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WIND ENERGY INVESTIGATION IN NORTHERN PART OF KUDAT, MALAYSIA

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Abstract:

A wind-resource analysis at Kudat was undertaken to augment the preliminary wind-energy study. The wind data for year 2004 till 2012 was collected from Malaysian Meteorological Department (MMD) station. The best and suitable sites for develop wind farm were selected from the created energy maps. Wind turbines with nominal powers 6 kW, 10 kW and 15 kW were selected for annual energy production calculations and best fitted ones were used on the micrositting analysis. By applying methods of spatial analysis, with WAsP software, a wind speed and wind energy map was produced. Furthermore,wind rose charts and weibull curves were also generated. The highest interpolated wind speed in selected site was 5.4 m/s, while the lowest wind speeds was 4.3m/s. The most common wind directions were Northeast (NE) and Southwest (SW). For the simulated wind farm, found that the best choice of turbines was wind turbine with capacity 10 kW and result showed the total AEP for 10 wind turbines were 92 MWh, with a capacity factor around 10.4% till 10.6%. This study prove that has potential for developing small scale wind farm for generating electricity in Malaysia.

Keywords: Wind Potential, WAsP, Wind Farm, Micrositting, Sabah, Malaysia

1. INTRODUCTION

Sabah is a state of Malaysia, where located on the northern portion of the island of borneo. It is the second largest state in the country after Sarawak, which it borders on its south-west. Malaysia lies in the equatorial zone and the climate is governed by the regime of the Northeast and Southwest monsoons which blow alternately during the course of the year (Sopian et al. 1994). Kudat is a district located on the north of Sabah. Kudat is well-known as potential region for developing wind farm in Malaysia (Albani et al. 2011).

Wind resource is a crucial assessments in planning a wind energy project and detailed information of the wind at a site, so that, needed to estimate the performance of a wind energy generation (Islam et al. 2011). The wind speed varies with location and needed to determine for the potential of wind energy generation in Malaysia (Muzathik et al. 2009). This study must be completed before making any decision to install wind energy plant (Mathew 2006). There is very limited research on the assessment of wind energy and wind farm potentiality in Malaysia. The government's vision of turning Malaysia into a developed nation by the year 2020 will have a great impact on the usage of energy in the country (Koh and Hoi 2002).

` A number of commercial softwares are available for developing wind maps such as WindPro (EMD) and WAsP (Risø National Laboratory). The Wind Analysis and Application Program (WAsP) was the software used in this

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study and it contains models for the vertical extrapolation of wind data taking into account sheltering of obstacles, surface roughness changes and terrain height variations (Lange and Hostrup 2001). These models are used twice in the process of predicting the wind resource at a site from wind measurements at a different site. First, a regional wind climatology is calculated from a measured wind speed and direction, wind speed distributions for 12 directional sectors for the geostrophic wind are calculated. It is then assumed that the geostrophic wind climate is representative also for the predicted site. The WAsP models are then used to predict the wind resource for the prediction site from the wind climatology calculated in the first step. The output consists of predictions of Weibull wind speed distributions in 12 directional sectors.

2. MATERIAL AND METHOD

2.1. Site selection

The wind data for year 2004 till 2012 was collected from Malaysian Meteorological Department (MMD) station at coordinates 481588.2 N, 764539.9 E (in UTM coordinate system). The meteorological station was located inside the Kudat airport and residential houses obstacle found near to the station.

The selected area for to build wind farm is located in northern part of Kudat, Malaysia. Topography of region is hilly and located at coastal area. The wind data for selected area was assumed has more better in energy potential than the data which is collected from the MMD station. Surface roughness was low due to low plant heights, which is important in wind shear. Fig. 1 shows the location of MMD station in Kudat map. The 'WAsP' softwares were played a key role to evaluate all collected data in order to make wind energy analysis and micrositting considering orography and topography at the site.

2.2 Wind Atlas Calculation

The WAsP numerical model was used for the extrapolation of the 9-year period wind speed values of the existing stations. WAsP is a software package implementing a comprehensive set of models for the horizontal and vertical extrapolation of wind data and the estimation of wind climate and wind resources (Mortensen et al. 2012). These models are employed in the European Wind Atlas methodology (Troen and Petersen 1989). The basic hypothesis of this model is that wind data must be distributed according to the Weibull distribution (Rehman et al. 1994). WAsP contains a complete set of models able to calculate the effects of sheltering obstacles, surface roughness changes and terrain height variations to generate the wind atlas. The wind atlas data set can subsequently be applied for the estimation of wind power potential, as well as for wind turbine siting. WAsP requires information about the elevation and roughness of the study area. The production of the elevation map was based on the Digital Elevation Model (DEM) of Kudat. A DEM of Kudat was used to produce a height contour map with 10 m interval with ArcGIS 10 functions (ArcGIS).

