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Marine Renewable Energy: Harnessing Power from Oceans

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ABSTRACT

Marine renewable energy (MRE) offers a chance to use the world's seas' immense and untapped capacity to fulfil rising energy demand. As fossil fuels become unsustainable, MRE provides a clean, renewable option for low-carbon energy. This study discusses wave, tidal, ocean thermal, and salinity gradient MRE and their conversion methods. MRE development's environmental implications, problems, and opportunities are also covered. While technical and environmental obstacles remain, MRE technology investment and innovation might help mitigate climate change and secure a sustainable energy future, according to the report.

Keywords: Marine Renewable Energy (MRE), Wave Energy, Tidal Energy, Ocean Thermal Energy Conversion (OTEC), Salinity Gradient Energy.

INTRODUCTION

The increasing global demand for energy, driven by technological advancements and urban population growth, necessitates the exploration of alternative energy sources beyond fossil fuels. Marine renewable energy (MRE), also referred to as ocean energy, is emerging as a promising and largely untapped source of clean, sustainable energy. In addition to helping power supply, a global shift towards a low-carbon energy mix is mandated to combat climate change and ensure a stable climate for future generations. As the underwater space is recognized as the finest, most uniform, most eternal, and most available large-scale energy resource used by mankind, various marine energy resources are emerging as potential candidates for clean and renewable energy supply systems. All these fresh and crisp resources are clean and sustainable, making them the cleanest candidates for energy supply. Maritime energy systems include various technological concepts for conversion of energy resources such as waves, tides, salinity differences, deep-ocean thermal gradients, and ocean currents [1]. The ocean covers 71% of Earth's surface, with waves and tides sweeping coasts daily. In sorcerous lands, wave energy could lead to massive offshore farms, providing independent energy. Seas also have energy resources like salinity difference. Ocean energy systems include conventional dam-based systems and direct ocean energy systems. MRE systems offer clean energy for coastal countries and islands. Offshore renewable energy systems exploit wind, waves, tides, and currents. Land countries with long shorelines can convert MRE resources through various techniques, including wave, tidal, and ocean thermal energy. Ocean energy is not widely used yet due to cost-effectiveness of land-based resources [2].

BACKGROUND AND IMPORTANCE

The oceans, covering 70% of the planet's surface, are vital for climate, carbon cycle, and biology. With 94% of living biomass, they support 40% of coastal population's needs. Evidence shows unprecedented changes due to natural and human factors. These changes include warming, acidification, sea-level rise, storms, and decreased productivity. These impacts have severe consequences for societies, cities, and ecosystems. Maintaining ocean health is crucial as they provide free oxygen and biomass. The deep ocean is ideal for carbon dioxide storage. Marine energy, including wind, wave, thermal, salinity, and currents, can meet up to 40% of global energy demand and 70% of megacity requirements [3]. This essay focuses on marine renewable energy from the oceans, with a brief description of the fundamentals, importance, and perspectives. It is anticipated that the harvested marine energy would be used to sustain a possible

mode of life by utilizing the oceans, thereby relieving catastrophes on land due to climate change, population increase, resource depletion, and poverty. As the oceans also harbor abundant natural resources of metal ores, fresh water, and biofuels, humanity may need to investigate the development of habitable zero-emission coastal cities with affordable ecological engineering technologies. For the successful and sustainable development of its abundant energy, biofuel, and freshwater resources, the oceans must be maintained as a healthy environment, as protecting the atmosphere, cryosphere, biosphere, and hydrosphere essential for humanity's survival [4].

TYPES OF MARINE RENEWABLE ENERGY SOURCES

Marine renewable energy (MRE) comes from sources in the seas and oceans, including waves, tides, currents, and thermal gradients. Each resource has specific devices and technologies for harvesting, and their potential and status are summarized here. Wave energy devices (WEDs) are still in development, with about 15 concepts being researched and only a few tested at sea. Tidal current devices, similar to wind turbines, are the most advanced and can harness the energy concentrated in deeper layers of water. The largest tidal power plant in operation uses cross-flow horizontal axis turbines. OTEC's efficiency is less than 1% [5]. Ocean salinity gradient arises where fresh water from rivers mixes into salt water from the sea. This form of energy has been recognized for a long time, with the first works from researchers in the XIX century. Additionally, the use of osmotic pressure for generating energy has been proposed. Nevertheless, salinity gradient energy converter prototypes have not been built yet. The salinity gradient energy potential is not well known but is higher than that of other sources, estimated at several TW [6].

OCEAN ENERGY CONVERSION TECHNOLOGIES

Ocean energy is an abundant and inexhaustible power source derived from the Earth's oceans. It includes various renewable resources such as waves, tides, thermal energy, and currents. Wave energy, captured through advanced wave energy converters (WEC), shows great promise for generating electricity. Tidal energy, harnessed through tidal energy converters (TEC) or tidal dams, offers clean and reliable power. Ocean thermal energy conversion (OTEC) technology uses temperature differences for energy production. Embracing these technologies can revolutionize the global energy landscape, reducing reliance on fossil fuels and mitigating climate change. Investing in research and development will unlock clean energy and ensure a sustainable future [7].

