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Reviewing Wind Speed and Energy Distribution in Malaysia

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Abstract:

Recent increase on negative issues related to global warming, greenhouse gases and other environmental concerns, the awareness in promoting alternative energy sources have increased significantly. Renewable energy is the most promising and sustainable energy source that will sustain and maintain environment; in particular, wind energy is considered as the clean and perfect solution to present environmental worries as well as to counter the limited hydrocarbon reserves that last for (30-40) years. This paper is to review recent wind speed and energy distribution in Malaysia and enumerate the potentials of using the available resources for wind power generation in the country. The extractable power output in a wind turbine is directly proportional to the speed cubed. Due to the location of the country in the equatorial zone, the annual mean wind speed falls within class 1, which ranges from 2.0-5.0m/s based on recent studies conducted by many researchers. With this, the areas that are suitable

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for small scale wind power generation were identified. Also some of the hindrances facing wind energy progress and possible recommendations were presented.

Key words: Malaysia, Renewable Energy, Wind energy, Wind speed distribution, Energy density

I. Introduction

Malaysia is one of the most developing ASIAN countries. The energy sources primarily comprise oil, natural gas, hydro power and coal, although Renewable Energy (RE) sources such as solar power and biomass are currently being exploited [1]. In parallel with rapid development, the final energy consumption rate grew at the rate of 5.6%; from 2000 to 2005 it hit 38.9Mtoe in 2005, almost 3 times the 2002 level, the projected ultimate consumption being expected to reach 98.7Mtoe in 2030 [2]. However, the transport sector will grow the fastest during the next 25 years with the annual growth projected at 5.3%. The industrial sector and other sectors like residential, commercial and agricultural sectors will grow at an annual rate of 4.8% and 4.2% respectively, and this indicates that to achieve the country energy need, oil will still remain as the most used fuel and it is probable to grow at 4.7% per annum, while renewable energy sources will be the least used resource for energy need and will have a growth rate of 1.5% [3].

The rapid development on wind technology in the developed countries like United State of America and part of Europe has geared the growing interest in the most developing countries like Malaysia. The global annual and cumulative installed capacity of the wind energy power of the world from 1996 to 2012 rose exponentially from 1280 to 44,711MW and 6100MW to 282,430MW respectively [4]. In Asia, China, India, Taiwan, South Korea and Pakistan are the leading countries with the total installed capacity of 75,564MW, 18,421MW,

2,614MW,564MW,483MW and 56MW [5]. The rest of the countries shared 108MW in which Malaysia is included.

The government of Malaysia has formulated a series of policies in order to boost other sources of energy other than oil. The best examples are the national energy policies which had started as far back as 1997 and were revised in 1999, with the announcement of the Five-Fuel Diversification Policy (FDP), which defines that the energy mix is contributed by 5 main resources: gas, coal, oil, hydro and renewable energy in the Eighth Malaysian Plan (MP). Currently, the Malaysian Government is focusing on replacing 5.5% of electricity sources using renewable energy as the country progresses towards becoming a developed nation by 2020 [6-7].

In order for Malaysia to benefit from abundant wind resource investment by Government and private sectors, it becomes necessary to know the general wind speed and energy potential distribution across the country. This paper reviews wind speed distribution and energy potential in Malaysia based on deep literature survey of published papers on wind energy within one decade. This information will benefit Government, private investors and wind turbine manufacturers who are interested in investing on wind technology.

II. Overview on Renewable Energy in Malaysia

A. Resource Assessment

Wind: Estimate of wind power potentials for Malaysia were done by many researchers who concluded that the annual average wind speed blow above 75% range from 2.5m/s and above, the energy intensities perpendicular to the wind direction range from 30W/m^2 and above [8].

Solar: Malaysia lies in the equatorial region with a high sunshine belt, and it has enormous solar potentials, the mean annual average of the total solar radiation varies from 4.12 to

5.56KWh/m^2, the country receives solar radiation at level of about 15MJm/day. Average sunshine hours are estimated at more than 4000hours per year [9-10].