3. RESULT AND DISCUSSION

3.1. Wind Direction and wind speed frequency distribution

Windrose is one of chart which use commonly to outline the frequency distribution of wind directions in an area. The result from windrose analysis at Kudat as showed in Fig. 2, the prevailing winds mainly blow from southwesterly to northeasterly in direction.

Wind Speeds are highly variable and their distribution at any given site can be reasonably described in terms of the so-called weibull distribution (Tiwari and Ghosal 2005). From the analysis of wind speed in Meteorology station site, the value of wind speed with range 1.0-1.4 m/s has the highest frequencies (28.2%), followed by wind speed with range 1.9-2.4 m/s (24.1%). The wind speed in range 3.9-5.5 m/s also shown in good frequencies (21.6%).

The wind data from MMD station was interpolated to the selected area for wind mapping creation by using WAsP functions. The interpolated wind value then analyzed for determine the energy potential on the site. The smaller value of k values correspond to more variable or gusty wind. The k

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value ranges from 1.4 to 1.6 and the A parameter ranges from 4.8 to 6.0 m/s as shown in Table 1. The area in turbine 9 (T9) with coordinate (470468.9 N, 767639.1 E) showed the highest value of mean wind speed in study site, 5.43 m/s, followed by turbine 8 (T8) with value 5.26 m/s. Area for Turbine 3 (T3) showed the lowest value of mean wind speed, 4.33 m/s. The value of mean wind speed for every turbine's area were still suitable for wind turbine with cut in 4.0 m/s and below. This prove that Kudat has potential for harvesting wind energy in Malaysia.

3.2. Wind Mapping

In this study, there are ten wind turbine with various capacity of turbine were placed on Kudat map for software calculation to predict the suitable area to develop wind farm in future. At the tip of borneo, hilly area shows the highest wind speed. Fig. 3 showed the wind speed map of Kudat. The area which showed highest wind speed value were the area in red and yellow colors, while other areas showed moderate value of wind speed. The sites seem suitable for wind turbine installation. Color from purple to red show the wind speed from low value to highest. The roughness length is low in tip of borneo because it is covered by grass lands and assumed no obstacle detected, resulting in good value of wind speeds; thus, there has potential for installing wind farms for commercially purposes.

3.3. Annual Energy Production (AEP)

From the wind atlas produced, an area for wind turbines installation on the north part of Kudat was identified for simulation (Fig. 5). The general site is in highland near to the coast of tip of Borneo. Ten units of wind turbine with three different rated power (6 kW, 10 kW and 15 kW) were used in energy calculation. Fig. 4 showed the wind energy map of Kudat. WAsP also can synchronized with google earth application for creating three dimensional (3D) view of wind energy map as shown in Fig. 5.

Table 2 show the Annual Energy Production (AEP) for three types of wind turbine in Kudat. The Total Annual Energy Production (AEP) for every turbine with rated power 6 kW, 10 kW and 15 kW were 32.1 MWh, 92 MWh and 98.1 MWh respectively. The average capacity factor for 10 kW turbine showed the highest value, 10.5 % and the lowest is turbine with rated power 6 kW. From this analysis, a turbine with rated power 10kW was suitable and recommended for developing of wind farm in Kudat.

CONCLUSIONS

In this study, the wind energy potential of Kudat was investigated by employing a 9-years period wind data from Malaysia Meteorological Data (MMD). By applying methods of spatial analysis, with WAsP software, a wind speed and wind energy map was produced. Furthermore,wind rose charts and weibull curves were also generated. The highest interpolated wind speed in selected site was 5.4 m/s, while the lowest wind speeds was 4.3m/s. The most common wind directions were Northeast (NE) and Southwest (SW). For the simulated wind farm, found that the best choice of turbines was wind turbine with capacity 10 KW and result showed the total AEP for 10 wind turbines were 92 MWh, with a capacity factor around 10.4% till 10.6%. The techniques and findings of this study could provide guidelines to potential investors in identifying wind power production capabilities of an area environment in the Tip of Borneo. Wind rose can contribute to a better understanding of prevailing wind directions, while Weibull curves could help identify the quality of the winds (frequency).

