ASSESSMENT OF WIND ENERGY POTENTIAL AT CIPATUJAH, TASIKMALAYA, WEST JAVA

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The energy scarcity and inequality of supply in Indonesia encourage efforts to find an alternative energy, particularly for remote areas. Alternative energy is expected to derive from renewable energy as an unlimited source. Wind energy is considered to be potentially safe and clean solution to meet energy needs in remote areas.

Previous research states that the south coast of Java island has a good potential. However, a feasibility study for the characteristics of diurnal and seasonal wind speed needs to be done before deciding to install wind turbines. The feasibility study is very important to estimate the amount of energy that can be produced, also determine the influence of wind speed variation of diurnal and seasonal on energy generated by the turbine. Thus, the selection for an appropriate wind turbine technology can be done.

This study describes the diurnal, monthly and seasonal wind speed characteristics, also the wind potential in Cipatujah Beach, West Java. The data were collected from wind speed measurement at a height of 5 meters above surface, from March 2012 to March 2013. Weibull distribution is used as a method to determine the wind speed probabilities of occurrence. It shows that wind speeds during the day are more likely to produce energy than at night. The average wind speed over a period of 13 months at the site is 2.27 m/s.

Wind potential obtained by wind turbine power calculations for KT500 with cut in and cut off value is 2.5 m/s and 12 m/s, respectively. The maximum energy was obtained during the peak time of monsoon, but minimum during season transitional. Total power obtained over a period of 13 months is 189.67 kWh, with an average of 14.59 kWh per month and 0.49 kWh per day.

Key words: weibull distribution, diurnal wind characteristics, monthly wind characteristics, seasonal wind characteristics, wind potential energy

INTRODUCTION

The increasing needs of energy stimulate the efforts to find alternative energy for the future. The alternative energy is hoped to be sourced from renewable energy so the usage will be unlimited. The wind energy is considered as a clean and good solution to tackle the huge needs of energy (Raichle and Carson, 2009).

Indonesia is located around the equatorial region which is the meeting point for Hadley, Walker, and local circulations (Habibie, Sasmito, and Kurniawan, 2011). Therefore, Indonesia has the wind potential than can be used as an alternative to substitute the electricity energy which has been using fuel oil, coal, and diesel as the source. Based on the mapping results from Lembaga Penerbangan dan Antariksa Nasional (LAPAN) on 120 locations showed that some regions has the wind velocity above 5 m/s, with the potential capacity between 10-100 kW for the wind velocity between 4 - 5 m/s, such as at East Nusa Tenggara, West Nusa Tenggara, South Sulawesi, and Javanese Southern Shore.

Some of the previous studies stated that the Javanese Southern Sea has a good wind potential, but before the installation of the wind turbine, the diurnal and seasonal wind velocity characteristics in a region needs to be surveyed first. The characteristics survey is very important to estimate the possible energy produced and later to know the effect of the wind velocity's diurnal and seasonal variations against the energy produced by the turbine, so the selection of the suitable turbine system technology can be done.

This study reviews the effect of the diurnal variation characteristics, each month (March 2012 - March 2013), and seasonal, which is on dry season (April 2012 - September 2012) and wet season (October 2012 - March 2013), against the 5 m surface wind velocity on Cipatujah Beach, Tasikmalaya West Java. Later on, the wind velocity data is simulated using the KT500 wind turbine to analyze the result of the energy that can be produced.

Research Method

The studied area is located on Cipatujah Beach, Tasikmalaya West Java with the coordinates 7,75^{o}S dan 108,01^{o}E (Image 1). The measurement site is located on the foot of the hill and around 35 m from the shoreline and on the south is facing the Indian Ocean so that the escalation of the wind velocity is very much affected by the sea breeze and land breeze. The condition of the surrounding areas, which is on the north side of the studied area, are consisted of coconut forest, field, iron sand mining field, and not densely populated settlement.

Image 1 The Map of the Studied Area (Google Maps, 2013). The red colored A point shows the location of Cipatujah Beach.

This study used observational data which consisted of velocity data (m/s) and surface wind direction (°) with the 5 meter altitude from March 2012 - March 2013. The data retrieval used three anemometers and wind vane, from Inspeed product. The data recording from both sensors were helped with a data logger using one second intervals.

The method used was statistical methods. The wind velocity with one second intervals were accumulated into data per minute. The daily, seasonal, and diurnal wind velocity were calculated using equation 1, Ali (2003, B. Ould Bilal, 2011).

$$V_m = \frac{1}{N}\sum_{i=1}^{N} Vi \qquad (1)$$

Where n is the amount of observations and Vi is the wond velocity on the i-th time.