Hydro: Hydropower is site specific, there is a substantial potential of hydro development in Malaysia, with the total technical estimated potential of about 123TWh/yr, because the annual rainfall in Malaysia is between 1500 to 4000mm [11-12].

Biomass: Biomass can be considered as a sustainable substitute for fossil fuels in Malaysia where about 76% of lands are covered by dense tropical forests and agricultural fields. Presently, Malaysia produces an estimated 60 million tons of biomass per year, which does not include 1200 tons of municipal solid waste per day [13].

Wave and Tidal: The mean wave power in Malaysia varies. Depending on the location, in west and east peninsular region, the values range from 0.5 to 2.0kW/m and1.0 to 12.0 kW/m depending upon the season, however in Sabah and Sarawak, the available mean wave power in the region is of 1.0 to 8.0kW/m [14].

Geothermal: Malaysia possesses a good potential of geothermal energy in some regions, and for this reason the potential resources are currently under investigation and development; in the Peninsular area, thermal springs are mainly found along the eastern part, however in Sarawak, few occurrences of thermal springs have been recorded, while in Sabah high concentrations are found within young volcanic areas.

Malaysia's first geothermal plant, to be built at Apas Kiri in Sabah's Tawau district, is expected to have the capability of generating more than 100MW of electricity[15-16]. Table 1 summarized types of renewable energy sources and their energy potential estimated in Malaysia.

Table 1: Renewable Energy Sources Estimates in Malaysia

Renewable Energy Sources	**Estimated**
Wind	2.5m/s and above
Solar	4.12 - 5.56kWh/m^2
Hydro (Pico-micro-mini-small and large)	123TWh/yr
Biomass	60 million tones of biomass / year
Wave and Tidal	0.5-12.0kW/m
Geothermal	Under Investigations

III. Wind Speed Distribution in Malaysia

Due to the importance of wind energy and data available from meteorological wind stations, there have been a lot of efforts by many researchers to investigate the potential of having wind energy in Malaysia. The authors [17-19] reported wind speed in each location as Perlis, Kuala Terengganu, Kuala-Lumpur, Pemanggil Island, Sabah and Nibong Tebal. Other researchers reported in more than one location, east coast of Malaysia, Kudat and Labuan, Mersing, Melacca, Kuantan, Kota Bahru, Langkawi, Penang, Sabah and Sarawak [20-28]. However, some investigated the wind speed characteristics only, while a number of other researchers take into account the energy potential.

Most of the wind data presented by the authors hereof are obtained from Malaysia Meteorological Department (MMD) at Petaling Jaya, Selangor, measured at 10m height mast using cup anemometer and a wind vane as shown in Figure 1 from various wind station across the country, with exceptional cases of measurement carried out based on experimental setup at the study locations [19, 21, 24-25], as shown in Figure 2.

Fig. 2: Weather station

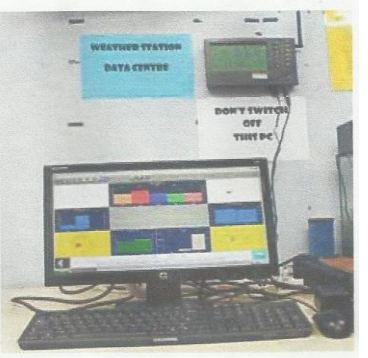


Fig. 3 Davis Vantage Pro2 weather station centre

Based on available wind data from 1995-2000, Sopian et al. [29] investigated the wind speed of four locations at Mersing, Kuatan, Kuala Terengganu and Kota Bharu. The mean wind speed in these sites falls within class 1 and Mersing records the high value of 3.0m/s. In addition to that, seven years wind speed data - 1996-2003 - were collected from a wind station located at Kota Kinabalu, the annual mean wind speed range from 1.0-3.6m/s [28].

