Wave power potential in Malaysian territorial waters

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Abstract. Up until today, Malaysia has used renewable energy technology such as biomass, solar and hydro energy for power generation and co-generation in palm oil industries and also for the generation of electricity, yet, we are still far behind other countries which have started to optimize waves for similar production. Wave power is a renewable energy (RE) transported by ocean waves. It is very eco-friendly and is easily reachable. This paper presents an assessment of wave power potential in Malaysian territorial waters including waters of Sabah and Sarawak. In this research, data from Malaysia Meteorology Department (MetMalaysia) is used and is supported by a satellite imaginary obtained from National Aeronautics and Space Administration (NASA) and Malaysia Remote Sensing Agency (ARSM) within the time range of the year 1992 until 2007. There were two types of analyses conducted which were mask analysis and comparative analysis. Mask analysis of a research area is the analysis conducted to filter restricted and sensitive areas. Meanwhile, comparative analysis is an analysis conducted to determine the most potential area for wave power generation. Four comparative analyses which have been carried out were wave power analysis, comparative analysis of wave energy power with the sea topography, hot-spot area analysis and comparative analysis of wave energy with the wind speed. These four analyses underwent clipping processes using Geographic Information System (GIS) to obtain the final result. At the end of this research, the most suitable area to develop a wave energy converter was found, which is in the waters of Terengganu and Sarawak. Besides that, it was concluded that the average potential energy that can be generated in Malaysian territorial waters is between 2.8kW/m to 8.6kW/m.

1. Introduction

Development of a country does not only depend on a sustainable development of energy resources, but also on its hygiene, safety and the ability of renewable energy (RE) itself. There is no doubt in the future that our world would still need oil for technological development and innovation since it is still dependent on it. However, dependence on certain energy sources cannot ensure sustainable development of a country. Therefore, RE is the best alternative which has fewer effects and impacts on the environment [1]. In the 1970s and the early 1980s, research and development on wave energy have been done to address the problem of world oil crisis. Since then, many countries have developed wave power for the generation of electricity, water desalination and also for pumping water into reservoirs.

Studies on the exploration of waves to be used as a new source of energy have newly taken the interest of researchers from all over the world. Malaysia is also one of the countries that are investing significantly in this research area, optimizing the production from the ocean [2]. Wave energy is related to solar energy where the wind generated by thermal heat reacts with the surface of the sea water producing energy to generate waves. The amount of energy produced and the size of waves depend on the wind speed, the duration of the wind blowing, and the distance of the wind to the waves [3]. Tenaga Nasional Berhad (TNB) has started to look at RE to meet the amount of energy needed in the future. Through projections that were supposed to be undertaken, TNB was expected to start generating RE of 2,013 GWh in 2012. This would increase to 5,385 GWh in 2015 and they expect to generate 11,244 GWh of RE by 2020 [4, 5].

Currently, the use of geographic information system (GIS) is very important especially when dealing with geospatial information and problems on earth. The concept and technology of GIS itself allow us to collect and manage spatial data and to also observe the correlation between the data [6, 7, 8, 9, 10, 11].

This study concerning spatial analysis is to determine suitable locations to generate waves in Malaysia. GIS analysis which was carried out included a variety of algorithms and parameters used to produce the best results in determining the location of optimal wave energy. In GIS, the calculation may be made either based on space or non-space data. The quantification of power delivered by a wave moving across the sea level has been measured and was used in this study for the South West region using the Seapower system [12].

2. Methodology

Wave data used in this research was provided by the Malaysia Meteorology Department (MetMalaysia) and is supported by satellite imaginary obtained from the National Aeronautics and Space Administration (NASA) and Malaysia Remote Sensing Agency (ARSM) within the time range of the year 1992 until 2007. In 2006, a comparison between the data from MetMalaysia and satellite images was made [13] with the results showing that the data from MetMalaysia can be applied to the study of wave energy in Malaysia. The process to identify the best location of wave energy is shown in Figure 1.

