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THE STATUS OF WIND RESOURCE ASSESSMENT (WRA) TECHNIQUES, WIND ENERGY POTENTIAL AND UTILISATION IN MALAYSIA AND OTHER COUNTRIES

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ABSTRACT
Current dependency on finite reserves fossil fuels and adverse environmental effects of conventional power system created new dimension interest in renewable energy sources toward building a sustainable and reliable energy in the near future. Wind energy is renewable and considered as one of the safest, cleanest and fastest growing forms of renewable energy in the world. Generation of electrical energy from wind can only be possible where there is considerable wind resource exists. For this reasons an accurate wind resource evaluation is a vital tool for harnessing energy content in a wind. This paper is critically reviews different techniques used in wind resource assessment, prospects and challenges of utilizing wind energy in some developed and developing countries; however recent progress and development of wind energy potential and utilizations in the countries neighboring Malaysia are discussed. Several recent wind energy potential studies, areas that are suitable for exploitation of wind energy for electrical power generation as well as the current situation of wind energy utilization in Malaysia and possible recommendations were presented.

Keywords: renewable energy, wind energy, Malaysia, wind resources assessment, wind energy potential, wind energy utilization.

1. INTRODUCTION

All countries of the world aim to provide sustainable energy in order to meet social and economic developments. In this regard energy is a vital resource and one of the key factors for the progress of any nation. Energy demands have increase rapidly due to urbanization, industrialization and population growth. Fossil based fuels pollutes lower layer of the atmosphere, generates greenhouse gases and acidification, moreover the resources is limited, and currently the rate of exploitation is expected to deplete within the next centuries [1-3].

Energy crisis witnessed in the early 70s makes other options such as natural gas; coal and hydro become viable [4-5]. The current focus of the world today is better and sustainable energy sources. In relation to the above, renewable energy resources can serve as catalyst for energy generation in the near future. Renewable energy sources, wind, solar, geothermal, hydro, biomass and ocean thermal energy have attracted much interest and attention from all over the world due to their unique inexhaustible and non-polluting characteristics. Wind energy as one of those important sources is perhaps the most suitable, most effective and inexpensive sources for electricity production as a result; it is vigorously pursued in many countries [6].

Wind power utilization in the world is currently at the scale-up development, the total installed global power capacity at the end of 2012 is 282, 482MW of this 38.67% installed Europe, followed 34.63% in Asia, 23.92% in North America, 1.24% in Latin American and Caribbean, 1.14% in pacific region and 0.4% in Middle East and Africa [7]. The global annual and cumulative installed wind capacity from 1996-2012 is shown in Figures 1 and 2, respectively.

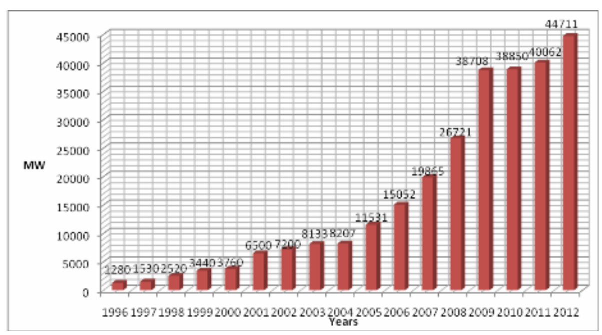

Figure-1. Global annual installed wind capacity.

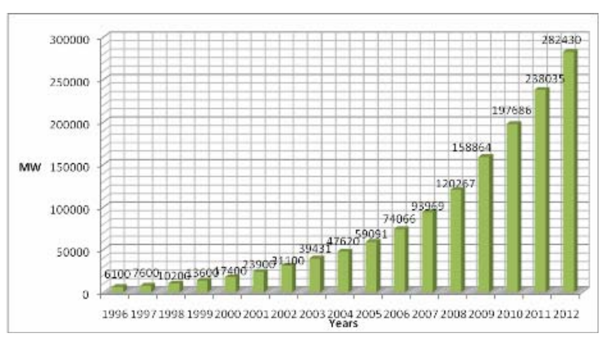

Figure-2. Global comulative installed wind capacity.

Considering rapid development of wind energy applications in the world scenario, it become necessary to identify the conventional practices of wind energy resource in the other countries and perform feasibility survey in context of Malaysian wind power progress in order to propose a good blue print for Malaysia to exploit the abundance of free clean energy. This paper reviews wind resource assessment techniques, wind energy potentials and utilizations in other countries and made comparison with the progress in the Malaysian perspective. The rest of the paper is organized as follows. Section 2 presents state-of-the-art in wind resource assessment. Sections 3 discuss previous wind energy potential and utilization in other countries and Malaysia. Discussion and concluding remarks are drawn in section 4.

2. WIND RESOURCE ASSESSMENT TECHNIQUES: STATE OF THE ART

2.1. Initial step

Wind Resource Assessment (WRA) is the most crucial stage in wind energy design and site planning, and plays an important role in developing successful wind farms, so for this reason wind energy potential analysis must be conducted precisely and in proper manner. Hunter and Eliton [8] have explained the procedures and approaches on how to carry WRA within a given land mass area which includes wind and topographic data, target site selection, topographical update maps, wind flow model development and various anemometric observation techniques. However detail knowledge of numerical wind flow model has assisted in site measurement programmes. In both cases site measurement and numerical model have merit and demerits. Hence most of the wind researchers [9] recommend the following steps for wind energy potential resource assessment.

