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Analysis of oscillating water column technology in East Nusa Tenggara Indonesia

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ABSTRACT

Utilization of new renewable energy can be one solution to the limitations of fossil energy. Ocean wave energy is renewable energy caused by tides, and this potential can be utilized as a source of electrical energy in Indonesia, especially East Nusa Tenggara. This ocean wave power plant uses oscillating water column (OWC) technology. This wave energy is energy that can be developed and environmentally friendly and available every time. This paper analyzes the amount of energy produced by ocean waves using OWC technology in the East Nusa Tenggara. The benefits of this paper can be used as a reference for planning the construction of a wave power plant around East Nusa Tenggara. The method used is to measure the condition of ocean waves for a year and analyze the amount of energy and electrical power that can be generated by ocean waves with the use of OWC. The results of the analysis show that the use of ocean wave power plants with OWC technology in the waters of East Nusa Tenggara can produce the highest energy of 20,291,728.83 Joules and the lowest is 17,062.62 Joules. The electrical power generated is between 3,645.45 Watt to 4,274,314.37 Watt, and average of power density by ocean waves using OWC is 19,021.89 Watt/m^2.

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1. INTRODUCTION

East Nusa Tenggara is one of the provinces in Indonesia which is located in East Indonesia. This area has a structure with many islands, as a place for people to live and now several islands have developed into tourism areas that are famous in Indonesia and one of the best exotic destinations [1]–[6]. However, the demand for electrical energy in this area is still limited. This should be a consideration for the government in providing sufficient electrical energy.

Currently, the state electricity company has distributed electricity through distribution cables from power plants that use fossil energy [7]. However, for now it is still limited due to the structure of the islands. This procurement uses very high financing and the lack of feedback from the consumption of electrical energy provided by state electricity company is still not balanced. The fulfillment of this energy comes mostly from the burning of fossil fuels that are millions of years old and cannot be renewed and only a small part comes from the use of other, more renewable sources [8]–[13]. Seeing the topography of East Nusa Tenggara which is surrounded by the sea, this type of ocean wave power plant is suitable to be built [10], [12], [14]. Apart from being environmentally friendly, this type of power plant will not damage the natural ecosystem during construction and operation, so it will become a famous tourist destination for its natural beauty [15]–[22].

The tides are a natural phenomenon with the movement of rising and falling sea levels periodically due to the gravitational force of the Earth and the Moon and the Sun causing an attractive force. Tides and currents generated by tides are very dominant in the process of circulating water masses in coastal waters. A movement that has an impact on the movement of water masses and their relationship with the spread of fluid circulation in a particular container is a lesson from tidal science. The Moon's gravitational force is greater than that of the Sun. Although the Moon is much smaller than the Sun, the Moon has a force of attraction that is twice as large as the attraction of the Sun in causing tides because it is closer to Earth. This attraction produces a gravitational tidal bulge or bulge in the ocean [14], [16], [20], [23].

Currently, many types of technology have been developed in ocean wave power plants, including buoy-type technology, overtopping devices technology, and oscillating water column (OWC) technology [20], [24]–[28]. For the East Nusa Tenggara region itself, the suitable technology to be developed is ocean wave power plant with OWC technology. This is because OWC technology is very suitable to be built in areas with sloping seabed topography, has a constant sea wave height, and does not require a large construction area [16]–[18], [20]–[23], [29]–[35].

Utilization of this ocean wave energy in East Nusa Tenggara as a new renewable energy can be one solution to the limitations of fossil energy. Theoretical planning and analysis of the electrical power that can be generated will be a good consideration. It is hoped that the results of this study can be a reference for planning the construction of a sea wave power plant in the East Nusa Tenggara area, so that later it will be able to generate electricity to serve consumers in East Nusa Tenggara.

2. METHOD

This research was conducted around the waters of East Nusa Tenggara, with data collection coordinates 10º12'57.99" S/S-123º31'21.63" T/E. Data collection is carried out for a year from January 1, 2021 - December 2021. The data taken are the height of the tide, wind speed, and wind direction angle. Tides are carried out for 24 hours.