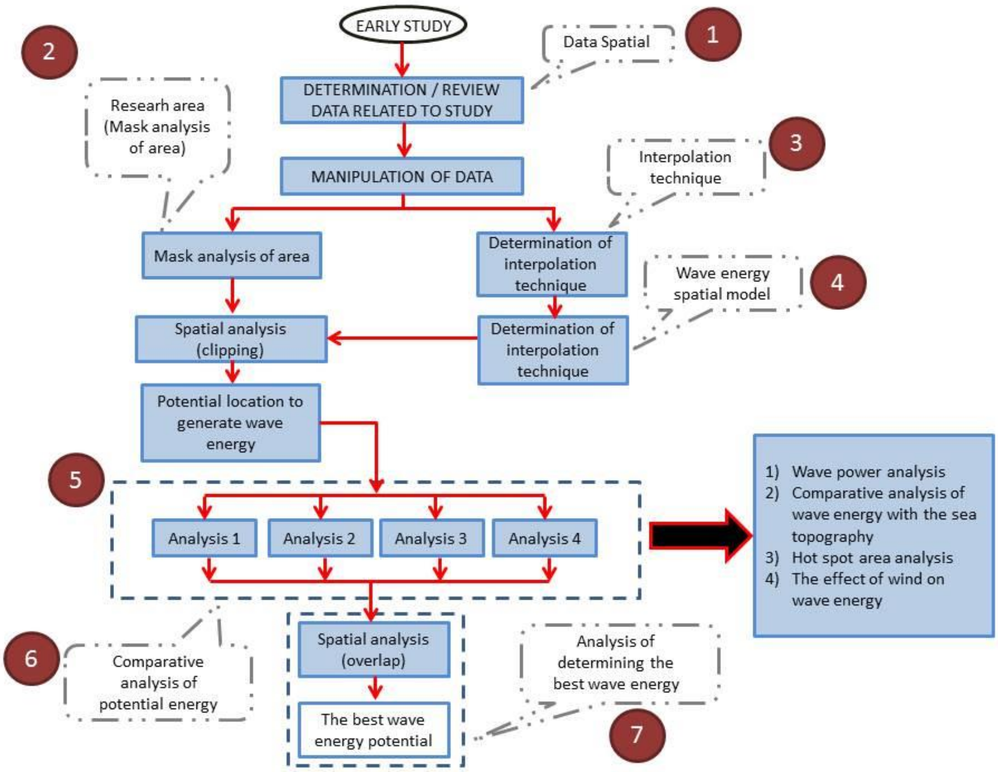

Figure 1. Wave locations identifying process.

2.1. Mask analysis of the research area

Mask analysis is an early process to identify suitable locations for the generation of wave power. In this analysis, all the sensitive and protected areas have been identified as they play an important role as a filter to determine which areas are the most ideal for generating waves. Factors that were used to obtain areas free from being sensitive and are protected are the Malaysian border, the bathymetry between 30 m to 250 m, 12 nautical miles from the coastline, oil and gas pipe routes, marine parks [14], oil and gas areas, underground cables and also ports [15,16]. Figure 2 show the map generated by using geographic information system (GIS) after considering the sensitive and protected area. The total area of Malaysian waters is 571,996.037 km^2. After the mask analysis has been carried out, the total area of research area (non-protected and sensitive areas) is 273,146.154 km^2. It shows that 48% of Malaysian waters are suitable for wave energy generation.

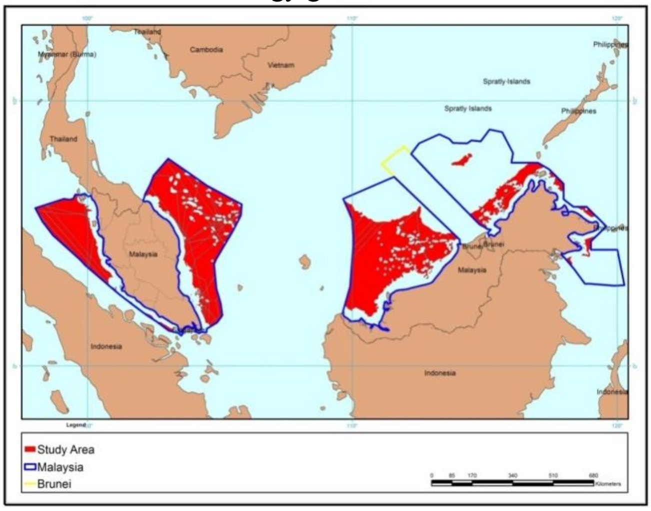

Figure 2. Map generated by mask analysis.

2.2. Comparative analysis

Comparative analysis is a method that has been accomplished to strengthen and evaluate the results obtained. It is conducted to compare between two or more groups of data samples. This analysis can prove the validity and accuracy of the results based on the criteria used and determines the pattern change in a set of data series compiled by factors such as year, month and hour. In this research, the data was collected from the year 1992 to 2007. Four analyses which have been carried out were:

1. Wave power analysis.
2. Comparative analysis of wave power with the sea topography.
3. Hot-spot area analysis.
4. The effects of the wind on wave energy.

