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Energizing Indonesia: Enhancing National Energy Security through Ocean Wave Power Plant Renewable Energy Policies

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Abstract

The objective of this study is to assess the effectiveness of renewable energy policies, specifically focusing on Sea Wave Power Plants, in enhancing national energy security. The employed study methodology entails legal research, namely utilising a statutory approach or reviewing policy regulations about the issue of illegal fishing in Indonesia. The study findings indicate that the current renewable energy strategy needs to effectively incentivise the Sea Wave Power Plant concerning the broader objective of national energy security. Indonesia is a nation characterised by a significant disparity in land and sea area, with the latter being three times more than the former. According to data from the Indonesian Ocean Energy Association, the expansive oceanic environment possesses numerous prospects, including the possibility of abundant fish resources, tourism, and alternative energy sources. Theoretically, the aggregate national marine energy resources exhibit significant abundance, encompassing various sources such as sea heat, ocean waves, and ocean currents, with a total estimated capacity of 727,000 MW. The current technological advancements in marine energy have opened up possibilities for practical utilisation, with a theoretical capacity of up to 49,000 MW. Within vast possibilities, the marine energy sector has considerable

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readiness, particularly in wave technology and tidal flow technology. These two branches hold significant promise, boasting a practical capacity of 6,000 MW.

Keywords: Renewable Energy, Tidal Wave Power Plants, National Energy.

Introduction

The tide, a fascinating natural phenomenon, plays a significant part in determining the appearance of the coastlines of our world. It is a process that is driven by the gravitational interactions that occur between the Earth, Sun, and Moon. These interactions cause the sea level to rise and fall regularly. This cyclical pattern affects the coastlines of the entire planet, causing there to be two high tides and two low tides every 24 hours (Jones & Barker, 2011).

The sea level rises during high tide, typically resulting in the beach's surface being completely covered in seawater (Hoover et al., 2017). On the other hand, low tide indicates a decrease in the level of the water, which causes the coastline to grow longer since it is exposed. These shifts in the tides have significant repercussions for the marine ecosystems and the communities that live along the coast (Griggs & Reguero, 2021).

With tides that may reach heights of up to 13.5 metres, one of the most significant tidal variations on Earth can be found in Baie du Mont-Saint-Michel, which is located in the country of France. Similarly, the Severn Estuary in northern England can have tides as high as 15 metres. At the same time, the Bay of Fundy in Canada is home to the world's most extraordinary tides, which can reach up to an incredible 16 metres. You can find videos demonstrating the astonishing and extremely beautiful natural phenomenon that is the tides in the Bay of Fundy by searching on websites such as YouTube. These videos depict the bay's magnificent tides.

It is interesting to note that the Indonesian island of Larantuka also has high tides, which have the potential to produce a significant amount of electrical energy. These tides are predicted to generate up to 300 Megawatts (MW) of power, which, while impressive, will not set any new world records. On the other hand, it is anticipated that the projected project will only result in installing 18-23 MW of power capacity, necessitating an initial investment of around 200 million USD or 3 trillion Rupiah (Quirapas et al., 2015).

Moving on from tides to waves, it is essential to point out that waves, when referred to in this context, relate to the oscillations of air above the water's surface. Several reasons, including wind, conditions at sea, and variations in the salinity of the air, bring about these motions. Waves, in contrast to tides, are rarely predictable, move at a snail's pace, and exhibit unpredictable patterns, which makes them an undesirable source of energy. Even while they can be awe-inspiring, there are more viable options for electricity generation than these natural phenomena.

Oceans cover nearly 71% of the surface of our world, which makes them a great source of energy (Brinkmann, 2021). Our planet is truly blessed with this feature. Significant amounts of kinetic energy are produced by various dimensions of movement that may be found within these enormous quantities of water. These range from large-scale ocean currents to turbulent eddies. It is essential, as Kang and Fringer pointed out in 2012, to have an in-depth understanding of the physical mechanisms that underlie water movement in order to harness marine energy effectively.

When viewed in this light, tides stand out as one of the key sources of energy that contribute to the mixing that occurs in the water. They can generate energy that is both renewable and sustainable while also reducing their negative influence on the environment. The potential to meet our expanding energy demands while also contributing to preserving our natural resources is a compelling argument in favour of developing technologies that can harness the power of tides.