Nik et al. [25] analyzed the wind data from 2004-2007 for the east coast of Malaysia; the monthly and yearly average minimum and maximum wind speed ranges from 2.00-5.20m/s and 2.90-3.90m/s respectively. However, based on wind data collected from 2005-2009, the highest wind speed observed at Perlis is 3.5m/s, which occurred in January, 2005 [23]. Similar studies [18] reported the annual wind speed of Perlis as varying from 1.5m/s to-3.0m/s, based on the 3 years wind data analyzed from 2005-2009.

Siti et al. [27] evaluated the potential of wind energy in five selected location of the peninsular area, which includes Langkawi, Penang, Kuala Terengganu, Kota Bharu and Mersing. The annual wind speed computed of these sites is 1.76, 1.15, 1.69, 1.58 and 2.65m/s respectively. Zaharim et al. [21] reported the mean wind speed for east coast Malaysia based on meteorological measurements for a period of two years from 2005-2006, the mean wind speed ranging from 2.041-

3.701m/s and the maximum annual wind speed of 6.544m/s observed in February, 2006. In 2006, Zaharim et al. [30] investigated the wind speed of Kuala Lumpur using observed available wind data available from January to December, the results showing the mean annual wind speed ranging from 1.5194-2.0871m/s respectively.

Islam et al. [26] have studied the wind energy potential of Kudat and Labuan based on the wind data for the duration of three years from 2006-2008, the average annual wind speed for the considered sites ranging from 4.76-3.39m/s. Islam et al. [2] have assessed the wind speed of Mesrsing, Melacca and Kuantan from 2006-2008; it was found from the study that the annual minimum and maximum wind speed varies from 2.70-2.90m/s, 1.80-1.90m/s and 1.60-1.66m/s. Razali et al. [20] investigated the wind power potential in Kuala Terengganu for 12 months wind data in 2008, the mean wind speed measured in the study site being 3.5-5.79m/s respectively. In a different study, Masari et al. [24] carried out an extensive wind recourse assessment at Nibong Tebal: the wind speed data measures at different heights of 10m and 30m respectively, the daily mean wind speed varies from above 2m/s to 6.1-18m/s.

Daut et al. [18] conducted a study on developing and assessing a wind potential at a location in Perlis with more complete coverage: an experimental set up was used to record the wind speed for a period of one year, findings from this study showing that, the maximum, minimum and mean wind speed are 3.2274, 0.1992 and 1.713m/s.

A research work using Wind Atlas Analysis and Application Program (WAsP) was performed by Albani, Ibrahim and Yong [31], an extensive investigation based on wind data available from wind station located in the airport, to evaluate the wind energy potential in northern part of Kudat. It is found that the region is suitable for developing small scale wind farm for generating electricity in Malaysia. From the analyzed wind speed in wind 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 highest interpolated wind speed in selected site was 5.4 m/s, while the lowest wind speeds was 4.3m/s.

Most recent studies on wind speed pattern in Malaysia: Rosly [32] investigated the wind characteristics of fourteen stations across the country based on 3 years of wind data for a period starting from January 2007 to December 2009. The stations are located at Alor Setar, Bayan Lepas, Ipoh, Kota Bharu, Kota Kinabalu, Kuala Terenggan, Kuantan, Kuching, Labuan, Melacca, Mersing, Miri, Senai and Subang. The research shows that Kota Kinabalu is the most potential location of installing wind turbine generator based on highest instantaneous wind speed of 4.25m/s among all the 14 stations. However, in terms of higher mean wind speed Mersing is the most potential compared to 13 other stations. The average wind speed during the North East (NE) monsoon ranges from 2.5m/s, while the lowest wind speed during the South West (SW) monsoon is around 2.3m/s, whereas, based on First Look software, Kudat was found to be the best location to install wind turbine. The mean monthly wind speed and maximum wind speed observed at the 14 stations shown in Figure 4 and 5 respectively. Table 2 presents the wind speed at various wind stations.

