plants under specific working conditions. Notably, KRISO designed and fabricated a 20 kW OTEC pilot plant as a prototype, and in 2015, they built a 200 kW High-Temperature OTEC (HOTEC) plant that leveraged 70–80°C industrial waste heat and cold deep seawater, achieving a 7.8% improvement in power generation efficiency [51], [52]. Their flagship project, the K-OTEC1000, is a 1 MW closed-cycle OTEC demonstration plant which was successfully tested offshore from Busan, South Korea, in September 2019 [51]. This system utilizes R32 (difluoromethane) as its working fluid, selected for its high heat transfer coefficient and low environmental impact (ODP 0, GWP 675) [51].

In addition to the study already discussed, there are several other notable OTEC projects worldwide that highlight the range of scales and applications of this technology. For instance, a 60-kW closed-cycle plant is under development at Kavaratti in the Lakshadweep Islands, India, aimed at supplying both electricity and freshwater to remote communities [4]. In Hawaii, OTEC International LLC operated a 1,000-kW demonstration facility between 1993 and 1998, providing valuable insights into the technical and operational challenges of large-scale ocean thermal systems [1], [44]. More recently, Lockheed Martin has advanced OTEC development through a 10,000-kW facility at its naval test site in Hawaii, marking one of the largest efforts to integrate OTEC into energy security and defense applications [44].

4.2.4 Salinity gradient energy case studies

The potential sources for PRO include natural water bodies like estuaries, lakes, and ponds, where rivers meet the sea, estimated to have a global energy output of 2.6 TW [46], approximately 20% of the worldwide energy demand [47]. Leading the development efforts are companies such as Kyowakiden Industry Co., Ltd., and Statkraft, both of whom have conducted significant demonstration tests [48]. Kyowakiden's pilot plant in Japan achieved a power density of 10 W/m^2 using concentrated seawater and treated sewage water, demonstrating over a year of continuous operation [49] [50] Reverse Electrodialysis (RED) is a promising membrane-based technology for generating electricity from salinity gradients, currently undergoing testing in demonstration projects [1]. A key case study for Reverse Electrodialysis (RED) involves its integration into a hybrid CDI (capacitive deionization)-RED system [48]. In this setup, a single feed saline water with a concentration of 15,000 ppm was used to produce both freshwater and electric power [48]. Idealized theoretical estimations also suggest significant potential, with 0.74 MJ of electricity possibly generated from the mixing of 1 m^3 of salt water with 1 m^3 of fresh water under ideal conditions (1:50 salinity gradient and 100% efficiency) [48].

APPLICABILITY IN SRI LANKA

5.1 Wave Energy Applicability

Sri Lanka exhibits significant potential for wave energy exploitation, particularly along its west to south-east coastline, due to the predominance of long-distance swell waves interacting with local monsoonal sea waves. Swell waves, being more consistent throughout the year, are particularly favorable for wave energy conversion systems, as they provide a steadier energy density compared to locally generated sea waves [60], [61]. Data from Matara shows that swell waves dominate monthly conditions for most of the year, with values ranging from 57.6% in May to 77.6% in November, indicating a consistently high contribution to the wave climate [61]. Similarly, long-term datasets from the coastal stretch between Negombo and Wadduwa (1979–2019) reveal that the annual average significant wave height is 1.38–1.39 m, with wave periods averaging 8.83–8.85 s, corresponding to an estimated wave energy potential of approximately 2.28 × 10^5 kW/m [62].

The spatial distribution of wave power along the Sri Lankan coast further highlights the west to south-east regions as optimal sites, with average power fluxes between 12–16 kW/m, while the north and east coasts exhibit significantly lower energy levels, ranging from 2–4 kW/m [60]. This makes southern and south-western coastal areas suitable for large-scale, deepwater installations, while most other locations are better suited for small to medium-scale developments [60]. In addition, the consistent swell-dominated waves offer potential synergies for combining energy harvesting with coastal defense, a critical consideration for regions experiencing erosion [60]. Continued high-resolution modeling and near-shore wave measurements are essential to optimize device placement and enhance wave energy extraction strategies across Sri Lanka's coastline [60].

5.2 Tidal energy applicability

Tidal energy potential is highly site-specific, with existing operational tidal barrage plants around the world demonstrating how tidal range, basin area, and turbine capacity influence energy generation. The La Rance plant in France, for instance, utilizes a tidal range of 9–14 m over a 22 km² basin with 24 × 10 MW turbines, yielding 240 MW of installed capacity and an annual output of 480 GWh [35], [36]. Similarly, the Sihwa Lake tidal power station in South Korea operates with a 7.8 m mean spring tidal range across a 42.4 km² basin and 254 MW of installed capacity [35], [37]. Smaller-scale installations, such as the Jiangxia Experimental TPP in China and Kislaya Guba in Russia, exploit tidal ranges of 5.08–8.39 m and 2.5 m, respectively, with installed capacities ranging from 0.5 MW to 4.1 MW [35], [38], [39]. These case studies indicate that effective tidal power generation relies on tidal ranges typically greater than 2.5 m and substantial impounded basin areas to achieve meaningful electricity output.