Material and Method

This study encompassed a comprehensive analysis of rules and regulations about tidal energy as a viable alternative for power generation. The study involved a limited examination of many tidal energy plants in different geographical areas. The research employed the ROCCIPI technique, an acronym for Rule, Opportunity, Capacity, Communication, Interest, and Ideology, as its chosen approach. The present methodology has been developed to conduct a comprehensive evaluation of the diverse facets and variables associated with the uptake and execution of tidal energy.

A thorough comprehension of the subject matter was achieved by implementing the ROCCIPI analysis, which encompasses the examination of Rule, Opportunity, Capacity, Communication, Interest, and Ideology. The research encompassed an exploration of the regulatory framework (Rule) that governs tidal energy, an identification of the opportunities and potential for development within this domain, an assessment of the capacity of different regions to harness tidal energy, an examination of the communication channels and strategies employed to promote tidal energy, an understanding of the interest (Interest) held by various stakeholders, and an evaluation of the underlying ideologies (Ideology) that influence the utilisation of tidal energy.

Following this, the data acquired by the ROCCIPI study were subjected to a synthesis analysis. The synthesis analysis encompassed diverse analytical tools and methodologies to extract valuable insights from the study objectives. The objective of this study phase was to integrate the results obtained from the ROCCIPI analysis and provide a comprehensive and knowledgeable viewpoint on the topic.

The synthesis analysis incorporated various analytical techniques and instruments, including statistical analysis, qualitative data analysis, and comparison analysis. Various methodologies were utilised to examine the data from diverse perspectives and produce a comprehensive analysis of the legislation and regulations about tidal energy and its potential as a sustainable energy option. The primary aim of this study was to offer a comprehensive evaluation that might effectively guide policymakers and those with vested interests in the energy policy domain.

Results and Discussion

1. National New Energy Utilization Policy

Comprehending renewable energy is crucial in the pursuit of a sustainable future (Dincer, 2000). Renewable energy pertains to the energy derived from sources with the inherent capacity for natural replenishment within a given timeframe. The sources in question are widely regarded as being nearly inexhaustible due to their ability to renew at a relatively rapid pace, thereby guaranteeing their perpetual availability. The dedication to sustainable energy in Indonesia is legally established in Law Number 30 of the Year on Energy. The legal document in question, specifically Article 1, Paragraph 6, provides a clear delineation of the concept of renewable energy, defining it as energy derived from sustainable resources that are effectively managed. The energy sources mentioned earlier sources encompass geothermal, wind, bioenergy, solar radiation, and hydroelectricity derived from flowing water and waterfalls, as well as the harnessing of oceanic layer movements and temperature disparities, with a specific focus on their application within the power industry (Yudha et al., 2021).

Renewable energy sources offer substantial environmental advantages (Owusu & Asumadu-Sarkodie, 2016). The intrinsic eco-friendliness of these entities stems from their lack of contribution to environmental pollution, as well as their non-involvement in the processes that lead to climate change and global warming. This phenomenon might be attributed to the fact that the energy they generate is obtained from natural and sustainable processes. Let us now explore in greater depth the diverse array of renewable energy sources that have been previously described.

Geothermal energy is derived from harnessing the Earth's internal heat. Indonesia, due to its abundant active volcanic activity and significant geothermal resources, possesses favourable conditions for the utilisation of this particular type of sustainable energy.

The utilisation of wind turbines derives wind energy. The extensive coastline and archipelago of Indonesia render it an optimal site for the development of wind energy.