2.2.1. Wave power analysis

Wave power can be generated when waves, currents and wind integrate into a steady rate. Wave power analysis is divided into two, which are the highest power and lowest power. This study provides an overview regarding the potential of wave energy that can be generated. From the results of the analysis to determine the highest and lowest power, the ability to generate wave energy is good. This is because there are areas with high values for the last 16 years. Process to get the maximum and minimum power was based on calculation of data from year 1992 to 2007. The total area of maximum or minimum power every year will divide with the total research area to get the percentage of maximum and minimum power. The wave power values have been computed using the expression [17,18,19]:

$$P = \frac{\rho g^2}{64\pi} H^2 mo.Te \approx (0.5 \frac{kW}{m^3 s}) H^2 mo.Te \quad (1)$$

Where P is the energy flux in watts per meter of crest (kW/m), H^2mo is the significant wave height, Te the wave energy period, ρ the water density and the g the acceleration by gravity.

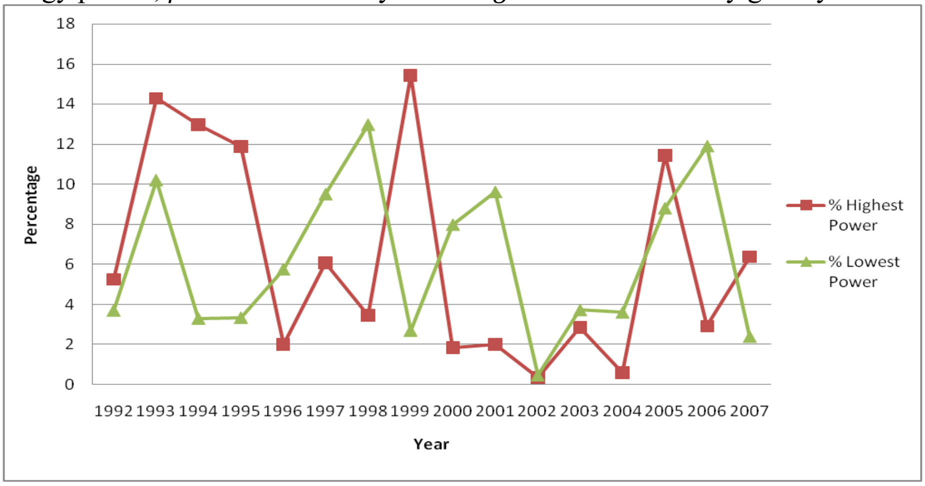

Figure 3. Results of the highest and lowest power generated from the year 1992 to 2007.

Figure 3 shows the results of analysis of the highest and lowest power generated from the year 1992 to 2007. The difference in value for each year depends on a variety of matters, including climate change, natural disasters, wind, changes in the sea temperature and other factors that affect the formation of waves. Based on the analysis, it is shown that the year 1993 and 1999 recorded the highest generation of wave energy while in 2002 and 2004, the rate of energy generated was at its lowest. The pattern of these changes indicates that the number of data capable of generating wave energy varies every year. From the lowest position analysis, the year 2002 gives the least percentage value, but in 1998 and 2006, it is shown that the percentage of the lowest position is high. In this analysis, the year 1993, 1999 and 2005 demonstrate the ability to generate wave energy which is high. This indicates that every six years, the value or rate of wave energy in Malaysian waters is high. However, this finding must be considered carefully to observe the significance with other factors such as tidal power.

2.2.2. *Comparative analysis of wave power with the sea topography*

A comparative analysis of the power of wave energy and the ocean topography provides a comparison between powers of wave energy with the characteristics of the ocean depth. In this analysis, the results of the ocean surface topography are overlaid with the wave energy potential.

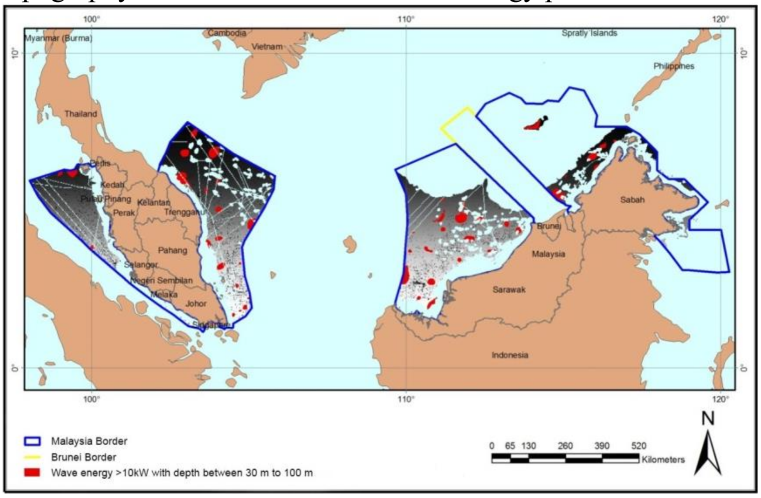

Figure 4. Wave power more than 10 kW with a depth of 30 m to 100 m.

