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Ocean-Based Renewable Energy: Technologies, Progress, and Comparative Potential

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Abstract

The ocean holds a vast and reliable source of clean, powerful, and predictable renewable energy. It comes from tides, waves, currents, and temperature differences in the sea. Advancements in technology now allow ocean motion to be converted into electricity more cost-effectively and efficiently. Ocean energy has big advantages. It can cut carbon, reduce fuel imports, and create local jobs. But there are challenges too, like high costs, limited sites, and environmental concerns. Still, the benefits are strong. Countries with long coastlines can lead the way. Bangladesh is one of them. With tidal estuaries and rising energy needs, it has great potential. With the right support, ocean energy can play a key role in producing clean power. This study highlights the global importance of adopting ocean energy and Bangladesh's potential to participate in this transition. Current progress and prospects in the sector are also examined. Ocean energy is steady, strong, waiting to be used. A cleaner future is riding the waves. Bold action today promises a sustainable tomorrow powered by the sea. The future of energy may be under the waves. Now is the time to dive in.

Keywords

Ocean power, SDG, Renewable Energy, Grid.

1. Introduction

The global demand for sustainable and environment friendly energy sources has accelerated the development of renewable technologies. Ocean-based renewable energy, such as tidal, wave, ocean current, thermal, and salinity energy, has great potential but is mostly unused. The ocean offers a continuous and high-density source of power as over 70% of the Earth's surface is covered by water. If properly harnessed, ocean could play a pivotal role in achieving global energy goals (Panwar et al., 2021; Shah et al., 2022). On 2015, United Nations (UN) created Sustainable Development Goals (SDG) to address global challenges such as poverty, inequality, climate change, and environmental degradation. They provide a shared blueprint for peace and prosperity, aiming for achievement by 2030. All countries (developed and developing) are expected to align their national policies and actions with these goals. The SDGs emphasize collective responsibility to ensure a sustainable future for both people and the planet (United Nations, 2015). Ocean energy aligns directly with Sustainable Development Goal (SDG) no 7 (Affordable and Clean Energy) by offering a non-polluting, long-term solution to the world's growing energy needs. Moreover, it supports SDG no 13 (Climate Action) and SDG no 14 (Life Below Water) by promoting energy strategies that reduce greenhouse gas emissions and safeguard marine ecosystems (United Nations, 2023; IRENA, 2020). Many countries are investing heavily on ocean energy technologies because of their great potential for clean and reliable power. Globally, the ocean energy sector attracted over $4 billion in investment between 2015 and 2020, and it is expected to reach a market value of $140 billion by 2030 (Global Ocean Energy Report, 2022). The UK aims to produce 2 gigawatts (GW) of tidal and wave energy by 2030, while South Korea's tidal power capacity has surpassed 254 megawatts (MW) (International Renewable Energy Agency [IRENA], 2023). China plans to increase its ocean energy capacity by 10 GW within the next decade, focusing on tidal and offshore wind hybrids (Ocean Energy Europe, 2023). These figures highlight the rapid growth and serious commitment of countries worldwide to ocean renewable energy.

Bangladesh imports over 80% of its energy resources, making it vulnerable to supply disruptions and price fluctuations (Bangladesh Power Development Board, 2022). Despite its vast coastal resources, Bangladesh has yet to capitalize on this opportunity. Harnessing ocean energy could provide a stable and sustainable energy source to support the national grid and remote coastal communities. The ocean renewable energy presents a dual opportunity for Bangladesh. First, it can help Bangladesh to use less fossil fuel and imported energy, making its energy supply more secure. Second, it can stimulate blue economic growth, particularly through investments in coastal and offshore infrastructure (Chowdhury et al., 2021; Akhtaruzzaman & Zohora, 2019). Bangladesh's long coastline, coupled with tidal estuaries and the Bay of Bengal's hydrodynamic activity, makes it a promising region for the development of tidal stream and wave energy technologies (Khan et al., 2020; Nasir et al., 2022). Despite this potential, the country faces technical, financial, and regulatory challenges that have slowed progress. However, global trends show increasing innovations in marine energy systems such as floating platforms, hybrid wave-wind systems, and AI-based monitoring tools which offer scalable models for developing countries (Panwar et al., 2021; Charlier & Finkl, 2009). Ocean energy offers better predictability and higher energy density than solar or wind. However, it comes with greater costs and technical challenges (Shah et al., 2022; Neary et al., 2014). For Bangladesh, strategic policy support, international collaboration, and targeted R&D can enable the successful integration of ocean energy into its renewable energy portfolio (Rahman et al., 2020).

Marine energy technologies are advancing globally, with nations exploring tides, waves, and ocean currents as clean and sustainable sources (Esteban & Leary, 2012; IEA, 2021). Bangladesh's geography and hydrodynamics offer opportunities to adopt these technologies (Chowdhury et al., 2021; Khan et al., 2020) though more research, infrastructure, or policy support are required. However, different studies highlight the importance of site-specific assessments and localized solutions (Fraenkel, 2006; Blunden & Bahaj, 2007). This article is based on a qualitative approach grounded on secondary data. Peer-reviewed articles, policy documents, and technical reports were reviewed. Resource mapping, SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, and comparative assessment with global benchmarks were applied to evaluate the potential of tidal, wave, and current energy can be utilized in Bangladesh with respect to other developed country.

1.1 Superiority of Marine Renewables

Ocean energy is different from other renewable energy sources (wind, solar, hydropower etc.). It is more reliable. The sea moves all the time. Tides come and go at regular times. Waves are always forming. Currents flow steadily under the surface. This movement is natural and constant. Solar energy works only when the sun shines. It cannot produce power at night or during cloudy days. Wind energy requires strong wind speed, a vast open area, and depends on direction. The changing wind speed affects how much power is produced. But ocean energy is more stable. The sea never stops moving. This makes ocean energy more predictable. Ocean energy distinguishes itself by offering highly predictable tidal power and relatively consistent wave and current energy, compared to the intermittency of solar and wind (IEA, 2021). Its energy density is higher than solar and comparable to wind, meaning more power can be generated in smaller areas. However, ocean technologies are less mature and more costly to deploy due to complex marine environments and engineering challenges (REN21, 2022). Environmental impacts of ocean energy are less severe than large hydropower dams but require careful ecosystem monitoring due to effects on marine life and sediment transport (Gill, 2005). Solar and wind enjoy wider adoption and declining costs. On the other hand ocean energy offers complementary benefits in diversifying renewable portfolios and enhancing grid stability through predictable generation (Shah et al., 2022).