- **Preliminary area identification**

This process screens a relatively large region (e.g., state or utility service territory) for suitable wind resource areas based on information such as airport wind data, available install wind observation station, nature of topography, population density, flagged trees, and other indicators. At this stage new wind measurement sites can be selected.

- **Area wind resource evaluation**

At the second stage of wind measurement programme is to characterize the wind resource in a defined area or set of areas where wind power development is being considered. The most common objectives of this scale of wind measurement are to:

- Determine or verify whether sufficient wind resources exist within the area to justify further site-specific investigations
- Compare areas to distinguish relative development potential
- Obtain representative data for estimating the performance and/or the economic viability of selected wind turbines
- Screen for potential wind turbine installation sites

- **Micrositing**

The third stage of WRA is Micrositing. Its main objective is to quantify the small-scale variability of the wind resource over the terrain of interest. Ultimately, Micrositing is used to position one or more wind turbines on a parcel of land to maximize the overall energy output of the wind plant.

2.2. Wind data sources

Wind data can be collected in a variety of ways from various sources like meteorological station, internet sources, published wind data books/magazine, prediction models and target site. Many authors used meteorological wind data to systematically carry out research on WRA in the world. Philippopoulos *et al.* [10] used a meteorological wind data, based on average hourly time series observed at National Observatory Athens (NOA), for statistical simulation of wind speed at Athens Greece. Bekele *et al.* [11] have used meteorological data to evaluate wind energy potential at four location of Ethiopia, where wind speed profile and Weibull parameters are calculated. Ahmad *et al.* [12] used meteorological observed data to evaluate wind speed and energy potential for coastal areas of Pakistan, wind energy and associated Weibull parameter for these coastal regions have been examined.

Gibescu *et al.* [13] used historical wind speed data measured at several weather stations to estimate average wind speed patterns and expresses the covariance between locations as a function of their distances. Wind turbine energy output investigated in [14] via power log law. The meteorological data were obtained from the British Atmospheric Data Centre MIDAS database for a station located at West Freugh airfield, Scotland. In [15] proposed that, the long term wind speed at a target site may be estimated by correlation model development based on wind measurement with data from a regional meteorological station.

Using internet data sources for wind energy research has become more popular in recent years. Wind energy potential in Kutahya, Turkey was analyzed using wind data retrieved from internet-WinPLAN [16]. Similar Studies conducted in Nigeria [17] used wind speed data obtained from National Aeronautic Space Administration (NASA) website to evaluate the wind speed characteristics in some coastal cities in Niger-Delta regions.

Predicted wind data also used by many researchers to model wind energy potential at various locations. Kusiak *et al.* [18] used short term predicted wind speed to estimate the energy output yield for wind farm. Moreover, Fripp and Wiser [19] gathered three wind datasets, modeled, anemometer and actual farm production to estimate the time-varying wind power available for California and Northwestern wind sites. Base on the wind data obtained from a yearly published book at Pemerhatian Cuaca Harian Pusat PengajianSosial, Pembangunan and Persekitaran (PPSPP), Fakulti Sains Sosial and Kemanusiaan (FSSK), Universiti Kebangsaan Malaysia (UKM), Zaharim *et al*. [20] described the suitability of fitting wind speed distribution in Malaysia.

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From the Malaysian scenario, wind energy potential studies conducted within the country, almost all the data type's data are obtained from the agency responsible for weather data observation and monitoring called Malaysia Meteorological Department (MMD). The measurement was carried out using a rotating cup electronic anemometer and a wind vane were installed at a 10m height mast for measuring the surface wind speed and direction, based on standard meteorological reference of 10m height in order to achieve representative recording of wind potential of the area [21]. Although, there are a few exceptional cases for instance Nibong Tebal and Perlis [22-23] where data were observed based on the experimental set up in the study areas.

2.3. Methods of data validation

The efficiency of wind energy potential investigation requires a reliable data; steady wind data play a key role in describing wind speed behaviour. Wind data are not always technically valid and cannot be used without careful validation process. If errors occur in the data set, there will be continuous bias in the treatment of the data [24]. After the field data about the wind speed are collected and transferred to the computing environment, the next steps is to validate and process the data and generate reports. Data validation is the process of inspection of all collected field data for completeness and elimination of erroneous values. The data can be validated manually or computer based using required validation software's such as Microsoft excel, lotus 123 and other spread sheet packages. The process consist of two part, data screening and verification, Figure-3 presents the flow chart sequence and roles of each steps [9, 25].

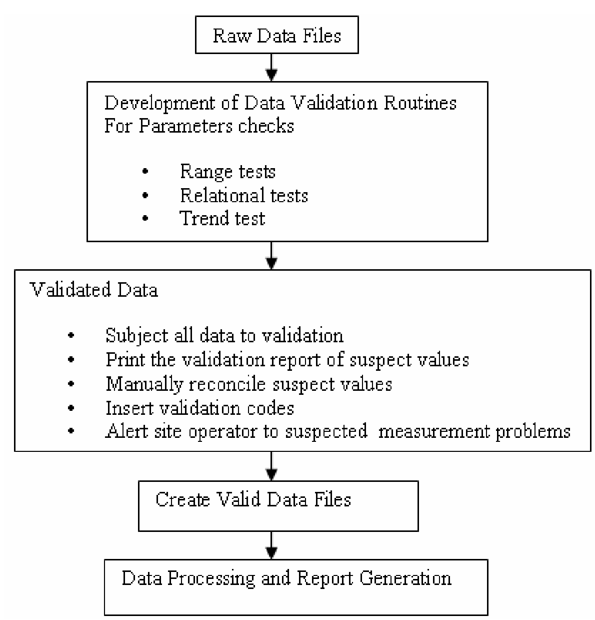

Figure-3. Wind data validation process.