Figure 4 shows the areas with a depth of 30 to 100 m which have the energy of more than 10 kW. Based on previous research conducted by other researchers, it is established that the ideal power to generate wave energy is 10 kW [20,21]. The analysis indicates that the areas that meet the analysis requirements are scattered. The results are not only focused on the South China Sea, but it also can be seen in the Straits of Malacca, though the area being considerably smaller compared to the South China Sea.

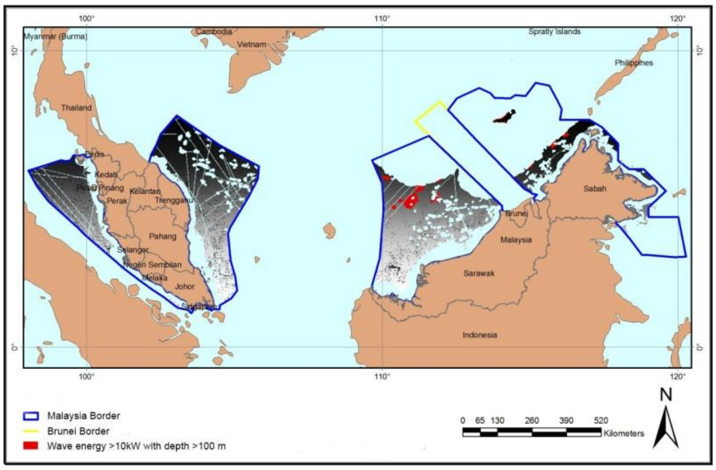

Figure 5. Wave power of more than 10 kW with depth of 100 m to 250 m.

Based on Figure 5, the areas which generate more than 10 kW are considerably limited, focusing more in the waters of Sabah and Sarawak. There is no spotted area around the Peninsular since the maximum water depth at Peninsular Malaysia is only about 90 m.

Based on this analysis, it clearly shows that the depth of the ocean plays a crucial role in determining the wave energy power. A depth of about 30 m to 100 m is able to generate more energy than a depth of 100 m to 250 m for more than 10 kW/m of energy generated.

2.2.3. Hot-spot area analysis

This analysis is to examine whether the potential wave energy produced has an influence on its surroundings. Figure 6 shows the hot-spot wave energy potential in Malaysia. The point indicating a wave energy that has a high value (positive) is the best area for generating wave energy. In reference to Figure 6, there are six potential locations, which are Kelantan, Terengganu, Pahang, Johor, Sarawak and Sabah. Based on this analysis, it shows that the South China Sea has the highest potential to generate wave energy compared to the Straits of Malacca. The position of the sea plays a crucial role since the Straits of Malacca is placed in between Peninsular Malaysia and Sumatera, Indonesia.

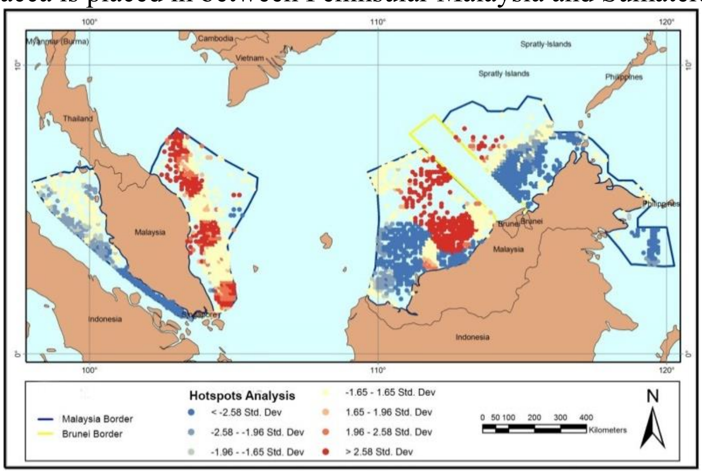

Figure 6. Hot-spot wave energy potential from the year 1992 to 2007.

