

VARIABILITY BETWEEN WIND AND SEA WAVES BASED ON ENVIRONMENTALLY FRIENDLY AS RENEWABLE ENERGY IN PARIAMAN CITY

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Abstract: The coastal waters of Pariaman City, directly linked to the Indian Ocean, hold a significant potential for harnessing energy from wind and sea waves. This study aims to identify an eco-friendly alternative energy source derived from wind and sea waves to reduce reliance on traditional fossil fuels such as oil and coal. The wind and sea wave patterns in this area exhibit considerable promise with wind speeds ranging from 0.2 to 11.5 m/s. Additionally, the sea wave heights are notable, particularly in October, where they range from 0.65 to 1.7 m annually. These natural features can be leveraged to generate electrical energy through wind and ocean wave power plants. The substantial renewable energy potential, largely influenced by recurring cycles such as monsoons, offers a bright future for energy sustainability in Pariaman City.

Keywords: Wind, sea waves, environmentally friendly, renewable energy, Pariaman.

Introduction

Being an archipelago country has challenges, especially in coastal and marine management. One of the challenges is fulfilling renewable energy sources considering that the geographical area in Indonesia has the second longest coastline in the world. This potential can be utilised to answer the challenges of energy needs to support national development. Until 2009, the majority of electricity required in Indonesia was still supplied by fossil fuel power plants. Petroleum still occupies the highest ranking, namely 51.66%. Natural gas occupies the second level, namely 28.57%, the remainder is supplied by oil energy at 15.34%, and renewable energy at 4.43% (Hasan *et al.*, 2012; Alhamid *et al.*, 2016).

Dependence on energy consumption based on fossil fuels and the underutilisation of new renewable energy sources is one of the areas for improvement in implementing equal distribution of energy policies (Candra *et al.*, 2023). The basis for marine energy

development is provided in Law No. 30/2007 concerning “Energy” and Law No. 17/2007 concerning “National Long-Term Development Plan” (Wardhani *et al.*, 2023).

One of the renewable energy resources that can be utilised comes from the sea. The sea stores usable energy such as waves, wind, currents, and tides. Wave and wind energy dynamics originate from different pressures between atmospheric layers and energy is transferred from the wind to the waves (Borthwick, 2016; Babari, 2017). The energy transferred depends on the speed of the wind, the length of time the wind blows, and the distance (fetch). In the process, the level of solar power with a power of around 100 W/m² is converted into waves with a power level of more than 1,000 kW/m (Thorpe, 1999; Goswami & Deshmukh, 2018). Predicting the power that can be generated on the coast is done by using wind data (Febriandi *et al.*, 2019). Wind blowing on the sea surface is the main factor causing sea waves. The wind that

blows over the surface of the water will transfer its energy to the water. The longer and stronger the wind blows, the bigger the waves that form (Livanov, 2023). According to Sverdrup, Munk, and Bretchnneider (SMB) theory, the minimum wind speed that can generate waves is around 10 knots or the equivalent of 5 m/s. The conversion of wave height and period involves the use of the wave equation for shallow water (Kotaška et al., 2024).

Pariaman City is one of the cities in West Sumatra Province with small islands, namely Ujung Island, Tengah Island, Angso Island, Kasik Island, and Gosong Sibarat Island. The total land area is 79.22 km² and the seawaters are 282.69 km² while the coastline is 12.7 km long (Putra et al., 2023). Within this area is a rich biodiversity ecosystem, including coral reefs, mangroves, seagrass, estuaries, and lagoons. Apart from that, Pariaman City is also a landing place and nesting habitat for several type of turtles (Putra et al., 2023) and is a seawater that directly faces the Indian Ocean with wave and wind characteristics that fluctuate throughout the year. This region is one of the areas with high wind wave strength, which is an implication of the Australian and Asian continents (monsoon) and borders the ocean. These wind and wave shifts fluctuate with the seasons which last about three months. For this reason, this research is an initial analysis to suggest that the seawaters of Pariaman City are suitable to be used as a case study area for the development of renewable energy originating from wind and waves in energy supply as a substitute for oil and coal.