The public acceptance for wind energy as alternative electric energy is high mainly due to the existence of available high potential wind resources as well as support and encouragement from the government. The proposed wind farm is expected to provide a substantial income to local authotities and new job created in future.

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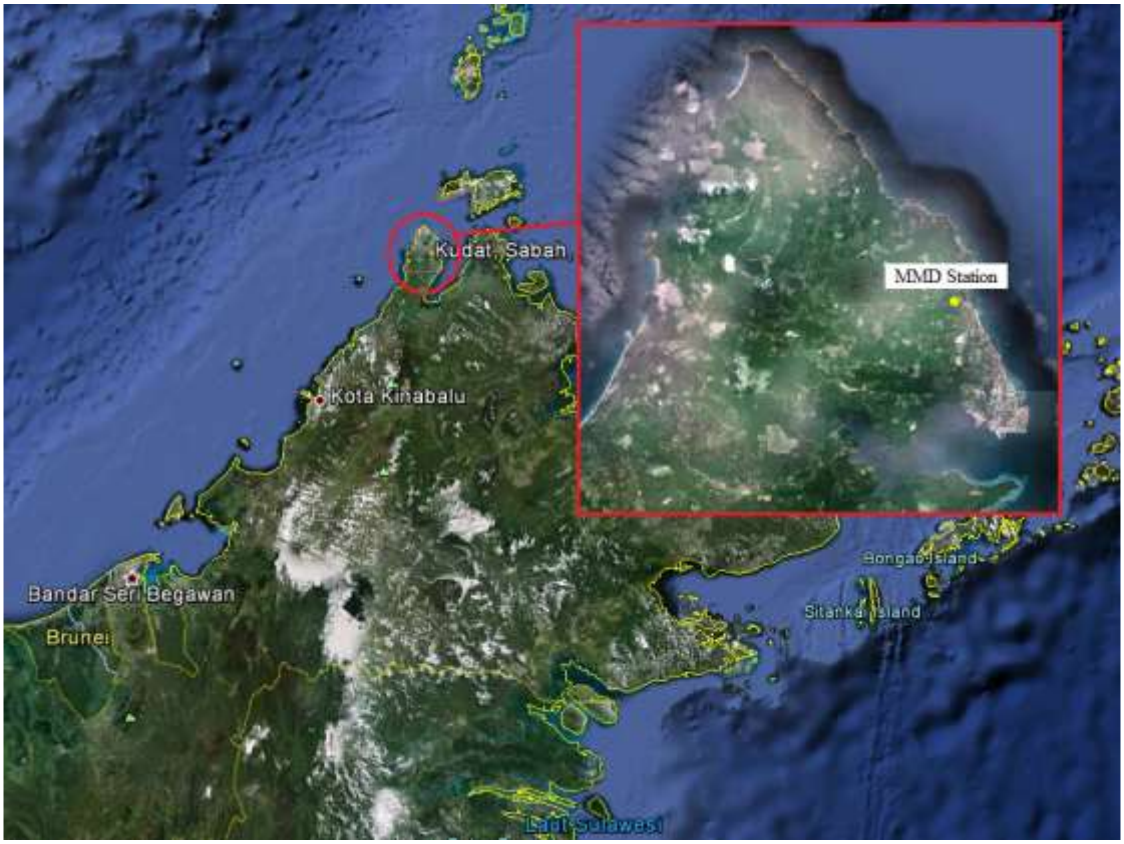

Fig. 1 Map of Kudat (Google Earth)