2.2.4. The effect of the wind on wave energy

There is no doubt that the wind is a major factor in the occurrence of waves in the ocean. The data from 1992 to 2007 illustrates the significant link between wind and wave power. Figure 7 shows the locations where the significant link between wind and wave power occurs. The location is described as a significant area with the wind of more than 6 m/s (average wind speed), and the wave energy potential exceeds 10 kW/m. It can be concluded from these findings that strong wind can create valuable wave energy potential. This is because the wind is able to produce high and long waves. Therefore, this analysis shows that Kelantan, Terengganu, Pahang, Sarawak and Kedah are suitable locations to generate wave energy.

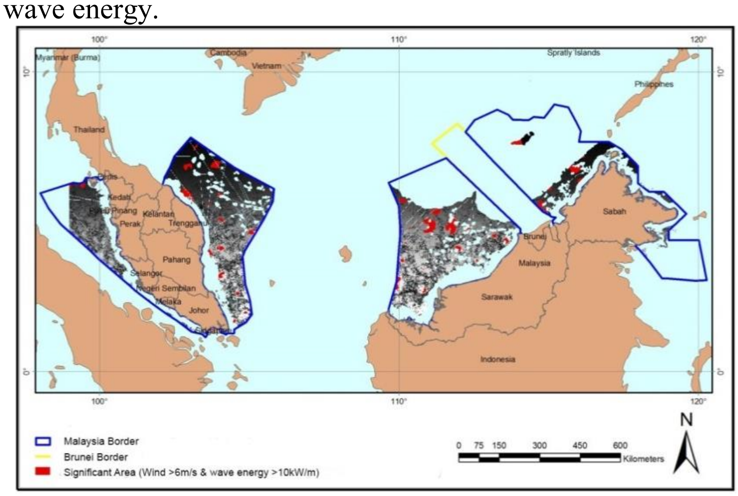

Figure 7. Suitable location to generate wave energy based on winds (>6 m/s).

3. The best locations for the generation of wave energy in Malaysia

The ability to locate the best location for the generation of wave energy requires extensive analysis of factors that needed to be carried out. The results of the comparative analysis conducted indicate the best location that can be explored and studied. There are six locations identified that have the best potential to generate wave energy. The total potential area to generate wave energy is about 59,227,711.71 m2. The details and the location of the potential place are shown in Table 1.

Table 1. Best location of wave energy generation.

No.	Latitude	Longitude	Location	Nearest Island	Total Area (m^2)
1.	5.3116	103.6067	Terengganu waters	Kapas Island (39km)	125 763.04
2.	4.9079	103.8294	Terengganu waters	Nyirih Island (19km) Tenggol Island (19km)	13 488.48
3.	4.8795	103.7162	Terengganu waters	Nyirih Island (5km) Tenggol Island (4km)	23 132 490.44
4.	4.7711	103.7228	Terengganu waters	Nyirih Island (9km) Tenggol Island (4km)	3 142 711.11
5.	4.6009	104.0952	Terengganu waters	Nyirih Island (51km) Tenggol Island (47km) Kerteh port (68km)	25 937 356.83
6.	5.1929	112.4087	Sarawak waters	Miri port (188km)	6 875 901.81
				Total Area (m^2) :	**59 227 711.71**

From Table 1, the best locations to generate wave energy are at the waters of Terengganu and Sarawak. The locations with the largest area that can generate wave energy are at location three and five. The most practical location being the third location since it is only 5 km and 4 km away from Nyirih Island and Tenggol Island, respectively. This location is the nearest location to the island, with a total area of 23,132,490.44 m^2. Currently, the electric power at Tenggol Island and Nyirih Island is generated using a generator to obtain electricity. The generator is powered by using diesel and it is not environmentally friendly. Since Tenggol Island is one of the most beautiful diving gateway islands in the south of Terengganu, a detailed study needs to be conducted to identify the level of commercialization of wave energy in that area to maximize the use of the energy.

4. Conclusion

This study shows that the average annual wave energy that can be generated in Malaysian territorial waters is between 2.8 kW/m to 8.6 kW/m. This shows that the rate of wave energy generated in Malaysia is comparable with other Asian countries such as China, Japan and India [22]. The value of the wave energy generated is the value without equipment that can help to increase wave energy power. Four detailed analyses have been carried out using the GIS models, and they have been proven to be helpful in strengthening the evidence of wave energy generation capability in Malaysia. In reference to the analyses that have been carried out, the waters of Terengganu and Sarawak have the highest potential to develop waves with a wave energy converter (WEC).

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