The research “Variability between Wind and Sea Waves based on Environmentally Friendly as Renewable Energy in Pariaman City” offers important contributions in two main aspects: (1) Measurement of Wind and Sea Wave Variability: This research provides a deeper understanding of the patterns and characteristics of wind and waves sea in the Pariaman City area. By measuring wind speed and sea wave height in detail, this research provides invaluable information about the variability of natural

resources that can be utilised as a source of renewable energy; and (2) Renewable Energy Potential: This research highlights the great potential that Pariaman City has in producing renewable energy through wind power plants and ocean wave power plants. This research provides a strong foundation for developing renewable energy infrastructure in the region by utilising data on wind speed and sea wave height.

This research also emphasises the importance of an environmentally friendly approach to utilise natural resources to produce energy. By focusing on renewable energy, Pariaman City can minimise negative impacts on the environment while still meeting the community’s energy needs. Thus, this research provides new insight into the potential of renewable energy in Pariaman City and encourages the development of environmentally friendly and sustainable energy solutions.

Methods

In this research, Pariaman City as the research location was determined based on an area of 110.31 km² or 11,031 ha for the ocean. Where spatially, the seawaters of Pariaman City are a functional area that includes waters, beaches, and land. More details can be seen in the following maps in Figure 1.

The data used in this research is secondary data obtained from central and regional government agencies. Secondary data collected included: Oceanographic data from wind and sea waves while primary data was obtained from field surveys carried out on the seawaters of Pariaman City.

The secondary data analysed is the average wind and wave speed based on the season. Where wave height data was obtained from the website of the European Center for Medium-range Weather Forecasts (ECMWF) and wind data was obtained from Automatic Weather Station (AWS) recording equipment from Meteorological, Climatological, and

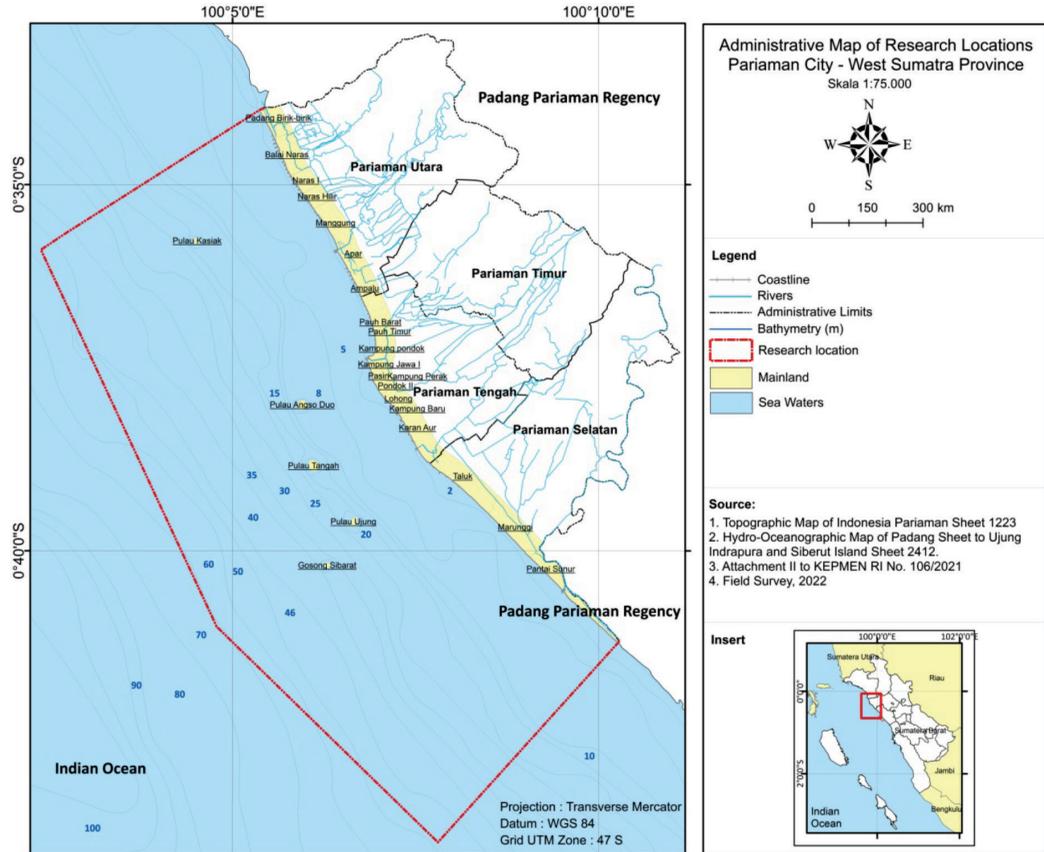


Figure 1: Map of research locations on the seawaters of Pariaman City

Geophysical Agency (BMKG), Kepala Hilalang Climatology Station. The data is then converted to determine whether or not the study area is suitable for potential alternative energy sources. This depends on existing technology but currently, the wind speed that can be used is at least 1 m/s, this value is also used to generate waves. Furthermore, the utilisation of ocean energy from waves is calculated based on the amount of electrical power produced using the following equation (Hulls) (Chen *et al.*, 2018).