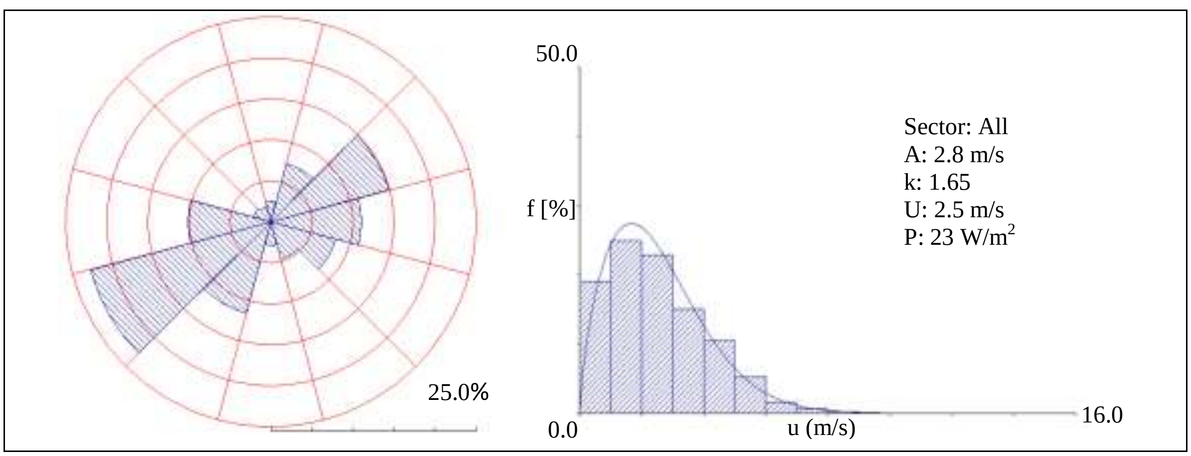

Fig. 2. Wind rose and frequency distribution using data from Malaysian Meteorological Department (MMD) station.

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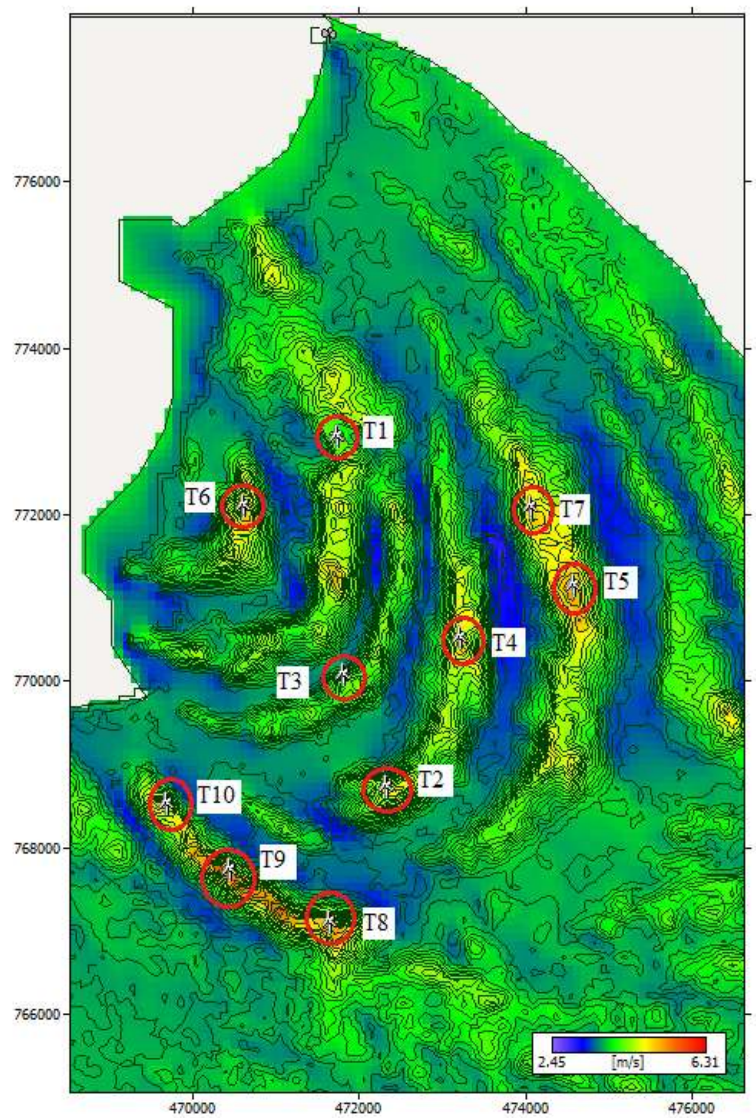

Fig. 3. Wind speed map of Kudat.