The main thing in utilizing this ocean wave is the availability of ocean waves that can be used as power generation energy. The energy of ocean waves can be known by adding up the kinetic energy and potential energy produced by the waves. Ocean wave potential energy is the energy generated by the relative position or configuration of ocean waves in a physical system. The kinetic energy of ocean waves is part of the energy associated with the motion of ocean waves. The amount of potential and kinetic energy of ocean waves can be calculated by (1) and (2). After the potential and kinetic energy is obtained, it can be seen that the energy of ocean waves is produced for more than 1 period by (3). From (3), it can be calculated the magnitude of energy density (E_{WD}), electrical power (P_W), and power density (P_{WD}) produced by ocean waves using (4), (5), and (6). Energy density is the amount of energy density produced by ocean waves per 1 unit surface area. Wave power is the amount of electrical power that can be generated by ocean waves. The p value is the density of seawater with a value of 1030 kg/m^3, w is the area of the measurement boundary with a value of 35 m, g is gravity with a value of 9.8 m/s^2.

$$P.E = \frac{1}{4} w\rho g a^2 \lambda \ (Joule) \tag{1}$$

$$K.E = \frac{1}{4} w\rho g a^2 \lambda \ (Joule) \tag{2}$$

$$E_W = P.E + K.E \ (Joule) \tag{3}$$

$$E_{WD} = \frac{1}{2} w\rho g a^2 \ (J/m^2) \tag{4}$$

$$P_W = \frac{E_W}{T} \ (Watt) \tag{5}$$

$$P_W = \frac{P_W}{\lambda W} \ (W/m^2) \tag{6}$$

The period and wavelength of the ocean will determine the amount of energy that can be generated. The wave parameters generated by the generation of ocean waves by the wind include the height of the ocean waves, the length of the ocean waves, and the period of the ocean waves. Ocean waves are influenced by the period of arrival of the waves. The period of arrival of the waves can be calculated by (7). The length of the ocean waves can be predicted using the Wilson formulation method, with (8).

$$T = 3.55\sqrt{H}) \quad (7)$$

$$\lambda = T(gH)^{\frac{1}{2}} \quad (8)$$

3. RESULTS AND DISCUSSION

The measurement results obtained for the location of the oscillating water column technology design can be seen in Table 1. The lowest sea wave height measurement is 0.1 m and the largest is 3.4 m, with an average wind speed of 4.5 m/s, and a wind direction between 119.5° to 269.7°. Annual wind rose, distribution of wind direction, and distribution of wind speed classes for the East Nusa Tenggara area can be seen in Figures 1, 2 and 3. The results of these measurements will be taken into consideration for OWC. The height of the ocean waves will determine the amount of potential electrical energy, and wind directions will determine the direction and shape of the ocean waves.

Table 1. Environmental measurement for wave power plant installation with OWC technology period January – December 2021

Month	Tide Height (m)			Wind Speed (m/s)	Wind Direction Degree
	Minimum	Maximum	Average		
1	0.2	3.2	1.8	4.3	269.7
2	0.2	3.1	1.8	5.5	266.8
3	0.2	3.3	1.8	3.3	243.0
4	0.1	3.4	1.8	4.8	174.8
5	0.1	3.3	1.8	5.4	119.5
6	0.1	3.2	1.7	4.8	133.3
7	0.2	3.2	1.8	5.7	136.5
8	0.3	3.2	1.8	5.5	131.6
9	0.4	3.2	1.8	4.9	136.6
10	0.2	3.3	1.8	3.7	189.3
11	0.1	3.2	1.8	2.3	195.0
12	0.1	3.3	1.8	3.8	251.6