Ocean energy is good for places with limited land. Also, many people live near the coast. Ocean energy can be used near where it is produced. This reduces the need to build long power lines. It saves money and energy. It also helps keep power systems safe and strong. Unlike fossil fuels, ocean energy does not pollute the air. It does not create greenhouse gases. It is clean and safe and helps fight climate change. Because of these reasons, ocean energy stands out. It is steady, strong, and clean. It can work well with other renewable sources. It is an important part of future energy mix. Table 1 presents a basic comparison of different renewable energy sources based on various aspects.

Table 1. Comparison of Renewable Energies in Various Aspects

Aspect	**Ocean Energy**	**Solar**	**Wind**	**Hydropower**
Predictability	High (tidal), Medium (wave)	Low	Medium	High
Energy Density	High	Medium	High	High
Environmental Impact	Medium	Low	Medium (noise, birds)	High (land use)
Technological Maturity	Low to Medium	High	High	High
Deployment Cost	High	Low	Medium	Medium

1,2 Ocean Power Generation Methods

The ocean offers several forms of renewable energy that can be converted into electricity. These include tidal, wave, current, and thermal energy. Power can be generated from these forms of energy using different technologies. Few technologies are discussed in this section.

A. Tidal Energy

Tides are the regular rise and fall of sea levels caused mainly by the **gravitational pull of the Moon and the Sun** on Earth's oceans. It occurs in a predictable pattern, typically twice a day in most coastal areas. Electricity can be produced by using the movement of ocean tides (Figure 1). When tides rise and fall, they move large amounts of water. This moving water is well enough to rotates turbines, which are connected to generators that produce electricity. Tidal energy systems can be set up in tidal barrages, underwater turbines, or tidal fences (Kerr, 2007; Blunden & Bahaj, 2007). The La Rance Tidal Power Station in France and the MeyGen project in Scotland are two prominent examples. While predictable and environmentally cleaner, tidal systems face limitations in site selection, ecological impact, and capital cost (O'Rourke et al., 2010; Shah et al., 2022).

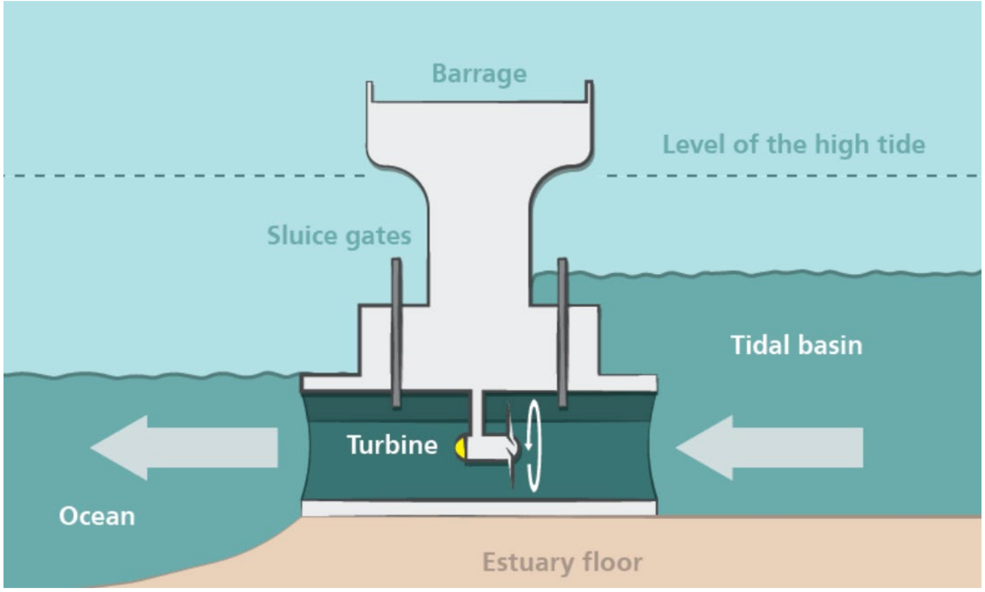

Figure 1. Harnessing Tidal Energy (Mia et al., 2021)

B. Wave Energy

Wave energy captures the energy of surface waves generated by wind over the ocean. As waves move across the surface of the water, they carry kinetic and potential energy. To harness this energy, technologies like point absorbers, oscillating water columns, and attenuators are used. A Point Absorber is a floating structure that absorbs energy from the vertical (up and down) motion of waves (Figure 2). It typically consists of a buoyant float connected to a fixed base or a submerged platform. As waves pass, the float bobs up and down, and this relative motion is converted into mechanical or electrical energy via a power take-off (PTO) system, often using hydraulics, linear generators, or mechanical systems. An oscillating water column (OWC) is a chamber partially submerged in the ocean with an opening below the waterline (Figure 3). As waves enter and exit the chamber, they compress and decompress the air inside. The moving air is forced through a turbine (usually a Wells turbine), which spins in the same direction regardless of airflow direction. The turbine is connected to a generator to produce electricity. An Attenuator is a long, multi-segmented floating structure aligned parallel to incoming waves (Figure 4). As waves travel along the length of the device, the segments flex and bend at the joints. This flexing motion is used to drive hydraulic pumps or other PTO systems, which in turn generate electricity. Examples of wave energy conversion powerplant include the Pelamis system and CETO technology in Australia (Cruz, 2008; Drew et al., 2009). Challenges include device survivability in harsh marine environments and high maintenance costs (Falcão,2010).

