WIND AS A SUSTAINABLE ALTERNATIVE ENERGY SOURCE IN MALAYSIA – A REVIEW

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ABSTRACT

Wind energy is being considered all over the world due to the clean characteristics that it possesses and prevalent virtually everywhere in the world. With the current existing technology, a wind turbine could only harness a small portion of energy from the available wind. The amount of harnessed energy could be significantly decreased, if proper wind energy assessments (i.e. micrositing, geographical condition, wind regime characteristics, etc.) were not performed carefully and effectively. As previous studies have shown that, most of the projects which seem to be unfeasible were due to environmental problems such as appropriate site selection, and not technological problems such as wind turbine design. This study presents and discusses the main factors to be considered when undertaking wind energy project in any potential site, so that significant amount of energy could be harvested.

Keywords: wind energy, wind turbine, wind speed, wind persistence, micrositing.

INTRODUCTION

Fossil fuel has been the source of energy and satisfying the need for electrical energy demand for centuries. However, the current increasing energy demand more than ever before and the problems associated with the fossil fuels such as finite amount, GHG emissions, climate change, high cost, air pollution, land surface damage etc. have triggered the stakeholders to look for other sources of sustainable energy. On the other hand, wind energy is proved to be one of the promising alternative energy, due to its free availability, and clean character. As of June 2014, a total of about 337 GW wind power generation capacity has been set up in more than 100 countries of the world (Hossain, 2014).

Wind turbine is one of the main machines used to harness wind energy. Typically there are two main types of wind turbine currently available in market. They are divided in terms of their rotation axis, as horizontal axis wind turbine (HAWT) which is widely available all over the world, and vertical axis wind turbine (VAWT) usually used in situations where wide space is crucial (Eriksson *et al*. 2008), (Dabiri, 2011).

In terms of rotor as well, there exist single-rotor wind turbine which is widely used and heavily adopted and dual-rotor wind turbine (Figure 1) which consist of two rotors rotating in opposite direction in the same axis, and separated by appropriate distance. It is usually used to increase the mechanical efficiency of the wind turbine. It is believed that it can increase efficiency by 30% to 43.5% (Habash *et al*. 2011, Appa, 2002, Shen *et al*. 2007), compared to the single rotor wind turbine.
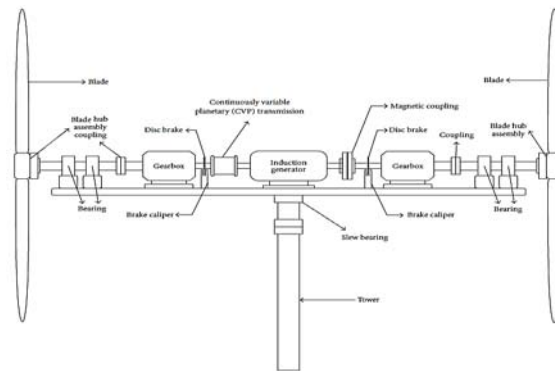
Figure-1. Contra rotating HAWT adopted from (Habash *et al*. 2011).

However, choosing which one to adopt in a particular site will relatively depend on so many factors such average wind speed, site topography, load demand, people's distribution in the region, the intended application or purpose (whether for urban or rural), single house basis, village basis or connecting to an existing grid, etc.

In some situations a hybrid system could be a better option than wind turbine system alone. The hybrid system may consist of wind and solar as in (Darus *et al*. 2009), (Maouedj *et al*. 2014), (Ekren and Banu, 2008), (Ekren, Banu and Baris, 2009) or PV/wind/fuel cell hybrid as in (Eroglu *et al*. 2011), (Aruldoss and Subathra, 2013). An omni-direction-guide-vane (ODGV) is also used in some cases to improve the wind turbine performance (Chong *et al*. 2013).

Basically, most of the existing wind turbines for onshore or offshore applications are meant to operate at a designed speed, greater than 6 m/s in order to be economically feasible. However, not all the regions of the world possess such wind potential especially the countries which are situated near the equator (tropical countries)

such as Malaysia, Chad, etc. which are known for their low wind speed (Wahab *et al*. 2008).

The lower speed in these countries would make such high wind speed wind turbine (HWSWT) not feasible to be used in these regions. Moreover, such successful low wind speed wind turbines (LWSWT) for low wind speed condition are hardly found in the market.