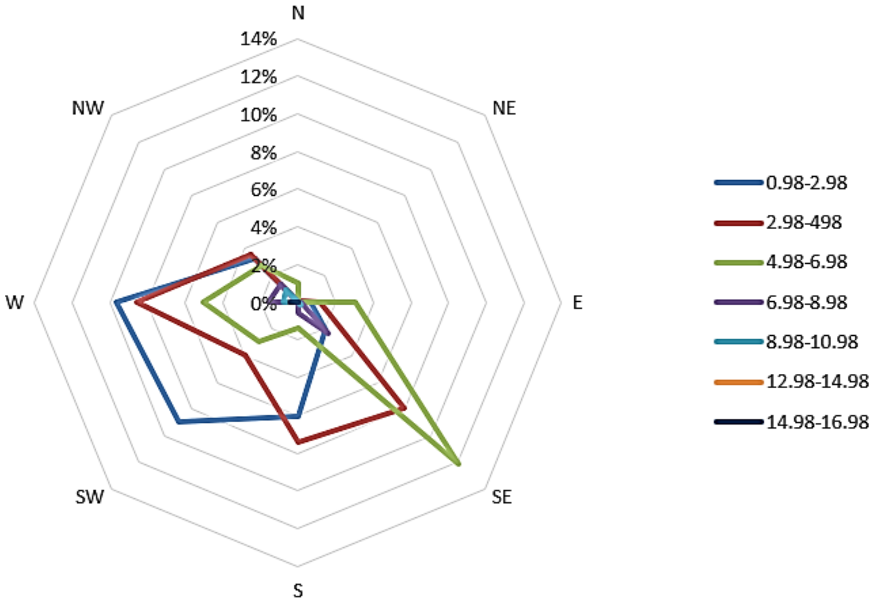

Figure 1. Annual wind rose in East Nusa Tenggara

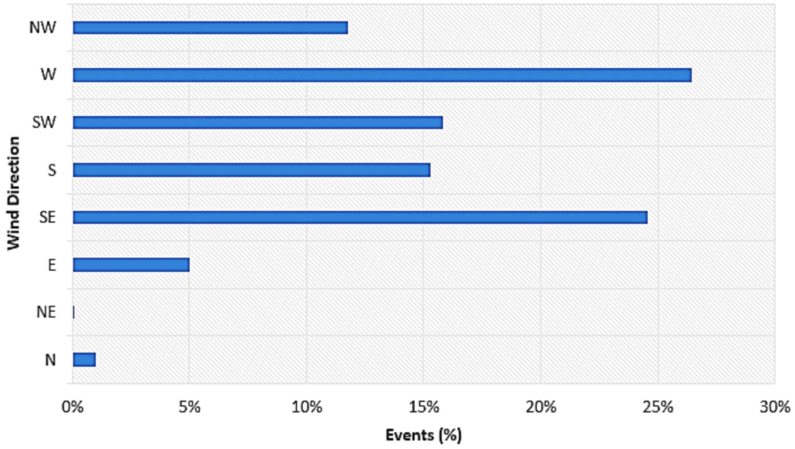

Figure 2. Distribution of wind direction in East Nusa Tenggara

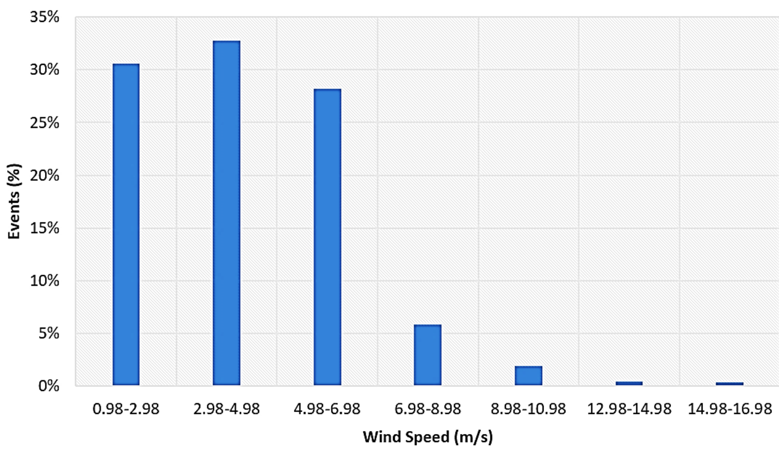

Figure 3. Distribution of wind speed classes in East Nusa Tenggara

From the results of Table 1, it can then be calculated the potential energy of ocean waves (E.P), the kinetic energy of ocean waves (K.E), ocean wave energy (E_W), density energy (E_{WD}), electric power (P_W), power density (P_{WD}), period and wavelength using the formula 1-8. The p value is the density of seawater with a value of 1030 kg/m^3, w is the area of the measurement boundary with a value of 35 m, g is gravity with a value of 9.8 m/s^2. The results for January can be seen in the following description, while the results of the analysis for other months can be seen in Tables 2 and 3.
January 2021, lowest wave height: 0.2 m