2.4. Uncertainties in wind speed

Wind Speed is an essential parameter in the field of wind power estimation and useful in establishing the annual energy yield from a particular wind project site. It is well know that an error of 1% in wind speed measurement lead to almost 2-3% error in the energy output. [26-27]. Tables 1 and 2 gives the uncertainty in wind speed when an annual wind speed is estimated

Table-1. Uncertainty in wind speed using different methods [28].

Methods	Uncertainty in wind speed
Wind atlas (mesoscale modeling)	10-30
Numerical wind Atlas (microscale modeling)	1-15
Wind atlas and application program (WAsP)	20-5.9
Artificial neural network (ANN)	1.7-6.8
Measured-correlate-predict	5-10

Table-2. Uncertainty in wind speed on site data collection [28].

Monitoring period for on-site wind data collection (Months)	**Uncertainty in wind speed,** (%)
1	6.4-11.8
3	4.9-10.3
6	3.5-7.8
12	1.2-2.8
24	0.6-1.5

2.5. Estimation of missing and invalid wind speed data

Due to the technical and unforeseen reasons wind speed data contain some missing and invalid value. The missing values should not exceed 10% of the total observations [29]. Numerous state-of-the art techniques have been identified for estimating missing and invalid wind speed data. These techniques can be cataloged into persistence, statistical methods and methods based upon artificial neural networks (ANNs).

- **Persistence**

The simplest way to estimate the missing wind data is to use persistence. This method is to give the value of the most recent observations [30]. The accuracy of this method reduces rapidly with increase in number of observations.

- **Statistical**

This approaches for imputing missing wind speed data is based on regression and seasonality.

a) Regression

Estimation of parameters and missing wind speed values under a regression model with less than 10% of observations removed. Maximum likelihood is used to find Weibull probability distribution function parameters for Annual Energy Production (AEP) calculations via simulation [31].

b) Seasonality

This method involves the removal of the seasonality present in both the wind speed and direction before fitting the Weibull distributions to each directional sector [30].

- **Artificial neural networks**

The neural network method is mostly aimed at short missing data predictions. Typical time series model is developed based on historical values. The advantage of the ANN is to learn the relation between inputs and outputs by a non-statistical approach. The accuracy of this forecast depends on how well the ANN is trained [32]. Siripitayananon *et al.* [33] have developed a neural network model that attempts to "learn" and "discover" wind speed behavior from available data and to estimate the missing data caused by instrumental failure due to birds, thunderstorms, or other unexpected events. In [34] introduced the use of Adaptive Neuro-Fuzzy Inference System (ANFIS) model to interpolate the missing and invalid wind data sets obtained from a wind farm in North China.

Kline and Milligam [35] have also illustrated three techniques of estimations hourly missing wind sped data, which are Markov transition matrix, trend method and Lag -1 Auto Regressive Markov chain. Zaharim *et al.* [20] have modeled hourly wind speed data of Malaysia, starting from January until December 2006. From the data collected, all missing data which were assumed defective were omitted. In case the data values are missing, wind speed can be estimated by taking a global value of v = 2 m s^{-1} [36].

2.6. Vertical profile of wind speed correction

Based on meteorological standard, the initial measurements are generally taken at ten meters height, although there are data captured at lower height for other purposes. The most widely used model to extrapolate wind speed at various altitudes is the Hellman equation and it is popularly known as 1/7th power law [37]:

$$\frac{v_1}{v_2} = \left(\frac{h_1}{h_2}\right)^{\alpha} \qquad (1)$$

in which v_1 is the speed to the height h_1, v_2 is the speed to the height h_2 (frequently refer to as standard level of 10m height) and α is the friction coefficient and can be approximated by (2) as stated by [38].

$$\alpha = 0.096 Log_{10} z_0 + 0.016 (Log_{10} z_0)^2 + 0.24 \qquad (2)$$

for 0.01m < z0 < 10m, where z0 represents the surface roughness in meters.

Another most important formula used in Europe to describe the change in wind speed with different hub heights is logarithmic equation [14, 39]:

$$\frac{v_1}{v_2} = \frac{\ln\left(\frac{h_1}{z_0}\right)}{\ln\left(\frac{h_2}{z_0}\right)} \qquad (3)$$

where z_o represents the surface roughness length. Tables 3 and 4 show various friction coefficient and surface roughness length for variety landscapes.

Table-3. Friction coefficient values [40].

Landscape type	**Friction coefficient α**
Lakes, ocean and smooth hard ground	0.10
Grassland (ground level)	0.15
Tall crops, hedges and shrubs	0.20
Heavily forested land	0.25
Small town with some trees and shrubs	0.30
City areas with high rise building	0.40

Table-4. Landscape and roughness values [40].