WAVE ENERGY CONVERSION

Waves are generated by the wind over the ocean surface. They can be harnessed using different devices: point absorbers, oscillating water columns, and overtopping devices/breakwater systems. Point absorbers use a floating body anchored to the ocean floor to generate electrical energy. Oscillating water columns rotate like pendulums due to wave motion, using the cyclic variation in water column height to generate air flow through turbines. These devices can be built close to or far off the coastline. shoreline [8]. Overtopping Devices/Breakwater Systems: Using the energy in the incoming waves, overtopping devices pump water to a reservoir located above the normal water level. Impoundment wave energy technology designed using overtopping technology works by allowing waves to run-up, creating an impoundment above the still water level. The water flows into the reservoir built above the water level, leading to a decrease in wave energy. Each overtopping reservoir system operates individually, is relatively noiseless, and acts as a breakwater. Ocean wave energy could also be harnessed by building a breakwater system [9].

TIDAL ENERGY CONVERSION: OVERVIEW AND TECHNOLOGIES

The sea level, influenced by the gravitational force of the sun and the moon, varies throughout the day. Most sea level variations are due to the moon's gravitational effect, which is approximately 6-12 inches a day, depending on the location. Additionally, the force of gravity (the height of the water's fall) and the type of wave-generated energy provided by the ebb and flow of water correspond to the amount of energy that can be generated from tidal energy. Consequently, the energy provided by the gravitational attraction that forms the oceanic tides is an endless resource, now offering power possibilities to Earth in the form of electricity and other forms. While tidal energy is not available in all countries, it can be provided in many countries worldwide, but tidal reverse, such as the reverse that hydro resources have [10]. The first sea energy plants, operating for many years, are the energy-generating stations of the tide. In many countries such as France, Canada, China, the United Kingdom, Germany, and Russia, a solid base for offshore energy technology has already been established. A few oceanographers have monitored the tides, worked on their tides, studied the conversion of ocean tides, and today investigate potential tidal sites, analyze potential infrastructure construction projects, suggest suitable sites for resource assessment, environmental impacts, and associated issues, and develop appropriate technologies and build tidal power plants. The majority of these studies concentrate on the location of tidal energy, device output estimation, strategic feasibility evaluation, and preliminary environmental evaluation [11].

OCEAN THERMAL ENERGY CONVERSION

Ocean Thermal Energy Conversion (OTEC) is a renewable energy system that utilizes the sun-heated surface water and cold deep water of the ocean to generate electricity. Development of OTEC systems began in the late 1800s and continued after World War II. However, as of 2021, no OTEC plants are currently operational. OTEC can use an open, closed, or hybrid cycle. The open cycle involves vaporizing warm seawater using low pressure to extract energy, which is then used to spin a turbine. The condensed vapor is returned to the surface as seawater, with fresh water being produced as a byproduct. In a closed cycle system, a low boiling point liquid, such as ammonia, is vaporized by warm surface seawater and condensed as it returns to the cold depths. A hybrid system combines elements from both systems. Other ocean technologies include temperature difference energy conversion and salinity gradient energy systems [12].

ENVIRONMENTAL IMPACTS AND SUSTAINABILITY

Marine renewable energy (MRE) uses ocean resources for renewable energy production. Wave and tide energy have potential in Europe due to their geographic benefits. However, development for these energy types is still in early stages. The technology for energy converters needs to be implemented and tested. Environmental impact is a concern and legislation promote sustainable options. There are questions about marine habitats and pollution. Little is known about how MRE affects marine life. Research is mainly focused on technological development, not environmental impact. The goal is to outline the environmental impacts of MRE and draw attention to the subject, which is currently under-researched [13].

CHALLENGES AND FUTURE PROSPECTS

Emerging from the initial phases of advanced development, the marine renewable energy sector is now witnessing an upsurge in the construction and installation of commercial energy generation projects utilizing various marine renewable energy technologies, spurring increased interest and activities worldwide. Considered one of the most abundant renewable energy resources, marine renewable energy has the potential to play a vital role in reducing humankind's reliance on fossil fuel-based energy generation and addressing climate change concerns. However, there are many challenges before marine renewable energy systems can be successfully deployed and utilized on a large scale [14]. Despite its abundant and renewable nature, the oceans pose substantial technical barriers in terms of energy collection, transmission, deployment, and accessibility. Considered a front-runner for offshore wind development, the rapidly advancing offshore wind sector can provide a stepping stone for developing more immature marine renewable energy technologies. Marine renewable energy is relatively mature around the US east coast, the UK, and the North Sea, while the Canadian east coast is in its infancy. The exceptions lie in the Mediterranean for offshore wind and the Pacific Northwest for wave energy, which although relatively mature, have yet to progress from pilot scale to commercial viability and large development [15]. Recent advancements in the marine renewable energy sector show promise in addressing some of the challenges to further commercialization. Continued efforts are needed to address the challenges so energy generation from marine renewable resource can be utilized on a large scale. Thanks to the contribution of numerous researchers, supporters, and stakeholders, this sector is expected to pick up steam and become a prominent contributor to the world's energy generation in the coming years [16].

CONCLUSION

Marine renewable energy (MRE) holds tremendous potential as a sustainable solution to the global energy crisis, offering a vast and consistent source of power from the world's oceans. The technologies required to harness wave, tidal, ocean thermal, and salinity gradient energies are progressing rapidly, yet they still face significant challenges, including high costs, environmental impacts, and technical barriers. However, with continued research, development, and investment, these challenges can be overcome, paving the way for MRE to play a central role in the global energy mix. As the world moves towards a low-carbon future, MRE can contribute significantly to reducing our reliance on fossil fuels and combating climate change, ensuring a stable and sustainable energy supply for generations to come.

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