$$P.E = \frac{1}{4}\, w\rho g a^2 \lambda \; (Joule)$$

$$P.E = \frac{1}{4}\,(35)(1030)\left(\frac{0.2}{2}\right)^2 (19.8)$$

$$P.E = 34{,}955.87 \; Joule$$

$$K.E = \frac{1}{4}\, w\rho g a^2 \lambda \; (Joule)$$

$$K.E = \frac{1}{4}\,(35)(1030)\left(\frac{0.2}{2}\right)^2 (19.8)$$

$$K.E = 34{,}955.87 \; Joule$$

$$E_W = P.E + K.E$$

$$E_W = 34{,}955.87\, Joule + 34{,}955.87\, Joule$$

$$E_W = 69{,}911.74\, Joule$$

$$P_W = \frac{E_W}{T}\ (Watt)$$

$$P_W = \frac{69{,}911.74\, Joule}{4.7\, second}\ (Watt)$$

$$P_W = 14{,}758.19\, Watt$$

January 2021, highest wave height: 3.2 m

$$P.E = \frac{1}{4}\, w\rho g a^2 \lambda\ (Joule)$$

$$P.E = \frac{1}{4}\,(35)(1030)\left(\frac{3.2}{2}\right)^2 (19.8)$$

$$P.E = 8{,}948{,}702.89\, Joule$$

$$K.E = \frac{1}{4}\, w\rho g a^2 \lambda\ (Joule)$$

$$K.E = \frac{1}{4}\,(35)(1030)\left(\frac{3.2}{2}\right)^2 (19.8)$$

$$K.E = 8{,}948{,}702.89\, Joule$$

$$E_W = P.E + K.E$$

$$E_W = 8{,}948{,}702.89\, Joule + 8{,}948{,}702.89\, Joule$$

$$E_W = 17{,}897{,}405.78\, Joule$$

$$P_W = \frac{E_W}{T}\ (Watt)$$

$$P_W = \frac{17{,}897{,}405.78\, Joule}{4.7\, second}\ (Watt)$$

$$P_W = 3{,}778{,}096.44\, Watt$$

From Tables 2 and 3 it can be seen that the wave height is proportional to the amount of power generated. The higher the wave, the more power it produces. The electrical power generated is between 3,645.45 Watt to 4,274,314.37 Watt with a height of 0.1 m to 3.4 m, and average of power density by ocean waves using OWC is 19,021.89 Watt/m^2. These results indicate that the potential for wave energy in East Nusa Tenggara with the use of OWC technology can be developed and utilized as a source of electrical energy. This potential can still be reviewed because there are still many locations that have not been measured. The advantages of this system if it can be utilized are that energy can be obtained for free, does not require fuel, does not produce waste and is environmentally friendly, easy to operate, has low operating costs, and produces adequate energy. Even so, the use of this energy still depends on the presence of waves, so this generator cannot be used for sure. Therefore, it is necessary to find a location that is suitable for large and consistent wave conditions, and requires a reliable conversion tool that is able to withstand harsh marine environmental conditions caused by high levels of corrosion and strong ocean currents. The development and utilization of this technology will also indirectly help the limited energy in East Nusa Tenggara and as a form of support for the Blue Economy policy set in Indonesia and the Ministry of Marine Affairs and Fisheries. Figure 4 is a form of utilizing ocean waves for electrical energy with OWC technology.

Table 2. Potential of ocean wave energy in the East Nusa Tenggara

Month	P.E (Joule)		K.E (Joule)		E_W (Joule)		E_{WD} (Joule/m^2)
	Min	Max	Min	Max	Min	Max	
1	34,955.87	8,948,702.89	34,955.87	8,948,702.89	69,911.74	17,897,405.78	453,977.65
2	35,370.88	8,497,854.20	35,370.88	8,497,854.20	70,741.76	16,995,708.40	426,156.06
3	35,304.16	9,611,558.34	35,304.16	9,611,558.34	70,608.33	19,223,116.68	482,682.46
4	8,776.70	10,145,864.42	8,776.70	10,145,864.42	17,553.40	20,291,728.83	510,945.66
5	8,588.57	9,352,951.39	8,588.57	9,352,951.39	17,177.14	18,705,902.78	481,357.63
6	8,531.31	8,736,063.12	8,531.31	8,736,063.12	17,062.62	17,472,126.24	452,652.81
7	34,544.25	8,843,328.67	34,544.25	8,843,328.67	69,088.51	17,686,657.35	453,977.65
8	78,152.02	8,891,962.93	78,152.02	8,891,962.93	156,304.04	17,783,925.86	456,185.71
9	144,484.27	9,246,992.99	144,484.27	9,246,992.99	288,968.53	18,493,985.98	459,277.00
10	35,399.15	9,637,419.03	35,399.15	9,637,419.03	70,798.30	19,274,838.07	482,682.46
11	8,825.78	9,037,595.50	8,825.78	9,037,595.50	17,651.55	18,075,191.00	452,652.81
12	8,675.64	9,447,773.94	8,675.64	9,447,773.94	17,351.28	18,895,547.87	481,357.63