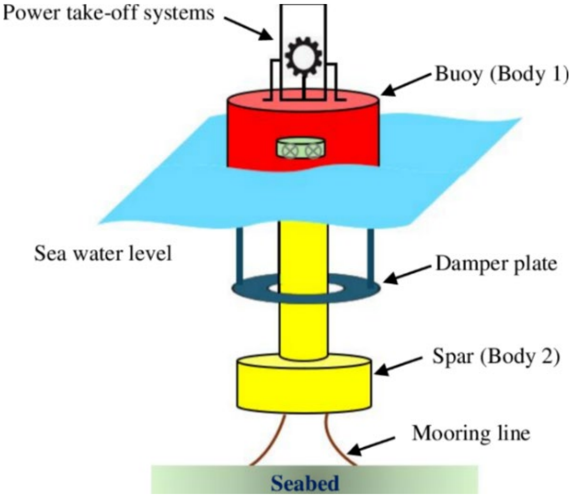

Figure 2. Point Absorber (Kumar et al., 2024)

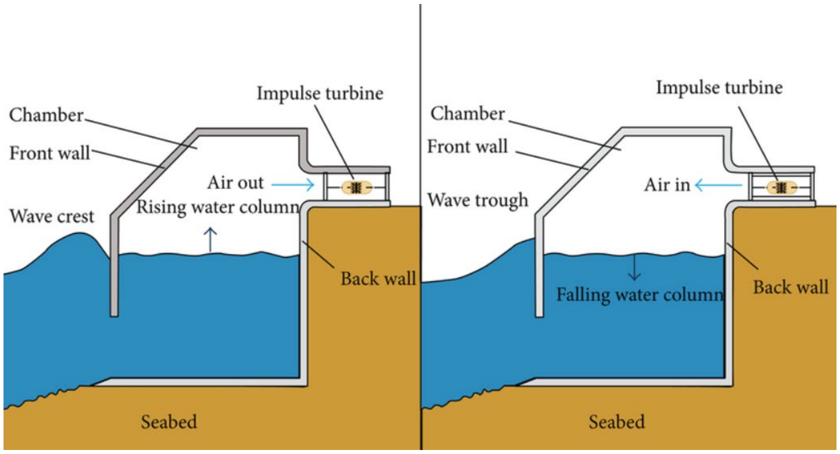

Figure 3. Oscillating Water Column (Cui & Liu, 2015)

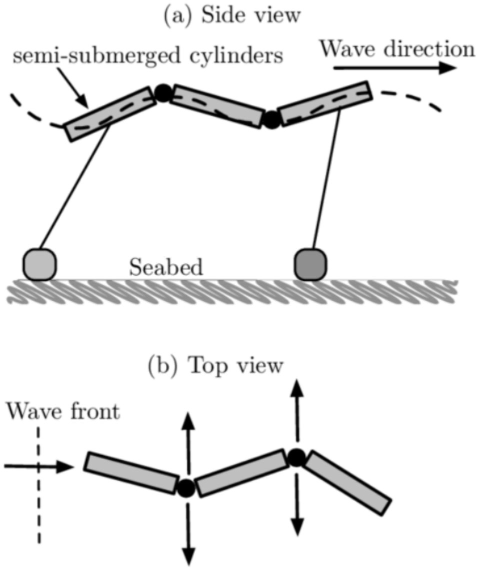

Figure 4. Attenuator (Cuadra et al., 2016)

C. Ocean Current Energy

Ocean current energy uses the kinetic energy of ocean currents to generate electricity via submerged turbines. Underwater turbines are placed in the path of strong currents. As the current flows through the turbine blades, it causes them to rotate, just like wind turns wind turbine blades (Figure 5). This mechanical rotation powers a generator, which converts the kinetic energy into electrical energy. The electricity is then transmitted to shore via submarine cables. It is still in the early stages of development, with limited pilot deployments due to high installation and maintenance costs and site-specific variability (Bahaj & Myers, 2003; Fraenkel,2006).

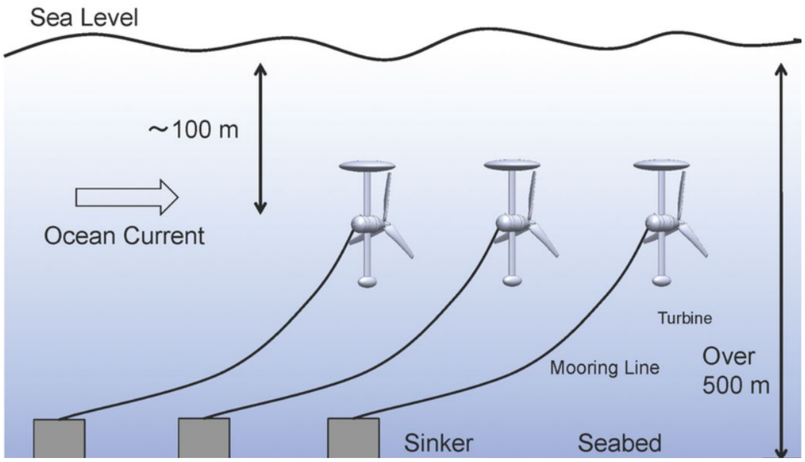

Figure 5. Ocean Current Turbine Schematic (Shirasawa et al., 2017)

D. Ocean Thermal Energy Conversion (OTEC)

OTEC exploits the temperature difference between warm surface seawater and cold deep seawater. It works following principles of heat engines (Figure 6). **Warm surface seawater** (around 25–30°C) is used to **vaporize a low-boiling-point fluid** (like ammonia). The vapor expands and **drives a turbine** connected to a generator, producing electricity. **Cold deep seawater** (around 4–5°C) is pumped up to **condense the vapor** back into liquid. The cycle repeats continuously. This technology is still under development. The Makai OTEC plant in Hawaii is a prominent pilot project

(IRENA, 2020). Tropical regions like Bangladesh could benefit from OTEC, though commercialization is still limited (Panwar et al., 2021; Shah et al., 2022).