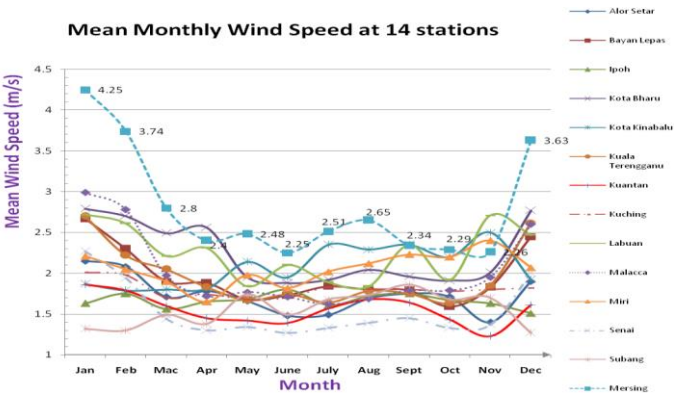


Figure 4: Mean Monthly Wind Speed at the 14 Selected Stations

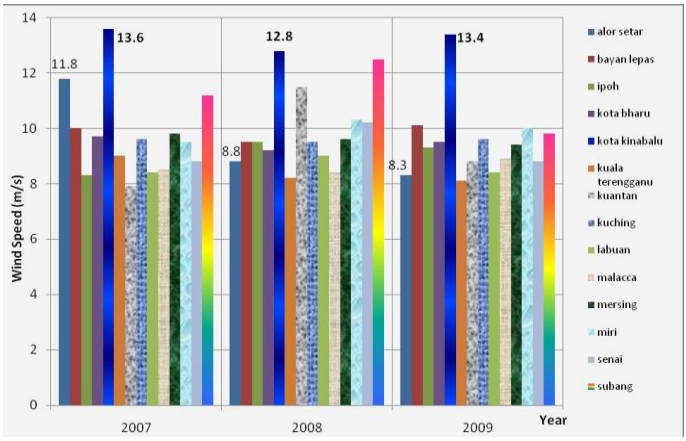


Figure 5:2007-2009 Wind Speed Variations at the Selected Locations

In terms of wind speed spatial prediction and wind mapping approaches, Albani et al. [33] used inverse distance weighting and universal kriging methods for spatial prediction of wind speed in Malaysia. They indicate high and low windy areas of Malaysia as shown in Figure 6. Table 2 presents summary of the average wind speed in Malaysia from 1995-2011.

Table 2: Average Annual Wind Speed from 1995-2011

Location	Data Year(s)	Maximum Average Wind Speed (m/s)	Class
Mersing	1995-2000	3.00	1
Kota Kinabalu	1993-2003	3.60	1
East coast of Malaysia	2004-2007	3.90	1
Perlis	2005 2005-2009	3.00 3.50	1
Langkawi Penang Kuala Terengganu Kota Bharu Mersing	2005-2009	1.76 1.15 1.69 1.58 2.65	1
East coast of Malaysia	2005-2006	3.701	1
Kuala Lampur	2006	2.0871	1

Kudat Labuan	2006-2008	4.76 3.39	1
Mersing Melacca Kuatan	2006-2008	2.90 1.90 1.66	1
Kula Terengganu	2008	5.79	2
Perlis	2011	3.2274	1

Classification Class1 (1-5m/s: Light Wind), Class 2(6-11m/s: Light wind) and Class 3 (12-19m/s: Moderate) [34].

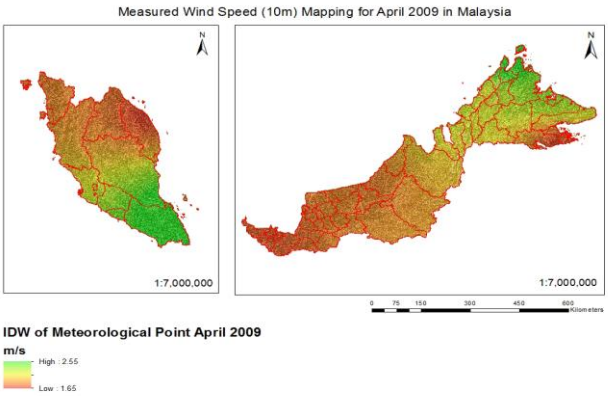


Figure 6: Measured Wind Speed Mapping at 10m Based on IDW

IV. Power and Energy Densities in Malaysia

Wind power per unit area is of fundamental importance in assessing wind power projects. It is well known that the power of the wind at speed V through the blade sweep area A increases as the cube of its velocity and is given, according to Mostafaeiipor et al. [35] by:

$$p(v) = \frac{1}{2}\rho A v^2 \quad (1)$$

where ρ is density of air at sea level with a mean temperature of 15°C and a pressure of 1 atm (1.225 kg/m3) and v is the mean wind speed (m/s).