Currently, iWind is the only LWSWT available in the local Malaysian market in commercial level, which is developed by iWind (M) Sdn Bhd (Rosly and Ohya, 2012). Thus, more extensive researches need to be done, so that low wind speed regions will also benefit from the many advantageous that wind energy would offer.

There are several studies (Sopian, Othman and Wirsat, 1995), (Abas, Yahaya, Chong, 1997), (Wahab and Chong, 2003), (Wahab *et al*. 2008), (Islam *et al*. 2009), have been conducted to establish suitable LWSWT for low wind condition. However, the commercialization of their research findings has not been fully undertaken on a large scale.

The first breakthrough for (LWSWT) implementation in Malaysia was developed by (Wahab *et al*. 2008) which was able to establish a potential wind turbine that can operate at a speed range of 3-5 m/s and capable to produce 0.5 -1.5 kW power, which is quite favorable for Malaysia wind condition. But unfortunately it was not commercialized due to mainly its high initial cost.

Another research team from Universiti Kebangsaan Malaysia (UKM) has also developed a wind turbine with a capacity of 150 kW, in Terumbu Layang-Layang Island. But again, it was not taken to commercial level (Islam *et al*. 2009). Moreover, a joint venture project between the State Government of Terengganu and National Electric Board was also conducted at Perhentian Island to establish a hybrid system (wind and solar) in order to minimize the usage of diesel as a source of electricity. The system comprises of 2 units of wind turbines and a 100 kW PV array. Each of the two wind turbines was able to produce 100 kW (Darus *et al*. 2009).

However, prior to undergoing any wind energy project, these few milestones i.e. wind speed, wind persistence, wind site selection (micrositing), topography, etc. should be considered and analyzed properly as a feasibility study in order to select suitable site and appropriate wind turbine type. Thus, the purpose of this paper is to outline and discuss such main factors which affect the suitability of wind turbine when undergoing any wind energy project especially at low wind speed regions.

WIND POWER

Wind is available and felt everywhere, yet the strength and the energy content in it varies from place to another. In order to extract energy, wind turbine is used to harvest the kinetic energy from the moving air, converting it into mechanical energy via the turbine rotor and then into electrical energy through the generator (Sunderland *et al*. 2013).

This mechanical energy can be used for specific tasks such as grinding grain, pumping water or for driving a generator that can convert the mechanical energy into electricity which can be supplied to the power grid or individual users (Aimu, 2012).

However, there are considerable losses occur during energy conversion process due to the aerodynamic effects such as blade roughness, wake effects, hub loss and tip losses in which reduce the efficiency of the turbine. According to the Betz's theory (Betz's limit), the maximum possible conversion coefficient of a wind rotor is 59.3%. Note that, this limit has nothing to do with inefficiencies in the generator, but in the very nature of wind turbines themselves (Habash *et al*. 2011), (Sunderland *et al*. 2013).

The power available in a wind stream *P*, is proportional to the cube of the velocity and it is can be calculated using the following equation (Eriksson *et al*. 2008):

$$P = \frac{1}{2}C_p\rho AV^3$$

(1)

Where the mechanical output power (*P*) is a function of:

C_p = performance coefficient of the turbine,
ρ = density of air,
A = swept area by the turbine projected in the direction of the wind
V = wind-speed

Essentially, wind power is not only meant for high wind speed regions. Low wind speed regions as well could significantly benefits from it, if technological problems such as adequate wind turbine design and environmental problems such as appropriate site location and wind resources were selected (Wahab, Ramli and Tong, 1997).

Moreover, wind power is also more conducive for places where big spaces are crucial, such as the ASEAN countries where the land is mostly used for agricultural purposes, because it is very fertile. Thus wind power for such countries is more favorable than other form of renewable energy such as solar (Rosly and Ohya, 2012). The same phenomena could be adopted in any region with the same criteria.

There are several power classes for wind energy as shown in Table 1. They are classified according to the wind speed at certain height. Higher classes offer greater productivity. A lowland might have low wind speed than an exposed site on the top of a hill. However, the degree of certainty with which the wind power class could be specified would depend mainly on three factors: the abundance and quality of wind data; the complexity of the terrain; and the geographical variability of the resource (NREL, 2015).