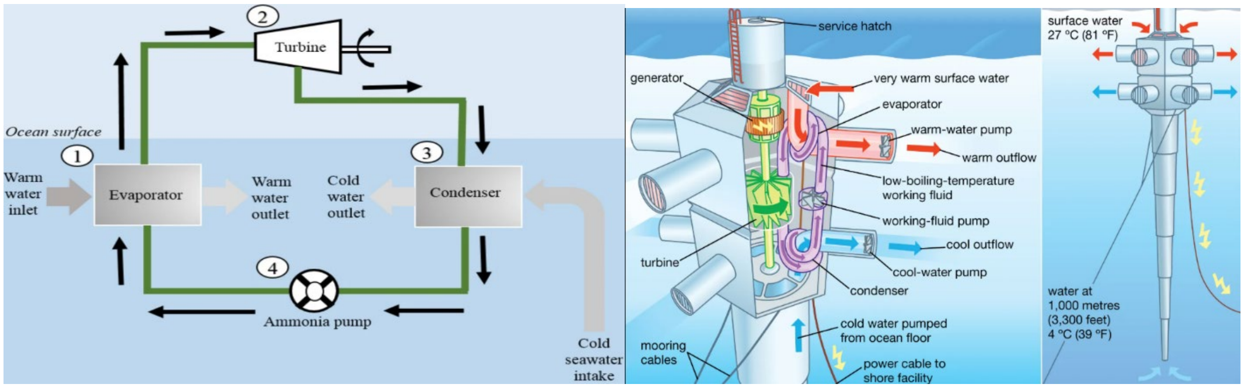

Figure 6. Working Principles of OTEC (Mero & Rafferty, 2024) and Schematic Diagram of OTEC (Adiputra et al., 2020)

E. Salinity Gradient Energy

Salinity gradient energy, also known as **blue energy** or **osmotic power**, is a renewable energy source that harnesses the chemical potential difference between saltwater (like seawater) and freshwater (like river water). The energy is released when these two types of water mix. This mixing happens naturally at estuaries where rivers meet the sea but special technologies can capture this energy to produce electricity. To capture this energy, this system is made up of stacks of alternating cation exchange membranes (CEMs) and anion exchange membranes (AEMs). These membranes selectively allow positive ions (e.g., Na^+) or negative ions (e.g., Cl^-) to pass through. Freshwater and saltwater are pumped into alternating compartments between the membranes (Figure 7). Due to the salinity difference, ions diffuse from the high-salinity side (seawater) to the low-salinity side (freshwater). Cations (Na^+) pass through cation-selective membranes; anions (Cl^-) pass through anion-selective membranes. This ion movement generates a voltage across each membrane pair. The voltages from multiple membrane pairs are stacked in series, creating a usable electric current when connected to electrodes and an external circuit. The Statkraft plant in Norway was a major demonstration project (Logan & Elimelech, 2012). Currently, salinity gradient energy is in the early research phase (IRENA, 2020).

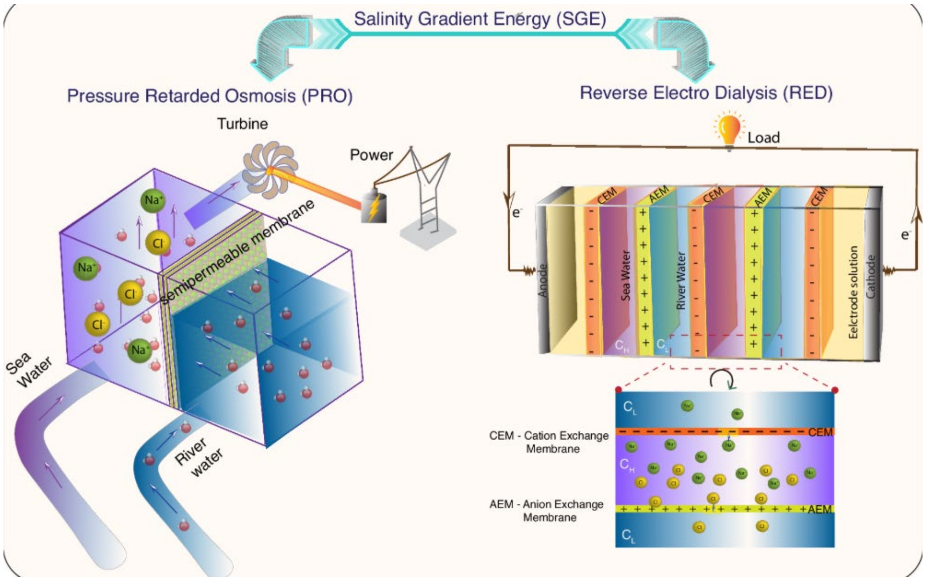

Figure 7. Salinity gradient energy (Manikandan et al., 2024)

1.3 Technological Progress and Innovations

Recent years have witnessed significant technological advances that enhance the feasibility, efficiency, and reliability of ocean renewable energy systems. Developments in materials science, such as corrosion-resistant alloys and advanced composites, have improved device durability and lifespan in harsh marine environments (Esteban & Leary, 2012; Li, Wang, & Sun, 2020). Floating platform technologies have enabled the deployment of wave and tidal devices in deeper waters, beyond shallow coastal areas (O'Sullivan & Lewis, 2017). Artificial intelligence (AI) and machine learning are increasingly applied for predictive maintenance, real-time monitoring, and adaptive control of marine energy devices. These digital tools reduce downtime and optimize power output by adjusting system parameters according to environmental conditions (Kim & Kim, 2022). Hybrid systems combining multiple ocean energy sources (e.g., wave-wind, solar-OTEC) improve overall energy reliability and grid integration by smoothing fluctuations inherent in individual sources (WindEurope, 2020).

Additionally, advancements in energy storage, such as underwater compressed air or battery systems, are helping address intermittency challenges. Integration with offshore aquaculture and desalination plants has maximized multi-use benefits of marine platforms (Panwar et al., 2021). Research in bio-inspired design mimics natural forms, such as fish fins, to enhance turbine efficiency and reduce environmental impact (Shah et al., 2022). These advances increase energy efficiency and reduce problems. Overall, these innovations make ocean energy more reliable and easier to use. Table 2 shows how new technologies improve ocean energy systems. The Efficiency values in this table represent the approximate ratio of electrical energy output to the theoretical energy available from the ocean resource. Data adapted from Panwar et al. (2021), Shah et al. (2022), and IRENA (2020).