The power density distribution indicates the potential of wind energy at different wind speed. Various studies

investigated characteristics of wind and energy potentials in Malaysia and reported the power and energy density.

Tiang et al. [19] investigated the wind characteristic and energy potential of Penang. The analysis was based upon wind speed data. The annual mean wind power and energy densities based on the data observed were computed as 24.54W/m^2 and 17.98kwh/m^2. Nik et al. [25] determined the wind energy potential using wind data obtained from Malaysia Meteorological Department (MMD) for east coast of Malaysia. They determine that the annual power density is 84.60W/m^2. Wind energy potential in Kuala Terengganu was analyzed by Razali et al. [20] based on one year data. The average annual power density was found to be 117.2019W/m^2, suitable for small scale power applications.

Siti et al. [27] evaluated the wind speed and energy potential of Mersing, Langkawi, Kuala Terengganu and Kota Bharu. They summarized their findings that Mersing possessed high potential mean power of 62W/m^2, other region having wind power close to 10W/m^2. In recent studies, Islam el al. [26] evaluated the wind energy potential at Kudat and Labuan using 2-parameter Weibuill function. Their findings indicate high potential of wind power in Kudat. The maximum wind power density for the two sites has been found 67.40 W/m^2 and 50.81 W/m^2 at Kudat and Labuan respectively.

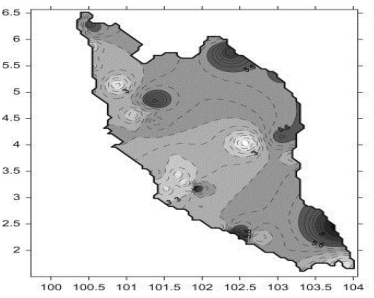
In similar studies conducted to assess the wind power potential of Mersing, Melacca and Kuantan by the same author, the power densities for the study sites were found to be 26.76, 11.98 and 8.4W/m^2 [2]. Maseeran et al. [36] used the concept of raw moment Monte Carlo approach to estimate the theoretical mean power in Malaysia. An analysis of semivariogram indicates the lack of spatial correlation of the wind power in Malaysia. The map of the mean power density over Malaysia indicates that several regions such as northeast, northwest and southeast region of Peninsular Malaysia and southern region of Sabah and Sarawak are having a potential to generate wind

energy due the wind strength that can reach 20 knot or more as shown in Figures7 and 8 respectively.

Table 3: Recent Wind Power Potential of Malaysia.

Location	Data Year(s)	Annual Power Density (W/m2)	Class
East coast of Malaysia	2004-2007	84.60	1
Penang	2005	24.54	1
Perlis	2005-2009	25.54	1
Langkawi Penang Kuala Terengganu Kota Bharu Mersing	2005-2009	≈10.00 ≈10.00 ≈10.00 ≈10.00 62.00	1
Kudat Labuan	2006-2008	67.40 50.81	1
Mersing Melacca Kuatan	2006-2008	26.71 11.98 8.40	1
Kuala Terengganu	2008	117.2019	2

Classification based on power density fair (P, W/m^2 < 100); fairly good (100 ≤ P, W/m^2 <300) good (300 ≤ P, W/m^2 700,); very good (P, W/m^2 ≥ 700) [35].