Weibull Distribution

Next the Weibull calculation was conductedto find out the frecuency distribution of the occurrence of diurnal, seasonal, monthly, and a year average wind velocity. The Weibull distribution has 2 main parameters, which are k (constants) as the result of the division of the standard deviation of a data with the middle value of the wind velocity, and then raised to the

-1.086 power (Equation 2) and the c parameter c which is the 1.12 times of the middle value of the wind velocity (Equation 3). The Weibull distribution function itself can be defined with equation 4 (Johnson, 2006).

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \qquad (2)$$

$$c = 1{,}12\,\bar{v} \qquad (1{,}5 \le k \le 4) \qquad (3)$$

$$f(v) = \left[\frac{k}{c}\left(\frac{v}{c}\right)^{k-1}\right] e^{-\left(\frac{v}{c}\right)^{k}} \qquad (4)$$

with:

ó : the standard deviation value of the wind velocity

$\overline{v}$: the middle value of the wind velocity (m/s)

The amount or duration is very much affected by the size of the k parameter, the greater the k value, the greater the duration, and vice versa. Meanwhile, the smaller the c value, then the curve are directing to a lower wind velocity, vice versa (MS & Ibrochim, 2009).

Wind Energy Potential

The capacity calculation used in this study is based on the specification from the KT500 wind turbine (equation 6), which is the prototype for micro-scaled wind energy.

$$P = \frac{1}{2} v^3 . ñ . ðr^2 . Eff_{blade} . Eff_{generator} . Eff_{controller} \quad (6)$$

with the following assumptions:

ñ	: air density (= 1.225 kg/m^3)
r	: radius blade (= 1 m)
Eff_{blade}	: Efficiency blade (= 0.41)
$Eff_{generator}$	: Efficiency generator (= 0.9)
$Eff_{kontroler}$	: Efficiency controller (= 0.85)
Cut in	: 2,5 m/s
Cut off	12 m/s
Watt peak	= 500 W

Based on the society needs in the under developed regions for each Head of the Family which is about 300 Wh/day then it is determined that the minimum wind potential standard that needs to be achieved with the turbine KT500 specification is 300 - 500 Wh/day from each turbine.

Results and Discussion

The data of the wind velocity were collected in a year period on Cipatujah Beach and then the data were used to calculate the wind potential. Furthermore the wind potential was calculated to find out about the effect of seasonal and diurnal cycle. The wind velocity average was calculated using equation 1.

The Characteristics of Diurnal Surface Wind

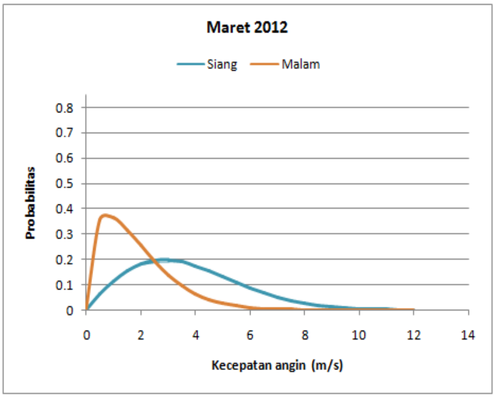
From the accumulated data in 13 months period, which are from March 2012 to March 2013, bothe Weibull parameters were calculated for each month (Table 1).

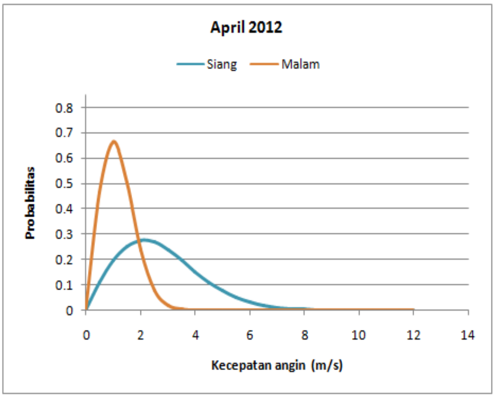
Based on the value of *k* and *c*, the *f(v)* graph retrieved for each month listed on Image 2 and Image 3. The bigger the value of *k* and *c*, then the curve are increasingly shifted to the right and the shape of the curve is less steep, and so it is vice versa.