Terrain	Landscape type	Roughness class	Roughness values z_0 (m)
Flat	Beach, ice, snow landscape, ocean	Z_0	0.005
Open	Low grass, airports, empty crop	Z_1	0.03
	Land, high grass, low crops	Z_2	0.1
Rough	Tall row crops, low woods	Z_3	0.25
Very Rough	Forests, orchards	Z_4	0.5
Closed	Villages, suburbs	Z_5	1
Towns	Town centers, open spaces in forests	Z_6	2

The changes of wind speed with height for different types of topography have been investigated by many researchers. Ko *et al.* [41] used power law to estimates the wind speed 37.5m, because of the malfunction of the anemometer at 45 m height. The computed wind speed was utilized to exploit the wind energy potential of Jeju Island, Korea. A logarithmic method [45] was used to find the wind power potential at 10.0-30.0 meters above the ground level in Chiang Mai, Thailand.

From the literature, friction and wind shear coefficients is generally approximated, however in real situations, the values is not constant for this reasons, Mohandes *et al.* [43] proposed a clustering algorithm based neuro-fuzzy method to compute the wind speed profile up to the height of 100m based on knowledge of wind speed at lower heights. The comparison with the $1/7^{th}$ law and logarithmic method further proofs show the suitability of the proposed method for generating wind speed profile based on knowledge of wind speed at lower heights.

Another technique uses Weibull probability density function to obtain the extrapolated values of wind speed at different heights. Parameters of Weibull distribution functions *Kz* and *Cz* for altitudes *z* above the anemometer level are obtained using the following relations [1]:

$$K_z = \frac{K_a\left[1-0.088\ \ln\left(\frac{Za}{10}\right)\right]}{\left[1-0.088\ \ln\left(\frac{Z}{10}\right)\right]} \tag{4}$$

$$Z_a = C_a\left(\frac{Z}{Z_a}\right)^n \tag{5}$$

where *Ka* and *Ca* are respectively the shape and the scale parameter at the anemometer height *Za* and the exponent n is given by the relation:

$$n = \frac{[0.37 - 0.088\ \ln C_a]}{\left[1-0.088\left(\ln\frac{Z_a}{10}\right)\right]} \tag{6}$$

In relation to the above, another extrapolation method suggested in [44], vertical wind velocity extrapolation formulation is derived on the basis of perturbation theory by considering power law and Weibull wind speed probability distribution function. The proposed methodology not only consider the mean values of the wind speeds at different elevations but also their standard deviations and the cross-correlation coefficient between different elevations are taken into account.

2.7. Wind speed modeling for WRA

Wind energy is characterized by climatic space-time variability. It becomes necessary to take a look at the actual wind speed distribution. Various researchers had conducted an extensive research works. Different analytical models are employed in fitting such as: statistical techniques, Weibull distribution and Rayleigh parameter, lognormal, Gamma, Pearson, Gumbel I distribution functions, stochastic simulation; seasonal autoregressive integrated moving average model; linear and multiple regression models; and artificial neural network models [45-46].

- **Statistical models**

A statistical method is commonly used to describe the measured wind speed. Many authors [47] used Weibull to model the wind speed, while others describe the wind characteristics using, Rayleigh [48], Lognormal [49] and Gamma models [50]. However [1] used a combination of Log-normal, Normal, Rayleigh, Gamma and Weibull to model wind speed and wind power distribution in Rwanda. Weibull probability distribution function has been used by many researchers to describe the wind behavior and assess the wind energy potential in various location of the world. Other studies have involved the use of Weibull in conjunction with Rayleigh to analyze and estimate the wind energy potentials [6]. In a nutshell, Carta *el al*., [51] performed an extensive investigation of 12 models using wind data of Canary Island in Spain. They summarized their findings that two parameter

Weibull model present series of advantages with respect to other model analyzed. The Weibull probability and cumulative model can be described as follow:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left\{-\left(\frac{v}{c}\right)\right\}^{k} \quad (7)$$

$$F(v) = 1 - \exp\left\{-\left(\frac{v}{c}\right)\right\}^{k} \quad (8)$$

where c is scale parameter , k stand for shape parameter and v is wind speed.

Different types of Weibull parameters estimation methods have been used from various studies and research works. Methods based on maximum likelihood [52], least square [53], energy pattern [54], standard deviation [55] and moment methods [56]. However artificial neural networks have been proposed in [57], this novel approach estimates the monthly Weibull parameters k and c only. An extensive comparison study of four Weibull estimation methods was conducted by [58]. They concluded their findings that the suitability of these methods may vary with the sample such as data size, data distribution months, and sample data format and of fit tests.

- **Stochastic simulation model**

Stochastic simulation and modeling of wind speed is useful tool in wind resource assessment. For that reasons, Hfaoui *et al*., [59] used twelve years of hourly average wind speed data to build an autoregressive model AR (2) to simulate the wind speed sequences in Tangiers, Morocco. Similar to that, in Athens, Greece [10] introduced the use of Autoregressive Moving Average (ARMA) models based on Box- Jenkins methodology. This approach improves the models and found to be superior in simulating the frequency distribution of wind speed compared to Weibull statistical simulation. Moreover, [60] proposed the use of wavelet to model the non stationary wind speed data, this approach allows to analyze insight context of the wind speed characteristics.

- **Artificial neural network models**

Artificial Neural Networks (ANNs) have been used to model complex non linear wind speed behavior without a mathematical or statistical formulation [61]. A novel Generalised Feed-forward Neural Network (GFNN) method to predict wind speed probability density functions has been presented in [62]. The methods used the Weibull functions' parameters as input to the network. The ANN based wind speed distribution estimation gives better results for calculating the energy output from some commercial wind turbine generators in Turkey.