Note that, each wind power class should represent two power densities. For example, wind power class 4

represents the wind power density range between 200 W/m^2 and 250 W/m^2.

Table-1. Wind power classes (NREL, 2015).

Elevation	10m		50m*	
Wind power class	Wind speed m/s	Power density W/m²	Wind speed m/s	Power density W/m²
1	0	0	0	0
	4.4	100	5.6	200
2				
	5.1	150	6.4	300
3				
	5.6	200	7.0	400
4				
	6.0	250	7.5	500
5				
	6.4	300	8.0	600
6				
	7.0	400	8.8	800
7				
	9.4	1000	11.9	2000

* Showing elevation effect based on 1/7 wind profile power law
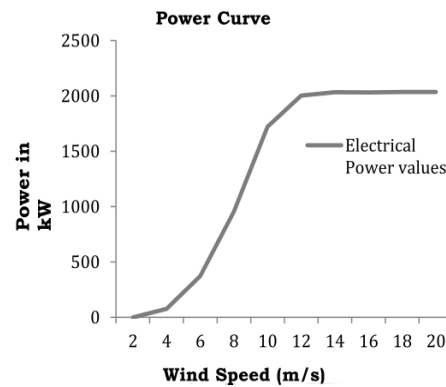
Power curve

The performance of a wind turbine is usually characterized by a power curve. It is a graphical representation of the turbine electric power output as a function of the wind speed, and an indicator of overall wind turbine health. With such curve, turbine power output and energy production can be predicted (Wan, Erik and Kirsten, 2010), (Uluyol *et al*. 2011).

Identifying the power curve of a wind turbine system will ensure the suitability of adopting it in a particular site. In this stage, the designed wind turbine's cut-in, cut-out and the rated speed will determine whether it is feasible to go forward with the project.

The cut-in speed is defined as the minimum wind speed at which a turbine starts to operate and produce electricity. Note that that, cut-in speed should not be confused with the start-up speed whereby the rotor starts its rotation. However, most of the commercial wind turbines cut-in at a speed ranging from 3 to 5 m/s (Mathew, 2006).

The rated speed is the speed at which the turbine reaches its rated power output or maximum power output. While, the cut-out speed is the wind speed at which the turbine shuts down to protect the rotor and drive trains from damage due to excessive loading, as obviously illustrated in Figure-2 (Albani, Ibrahim and Hamzah, 2013), (Mathew, Philip and Lim, 2011).

Moreover, for low wind speed conditions, lower cut-in speed is needed. Thus such consideration has to be made in the early stages of wind turbine design specifications or wind turbine selection phase. However, the amount of power that could be obtained from a wind turbine will depend on the size and design of the wind turbine as well as on wind conditions (Richard, 2015).

Figure-2. Typical power curve (Hossain, 2014).

WIND SPEED

The wind potential of a site is usually measured by its wind strengths. As a rule of thumb, the higher the wind speed the more power could be harvested. (Cancino, Gutiérrez and Xiberta, 2010) suggested that, the wind speed is the most important factor in choosing appropriate wind potential site. Thus, before investing in wind energy, a good understanding of wind regime characteristics is essential for efficient planning and implementation of any wind energy project.

In order to obtain a proper sizing and siting of a wind power project, knowledge of wind velocity distribution at different time scales is also necessary. This is because the wind speed and direction could vary dramatically in a short period of time, which significantly affect the energy output of a wind turbine at a site (Mathew, Sathyajith and Pandey, 2002) (Mathew, Philip and Lim, 2011).

Moreover, the prevailing wind directions along the months of the year have to be known, in order to obtain a general idea of the energy potential of the site, as well as to get insight on the selection of the appropriate wind turbine type for that particular location. Wind speed measurements using anemometer can be used to estimate the energy potential of an area. A three-cup anemometer and a wind vane are usually used in order to measure wind speed and prevailing wind direction. The measurements are usually taken at the standard height of 10 m (Ekren, Banu and Baris, 2009).

Alternatively, statistical methods such as Weibull distribution (Mathew, Philip and Lim, 2011), (Sunderland *et al*. 2013), Rayleigh distribution (Mathew, Sathyajith and Pandey, 2002) which is a simplified form of Weibull distribution, Pearson type VI distribution, Exponential

distribution, Gamma distribution and logistics distribution, etc. can be used to assess the wind energy potential. However, Rayleigh distribution is widely used and also recommended by The American Wind Energy Association (AWEA), due to its effective characterization of wind energy potential of a site in terms of energy density, energy availability for a period, most frequent wind speed and wind speed of maximum energy carrier (Mathew, Sathyajith and Pandey, 2002).