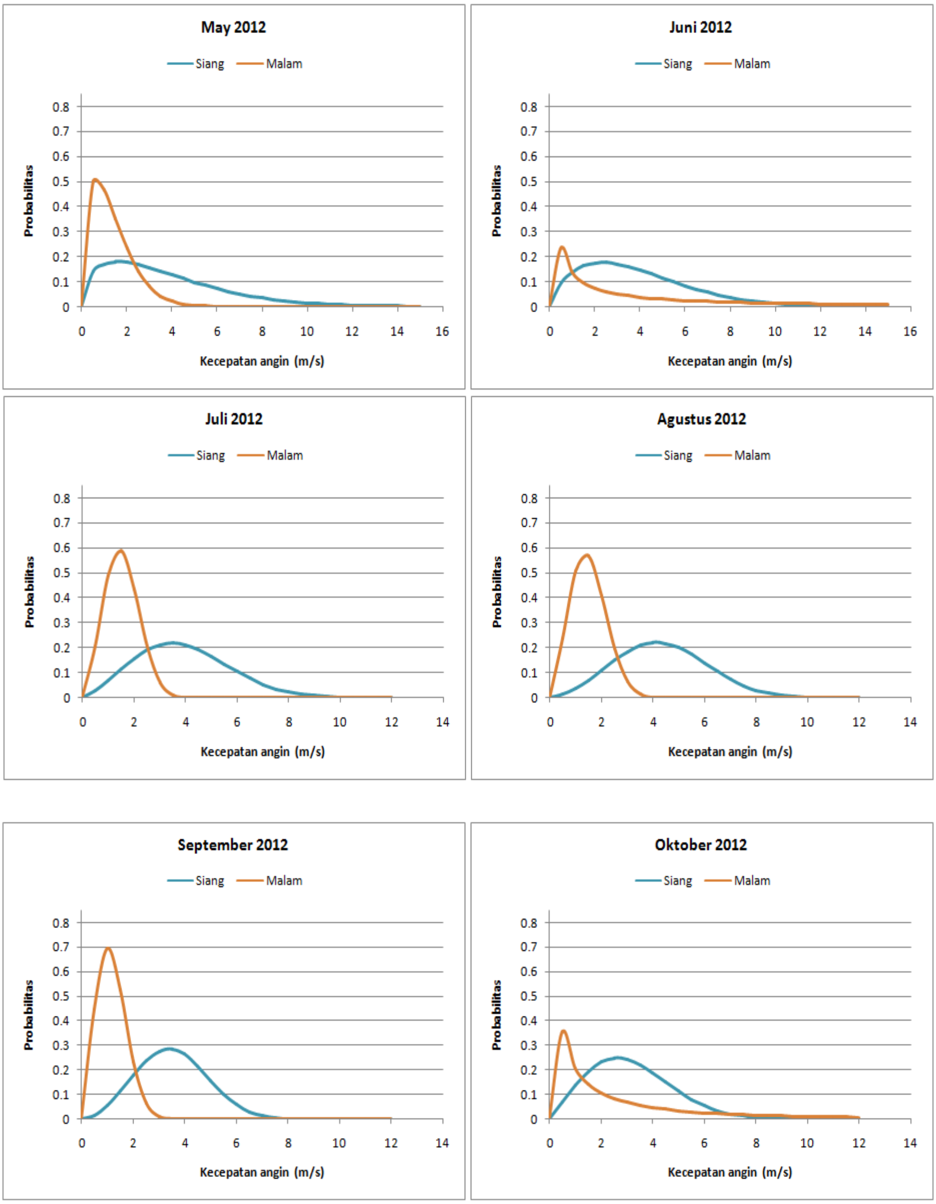
Therefore it can be discovered that the wind velocity on day time is higher compared to night time. The duration of the wind breeze is also longer on day time compared to night time. Therefore the chance of the best wind potential is on day time.