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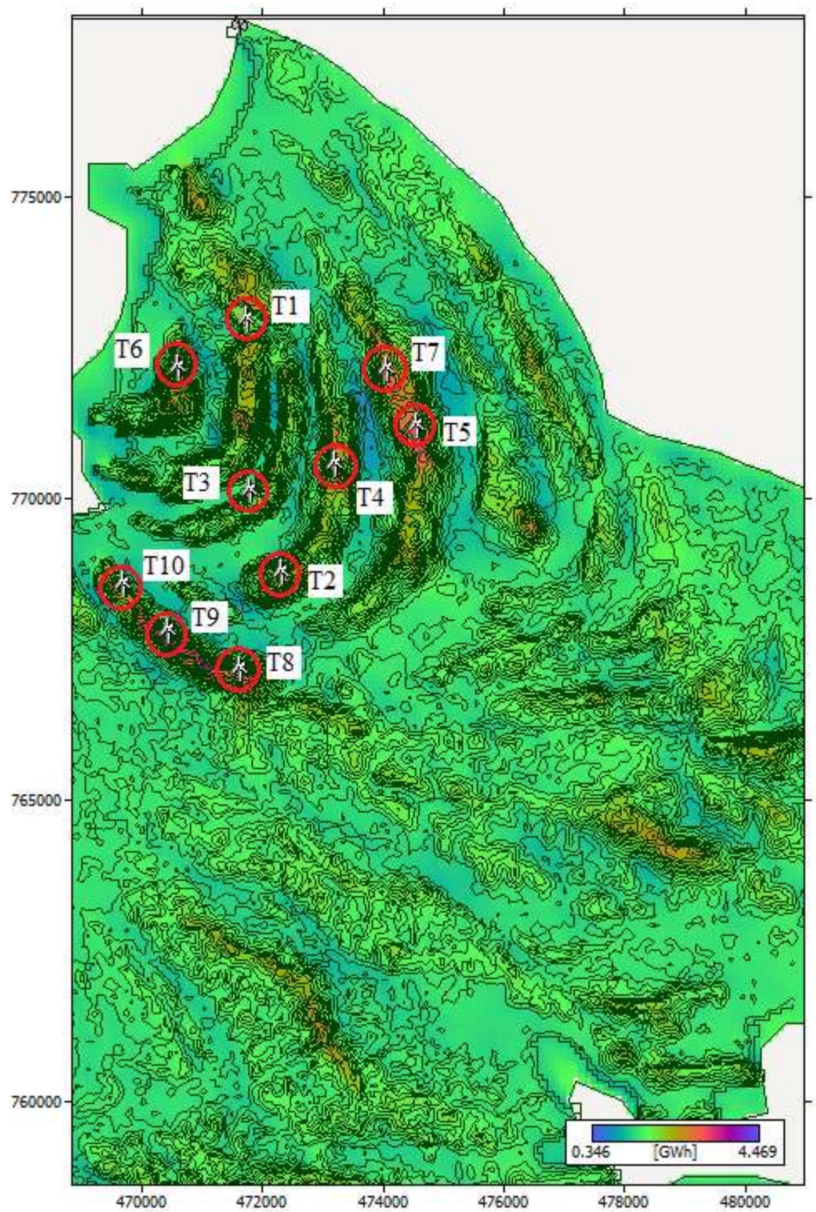

Fig. 4. Wind energy map of Kudat.

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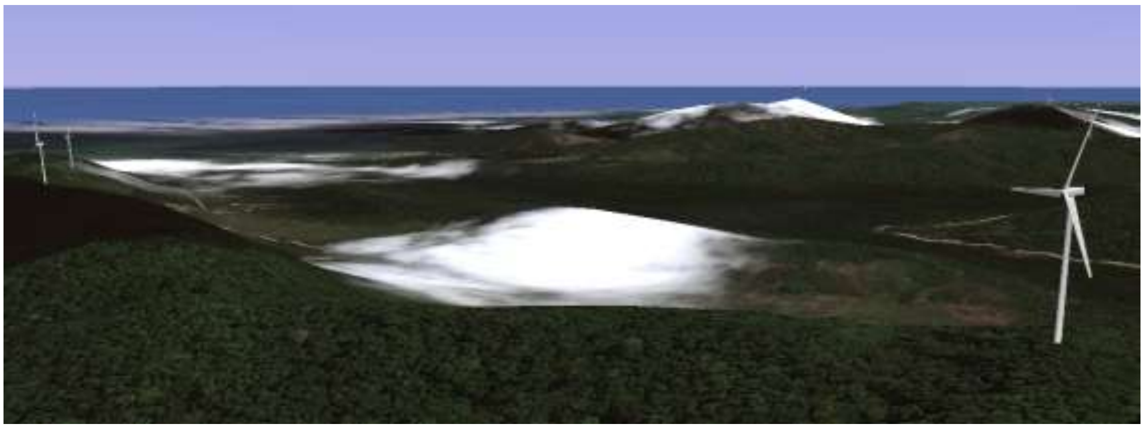
A.