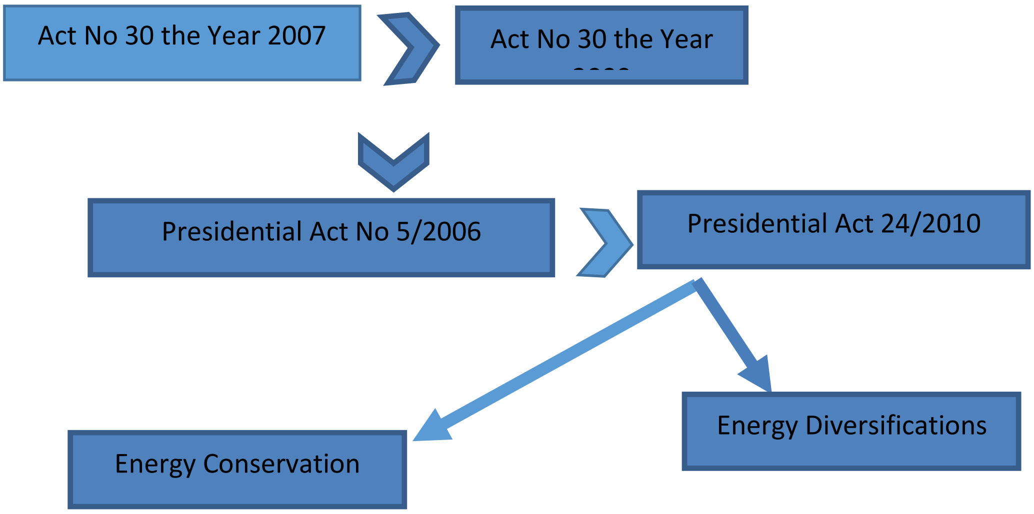
Bioenergy refers to the energy that is obtained from organic matter, including but not limited to crops, wood, and agricultural waste. In Indonesia, diverse sources, such as palm oil waste and other agricultural byproducts, can be utilised to obtain this.

Solar energy is acquired by capturing the radiant energy emitted by the sun using photovoltaic cells. The geographical positioning of Indonesia near the equator results in a substantial amount of solar radiation, rendering it a highly suitable region for the generation of solar energy (Susanto et al., 2022).

Hydropower, often known as hydroelectric power, is derived from the kinetic energy of flowing water or the potential energy harnessed from waterfalls. Indonesia possesses considerable hydropower potential due to its many rivers and water resources (Rospriandana et al., 2023).

The extraction of energy from the movement and temperature disparities present in different strata of the ocean is also feasible. The technology, as mentioned earlier, is now in its nascent stage of development, although it has significant promise within a nation such as Indonesia, which possesses large coasts (Rissman et al., 2020).

Integrating renewable energy sources is a pivotal element in establishing an enduring and environmentally responsible energy portfolio (Farghali et al., 2023). Using renewable energy sources decreases reliance on limited fossil fuel resources and mitigates adverse climate change impacts. Using renewable energy sources not only contributes to promoting a more environmentally sustainable and healthier ecosystem but also enhances energy security through the diversification of the energy portfolio. Indonesia's dedication to renewable energy, as delineated in its energy strategy, represents a noteworthy stride in attaining a more environmentally friendly and enduring future for the country. Using renewable energy sources not only yields positive environmental outcomes but also fosters economic growth, encourages innovation, and generates employment possibilities within the renewable energy industry.



Thus, the government encourages renewable energy utilization policies through a variety of regulations to encourage the use of renewable energy.

2. Renewable Energy Potential in Indonesia

Indonesia, as a nation, possesses significant potential for harnessing renewable energy sources on a large scale, owing to the substantial astrological and geographical factors that influence the country. Indonesia has various potential renewable energy sources, including geothermal energy, solar power, hydropower, marine energy, and biofuels. Indonesia is situated near the equator, resulting in a tropical climate with predominantly sunny conditions over most areas (Bilgen et al., 2010; Nugroho & Fei-lu, 2017; Praharyawan, 2016).

Based on solar radiation data in Indonesia, it is observed that the distribution of solar radiation in the western and eastern regions of the country is approximately 4.5 kWh/m2.day and 5.1 kWh/m2. day, respectively. The western region exhibits a monthly variation of approximately 10%, while the eastern region experiences a monthly variation of around 9%. Consequently, the overall potential for solar radiation in Indonesia is estimated to be approximately 4.8 kWh/m2.day, with a monthly variation of approximately 9%.

Indonesia, as a nation situated within volcanic regions, possesses significant geothermal potential (Pambudi, 2018). The presence of the Ring of Fire, a volcanic belt spanning throughout Indonesia from Sumatra Island to the Banda Islands, Halmahera, and Sulawesi, can be attributed to the country's geological characteristics. According to the survey findings, it has been determined that there exists a total of 70 geothermal sites characterised by high-temperature conditions.

These sites collectively possess a combined capacity of 19,658 megawatts (MW). The majority of these areas have yet to undergo extensive exploitation.