Table 1.Weilbull Distribution for Diurnal and Monthly Wind Velocity

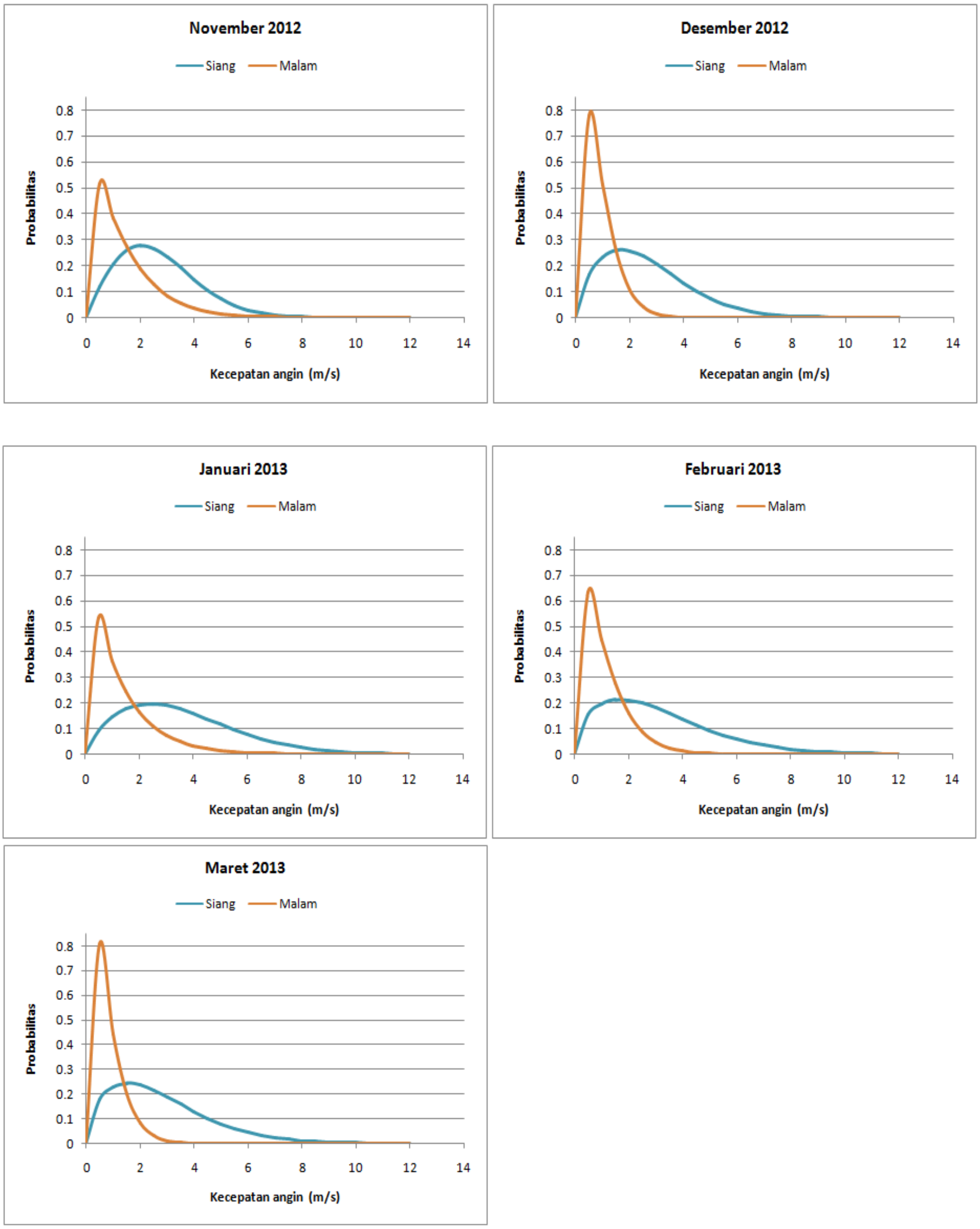
Month	Standard Deviation		Median		*k*		*c*	
	Day	Night	Day	Night	Day	Night	Day	Night
Mar-12	2.06	1.31	3.75	1.76	1.91	1.38	4.20	1.97
Apr-12	1.48	0.60	2.73	1.20	1.95	2.11	3.06	1.34
May-12	2.70	0.93	3.66	1.30	1.39	1.43	4.09	1.45
Jun-12	2.50	6.15	3.87	2.74	1.61	0.41	4.33	3.56
Jul-12	1.79	0.65	3.95	1.55	2.35	2.55	4.42	1.73
Aug-12	1.74	0.68	4.37	1.52	2.71	2.42	4.89	1.70
Sep-12	1.34	0.57	3.52	1.19	2.86	2.23	3.94	1.33
Oct-12	1.61	2.41	3.19	1.46	2.10	0.58	3.57	1.64
Nov-12	1.48	1.13	2.69	1.25	1.92	1.12	3.01	1.40
Dec-12	1.66	0.60	2.64	0.82	1.66	1.40	2.96	0.92
Jan-13	2.15	1.12	3.56	1.14	1.73	1.02	3.98	1.28
Feb-13	2.13	0.82	3.10	0.99	1.50	1.23	3.47	1.11
Mar-13	1.86	0.57	2.75	0.70	1.53	1.26	3.08	0.79







Gambar 2. The monthly diurnal wind velocity graph (March-October 2012) using Weilbull Distribution



Gambar 3. The monthly diurnal wind velocity graph (November 2012 - March 2013) using Weilbull Distribution

If reviewed from the wind direction data, on day time the direction of the wind tends to come from the south, meanwhile on night time it tends to come from the north. The difference of the wind direction tendencies on day and night time is affected by the measurement position which is located on the edge of the southern shoreline, where the area is affected by the land breeze on night time from the north. Meanwhile on day time it is affected by the sea breeze from the south.