$$P = \frac{\tilde{n}g}{64\delta} H T$$

With provisions = 1,030kg/m³; g = 9.81 m/s; π of 3.14; P is the electrical power produced (Watt/m); H is the wave height (m); and T is the period of the two wave peaks.

Results

Analysis Result of Wind Data

The results obtained from the AWS recording at BMKG, Kepala Hilalang Climatology Station in October 2022 show that most of the wind is towards the west (32.5%), east (17.36%), southwest (13.47%), and with a dominant wind direction (resultant vector) of 244° which is in the direction between west and southwest. More details can be seen in Figure 2 below.

The wind speed in October 2022 is 0.2 to 11.5 m/sec, based on the Beaufort scale (Huler, 2007), meaning that the wind speed is light and light. Significant wind speed (storm) occurred on 3rd October 2022 at 07:22:13 with a speed of 17.3 m/sec and direction to the north-east, and on 27th October 2022 at

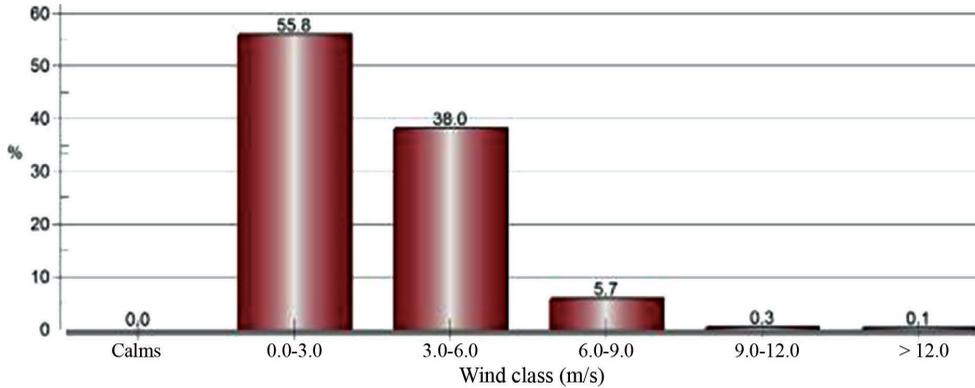


Figure 2: Diagram of wind speed distribution in October 2022

10:42:13 until 28th October 2022 at 00:12:13 with a speed reaching 24.7 to 30.8 m/sec (storm) and a direction heading north. More detailed information regarding wind speed and direction using wind rose can be seen in Table 1 and Figure 3.

Wind variability which is environmentally friendly at Pariaman City can be a potential resource for renewable energy, especially if utilised wisely. The following discussion will cover two significant events in wind speed variability on the seawaters of Pariaman City as follows:

- Occurrence on 3rd October 2022 at 07:22:13, wind speed: 17.3 m/sec and wind direction: North-east. On that date, there was significant wind speed in a direction towards the north-east. Analysis of this incident may include: (1) Renewable energy potential: High enough wind speeds can provide the potential for Wind Power Generation (WPG). Utilising wind energy at this speed can be a renewable and environmentally friendly resource (Azam *et al.*, 2021) and (2) infrastructure development: The sustainability of infrastructure development

Table 1: Classes of wind speed according to the Beaufort scale

Scale	Tiers	Speed (knots)	Speed (m/s)	Speed (km/h)
0	Calms	< 1	0-0.2	< 1
1	Shady	1-3	0.3-1.5	1-5
2	Weak breeze	4-6	1.6-3.3	6-11
3	Soft breeze	7-10	3.4-5.4	12-19
4	Medium breeze	11-16	5.5-7.9	20-28
5	Fresh breeze	17-21	8-10.7	29-38
6	Strong spot	22-27	10.8-13.8	39-49
7	The wind is weak	28-33	13.9-17.1	50-61
8	Windstorm	34-40	17.2-20.7	62-74
9	Strong gale	41-47	20.8-24.4	75-88
10	Storm	48.55-55	24.5-28.4	89-102
11	Storm rages	56-63	28.5-32.6	103-117
12	Typhoon	> 63	> 32.6	> 117