Table 2. Performance Metrics of Marine-based Renewable Energy

Technology	Typical Energy Conversion Efficiency (%)	Key Advantages	Key Challenges	Typical Power Range
Tidal Stream Turbines	35–45%	Predictable energy source, high power density	Marine biofouling, environmental impact	kW to several MW per turbine
Wave Energy Converters	20–40%	Abundant coastal resource, scalable	Variable wave patterns, mechanical complexity	kW to MW scale
Ocean Current Turbines	30–40%	Continuous flow, high energy density	Complex installation, limited sites	kW to MW
Ocean Thermal Energy Conversion (OTEC)	3–5%	Base-load power, uses temperature gradients	Low thermal gradient in many locations, large infrastructure	100+ MW
Salinity Gradient Energy	10–15%	Uses natural salinity differences	Early-stage technology, membrane durability	kW to MW

1.4 Global Status of Ocean Renewables

Ocean renewable energy is progressing steadily, driven by public investment, technological innovation, and climate commitments. The UK remains a global leader with extensive deployments of wave and tidal devices through the European Marine Energy Centre (EMEC). France has advanced commercial-scale tidal projects like Paimpol-Bréhat. South Korea has commissioned the Sihwa Lake Tidal Power Station—the world's largest tidal plant—and continues to invest in tidal barrage and lagoon systems. The USA is expanding ocean energy R&D with pilot programs through the U.S. Department of Energy’s Waterpower Technologies Office, in Oregon, Alaska, and Hawaii. China has recently accelerated investment in ocean energy, launching demonstration sites for tidal and OTEC technologies. Similarly, Canada is testing tidal stream systems in the Bay of Fundy, and Portugal has resumed wave energy testing along its Atlantic coast. Globally, more than 500 MW of marine energy devices have been installed cumulatively, though most remain pre-commercial.

The future of marine renewable energy is promising. The International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) forecast that ocean energy could provide 10% of global electricity by 2050 with supportive policies and continued cost reductions. Hybrid systems (e.g., wave-wind, solar-OTEC) and digitalization (e.g., AI for maintenance) are improving system efficiency and reliability. However, large-scale deployment still depends on stable policy frameworks, grid integration, and environmental monitoring.

For Bangladesh, international collaboration and knowledge transfer offer pathways to accelerate marine energy development, harnessing local resources to address energy poverty and climate resilience (Chowdhury et al., 2021; Nasir et al., 2022).

1.5 Potential of Ocean Renewable Energy in Bangladesh

Bangladesh's geographical location on the Bay of Bengal, extensive coastline (~710 km), and numerous tidal estuaries create significant opportunities for ocean renewable energy development. Studies estimate that tidal energy potential along the Meghna estuary and the Karnaphuli river delta could provide up to 600 MW, sufficient to power several coastal districts (Khan et al., 2020; Nasir et al., 2022). The Bay has relatively low wave heights, so the wave energy potential is moderate. However, it is still useful for small coastal projects and providing electricity to islands (Rahman et al., 2020). Ocean current energy is less explored but could be developed near strong current zones such as the channel between St. Martin's Island and the mainland (Chowdhury et al., 2021).

Bangladesh is actively pursuing renewable energy goals aligned with its Vision 2041 and Sustainable Development Goals (SDG), particularly SDG 7 (clean energy), SDG 13 (climate action), and SDG 14 (life below water). Renewable energy currently contributes around 3% of the total energy mix with solar power dominating in Bangladesh. However, ocean energy remains largely untapped despite significant potential (SREDA, 2023; Alam et al., 2020). Research indicates various coastal and offshore locations suitable for different ocean energy technologies. The following Table 3 summarizes regional potential and suitability for ocean renewable energy deployment in Bangladesh.

Table 3. Comparative Analysis of Marine Renewable Energy Resources of Bangladesh

Technology	**Region/Location**	**Resource Characteristics**	**Suitability and Opportunities**	**Challenges**
Tidal Stream Turbines	Meghna Estuary, Sundarbans	Strong tidal currents with high velocity	High potential for tidal stream energy; near-shore installation possible	Environmental concerns; navigation safety
Wave Energy Converters	Cox's Bazar, Bay of Bengal	Consistent moderate wave heights	Good potential for wave energy; supports coastal communities	Device survivability; maintenance cost
Ocean Current Turbines	Bay of Bengal (offshore)	Persistent ocean currents	Continuous energy supply; potential for offshore farms	Deep-water deployment costs; limited data
OTEC	Offshore Bay of Bengal	Tropical waters with significant temperature gradient	Feasible due to warm surface and cold deep water	High initial capital; technology readiness
Salinity Gradient Energy	River mouths (Padma, Meghna)	Freshwater meets seawater with large salinity difference	Continuous freshwater discharge from around 700 rivers; Flat coastal terrain for infrastructure; Energy access off-grid areas	High Capital Cost; High Erosion and siltation of coastal area

Beyond power generation, marine energy platforms could support offshore aquaculture, desalination, and disaster-resilient infrastructure, aligning with Bangladesh's Blue Economy goals (Akhtaruzzaman & Zohora, 2019). Government initiatives promoting renewable energy, coupled with international funding, have begun exploratory projects. Significant key challenges include limited local technical expertise, lack of funding for large pilot projects, and complex maritime governance frameworks. However, the country's commitment to Sustainable Development Goals and climate adaptation plans creates a favorable policy environment for fostering ocean energy innovation (United Nations, 2023; Rahman et al., 2020).

2. Global Challenges and Ways to Overcome

Marine renewable energy technologies hold immense promises for sustainable energy generation. However, their development and deployment face several technical, environmental, economic, and regulatory challenges that must be addressed to realize their full potential. Prominent challenges and their potential solutions in various aspects are discussed below:

A. Technical Aspect

i. Challenges

One of the foremost technical hurdles involves the harsh and dynamic marine environment. Devices must withstand extreme weather, corrosion from saltwater, biofouling (accumulation of organisms on surfaces), and mechanical wear from constant wave and current action (Li et al., 2020). The engineering of robust, durable materials and components remains a priority. Additionally, energy conversion efficiency and reliability must be improved to make these technologies commercially viable. For instance, tidal turbines require optimized blade designs and control systems to maximize power capture under variable flow conditions (Liu et al., 2019). Wave energy converters (WECs) face challenges in capturing energy efficiently from irregular wave patterns. Power take-off mechanisms must be designed to handle the fluctuating loads (Falcão, 2010).

ii. Mitigation Strategies

To reduce rust and wear, new suitable materials like corrosion-resistant metals and coatings can be used. Modular parts also make repair and upgrade easier (Sharma et al., 2020). Waves and tides change quickly. Smart systems using AI can adjust to these changes in real time. This helps produce more energy and keeps machines working well (Bakhshian et al., 2022). Standard tests help to measure how well devices work. By sharing data with other companies to compare results will help to improve designs (IEA-OES, 2021).