The effect of the land breeze and sea breeze become smaller if compared with the effect from the west and east monsoon and moreover the weather condition in Australia which cyclone often occurs and has direct impact to the wind velocity on this site. On March 2012 and December 2012 until March 2013 the wind blow dominantly from between west and southwest (*West South West*) because of the effect from west monsoon. While from April 2012 until November 2012, the transition to east monsoon happens so the wind blows dominantly from Southeast direction.

In those 13 months not all of the *k* and *c* values larger on day time than on night time, some anomalies happened on April, May, and July. On those three months the wind duration on day time are almost the same or even smaller compared to night time, although the wind velocity were still larger on day time.

The Wind Direction Diurnal Distribution on Cipatujah Beach (Mar 2012 – Mar 2013)

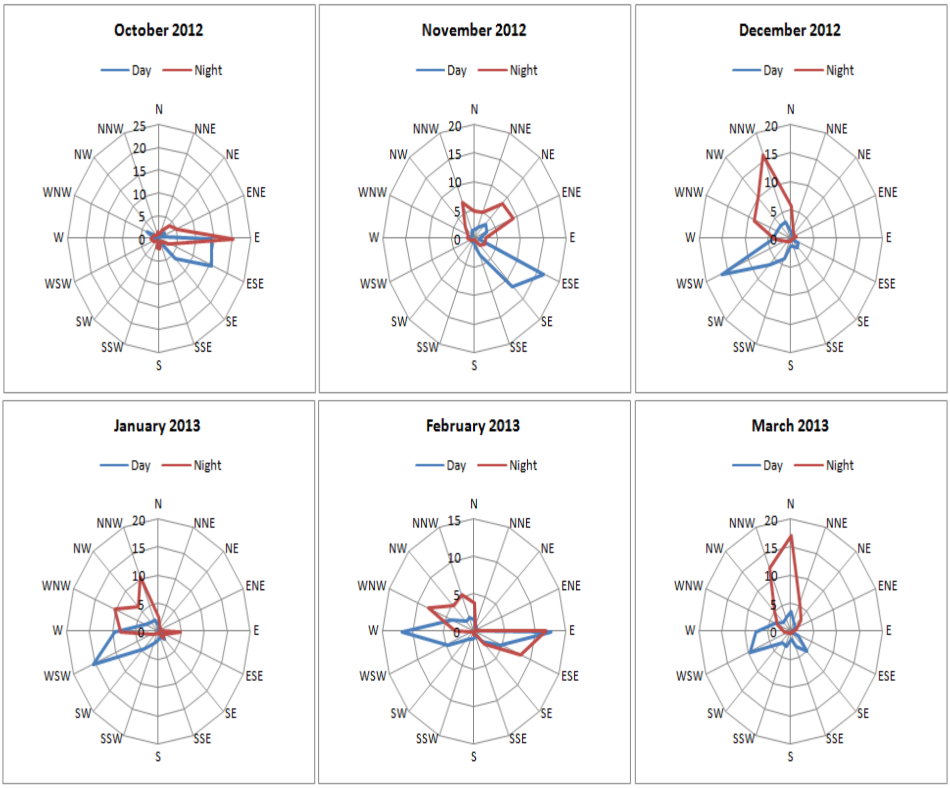


Image 3 The Windrose of the Monthly Diurnal Surface Wind Direction (Maret 2012 - Maret 2013). In the graph, the daytime wind direction is shown in blue and the night time is shown in red.

The Characteristics of the Monthly Surface Wind (March 2012 – March 2013)

The values of minimum, average, and maximum wind velocity are obtained from the data processing results on each month are shown by Image 6. The minimum surface wind velocity ranged between 0 - 0,45 m/s, while the maximum ranged between 7,44 - 15,30 m/s, and the average wind velocity around 1,77 - 2,87 m/s. The maximum wind velocity in general happens on the peaks of monsoon, while in the transitional season the wind velocity tends to minimize (Image 6). Based on the cut in (2,5 m/s) and cut off (12 m/s) values from the wind turbine that was used in this study therefore the wind velocity condition on the site is suitable for the KT500 turbine type.

The wet season in Indonesia, especially in the West Java region, ranges between October until March while the dry season on April until September. From Image 5 it is shown that the wind velocity between 0 - 3 m/s has the larger probability of wind occurrence on wet season while the 3 - 12 m/s wind velocity has the bigger probability on dry season.