Table 3. Potential electrical power from ocean waves in East Nusa Tenggara

Month	P_W (Watt)		P_{WD} (Watt/m^2)	Month	PW (Watt)		PWD (Watt/m^2)
	Min	Max			Min	Max	
1	14,758.19	3,778,096.44	18,951.57	7	14,671.04	3,755,786.34	18,398.58
2	14,845.54	3,566,640.60	19,519.09	8	33,100.49	3,766,099.73	18,652.58
3	14,831.53	4,037,884.20	19,427.17	9	60,008.57	3,840,548.55	20,570.57
4	3,697.50	4,274,314.37	19,156.79	10	14,851.47	4,043,312.68	19,558.11
5	3,657.66	3,983,192.50	18,146.66	11	3,707.83	3,796,815.07	19,425.72
6	3,645.45	3,732,938.86	17,845.73	12	3,676.16	4,003,332.88	18,610.11

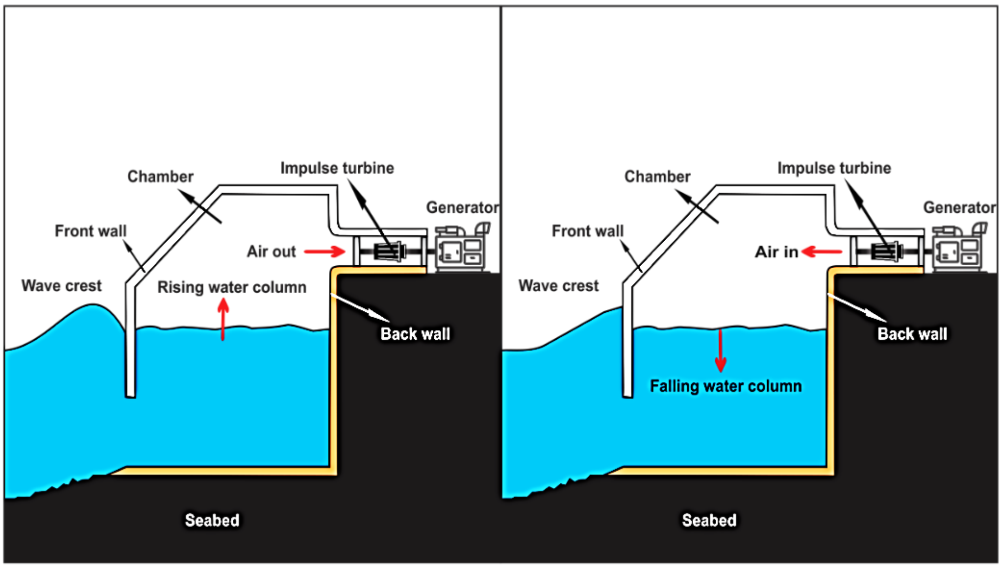

Figure 4. Utilization of ocean waves for electrical energy with OWC technology

4. CONCLUSION

The results of the analysis show that the use of ocean wave power plants with OWC technology in the waters of East Nusa Tenggara can produce the highest energy of 20,291,728.83 Joules and the lowest is 17,062.62 Joules. The electrical power generated is between 3,645.45 Watt to 4,274,314.37 Watt, and average of power density by ocean waves using OWC is 19,021.89 Watt/m^2. Based on these results, the development of the use of OWC as a device that produces energy in the form of electricity and is obtained from waves or tides in the sea can be developed in East Nusa Tenggara. This can be considered by the central and regional governments in utilizing renewable energy in East Nusa Tenggara.

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