B. Environmental and Ecological Aspects

i. Challenges

Marine renewable energy installations can impact local ecosystems, such as altering sediment transport, noise pollution affecting marine fauna, and potential risks to migratory species (Gill, 2005; Inger et al., 2009). Environmental monitoring and impact assessments are crucial for sustainable development. Designing devices to minimize ecological footprints, such as using fish-friendly turbines and environmentally sensitive placement strategies can help mitigate adverse effects.

ii. Mitigation Strategies

Special shapes and slower-moving parts can be used to keep the system ecofriendly. Choosing a convenient and safer position for device will also help the environment (Copping et al., 2016). The ocean can change over time. Regular checks can show if animals or habitats are being harmed. This helps to adjust the running time of the devices (Inger et al., 2009). Local fishers and communities use the sea too. Talking with them early builds trust. Their help can guide better, safer projects (Gill, 2005).

C. Economic and Financial Aspects

i. Challenges

High upfront capital costs and uncertainties around long-term performance and maintenance contribute to financial risks, deterring investment (Leeney et al., 2014). The lack of established supply chains and economies of scale for marine technologies means costs remain significantly higher than onshore renewables or fossil fuels (REN21, 2022). Financing models, incentives, and government support play a vital role in overcoming these barriers. Innovations in manufacturing and deployment methods could reduce costs over time (Batchelor et al., 2017).

ii. Mitigation Strategies

Marine energy is expensive to start. Governments and companies can share the cost. This reduces risk and helps big projects to move forward (Batchelor et al., 2017). New technologies need support. Feed-in tariffs and subsidies make them more affordable. This attracts more investors (REN21, 2022). Grants, loans, and green bonds can provide money for clean energy.

D. Grid Integration and Infrastructural Aspect

i. Challenges

Marine energy sites are often located far offshore, posing challenges for grid connectivity and energy transmission (O'Sullivan & Lewis, 2017). The integration of intermittent and variable marine power into existing electrical grids requires advanced grid management, energy storage solutions, and hybrid systems combining multiple renewable sources (WindEurope, 2020; Zhao et al., 2023). Development of subsea cables and smart grids is essential for smooth power delivery.

ii. Mitigation Strategies

Marine energy can work with solar or wind. This makes power steadier and more reliable. It helps during times when waves are weak (Zhao et al., 2023). Generated energy needs to travel from the sea to land. Special cables and offshore stations can do this (WindEurope, 2020). Stored energy is useful when the sea is calm. Batteries or hydrogen can hold power for later use. This keeps supply stable (O'Sullivan & Lewis, 2017).

E. Regulatory and Policy Issues

i. Challenges

A complex regulatory landscape involving maritime laws, environmental regulations, and competing marine space uses complicates project approvals (Rahman et al., 2020). Coordination among government agencies, clarity in permitting processes, and comprehensive marine spatial planning can streamline development. Policies supporting research, pilot projects, and commercial deployment are crucial.

ii. Mitigation Strategies

Many projects get delayed by long permit times. A clear and fast system helps things move quickly. This also gives investors more confidence (Rahman, Islam, & Hasan, 2020). Many people and animals use the ocean. Marine spatial planning finds the best places for energy without disturbing people and animal’s habitants. It helps avoid user conflicts (Douvere, 2008). Sharing knowledge saves time and money. Countries can learn from each other’s research and projects. This helps the whole sector grow faster (IEA-OES, 2021).

3. Conclusion

Ocean-based renewable energy is an emerging solution for the world’s growing energy needs. Technologies such as tidal, wave, and ocean current energy can provide clean power. Among the many renewable sources, ocean energy stands out for its predictability and steady output. Tidal, wave, and ocean current energy all come from the natural movements of water. These forces are continuous and reliable. Unlike wind or solar, ocean energy does not depend on daily weather or sunlight. This makes it easier to plan for energy generation and delivery. In coastal regions, marine energy can supply power to communities that are hard to reach by national power grids. It can also reduce dependence on imported fuels. Using local energy from the sea can support long-term energy security. Countries with large coastlines or islands have a special advantage in developing these resources. It allows them to meet climate goals while creating new economic opportunities. Ocean energy projects can provide jobs in construction, engineering, monitoring, and repair. Local businesses can also benefit from the infrastructure development needed to support such systems. Additionally, ocean energy is aligned with environmental goals if done responsibly. New technologies are being designed to avoid harming marine life and ecosystems. Careful site selection and environmental monitoring can reduce risks. As technology improves, the cost of these systems will fall. This will allow more countries to invest in them. Today, only a few countries are testing ocean energy at a large scale. However, many more are beginning to show interest. With international cooperation, shared research, and supportive policies, the world can unlock the full power of the ocean. In the future, it could become a major part of a global, clean energy mix. The sea offers a constant, renewable force that is waiting to be used wisely.

Bangladesh has much to gain from ocean energy. The country has a long coastline that stretches along the Bay of Bengal. It also has many rivers and estuaries that flow into the sea. These natural conditions provide a perfect environment to test and apply tidal and ocean current technologies. Bangladesh faces regular power shortages, especially in rural and coastal areas. Ocean energy can offer a clean and stable alternative. Small-scale systems could power fishing villages, ports, and island communities that have little or no access to the national grid. Implementing marine energy would not only solve local energy problems but also reduce pressure on the central grid. It could help manage peak demand and ensure energy is available during emergencies or natural disasters. In addition, developing this sector could create new job opportunities. Skilled workers would be needed to install, operate, and maintain these systems. Universities and technical institutions in Bangladesh could offer courses and training programs focused on marine energy. This would prepare a new generation of engineers, scientists, and technicians who can lead the sector. Research organizations in Bangladesh, such as the Bangladesh University of Engineering and Technology (BUET) and the Institute of Water Modelling (IWM), can play key roles. They can carry out studies, support pilot projects, and help develop local technology suited to the country's needs. Collaborating with international experts and donors could bring the necessary funding and technical skills. The government must also play a strong role. It should provide policy support, financial incentives, and public education campaigns to raise awareness. Clear regulations and environmental safeguards will ensure projects are safe and sustainable. If planned wisely, ocean energy can support economic development, energy access, and environmental protection in Bangladesh. It aligns with the country's commitment to the Sustainable Development Goals (SDGs), especially clean energy, climate action, and economic growth. With long-term vision and cooperation, Bangladesh can lead the way in marine renewable energy in the South Asian region.