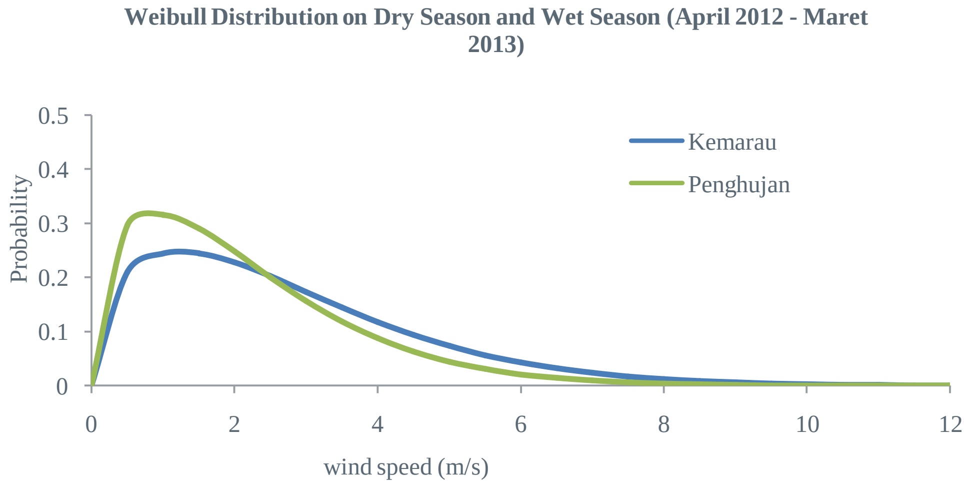
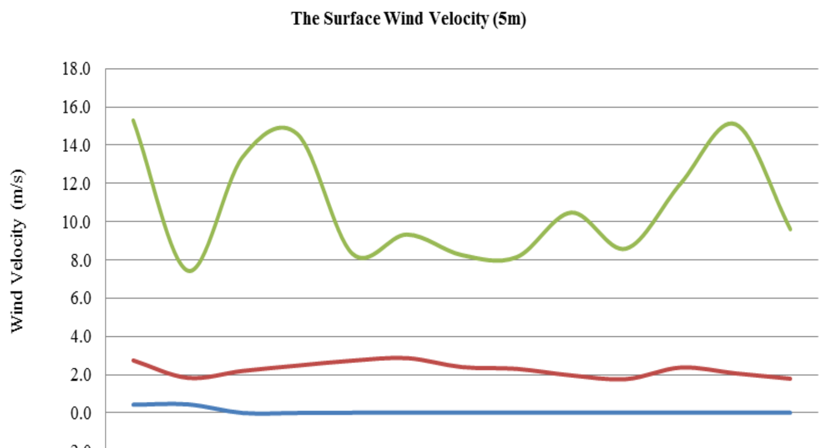
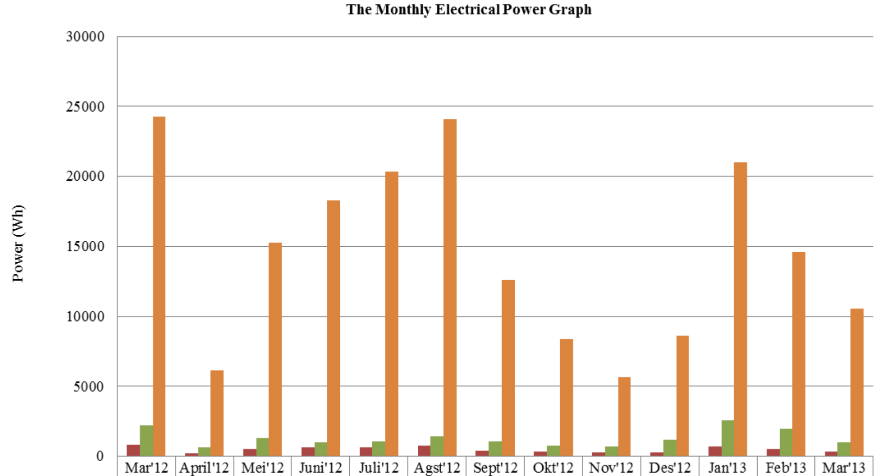


Image 4 The Surface Wind Velocity on Dry Season (April - September 2012) and Wet Season (Oktober 2012 - Maret 2013)