Moreover, Indonesia exhibits significant potential for the establishment and advancement of hydroelectric power facilities due to the presence of ample sources of hydropower energy within its borders (Langer et al., 2021). The presence of potential water energy in Indonesia can be attributed to its rugged and hilly landscape, as well as the abundance of rivers and lakes/reservoirs in specific locations. Indonesia, a nation with a strong focus on agriculture, possesses a considerable capacity for biomass generation derived from various sources such as agricultural activities, plantations, forests, livestock, and municipal trash (Gani et al., 2023).

Indonesia is commonly classified as a country with limited wind resources, as it typically experiences low wind speeds. Wind speeds below 4m/s are generally not economically viable for developing wind energy services (Silalahi et al., 2021). However, certain regions in Indonesia exhibit promising possibilities for harnessing wind energy as a renewable power source. The regions mentioned earlier encompass East Nusa Tenggara (NTT), West Nusa Tenggara (NTB), South and Southeast Sulawesi, and the North and South Coasts of Java. Indonesia possesses significant ocean energy potential due to its archipelagic nature, characterised by a greater expanse of the sea than land. Indonesia's maritime expanse encompasses around 65% of its land area, 3,544,743.9 square kilometres. This vast maritime territory is characterised by an extensive coastline spanning 81,000 kilometres, encompassing both deep-sea and shallow-water regions. Upon seeing the expansive expanse of the sea and ocean within the geographical boundaries of Indonesia, it is plausible to infer that the country possesses potential marine resources for harnessing various forms of oceanic energy, such as ocean thermal energy, tidal energy, wave energy, and ocean current energy, which can be utilised for the generation of electrical power.

3. Wave Energy as a National Energy Security

Indonesia, a Southeast Asian archipelago, possesses a distinctive and advantageous geographical position. The geographical location of the subject under discussion is characterised by its proximity to two expansive bodies of water, namely the Indian Ocean, situated to the west and the Pacific Ocean, located to the east. The geographical location of this region at the equator gives rise to a notable interaction of natural phenomena, resulting in notable tidal patterns, robust winds, substantial waves, and vigorous ocean currents across its vast expanse (Prasodjo et al., 2016; Sumotarto, 2003).

The geographical diversity of Indonesia is a subject of great admiration since it presents significant opportunities for harnessing abundant energy resources, specifically in the domain of tidal energy. The utilisation of this sustainable energy source holds the capacity to significantly transform Indonesia's energy framework and make a substantial contribution towards attaining a sustainable future. This study aims to investigate the distinctive attributes and unexplored possibilities of tidal energy in Indonesia, with a specific emphasis on the seas of Cilacap Regency located in the Central Java Province.

The expansive waterways of Indonesia possess significant untapped potential for tidal energy generation. The disparity in tidal conditions across various geographical areas is a subject of great interest. The tidal range in the seas of Tanjung Priok in Jakarta is estimated to be around 1 metre; however, in Ambon, the tidal range is seen to be approximately 2 metres. The Bagan Siapi-api region exhibits significant potential, as tides in this area can reach almost 4 metres in height. Nevertheless, the most significant tidal range can be observed in the isolated areas of the Digul River and the Muli Strait in Papua, where tides reach an astonishing magnitude of 7 to 8 metres (Dahuri & Dutton, 2000).

The escalating global population and rapid industrialisation have led to a significant increase in energy demands, resulting in a heavy dependence on traditional energy sources. The sources mentioned earlier, such as petroleum, possess the characteristic of being non-renewable and having a finite supply. According to Azhar, Solechan, Saraswati, and Suharso (2018), the persistent utilisation of these resources not only gives rise to a crisis in energy scarcity but also intensifies environmental concerns due to pollution and depletion.

Given the limitations mentioned earlier, tidal energy is a viable alternative. Using kinetic energy in the motion of water enables it to serve as a sustainable and ecologically sound energy source. In contrast to traditional forms of energy, tidal energy does not have a detrimental impact on the environment, as it does not contribute to pollution. Furthermore, the supply of tidal energy is not susceptible to depletion.

Multiple research studies have underscored the importance of tidal energy as a viable and environmentally friendly substitute for traditional energy sources. The promise of this technology has been acknowledged by researchers and specialists in the field, who have advocated for its further development. Several researchers have significantly contributed to the expanding knowledge of tidal energy in Indonesia. Notably, Alifdini, Widodo, Sugianto, and Andrawina (2016), Handoyo and Suryoputro (2015), Surinati (2007), and Zainuddin and Ervianto (2016) have all played a role in this field of study.