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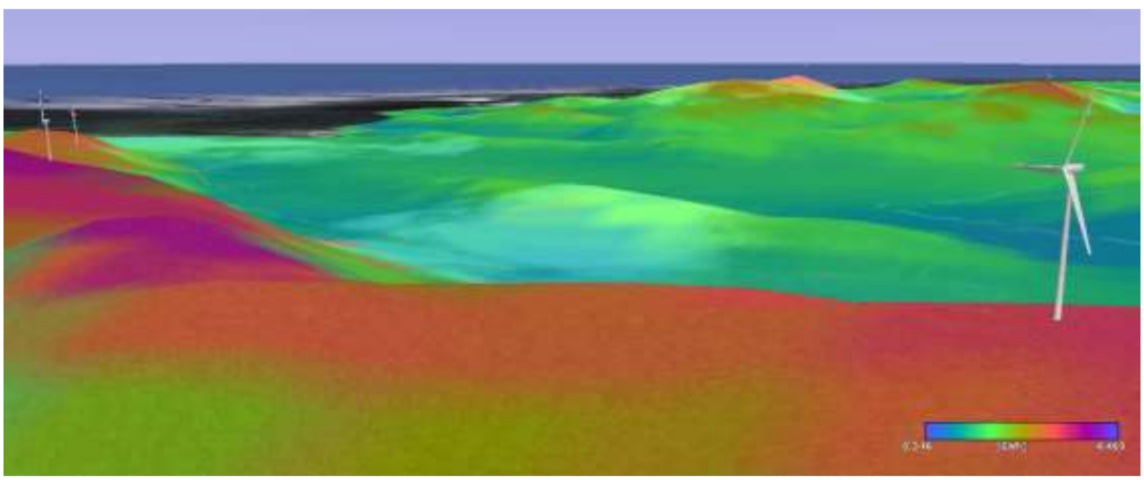

Fig. 5. Annual Energy Production (AEP) three dimensional Map of Kudat. (A) Without WAsP AEP's colour layer. (B) With WAsP AEP's colour layer.

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Table 1. Wind climate analysis in Kudat

Turbines	Locations [m]	A [m/s]	k	U [m/s]
Turbine 1 (T1)	(471763.3 N, 772827.8 E)	4.8	1.4	4.3
Turbine 2 (T2)	(472357.2 N, 768626.8 E)	5.3	1.6	4.7
Turbine 3 (T3)	(471825.5 N, 769965.2 E)	4.8	1.5	4.3
Turbine 4 (T4)	(473233.7 N, 770416.0 E)	5.6	1.5	5.0
Turbine 5 (T5)	(474591.3 N, 771048.3 E)	5.7	1.4	5.1
Turbine 6 (T6)	(470634.8 N, 772009.1 E)	5.8	1.5	5.1
Turbine 7 (T7)	(474082.9 N, 771990.7 E)	5.6	1.5	5.0
Turbine 8 (T8)	(471667.4 N, 767012.2 E)	5.8	1.4	5.3
Turbine 9 (T9)	(470468.9 N, 767639.1 E)	6.0	1.4	5.4
Turbine10 (T10)	(469712.9 N, 768432.0 E)	5.4	1.4	4.9

Table 2: Annual Energy Production for various Turbine

Turbines	m.a.s.l	Turbine 6 kW			Turbine 10 kW			Turbine 15 kW		
		AEP (MWh)	CF (%)	m.a.g.l	AEP (MWh)	CF (%)	m.a.g.l	AEP (MWh)	CF (%)	m.a.g.l
Turbine 1	85.4	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 2	200.8	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 3	125.7	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 4	179.6	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 5	179.8	3.2	6.1	10	9.3	10.6	12	9.8	7.5	15
Turbine 6	190	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 7	174.6	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine 8	189.6	3.2	6.1	10	9.1	10.4	12	9.8	7.5	15
Turbine 9	155.6	3.2	6.1	10	9.2	10.5	12	9.8	7.5	15
Turbine10	108.9	3.3	6.3	10	9.2	10.5	12	9.9	7.5	15
Total	-	32.1	-	-	92	-	-	98.1	-	-
Average	-	3.2	-	-	9.2	-	-	9.8	-	-