2.8. Software used in WRA

There are several software applications for wind resource assessment. A variety of different software has been used by various authors. Oner *et al.* [63] have used Wind Atlas Analysis and Application Program (WAsP) to investigate the wind energy potential based on wind data analysis in Babarun-Turkey. In Algeria, work on wind resource assessment was conducted by [26] giving the results of the statistical study of 37 locations using the WAsP. Wind data that has been extracted from Renewable Energies Organization of Iran (SUNA), collected near 2 years from 2007 to 2009 in the time interval of 10 min was analyzed using Windographer 2.5 software [64]. WindSim and WindPRO software's has been used to estimates and compares the annual energy production results produced for two wind farm site located in Greece [65].

In [66] a comparison study of WAsP and two Computational Fluid Dynamics (CFD) models were presented. The analysis shows that, despite the complex terrain, WAsP compares better than the CFD-models. Performance analysis of wind resource assessment program in complex terrain presented in [67], their findings reveal that Navier Stokes model can produce more accurate results in complex terrain, however In terms of real production; the CFD model Windsim keeps being closer to reality than a linear model such as WAsP. CALLaLOG 98 and ALWIN software programs has been used to evaluated and stored average time series sequence wind speed data [68].

Due to the very spatial nature and characteristics of wind, it becomes essential to estimate winds at each of the wind turbine location. The simplest mean for doing this is by taking the actual measurements, it is not recommended because is time consuming and cost implication. As a result, simulation codes based on theoretical and empirical results are used to estimate winds at all wind turbine locations based on wind measurements made at one reference location [69]. MapInfo GIS software package assists in creating all the input spatial data for the WAsP program to work with and also in presenting the results spatially.

3. WIND ENERGY POTENTIAL AND UTILIZATION

3.1. Wind energy potential and utilization in developed countries

In recent times a large number of studies have been carried out in order to determine the wind energy potential in the world. A technical wind resources assessment completed by the Wind Program in 2009, estimated that the land-based wind energy potential for the contiguous United State is 10, 500GW capacity at 80m and 12, 000GW capacity at 100m heights, the estimate was computed from the total offshore area within 50 nautical miles of shore in areas. The average annual wind speed is at least 7m/s at the height of 90m [70]. However, the 13, 124 MW of wind capacity installed in 2012 represented 42 percent of new generating capacity in the country [71].

There are real-time measurements from weather stations in Germany. The wind speed strength range from 7-10.5m/s, however, the southern part of the country experience a wind speed up to 12-14m/s [72]. In the year

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2012, the installed capacity of wind power in Germany was 31308 MW with wind power producing about 9 percent of the total Germany's electrical power [73]. The average wind speed in Spain fall within beaufort scale of 2 and 3, for this reasons there is rapid growth in wind power generation in the country. Spain had achieved relatively high levels of wind power utilization, the total installed capacity at the end of 2012 is 22, 796MW [74].

Denmark has relatively modest average wind speeds in the range of 4.9-5.6 m/s measured at 10 m height. Onshore wind resources are highest in the eastern part of the country, and on the eastern islands with coastlines facing south or west [75]. The country has very large offshore wind resources and big areas of sea territory with a shallow water depth of 5-15 m, where sitting is most feasible. These sites offer higher wind speeds, in the range of roughly 8.5-9.0 m/s at 50 m height [76].

Denmark generates more wind power per head of population than any other country in the world. Its 5500 wind turbines, including the world's two largest offshore wind farms, generate 16% of national energy demand. At the end of 2012, the installed wind capacity hits 4, 162MW [77]. Based on historic data starting from 1996 to 2011obtained from 50 meteorological stations spread across the mainland of United Kingdom (UK), the result shows that, the average annual wind speed varies from 3-11m/s [78].Wind power developments in the UK do not operate as stand-alone systems, but they are integrated into existing electricity generation and supply systems [79]. The UK ranks sixth in the world for installed wind power, with 8.5GW capacity in Europe [80]. Table-5 reported the top wind power usage countries at the end of the 2012.

Table-5. Top 10 wind power usage countries.

Rank	Country	Wind power capacity (MW)	Share in total
1	China	75, 324	26.67
2	USA	60, 007	21.25
3	Germany	31308	11.09
4	Spain	22796	8.07
5	India	18241	6.46
6	UK	8445	2.99
7	Italy	8144	2.88
8	France	7564	2.68
9	Canada	6200	2.20
10	Portugal	4525	1.60
11	Rest of the world	39853	14.11
	Total	282, 407	100.00

3.2. Wind energy potential and utilization in developing countries

Developing parts of the world have considerable amount of wind resource, hence utilization of wind energy has become increasingly attractive [81]. In recent years couples of wind potential studies have been conducted in the developing nation among them are discussed below.

China has vast wind resource, the estimated wind power density potentials in the northern part of China is above 200W/m^2, sometime the density can reach 500W/m^2. However, the southern part of China along and the near coast, the wind power density is 200W/m^2 [82]. The annual hours of wind speed in China is range from 3-6m/s [27]. China remains the largest market of wind power plant, both in terms of capacity added and installed plant, according to Global Wind Energy (GWE), China had 75, 564MW installed wind power plant at the end of 2012 [83]. Similar studies were conducted in different developing nations, in Iran [84], Nigeria [17], Egypt [85], Algeria [26], India [86], Turkey, [26], Rwanda [1], Senegal [87], Ethiopia [11], Pakistan [12], Sudan [88] and Saudi Arabia [89]. All the authors investigated the wind energy potential using meteorological stations data available based on simple set of parameters, including average wind power density (W/m^2) and wind speed.