	Mar' 12	Apri l'12	Mei' 12	Juni' 12	Juli' 12	Agst' 12	Sept' 12	Okt' 12	Nov' 12	Des' 12	Jan'1 3	Feb' 13	Mar' 13
Minimum Wind Velocity	0.43	0.45	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Average Wind Velocity	2.75	1.84	2.20	2.48	2.74	2.87	2.40	2.31	1.97	1.77	2.38	2.07	1.79
Maximum Wind Velocity	15.30	7.44	13.40	14.59	8.33	9.33	8.26	8.14	10.48	8.59	12.01	15.10	9.61

Image 5 *The 5 m Surface Wind Velocity Graph on March 2012 - March 2013. The minimum wind velocity each month are shown in the blue line, while the monthly average wind velocity are shown in the red line, and the monthly maximum wind velocity are shown in the green line.*



	Mar'12	April'12	Mei'12	Juni'12	Juli'12	Agst'12	Sept'12	Okt'12	Nov'12	Des'12	Jan'13	Feb'13	Mar'13
Average Power (Wh)	808	204	493	609	655	776	420	335	269	277	677	522	340
Maximum Power (Wh)	2184	663	1309	999	1089	1435	1060	773	706	1198	2554	1978	992
Total Power (Wh)	24248	6133	15269	18258	20316	24069	12609	8386	5639	8589	20994	14627	10529

Image 6 The Monthly Electrical Power Graph along the period of March 2012 - March 2013. The average power (Wh) produced each month are shown in red, while the maximum power (Wh) on each month are shown in green line, and the total power (Wh) each month are shown in orange line.

The wind potential on Image 7 shows the average, maximum, and total power value obtained each month. The monthly total ranges between 5639 - 24248 Wh. Meanwhile, on each month the average producible power in one day ranges between 204 - 808 Wh with the maximum power obtained around 663 - 2554 Wh. The sum of wind potential in dry season is bigger which is 96,665 kWh compared to wet season which is 93,012 kWh. On the top of dry season and wet season, the wind potential obtained are higher compared to the months on the transitional seasons which has smaller potentials.

The Distribution of the Average Surface Wind on Dry & Wet Season

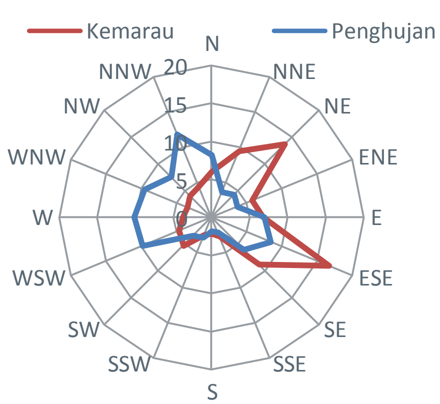


Image 7 The average surface wind direction Windrose on Dry Season (April - September 2012) and Wet Season (October 2012 - March 2013)

The wind direction on the site were dominated West and East directions, this is because of the influence from west and east monsoon. Based on the wind direction distribution graph, (Image 8), the wind direction on wet season dominantly come from the west, while in dry season dominantly from the east.

The Characteristics of Wind Potential in a Year

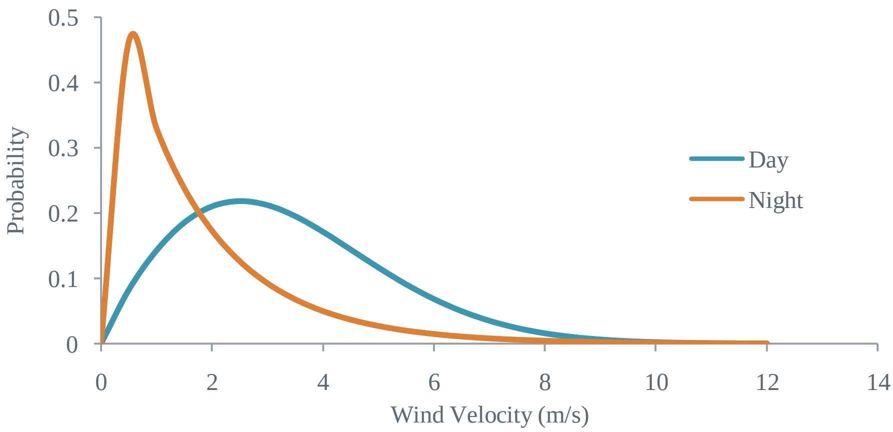


Image 9 The Surface Diurnal Wind Velocity Graph in a Year (March 2012 - March 2013) with Weilbull Distribution

The occurrence chance of diurnal wind velocity along March 2012 - March 2013 are shown by the Weibull distribution on Image 9. On night time the wind velocity that ofter occur in general is the low velocity (0- 2 m/s), while on day time the wind velocity of 2 - 12 m/s occurs more often.