By contrast, Sri Lanka exhibits relatively modest tidal ranges along its coastline. The highest observed tidal range is 0.60 m at Colombo, followed closely by Galle at 0.55 m, with other locations ranging between 0.37 m and 0.46 m [63]. From factors vary from 0.16 at Hambantota to 0.46 at Kalpitiya, suggesting moderate asymmetry in tidal cycles [63]. Compared with existing global tidal plants, these low tidal ranges indicate that traditional tidal barrage schemes, which require large tidal amplitudes for economic viability, would not be feasible in Sri Lanka. The standard deviations of the mean sea level are also low (0.03–0.06 m), reflecting limited variability and energy flux potential [63]. Consequently, Sri Lanka's tidal energy exploitation would likely necessitate alternative approaches such as micro-tidal turbines or in-stream tidal generators, rather than large-scale barrages [63]. While the global case studies emphasize large-scale, high-tidal-range installations, Sri Lanka's conditions necessitate technology adaptation to harness its comparatively modest tidal resource effectively.

5.3 Thermal Gradient energy applicability

Ocean Thermal Energy Conversion (OTEC) harnesses the temperature difference between warm surface waters and cold deep waters, requiring a minimum gradient of 20 °C to operate efficiently [64], [65]. Sri Lanka, located in the tropical Indian Ocean, exhibits surface temperatures ranging from 27.5 to 28.6 °C and temperatures at 1000 m depth of 6.5–6.7 °C, resulting in an annual mean ΔT of 18.0 °C at 500 m and 21.3 °C at 1000 m [66].

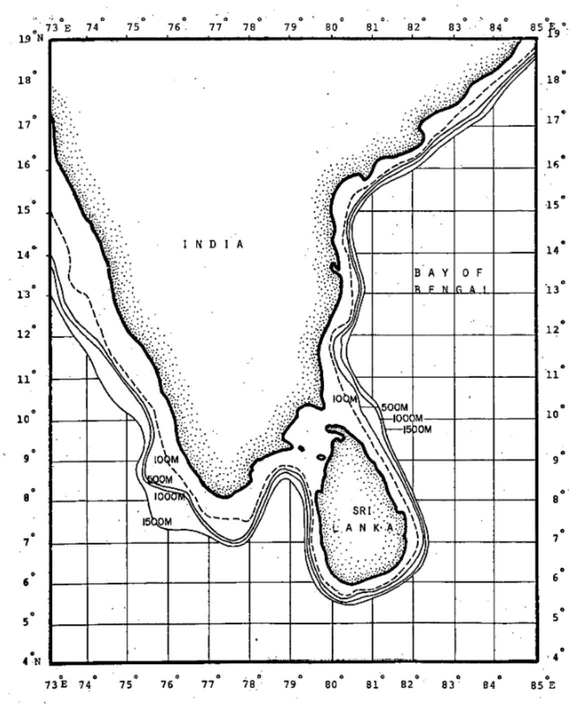

Figure 2: Rough Bathymetry 0-1500 Meters Off Sri Lanka [72]

Even during the coldest months, the ΔT remains above 17.5 °C at 500 m and 20.8 °C at 1000 m, demonstrating that Sri Lanka maintains a sufficiently large thermal gradient throughout the year for OTEC feasibility [66]. Ideal OTEC sites are generally located within 10–15 km of the shoreline to minimize pumping losses for cold-water intake, although sites farther offshore may still be viable if the thermal potential is higher, necessitating detailed analysis [65]. In Sri Lanka, suitable OTEC locations are 22–55 km from shore, which may require additional engineering considerations for cold-water pipelines [66].

With a 1,300-kilometer coastline and tropical location, Sri Lanka is estimated to have over 4,000 MW of potential OTEC capacity, equivalent to approximately 40% of the country's current electricity demand [67]. The western and southern coasts are identified as the most promising regions due to higher surface temperatures and stable deep-water gradients [67]. Overall, the thermal resource in Sri Lanka is adequate for OTEC deployment, although the slightly greater distances to cold-water intake points suggest that system design must carefully balance energy extraction efficiency against infrastructural costs [65], [66].

5.4 Salinity Gradient energy generation

Pressure Retarded Osmosis (PRO) is a promising salinity gradient energy technology that exploits the osmotic pressure difference between freshwater and saline water to generate electricity. The first operational PRO power plant, Stakraft, highlighted the potential of this technology, but also underscored several challenges that currently hinder large-scale adoption. Key barriers include the high cost of membrane production, susceptibility of membranes to fouling by impurities, and the substantial expense of pre-treating feedwater, which collectively make electricity generated from PRO relatively expensive compared to conventional sources [68]. Despite these constraints, PRO remains an attractive renewable energy option due to the continuous availability of riverine freshwater, and the additional potential to extract valuable compounds from the brine byproduct [68].