Iran is blessed with large oil reserve, wind resource potential in the country were range from 1.85-3.44m/s [90]. The wind power potential is approximately 6.5GW, and currently Iran wind energy station has 9.7MW capacity [91]. Nigeria has abundant of renewable and non-renewable energy sources. Wind speed in the northern part of the country fall within class 2 and 3 respectively, however in the southern region range from 2.1-3.0 m/s [17, 92]. Wind power utilization in Nigeria is practically minimal relatively insignificant. The Tractor and Equipment division of United Africa Company (UAC) has started manufacturing the wind pump in Nigeria [93]. At Present, there is no established supplier of wind turbine in Nigeria.

Egypt is currently the largest installed wind capacity in Africa and the Middle East. By 2020, the Egyptian energy sector targets to generate 12% of the electricity needs from wind, making it the major renewable energy source in the country electricity mix [85]. Currently, wind power plants installed in Cairo is 550MW [94]. Wind speed in the most region of Algeria range from 3-6m/s at 10 m above ground level. Wind energy utilization knew a considerable delay due to two main reasons. Firstly, fossil energy is available in the country. Secondly, a large proportion of electricity is generated by gas and water vapour turbines [95].

Recent studies conducted in western and metropolitan locations of India shows that, the wind speed is generally low during the fair weather months of January, February and March. The average wind speeds range up to 14.2 m/s during the peak south-west monsoon [96-97]. Based on wind resource assessment estimates, the total wind power potential is 45, 000MW; this potential is distributed mainly in the states of Tamil Nadu, Andhra

Pradesh, Karnataka, Gujurat, Maharashtra and Rajasthan, the wind power density being in the range of 250-450W/m^2 [98]. The contribution of wind power in India is high; currently it is the fifth largest wind power producer in the world. The installed capacity of wind power in India was 18, 634.9MW as of 31st January, 2013 [99].

Turkish energy policy is concentrated mainly on ensuring a supply of reliable, sufficient, economic and clean energy; the country is endowed with strong wind conditions, particularly in the south of the Marmara region, coastal and some inner parts of the Aegean region, some parts of the Black Sea, the eastern part of the Mediterranean, and locations with rugged mountains in Eastern Anatolia are the most promising regions [63,100].With the heavy reliance on fossil fuel Senegal wind power wind power potential is concentrated along the coast, particularly at the north coast between Dakar and Saint-Louis. In a study carried out by the Senegal Meteorological Service, wind velocities in the 50 km-long coastal strip between Dakar and Saint-Louis is fluctuating between 3.7-6.1m/s. The Centre d'Études et de Recherches sur les Energies Renouvelables (CERER) measured an average annual speed of 5.8 m/s at the north coast and 4.2 m/s at the south coast, Senegal has been slow to deploy wind turbines. At present wind power in Senegal is primarily utilized for operating water pumps [87, 101].

It has been found that Ethiopian wind speeds suitable for electricity generation diverge across the territory. According to a recent survey conducted, there are several wind stations with higher than 6 m/s annual average wind speed, the speed generally considered as the minimum necessary for power production. The highest wind speeds measured in the Mekelle Region at Ashegoda is 8 m/s and 6.84 m/s in Harena. Other high wind speed sites were found at Nazareth and Gondar with 6.64 m/s and 6.07 m/s respectively. Wind speeds at around 4 m/s were recorded in Harar, Debre Birhan and Sululta [81]. Based on the wind resource map of Pakistan, the major windy areas are southeastern, northern Indus valley, southwestern and central Pakistan [102]. Recent study conducted [103] reveals that, the average wind speed of Quetta and Karachi is 3.5 and 4.4 m/s respectively. Currently the Government of Pakistan is building a 49.5 MW wind energy farm at Jhimpir near Karachi [104].

In Sudan, various research works on wind power potential have been conducted, and the results proved that wind power would be more profitably used for local and small scale applications especially for remote rural areas [105]. Although Saudi's energy generation mix is almost wholly dominated by fossil fuels, with oil representing around 60% of energy sources and natural gas is making up the rest [106]. The wind map of Saudi Arabia indicates that, the Kingdom is characterised by the existence of two vast windy regions along the Arabian Gulf and the Red Sea coastal areas.

The mean annual wind speed in these two windy regions exceeds 9 knots (16.7 km/hr) and ranges from about 14 to 22 km/hr and 16 to 19 km/hr over the Arabian Gulf and Red Sea coastal areas, respectively [107].

3.3. Wind energy potentials and utilization in countries neighboring Malaysia

Malaysia is located in the Southeast Asia region have these six neighbors: Indonesia, Philippines, Brunei, Vietnam, Thailand and Singapore. The climatic condition of Indonesia is tropical in nature with low wind speeds (2.8-7.5m/s) has 1.4MW wind turbine installed, however a new plant had been built in South Sulawesi and Aceh Bulukumba, which consist of 0.5 MW and 10 MW, respectively [108]. Singapore's wind speed is too low to generate power efficiently. Moreover, due to the strong capabilities in electronics, precision engineering and the chemicals sector, the viable renewable energies in Singapore are solar, fuel cells and biofuels [109]. But according to the recent studies conducted by [110], Singapore's wind speed is less than 5m/s, the minimum speed for wind turbines to operate. The findings will allow the Energy Research Institute at Nanyang Technological University to modify wind turbines to operate effectively in urban environments and to install 250 to 500 kW wind turbine in the Semakau landfill.