The average surface wind velocity in total in this site is 2,27 m/s. the dominant wind direction is from the east and west (Image 10), this is because of the influence of east and west monsoon which dominates more if compared to the land and sea breeze. In the north direction the surface friction is bigger because the abundance of trees and buildings which gives blockages, so the wind velocity from the north become low.

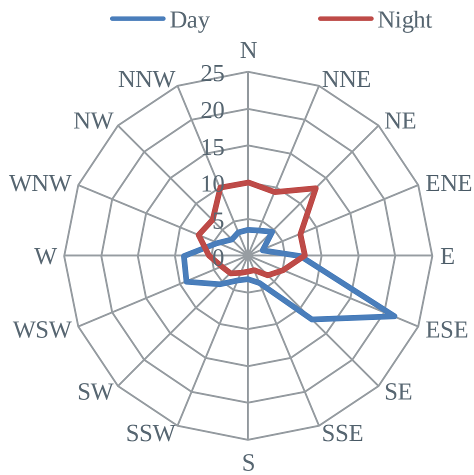


Image 10 The Average Wind Direction Windrose for one Year (March 2012 - March 2013). The average wind direction on day time is shown on the graph in blue while on night time it is shown in red.

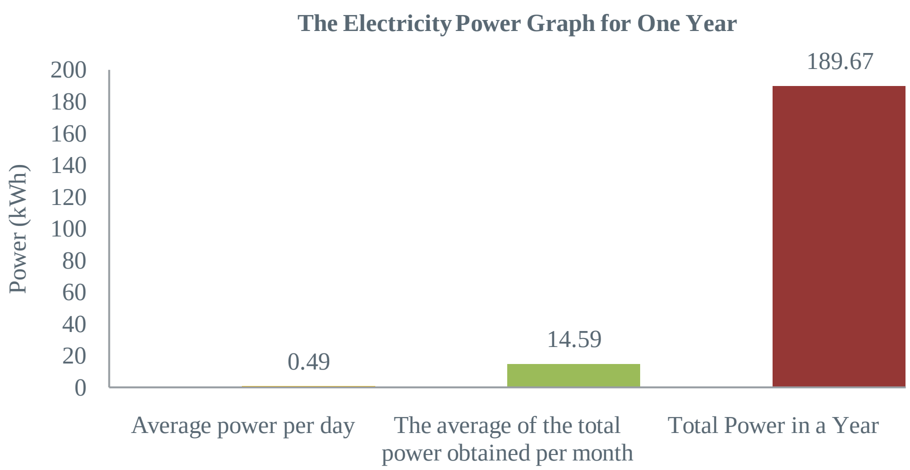


Image 11 The Electricity Power Graph for One Year (Mar 2012 - Mar 2013). The obtained daily average in one year is shown in orange, while the average total power obtained each month is shown in green, and the overall total power in one year is shown in red.

The knowledge about the dominant wind direction is very helpful in planning the placing of the wind turbine. Based on the dominating wind direction in this site, the wind turbine is not very suitable when positioned facing north or south. The wind turbine is better when positioned facing west or east.

The surface wind potential on this site is considered big and promising enough for the development of Wind Power Plant. In 13 months period, the power that can be generated by this kind of turbine is as big as 189, 67 kWh with obtainable average daily power as big as 0,49 kWh and the average of the total obtained power in one month is 14,59 kWh (Image 11).

Conclution

This study aims to determine the wind characteristics diurnally, monthly, and seasonally on this site. The result of the study can be used as the initial analysis for the wind power plant development.

The chance of wind velocity occurrence is obtained by using the Weibull distribution and reviewed each month in one year period. The high wind velocity has the bigger occurrence probability on day time compared to night time. The dominant wind direction on day time is from the South because of the influence from the sea breeze, while on night time the direction is from the north because of the influence of the land breeze.

The maximum wind potential happens on the peaks of the wet and dry season, but the wind potential on the transitional seasons becomes minimal. The dominant wind direction on wet season is from the west, while on dry season is from the east. The monthly wind potential has average power of 0,49 kWh/day (491,25 Wh/day). This shows that this area is suitable for the development of micro scale wind power plant with the KT500 turbine because the producible daily power has meet the wind potential energy standard which ranges between 300 - 500 Wh/day.

In a one year period, the average 5 m wind surface velocity in Cipatujah Beach, West Java is 2,27 m/s. The total obtainable power with the use of KT500 turbine for a 13 month period is as big as 189,67 kWh. The determination of the turbine position installation pays more attention to face west and east because on this site the wind direction is more influenced by east and west monsoon compared to the sea and land breeze.

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