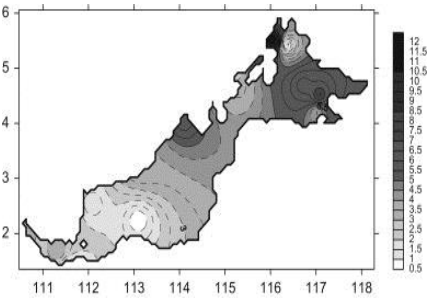


Figure 7: Map of Theoretical Mean Power of Peninsular Figure 8: Map of Theoretical Mean Power of East Malaysia

V. Discussion

The energy content in a wind is totally depending on the average wind speed at a particular or specific location where

the wind energy system is to install. Hence due to the variability nature of wind, the energy available in the wind varies as the cube of wind speed. It is a well-known fact that 1% error in wind speed leads to a 2-3% error in energy output [37-38].

The first step in sitting wind turbine is accurate wind recourse assessment, which is an accurate and precise estimate of wind speed and amount of wind power density at the targeted site. For investing on large (660kW- +2MW) and intermediate (10-250kW) scale wind energy conversion system, the wind speed at the site should range from 5.0m/s and above. However for small scale wind power generation less than 10kW, the wind speed must range from 2.0-5.0m/s.

From section III of this paper, it is understandable that Malaysia is a light wind speed country and this is clear due to the country location in the equatorial zone, the wind speed in Malaysia ranging from 2.0-8.93m/s. The difference is due to inconsistency in nature of wind, annual and seasonal variations.

The wind power density measured in watts per meter square indicates how much energy is obtainable in the site for conversion by a wind turbine, the estimated power density value in Malaysia falling into fairly class with an exceptional case in Kuala Terengganu, which falls within the marginal value. Vertical Axis Wind Turbine (VAWT) is the best option for low wind speed country like Malaysia as it can produce high energy at low wind speed.

Also, the Research Institute for Applied Mathematics of Kyushu University, Japan, has developed a new mechanism called wind lenses; the brim around the wind turbine generates strong vortices with a low-pressure area beyond them. Wind flows into the low-pressure area, and wind velocity increases dramatically near the entrance of the diffuser. At present, twenty-five wind lenses are being trialed in Fukuoka Prefecture, home to Kyushu University [37]. They are

generating electricity as expected; this technology is also good for low wind speed regions.

Figure 9: Wind Lens on the Ito Campus of Kyushu University

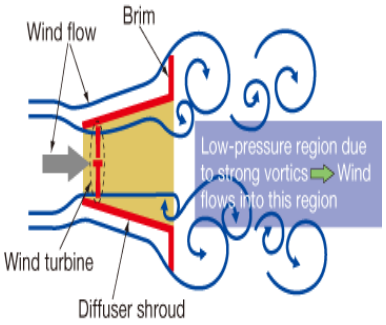


Figure 10: Wind Lens Mechanism

The developed nations that utilize wind power are governed by specifics policies [40]. The best example cases are China, USA, Canada, and Denmark. However, for the current situation in Malaysia, there are no specific policies on wind, since wind energy is a relatively new issue to the country and its potential has not been fully explored.

VI. Conclusion

The wind energy resource and potential in many developing nations is important. In many locations, electrical power generation from wind energy presents an economical feasible alternative to the current dependency of conventional hydrocarbon energy sources such as, petrol, diesel and coal. Hence wind turbines are the alternative to conventional power stations. In comparison to fossil based fuel power stations, wind turbines are cost-effective and affordable in today's world, in addition to being non-polluting and reducing dependence on fossil fuels.

The availability and suitability of wind energy in Malaysia varies depending on the location; from the review hereof most of the studies conducted used available wind speed data obtained from the wind stations, other used evaluation

techniques such as numerical models, Measure- Correlate Predicts (MCP) and wind grid map should be used in order to carry out successfully wind resource assessment in the region with no or limited data.

Lastly, Malaysia power generation sector relies on fossil fuel, considering that wind speed in Malaysia is generally low. More research work is needed especially in rural areas to convert the useful energy resources into electrical power for small scale applications using wind- lens turbines and other low wind speed turbine technology. Also for the dream of wind energy generation in the country to be realistic, more support and funding from government and private investors are highly required.

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