Ocean energy offers great promise, but real progress will need strong action from many sides. There are technical and financial challenges. Many marine energy technologies are still in the early stages. They are expensive to build and test. More research and development is needed to make them practical. Governments and companies must invest in new designs that are cheaper, more efficient, and easier to maintain. Universities and research centers can support this work through experiments and trials. Open sharing of knowledge will help everyone advance faster. Safety and environmental care must be at the center of every project. Building systems in the ocean can affect marine life, water quality, and coastlines. It is essential to study each site carefully before development begins. Marine biologists and local communities should be involved in these studies. Projects should use methods that avoid harming fish, corals, and sea birds. Technologies must be quiet, slow-moving, and placed in areas with low ecological risk. Governments should set clear rules and ensure companies follow them. Community support is critical. Local people must understand what ocean energy is and how it will affect their lives. Good communication and fair planning will help avoid conflicts. If people see the benefits like more reliable power, lower energy bills, or new jobs, they are more likely to support these projects. Governments should also provide training programs and scholarships for young people who want to work in this field. This will ensure that the benefits of ocean energy reach everyone, not just a few. Finally, global cooperation is key. No country can succeed alone. Countries should share data, tools, and experiences. International organizations can help fund projects and offer expert advice. Ocean energy is a long-term investment for the future. It can help to reduce pollution, fight climate change, and create a fairer energy system. The ocean is vast, and its power is renewable. It need to be used carefully, smartly, and together. The time to act is now, before the opportunity slips away.

References

Akhtaruzzaman, M., and Zohora, F. T., Coastal energy resources and potential for tidal power in Bangladesh, *Journal of Marine Science and Engineering*, vol. 7, no. 3, p. 75, 2019. https://doi.org/10.3390/jmse7030075

Adiputra, R., Utsunomiya, T., Koto, J., et al., Preliminary design of a 100 MW-net ocean thermal energy conversion (OTEC) power plant: Study case—Mentawai Island, Indonesia, *Journal of Marine Science and Technology*, vol. 25, no. 1, pp. 48–68, 2020. https://doi.org/10.1007/s00773-019-00630-7

Bahaj, A. S., and Myers, L. E., Fundamentals applicable to the utilisation of marine current turbines for energy production, *Renewable Energy*, vol. 28, no. 14, pp. 2205–2211, 2003. https://doi.org/10.1016/S0960-1481(03)00152-1

Bakhshian, A., Nasiri, A., and Savaghebi, M., Intelligent control systems for ocean energy converters: A review, *Renewable and Sustainable Energy Reviews*, vol. 158, p. 112129, 2022. https://doi.org/10.1016/j.rser.2022.112129

Bangladesh Power Development Board, *Annual Report 2021–2022*, BPDB, Bangladesh, 2022. https://bpdb.gov.bd/

Batchelor, C., Sharpe, R., and Painschab, M., Costs and performance of marine energy technology, *Renewable Energy*, vol. 112, pp. 163–174, 2017. https://doi.org/10.1016/j.renene.2017.05.067

Blunden, L. S., and Bahaj, A. S., Tidal current energy resource assessment for tidal sites in the UK, *Proc. IMechE Part A: Journal of Power and Energy*, vol. 221, no. 2, pp. 125–135, 2007. https://doi.org/10.1243/09576509JPE548

Charlier, R. H., and Finkl, C. W., *Ocean Energy: Tide and Tidal Power*, Springer, Berlin, 2009. https://doi.org/10.1007/978-3-540-78755-7

Chowdhury, M. A., Hossain, M. M., and Islam, M. M., Potential of renewable ocean energy in Bangladesh: A review, *Renewable and Sustainable Energy Reviews*, vol. 144, p. 111001, 2021. https://doi.org/10.1016/j.rser.2021.111001

Copping, A., Hanna, L., Whiting, J., Geerlofs, S., Grear, M., Blake, K., et al., Environmental effects of marine renewable energy development around the world, *Oceanography*, vol. 29, no. 4, pp. 102–111, 2016. https://doi.org/10.5670/oceanog.2016.84

Cruz, J., *Ocean Wave Energy: Current Status and Future Perspectives*, Springer, Berlin, 2008.

Cuadra, L., Salcedo-Sanz, S., Nieto-Borge, J., Alexandre, E., and Rodriguez, G., Computational intelligence in wave energy: Comprehensive review and case study, *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 1223–1246, 2016. https://doi.org/10.1016/j.rser.2015.12.253

Cui, Y., and Liu, Z., Effects of solidity ratio on performance of OWC impulse turbine, *Advances in Mechanical Engineering*, vol. 7, Article ID 121373, 2015. https://doi.org/10.1155/2014/121373

Douvere, F., The importance of marine spatial planning in advancing ecosystem-based sea use management, *Marine Policy*, vol. 32, no. 5, pp. 762–771, 2008. https://doi.org/10.1016/j.marpol.2008.03.021

Drew, B., Plummer, A. R., and Sahinkaya, M. N., A review of wave energy converter technology, *Proc. IMechE Part A: Journal of Power and Energy*, vol. 223, no. 8, pp. 887–902, 2009. https://doi.org/10.1243/09576509JPE782

Esteban, M., and Leary, D., Current developments and future prospects of offshore wind and ocean energy, *Applied Energy*, vol. 90, no. 1, pp. 128–136, 2012. https://doi.org/10.1016/j.apenergy.2011.05.042

Falcão, A. F. de O., Wave energy utilization: A review of the technologies, *Renewable and Sustainable Energy Reviews*, vol. 14, no. 3, pp. 899–918, 2010. https://doi.org/10.1016/j.rser.2009.11.003