Vietnam wind resource is quite modest, good wind condition areas are near the China border and in the southern part. Based on data from World Bank (2001), the theoretical potential is 500GW at 65m above the ground level at the average wind speed of 6m/s and above. The areas where annual wind speed is in the range of 6m/s or above is about 2,435Km^2 with estimated potential of 24, 351MW [111]. At present time, Vietnam wind power projects include hybrid 2-30kW wind turbines - diesel generators, the family-scale 150-200kW wind turbines installed for standalone application in islands, and the industrial scale wind power stations [112]. Currently, Vietnam Renewable Energy Joint Stock Company (REVN) has successfully installed 20 (Furhlaender 1.5 MW) wind turbines and 10 (GE 1.6 MW) under development for grid connected applications, moreover, wind power projects ranging from 6 MW to 150 MW are at different development stage [112].

Brunei has been for a long time depends on its oil and gas for power generation, the country has a long coastal area which makes it possible to develop wind power plant [112]. There are 19 onshore/offshore potential sites identified in Brunei for the development of wind power, both sites deemed ideal to harness wind power, the estimated wind power is about 20-30MW which represent less than 2% of the country annual generation demand [112]. Northern coastal area is one of the most shows potential sites, with generation speeds of more than 6m/s, technically exploitable capability for offshore sites has been assessed to have potential at around 1, 800MW [113].

The wind resource in the Philippines is strongly dependent on latitude, elevation, and proximity to the coastline. In general, the best wind resources are in the north and northeast, and the worst source are in the south and southwest of the archipelago [114]. These windy areas can support a potential installed capacity of 76,600MW [115]. Philippines is the top wind power producer in

Southeast Asia having 33 MW wind turbines in Bangui, Ilocos Norte that started operation in 2005, however United State National Renewable (NREL) and Energy Laboratory Department of Energy (DOE) shows that out of the 73 provinces in the Philippines 47 have at least 500 MW wind potential and 25 have at least 1, 000 MW [115].

Historically, wind power generation technology has been introduced in Thailand since 1983. In recent years attention has turned to utilising the resource for power generation. A Thailand promising area is in high altitudes and along the coast [116]. Wind speed pattern in Thailand is mostly influenced by Northeast-monsoon during November to April and Southwest-monsoon during May-October The mean wind speed varies from 2.5 m/s in the north to 5.0 m/s in the south of Thailand. Based on the wind speed map [117] showed that Thailand experiences generally very low wind speeds with typically average speeds of not more than 3 m/s. Wind energy in Thailand is given special emphases on the usage for water pumping, rice field irrigation, salt farm and electric generation [118]. Thailand's current biggest project in wind energy is 2.5MW Lam Thakong wind turbine power system built in Nakoh Ratchasima [119].

3.4. Wind energy potential and utilization in Malaysia

Various studies were carried out in order to investigate wind speed and wind energy potentials in Malaysia. Research works on wind energy potential assessment in Malaysia dates back to 1995, when Sopian *et al.* [120] have used hourly wind speed data to investigate the wind speed and energy potential of 10 wind stations in Malaysia using Weibuill model. Their results show Mersing and Kuala Terengganu possessed high potential to implement small wind drive systems for underdeveloped areas in the east coast of peninsular.

Daut *et al.* [23] presented analysis of solar and wind speed characteristics in Perlis. The Weibuill model is used to analyse the wind speed. The results of this study shows that, based on Weibull parameters, the site is suitable for small scale power generation. Similar studies of wind energy conducted in [121] which investigated the potential of wind energy in Perlis by implementing Weibull distribution method; they concluded that Perils has a strong potential of developing wind energy system as one of its resource of renewable energy. Potential of wind and solar energy using Weibull and Hargreaves methods in Perlis presented by [122], they summarized their results that, the potential of both wind and solar radiation is highly suitable to assess in Perlis.

Wind speed and energy potential at the East coast of peninsular studied by [123]. The wind power of the investigated site is lowest in Southwest monsoon seasons, while highest in the Northeast monsoon seasons as 84.60W/m^2. Anwari *et al*., [124] studied technical and economic assessments of hybrid wind-diesel energy system for Pemanggil Island in Malaysia, the investigation demonstrated the suitability of using the hybrid system compared to standalone diesel system. Similar research works [125] introduced wind and photovoltaic hybrid for a household's application in Malaysia.

Findings of this study revealed that in the year 2004, average annual wind speed in Kuala Terengganu is 3 m/s and annual average solar energy resource available is 5.2kWh/m^2/ day.