On the other hand, (Albani, Ibrahim and Hamzah, 2013) also asserted that, in order to determine the regional wind energy resources, accurate prediction of the wind speed at any given site is crucial. Therefore, it is been indicated that WindPRO and WAsP softwares are good tools to achieve that.

It used to be a common believe that, a minimum of 5 m/s average wind speed is required in order to be profitably feasible to invest in wind energy (Stuart, Terry and Annop, 2008). However, that is not entirely true with the current existing technology of the wind turbine. For example, the iWind vertical axis wind turbine technology from Taiwan can operate effectively as low as 2.5- 9 m/s which is ideal for low wind speed zones (Rosly and Ohya, 2012). Not only that, as of 2012 the iWind Energy (M) Sdn Bhd has installed 40 units of its iWind VAWT in Malaysia alone, which clearly indicates profits here, in which makes such believe inadmissible today.

WIND PERSISTENCE

Wind speed persistence is another important factor to take into account when dealing with wind energy, since it offers useful information on the general characteristics of the wind at a given site. The wind speed persistence is defined as, a measure of the mean wind speed duration over a given period of time at any location (Kasım, 2008), (Cancino, Gutiérrez and Xiberta, 2010).

It is well known from wind profile power law that wind speed increases with the increase of the height proportionally, due to reduced influence of the drag at higher altitudes. Figure-3 shows the variation of wind velocity with height. Notice that low wind speed is experienced at lower altitude due to the surrounding obstacles such as surface roughness, trees and buildings, etc. (Nurhayati and Sofian, 2014).

However, knowledge of wind speed alone is not enough. Properties of wind persistence towards the seasonal variations are required since the energy output of a wind turbine depends significantly on the velocity distribution of the site. Due to these different velocity distributions, a completely different energy output would be obtained, if a wind turbine is installed in two sites with the same average wind speed. Moreover, if two wind turbines with the same output rating are installed at the same site, but different in the cut-in, rated and cut-out speeds, they may generate varying energy output as well. However, statistical distributions are usually used to take care of these variations in wind energy calculations (Mathew, Philip and Lim, 2011).

Therefore, properties of wind such the intermittent behavior which causes problems when forecasting the wind energy value, must be known in order to determine the ideal location for the production of electric energy from wind at a particular site (Cancino, Gutiérrez and Xiberta, 2010).
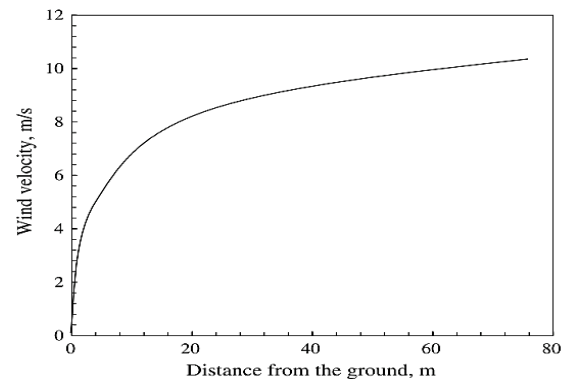
**Figure-3.** Distance from the ground (Mathew, Philip and Lim, 2011).

TOPOGRAPHY

The arrangement of the physical features of an area or its geographical nature is of great importance when wind turbine project is considered in a particular site. Choosing the right site and avoiding obstacles in which gives a clear exposure to the prevailing wind will have a significant enhancement on the wind turbine energy output. Many projects are thought to be inefficient due to inappropriate site selection. Therefore, technological and environmental problems had to be solved, before significant benefits from the wind power could be realized.

Figure-4 shows the wind flow over a hill. Selection of good, bad sites and site with obstacles might affect the performance of a wind turbine. In a smooth hill, speed up effect towards the top of the hill is realized and less turbulence occurs behind the wind turbine which represents a good site as shown in Figure-4a.