The seas of Cilacap Regency, located in the southern section of Java Island, exhibit significant potential for tidal energy generation. The seas in question are subject to direct influence from the Indian Ocean, rendering them a highly suitable site for the utilisation of tidal energy.

The seas of Cilacap Regency exhibit significant potential for tidal energy generation, particularly in height. The harnessing of energy is feasible during both high and low tides, rendering it a versatile and adaptable source. The heightened potential of tidal energy in this location is attributed to breakwaters or artificial beach morphologies. Stations equipped with breakwaters, such as station 1, exhibit increased water flow during high tide, rendering them a favourable site for the generation of tidal energy.

The potential of tidal energy exhibits temporal variability over a year. The phenomenon strongly correlates with lunar and solar cycles, specifically concerning the various lunar phases. The lunar position is a crucial factor in ascertaining the accessibility of tidal energy. The study of seasonal variation plays a crucial role in the planning of tidal energy installations.

The variety in tidal behaviour throughout the south coast of Java has been emphasised in studies, such as the one conducted by Setyawan in 2008. A comprehensive comprehension of these patterns is important in order to effectively optimise the production of tidal energy in locations such as Cilacap Regency.

In order to enhance understanding of the possibilities of tidal energy in the waters of Cilacap Regency, simulations have been utilised. The simulations encompass the establishment of tidal pools with diverse surface areas. The findings indicate that an area measuring 1.1 square kilometres has the potential to achieve a noteworthy annual energy conversion of 61,161 kilowatt-hours (kWh). This observation suggests that the dimensions of the tidal pool and the length of production activities play crucial roles in optimising energy generation.

Conclusions

The current state of renewable energy policy in Indonesia has yet to fully realise its potential in effectively encouraging the utilisation of Sea Wave Power Plants to enhance national energy security. Indonesia is a country renowned for its extensive archipelago, with a maritime territory that exceeds its land area by a factor of three. The vast oceanic expanse presents many opportunities, including plentiful fish stocks, attractive tourist destinations, and potential for harnessing alternative energy. The untapped potential of maritime resources is highlighted by data provided by the Indonesian Ocean Energy Association.

The maritime energy resources of Indonesia are theoretically abundant, comprising a diverse range of energy sources, including sea heat, ocean waves, and ocean currents. These resources possess a combined potential capacity of 727,000 MW. Currently, the practical implementation of harnessing this potential energy has achieved an approximate capacity of 49,000 MW. Among the numerous possibilities in marine energy technologies, two categories are highly suitable for further development: wave technology-based companies and tidal flow technology-based industries. These technologies have a practical capacity of 6,000 MW, highlighting their substantial contribution to Indonesia's renewable energy sector.

The potential of using sea waves for renewable energy in Indonesia is highly promising. Sea wave power plants utilise the kinetic energy derived from the motion of ocean waves in order to generate electrical power. The method, as mentioned earlier, of energy production possesses several notable benefits, such as its inherent dependability, ability to be forecasted, and limited ecological footprint. Moreover, considering Indonesia's distinctive geographical location, it is highly suitable for exploiting this energy resource.

The establishment of a comprehensive and effective renewable energy policy is a crucial obstacle to overcome in order to harness the potential of Sea Wave Power Plants fully. The government must establish a regulatory framework conducive to investment in marine energy technology and infrastructure, providing incentives for such endeavours. This includes the provision of financial incentives, the optimisation of permitting procedures, and the facilitation of long-term energy purchase agreements. These regulations can appeal to both domestic and foreign investors, aiding the advancement of wave and tidal flow technology.
Research and development constitute a pivotal element in the progression of marine energy technology in Indonesia. The establishment of partnerships among governmental entities, private enterprises, and academic institutions is vital in order to foster and propel innovation within this particular domain. Research endeavours should prioritise the augmentation of the efficacy and economic viability of sea wave and tidal flow technology.

Furthermore, it is crucial to consider the environmental ramifications associated with marine energy initiatives. It is imperative to establish comprehensive environmental evaluations and implement appropriate mitigation strategies to save the vulnerable marine ecosystems present in the waters of Indonesia.

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