In a separate study [126] proposed the use of a PV wind diesel generator hybrid system in order to determine the optimal configuration of renewable energy in Malaysia and to compare the production cost of solar and wind power with its annual yield relevant to different regions namely, Johor, Sarawak, Penang and Selangor. Based on the findings of this study, a PV diesel generator hybrid system is the most suitable solution in terms of economic performance and pollution. However, the cost of production of solar and wind energy proved to be cheaper and more environmentally friendly than the energy produced from diesel generators. Optimum green energy systems for electricity generation of island resorts in Malaysia proposed in [127], the system consist of solar energy and wind energy as intermittent renewable energy sources with a fuel cell (FC) system and a battery storage energy system as a backup. It has been proven that the green system with 200 kW solar energy and 40 kW wind energy along with a converter system and a battery as backup can supply the electric energy load demands of all villagers and tourists in Juara and Tioman Island.

Siti *et al.* [128] presented statistical characteristics of wind speed and energy potential for five selected sites in Peninsular, Malaysia which comprises of Langkawi, Penang, Kuala Terengganu, Kota Bharu and Mersing. The results of mean power density indicate that Mersing experience peak mean wind speed during the northeast monsoon seasons with total estimated power density of 62W/m^2 which is suitable for applying small-scale wind turbine system for power generation purposes. The new studies conducted by [129] which was published in February 2013, the study provide evidences that the northern part of Kudat possessed high potential for developing small scale wind farm for generating electricity in Malaysia. The total Annual Energy Production (AEP) for the 10 simulated wind turbines was estimated to be 92 MWh, with a capacity factor around 10.4% till 10.6%.

Wind energy utilisation in Malaysia is still limited. The first wind power plants were constructed in Layang-Layang northeast of Kota Kinabalu in 1995 with Installed capacity of 150kW, same capacity was built in Terumbu Layang-Layang in 2005 [130-131]. In 2007, Malaysian Government under joint venture partnership with the State Government of Terengganu and Tenaga Nasional Berhad (TNB), which is the only electricity supplier in Malaysia, is embarked on the project of integrating power supply at Pulau Perhentian. The project consists of installing two wind turbine, solar farm (Solar Panel), generator and battery. On the other hand, the Ministry of Rural and Regional Development had built 8 small units of wind turbine in Sabah and Sarawak for local communities [l31]. Currently, iWind (M) Sdn Bhd brings in new low wind speed turbine technology from Taiwan and they have successfully installed and commissioned forty units for use across Malaysia [119].

4. DISCUSSIONS AND CONCLUDING REMARKS

Wind Resource Assessment (WRA) development techniques is increasingly gaining importance in recent years, because it is the basic for determining technical feasibility of wind power project. Planning and establishing of wind system depend on several factors like wind speed distribution, energy potential modeling, cut-in, cut-out and rated wind turbine velocities, wind speed profile and proper software selection. Once the wind resource assessment techniques is performed in a target site, based on the results information Micrositing is used to position the wind turbines. The energy available in the wind speed turbine varies as cube wind speed, for this 1% error in wind speed leads to 2-3% errors in the energy output. Therefore accurate wind resource is most importance building block for successful wind energy potential assessment.

It can been seen that utilizations of wind energy is increasing rapidly as a result of high energy demand, population growth and recent urbanization trends in the world, This result is noticeable increase on renewable energy installations in different part of the world which shows that, the total installed global power capacity at the end of 2012 is 282, 482MW. However, the global wind power capacity increased by 20% in 2012 around the world to reach a new level of 282GW, making it fastest growing energy in the world.

From section two of this paper it was noticeable that, wind energy utilization in developed countries are currently increasing, for example, a lot of high capacity wind turbines are being installed in United State, United Kingdom, Denmark, Spain and Germany. Similarly wind farm technologies are much more advance applications in US and Europe.

Wind energy potential is naturally abundant everywhere in the world, but there are wide variations in wind speed strength and consistency. There is substantial wind resource potential in developing nations like Iran, Nigeria, Algeria, Turkey, Pakistan etc although there has been limited utilization. China and India are among the leading countries in the world in terms of installing new turbine in 2012 with capacity of 13GW and 3GW, respectively.

The countries neighboring Malaysia in the Southeast Asia that experiences similar wind speed strength has move ahead in making use of the wind energy in their respective countries. An example of best-case are 1.5GW wind turbine installed in Vietnam, 33MW wind power plant in Bangul, Ilocos Norte in Philippines, 2.5MW Lam Thakong wind energy system installed in Thailand and 11.90MW wind turbines in Indonesia.

Malaysia has abundant of renewable energy resources such as hydro, solar, biomass, wave tidal and wind. Currently wind energy resources assessment and energy conversion system is given due consideration. Malaysia wind energy resource varies depending on the locations. The major wind resource areas that have been estimated to have suitable wind energy potential for wind turbine applications are presented above.

Considering Malaysia has light wind speeds of between 1.6-5.79 m/s and energy density values between 10-117.20W/m^2 this understandable due to the country location in the equatorial region, the utilization of wind energy sources is still limited compared to other neighboring countries in Southeast Asian regions.

There is great need for Malaysia to join other countries in utilizing abundant wind resources, in relation to this, it's of outmost important for Government and private sectors cooperation to accelerate the development of wind turbine technology especially for standalone applications in rural and remote areas of the country.

Based on deep literature survey, this paper firstly described various state-of-the art used in wind resources assessment and steps required to be carried out. Then wind energy potential and utilization in some developed and developing nations has been discussed. Next, recent researches on wind energy potential and utilization in the counties neighboring Malaysia are discussed such as, wind speed, power density and wind power utilization. Finally, wind energy potential resources studies and utilization in Malaysia and possible suggestions has been presented.

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