While in Figure-4b, it is evident that turbulence effects occurred at the top and bottom of the cliffs which affect not only the performance of the wind turbine, but also the structural failure of it, which is known as terrain-induced turbulence (ARE, 2012), (Uchida and Ohya, 2011). Terrain-induced turbulence could cause many problems such as low power output, damage and breakage of the exteriors and interiors of the wind turbine generators (WTGs), (Sunderland *et al*. 2013).

However, in order to obtain optimum wind turbine performance, the location of the wind turbine has to be placed as far as 10 times the height of the obstacle as a minimum allowable distance, or installation should be made in a taller tower which will surely have an increase on the total cost of the wind turbine, as shown in Figure 4-c (ARE, 2012).
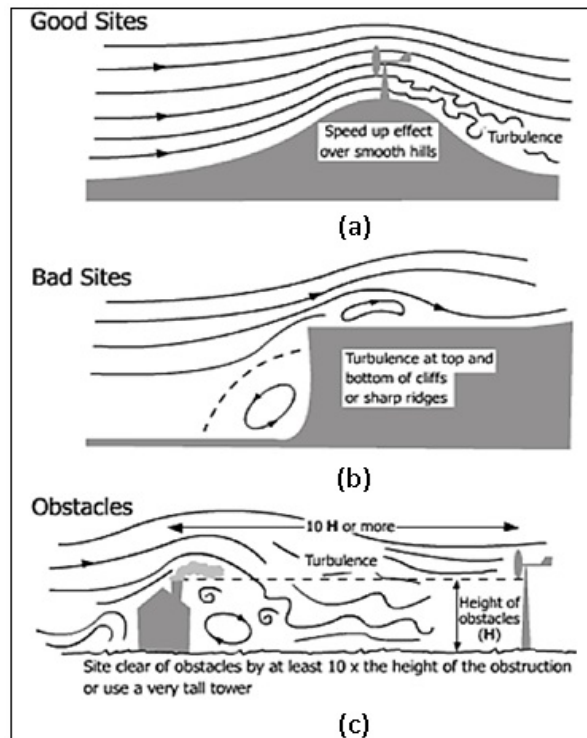
Figure-4. Wind flow over hills and obstacles: (a) Good site; (b) Bad site; (c) Site with obstacles (ARE, 2012).

MICROSITING

Most of the wind energy development problems are associated with the issue of "micrositing." Micrositing refers to the particular placement of a wind turbine within a wind farm site to optimize electricity production (National grid, 2006). It is one of the most important techniques adopted to identify a potential location to harvest wind energy efficiently.

As it has been mentioned earlier, in order to harvest maximum amount of the wind available, optimum location to install the wind turbine is required. In this case, meteorological wind data alone are not sufficient for the accurate siting of a single wind turbine or of wind farm. Thus, micro-siting technique is applied (Nurhayati and Sofian, 2014). As it is also a useful tool in establishing a wind map or wind atlas in a region.

The FirstLook software is one of the widely used numerical techniques to select an appropriate site. While the RIAM-COMPACT numerical model is used to find the exact potential point to install a wind turbine in a site in order to obtain optimum performance. Both methods are used to establish a wind map numerically (Nurhayati and Sofian, 2014).

Recently (Nurhayati and Sofian, 2014) conducted a numerical experiment in order to identify optimum site location in Tioman Island, Malaysia, and suggested that, wind turbine has to be installed at a less obstructed areas with greater wind speeds so that efficient power output could be produced.

There are many other numerical methods available for the same purpose, such as Karlsruhe Atmospheric Mesoscale Model (KAMM) which is developed in some countries like India, Thailand, and Philippine (Promsen, Masiri and Janjai, 2012).

KAMM is a software used to establish wind atlas (wind map). Since the mapping of wind potential and the size of potential output are significant in establishing the utmost limits of the wind energy development in a region. These limits could justify wind energy when compared with existing technologies and other important considerations in wind energy development (Mukasa *et al*. 2013).

Thus, it is very necessary that a wind turbine should be placed at exactly the right place on a site.

COST

Project cost is another important factor to be addressed and assessed carefully before undergoing a wind turbine project. This may include from the very beginning design stages, fabrication, installation and operation and maintenance costs. However, project costs do not just depend on installed capacity, but also on the location of project, the requisite off-take infrastructure and many other general costs of doing business (Mukasa *et al*. 2013).