Source: (Huler, 2007)

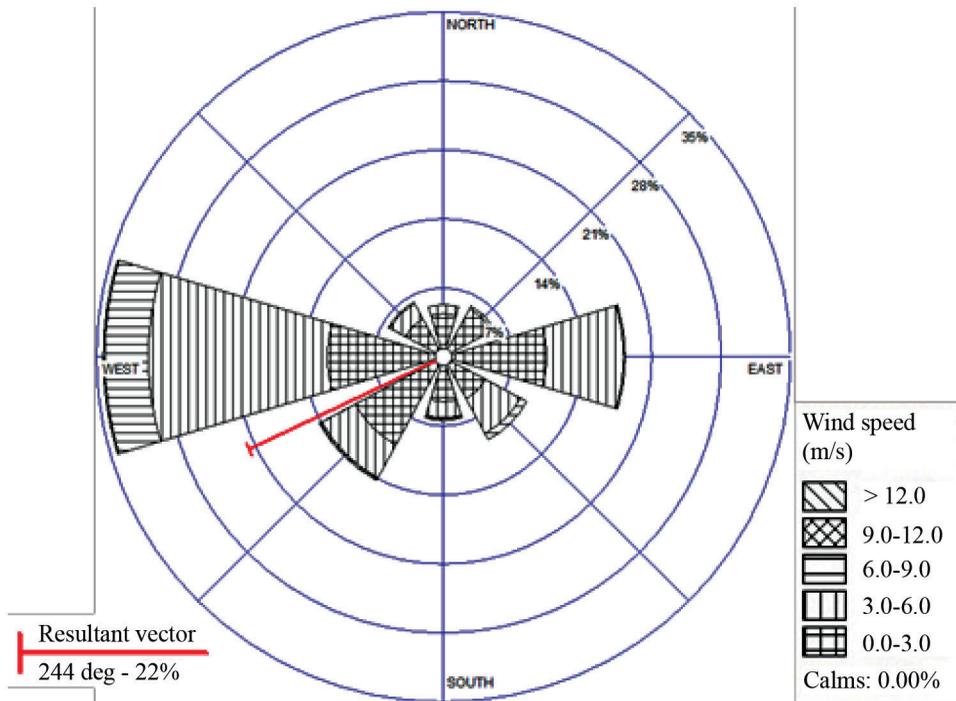


Figure 3: Results of wind rose in October 2022

that supports using renewable energy such as wind turbines, needs to be considered. This may include placing turbines in strategic locations based on wind patterns on that date (Yu *et al.*, 2023).

- Occurrence on 27th October 2022 from 10:42:13 to 28th October 2022 at 00:12:13, wind speed range: 24.7-30.8 m/sec (storm) and wind direction: North. During this period, a storm occurred with high wind speeds and a direction towards the north. Analysis of this incident may include: (1) Security challenges: High wind speeds and storm events can pose security challenges. There is a need to plan and mitigate risks related to infrastructure that can be adversely affected by extreme weather conditions (Liu *et al.*, 2024). (2) Emergency energy potential: Although high wind conditions can pose challenges, this situation can also be utilised for emergency energy. Emergency power plants or energy storage systems can be mobilised to address potential power outages due to extreme weather conditions (Li *et al.*,

2020). (3) Monitoring system: An effective weather monitoring system is needed to obtain real-time information about wind and weather conditions (Dip *et al.*, 2023). This can help make quick decisions regarding managing renewable energy resources and public safety.

The wind variability recorded in Pariaman City shows great potential for utilising renewable energy. However, while exploiting this potential, there is a need for careful planning, effective weather monitoring, and safety measures to ensure the use of wind energy is sustainable and safe for the environment and society.

Analysis Results of Ocean Wave Data

The sea waves that occur are in the form of significant wave heights, according to the ECMWF website. The waves that occurred in the sea waters of Pariaman City in January to October 2022 had a wave height of 0.42 to 1.7 m. Quite large wave heights occurred in October 2022 with a value of 0.65 to 1.7 m, especially on 9th to 11th October 2022 with 1.5 to 1.7 m wave

heights. However, this fairly large sea wave event is not influenced by wind factors on land recorded on the ECMWF website. More details can be seen in Figure 4.