Fraenkel, P. L., Tidal current technologies, *Proc. IMechE Part A: Journal of Power and Energy*, vol. 220, no. 7, pp. 653–663, 2006. https://doi.org/10.1243/09576509JPE459

Gill, A. B., Offshore renewable energy: Ecological implications of generating electricity in the coastal zone, *Journal of Applied Ecology*, vol. 42, no. 4, pp. 605–615, 2005. https://doi.org/10.1111/j.1365-2664.2005.01060.x

Global Ocean Energy Report, *Market Outlook and Investment Trends*, 2022. https://globaloceanenergyreport.org/

Inger, R., Attrill, M. J., Bearhop, S., Broderick, A. C., Grecian, W. J., Hodgson, D. J., et al., Marine renewable energy: Potential benefits to biodiversity?, *Journal of Applied Ecology*, vol. 46, no. 6, pp. 1145–1153, 2009. https://doi.org/10.1111/j.1365-2664.2009.01697.x

International Energy Agency, *Ocean Energy*, IEA, Paris, 2021. https://www.iea.org/reports/ocean-energy

International Renewable Energy Agency, *Ocean Energy: Technology Brief*, IRENA, Abu Dhabi, 2020.

International Renewable Energy Agency, *Ocean Energy Capacity Statistics 2023*, IRENA, 2023.

IEA-OES, *Annual Report 2021: Implementing Agreement on Ocean Energy Systems*, IEA, 2021. https://www.ocean-energy-systems.org

Khan, M. A., Rahman, M. M., and Islam, M. R., Assessment of tidal energy potential in Bangladesh, *Energy Reports*, vol. 6, pp. 273–281, 2020. https://doi.org/10.1016/j.egyr.2019.11.005

Kim, J., and Kim, H., Application of artificial intelligence in marine energy systems, *Renewable Energy*, vol. 182, pp. 1240–1253, 2022. https://doi.org/10.1016/j.renene.2021.10.019

Kumar, S., Vijayasankar, V., and Samad, A., Performance of a multibody point absorber with a damper plate in irregular waves, *Preprint*, 2024. https://doi.org/10.21203/rs.3.rs-5393755/v1

Leeney, R. H., O'Hagan, A. M., Sclafani, M., and Nash, S., Marine renewable energy: Potential impacts on marine mammals and seabirds, *Marine Policy*, vol. 44, pp. 260–268, 2014. https://doi.org/10.1016/j.marpol.2013.10.014

Li, Y., Wang, X., and Sun, Y., Advances in materials for marine renewable energy devices, *Materials Today Energy*, vol. 15, p. 100374, 2020. https://doi.org/10.1016/j.mtener.2019.100374

Logan, B. E., and Elimelech, M., Membrane-based processes for sustainable power generation using water, *Nature*, vol. 488, no. 7411, pp. 313–319, 2012. https://doi.org/10.1038/nature11477

Manikandan, D., Karishma, S., Kumar, M., Aiswarya, R., and Krishnaswamy, S., Salinity gradient induced blue energy generation using two-dimensional membranes, *npj 2D Materials and Applications*, vol. 8, p. 47, 2024. https://doi.org/10.1038/s41699-024-00486-5

Mero, J. L., and Rafferty, J. P., Ocean thermal energy conversion, *Encyclopedia Britannica*, Nov. 18, 2024.

Mia, M., Islam, M. A., and Islam, M., Powering offshore structure using renewable energy: A review, *SSRN*, 2021. https://doi.org/10.2139/ssrn.3807353

Nasir, U., Hasan, M. M., and Rahman, M. S., Wave energy potential in the Bay of Bengal for Bangladesh, *Ocean Engineering*, vol. 254, p. 111444, 2022. https://doi.org/10.1016/j.oceaneng.2022.111444

Neary, V. S., Gunawan, B., Previsic, M., and Lawson, M., A review of marine hydrokinetic resource characterization, *Renewable and Sustainable Energy Reviews*, vol. 29, pp. 796–813, 2014. https://doi.org/10.1016/j.rser.2013.08.014

Ocean Energy Europe, *State of the Ocean Energy Sector Report*, 2023.

O'Rourke, F., Boyle, F., and Reynolds, A., Tidal energy update 2009, *Applied Energy*, vol. 87, no. 2, pp. 398–409, 2010. https://doi.org/10.1016/j.apenergy.2009.06.041

O'Sullivan, K., and Lewis, T., Developments in marine renewable energy devices and the challenges for grid integration, *Renewable and Sustainable Energy Reviews*, vol. 75, pp. 60–73, 2017. https://doi.org/10.1016/j.rser.2016.10.045

Panwar, N. L., Kaushik, S. C., and Kothari, S., Role of renewable energy sources in environmental protection: A review, *Renewable and Sustainable Energy Reviews*, vol. 15, no. 3, pp. 1513–1524, 2011. https://doi.org/10.1016/j.rser.2010.11.037

Rahman, M. M., Chowdhury, M. A., and Islam, M. M., Policy framework for ocean renewable energy in Bangladesh: Challenges and opportunities, *Energy Policy*, vol. 140, p. 111373, 2020. https://doi.org/10.1016/j.enpol.2020.111373

REN21, *Renewables 2022 Global Status Report*, Paris, 2022.

Shah, A., Khan, I., and Qureshi, M. I., Advances in marine renewable energy: A review, *Energy Reports*, vol. 8, pp. 4663–4680, 2022. https://doi.org/10.1016/j.egyr.2022.07.009

Sharma, S., Bhattacharya, B., and Patankar, V., Corrosion-resistant materials for ocean energy devices: A review, *Journal of Materials Research and Technology*, vol. 9, no. 6, pp. 15496–15512, 2020. https://doi.org/10.1016/j.jmrt.2020.10.022

Shirasawa, K., Minami, J., and Shintake, T., Scale-model experiments for the surface wave influence on a submerged floating ocean-current turbine, *Energies*, vol. 10, no. 5, Article 702, 2017. https://doi.org/10.3390/en10050702

United Nations, *Transforming Our World: The 2030 Agenda for Sustainable Development*, United Nations, New York, 2015.

United Nations, *Sustainable Development Goals*, United Nations, 2023.

Wind Europe, *Offshore Hybrid Energy Systems*, 2020.

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