Sri Lanka's river basins present significant potential for PRO-based power generation. Analysis of selected rivers indicates that harnessing just 5% of total river flow could yield approximately 62.77 MW of electricity, with the highest contributions coming from large rivers such as Kalu Ganga (12.91 MW), Kalani Ganga (8.85 MW), and Mahaweli Ganga (12.91 MW) [68]. Increasing the proportion of river flow allocated to the PRO process directly scales power output, with 10%, 15%, and 20% usage yielding 125.54 MW, 188.31 MW, and 251.08 MW respectively [68]. Under the 20% flow scenario, PRO power generation could account for roughly 7.84% of Sri Lanka's gross electricity generation, indicating substantial potential for supplementing the national grid and reducing reliance on conventional thermal power [68].

It is important to note that this study considers only a small number of river basins. With proper engineering design, optimal site selection, and consideration of additional river systems across the country, the contribution of PRO technology could be significantly higher. Integrating more rivers, enhancing flow allocation strategies, and improving membrane technology could allow Sri Lanka to tap a much larger portion of its salinity gradient energy potential. Furthermore, coupling PRO with existing hydropower infrastructure could maximize efficiency by utilizing existing reservoirs and flow regulation systems [68]. Overall, with appropriate planning and engineering considerations, PRO represents a viable, renewable, and continuous energy source that could play a substantial role in Sri Lanka's future energy mix.

IMPLEMENTATION CHALLENGES OF OCEAN ENERGY IN SRI LANKA

Sri Lanka's ocean energy sector faces significant policy voids, hindering its potential as a renewable resource. Despite studies indicating feasibility for technologies like tidal and wave energy at select coastal sites, site-specific assessments remain constrained by unreliable and insufficient data, impeding informed development. The absence of governmental incentives and robust regulatory frameworks fosters private sector hesitancy toward investments, exacerbating financial barriers. Implementation challenges further compound issues, including the imperative to safeguard marine ecosystems and mitigate disruptions to the vital tourism industry, which may deter stakeholders. Existing GIS maps, while available, lack the granularity and focus required for ocean energy applications, underscoring the urgent need for targeted, high-resolution mapping to guide sustainable progress.

To unlock Sri Lanka's ocean energy potential, efforts should prioritize Ocean Thermal Energy Conversion (OTEC) and wave energy, which is well-suited to the country's tropical waters and consistent wave regimes along the southern and eastern coasts. Tidal energy is deemed unsuitable owing to insufficient tidal ranges in surrounding waters, whereas salinity gradient systems remain nascent, necessitating further global technological advancements to ensure minimal deployment risks.

WAY FORWARD AND FUTURE DIRECTION

Immediate actions must encompass site-specific data acquisition for OTEC and wave energy to underpin robust feasibility analyses and environmental impact assessments. Concurrently, policymakers should formulate comprehensive regulatory frameworks with incentives to mitigate investment risks and streamline permitting processes. Establishing public-private partnerships (PPPs) through targeted engagement with private investors will facilitate capital mobilization, pilot demonstrations, and technology transfer. Public awareness initiatives should emphasize benefits including enhanced energy security, greenhouse gas reductions, and compatibility with marine ecosystems and tourism. International collaborations, particularly with organizations like the International Renewable Energy Agency (IRENA), can provide technical expertise and funding to expedite commercialization and align with national sustainability objectives.

CONCLUSION

Sri Lanka possesses considerable potential for various forms of marine energy, each with unique opportunities and constraints. Wave energy is particularly promising along the west to south-east coastline, where long-distance swell waves consistently interact with local monsoonal seas, producing average power fluxes of 12–16 kW/m suitable for large-scale, deepwater installations, while smaller coastal areas can support medium- to small-scale devices [60], [61], [62]. Tidal energy, in contrast, is limited by the low tidal ranges along the coast, which rarely exceed 0.6 m, making traditional tidal barrages economically unfeasible; micro-tidal turbines or in-stream tidal generators may be more suitable for harnessing these modest tidal resources [63]. Ocean Thermal Energy Conversion (OTEC) benefits from Sri Lanka's tropical location, with warm surface waters (27.5–28.6 °C) and cold deep waters (6.5–6.7 °C at 1000 m) providing a stable thermal gradient of 18–21 °C, enabling a potential base-load capacity exceeding 4,000 MW, particularly along the western and southern coasts [64], [65], [66], [67]. Salinity gradient energy, specifically via Pressure Retarded Osmosis (PRO), shows promise in selected river basins, generating between 62.77 MW and 251.08 MW depending on flow allocation, with the potential to contribute significantly more if additional rivers are utilized and membrane technologies are optimized. Collectively, these marine energy resources, when combined with proper engineering, site selection, and integration into the national grid, could substantially diversify Sri Lanka's renewable energy portfolio, reduce reliance on conventional thermal power, and provide continuous, sustainable electricity for the nation.

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