This result can be strengthened from the wind data values when large waves occur, the wind on land is still low (breeze) to medium. This can happen because the significant wave height measured is in the open sea, while the wind measured is still close to the coast which can only generate waves in the seawaters of Pariaman City.

The environmentally friendly variability of sea waves in Pariaman City is an important topic to consider in the context of renewable energy. Ocean waves have great potential as a renewable energy source because they can be converted into electricity through wave generator technology.

The following is some discussion regarding the variability of sea waves in the seawaters of Pariaman City, described as follows:

- Renewable energy potential: Wave height varies between 0.42 to 1.7 m, with a peak height in October, indicating great potential for utilising wave energy as a renewable resource in Pariaman City. Using wave energy can help reduce dependence on fossil energy sources and reduce negative environmental impacts (Hamdani et al., 2023).
- Seasonal variability: Significant wave heights in October, particularly on 9th to 11th October 2022, indicate seasonal variability in ocean wave patterns in the region. A deeper

understanding of this seasonal variability can help plan and manage wave energy resources (Candra et al., 2023).

- Limitation of wind factors on land: The fact that this large wave event is not influenced by wind factors on land indicates that sea waves in Pariaman City can be considered a more stable energy source. This makes developing and operating wave-generating installations easier without being too dependent on wind conditions on land (Ghosh, 2023).
- The importance of monitoring and forecasting: With the recorded wave variability, it is important to have an accurate wave monitoring and forecasting system. This helps in the operational planning of wave generators and ensures optimal utilisation of wave energy resources (Candra et al., 2023).
- Environmental impact: Renewable energy development must still consider environmental effects (Wagianto et al., 2024). Environmental impact studies must be carried out to ensure that wave energy does not damage the marine ecosystem and that the aquatic environment around Pariaman City is sustainable.
- Technology development: By utilising the potential of ocean waves, it is necessary to develop wave-generating technology that is efficient and environmentally friendly. Investment in research and development of wave energy technology will accelerate the utilisation of renewable energy potential in the region (Aryantie et al., 2023).

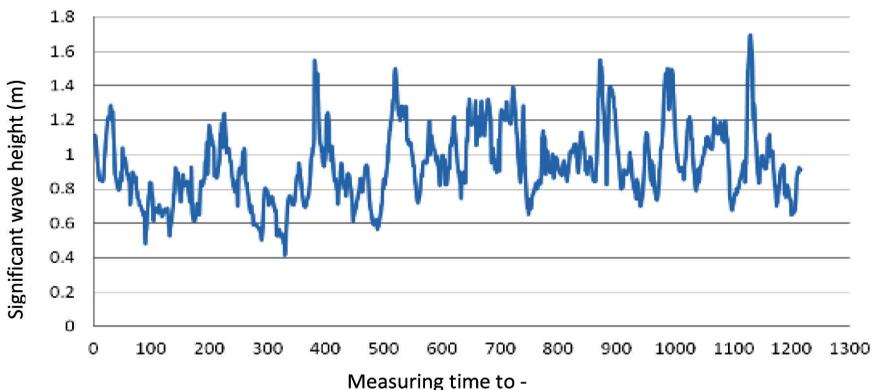


Figure 4: Significant wave height in the seawaters of Pariaman City

By understanding the characteristics of ocean wave variability in Pariaman City, authorities and renewable energy developers can plan effective measures to harness the potential of wave energy in a sustainable and environmentally friendly manner.

Conclusions

The research findings indicate that the region of Pariaman City possesses substantial potential for renewable energy derived from wind and sea waves. This potential offers an environmentally friendly alternative to traditional petroleum and coal-based energy sources. The observed wind and sea wave patterns demonstrate significant results, with wind speeds averaging between 0.2 to 11.5 m/s and sea wave heights ranging from 0.65 to 1.7 m annually, particularly prominent in October. This potential can be harnessed by establishing wind and ocean wave power plants. The high renewable energy potential is underpinned by recurring wind and sea wave patterns aligned with seasonal cycles such as monsoon winds. Consequently, the development of renewable energy in the Pariaman City region presents the opportunity to diminish reliance on fossil fuels and foster long-term energy sustainability.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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