(Mukasa *et al.* 2013) proposed that, project costs are very important, because they may give indication on the resource needs per unit of installed capacity, and signal affordability of wind technologies as well as the level of maturity of the market. However, high cost associated with wind energy was the greatest barrier to the use of wind energy conversion systems (WECS) around the world (Wahab, Ramli and Tong, 1997).

The average capital costs for wind energy projects declined markedly all over the world. In the United States for example, capital costs were at their lowest level from around 2001 to 2004, about 65% below costs from the early 1980s (Wiser and Bolinger, 2011). The same trend is found in Denmark, a lowest level was achieved in 2003, more than 55% below the levels seen in the early 1980s. That is due to the advanced technology of increased efficiency of the wind turbine, which come from the more understanding of the behavior of the wind energy as well as enhanced technologies such as contra rotating blades, gearbox system, bigger rotor diameter, taller tower, availability of domestic original equipment manufacturers (OEMs), as in Figure-5, (Merchant and Gregg, 2009), (Lantz, Wiser and Hand, 2012).

The combined effects of falling costs and enhanced performances had the major impact of dramatically reducing the levelized cost of energy (LCOE) for onshore wind energy between the early 1980s and the early 2000s. However, the good news is that, onshore wind energy is estimated to fall by 20%–30% over the next two decades (Lantz, Wiser and Hand, 2012) added.

However, the question that arises is, why there are still some parts of the world have not adopted wind energy yet even though the potentials are there? the answer of this question may depend on several issues; for

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example in African countries as mentioned by (Mukasa *et al*. 2013) lack of government policy on reducing the fossil fuel emissions, lack of subsidy initiatives from the government and less attractiveness of wind based electricity generation from a commercial viability perspective, because of the associated high initial cost of the wind turbine project, and sometimes the lower cost of the available fossil fuel, among others.

In situation where the electricity cost is relatively low, wind energy seems to be less attractive to invest on it, such as the Middle Eastern countries. They might have somehow good wind energy potentials, but since the fuel price is relatively cheap, it did not get much attention, because it is economically not feasible. However, from environmental point of view, this statement will have quite altered direction.

Furthermore, in places where the fuel prices is high, which is the case in most of regions of the world, small and medium wind turbines (SMWT) should become a mainstream option and can be massively integrated with the local energy mix, since with such conditions, small wind turbine is competitive with any other energy source. Even in regions typically considered as having fewer wind resources, there can be specific areas with particularly good wind availability, it is just a matter of proper micrositing is needed.

This approach is already used in various places around the world, and should be promoted more, as it greatly reduces energy costs for the end-users and decreases the energy costs burden for governments (ARE, 2012).

However, the prices of a wind turbine usually depend on the type of the turbine and its size. Therefore, it is very important to make the cost calculations and breakdown before starting a project in order to determine electricity prices compared to the existing alternatives, such as diesel or gas. It is also worth to mention that the costs also vary significantly from one place to another, based on production expenses on a particular location (ARE, 2012).
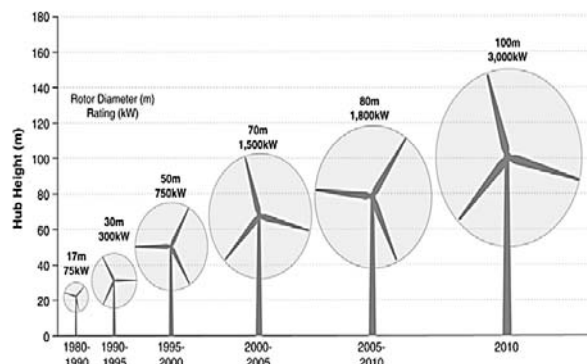
Figure-5. Representative turbine architectures from 1980 to 2010 (Lantz, Wiser and Hand, 2012).

CONCLUSIONS

As a conclusion, wind energy would be a very promising alternative energy source if a careful assessment of the resources is made before undergoing the project. Because, in most of the world regions, wind energy would be harvested in a profitable manner, even in places with low wind potential, if an exact point to install a wind turbine could have been determined. Poor site sitting is turned out to be one of the major problems in wind energy world. With the current available technology all of these are possible. In addition, failing to choose the right wind turbine type for a particular location is another considerable issue. For example, urban areas are usually characterized with low wind speed and high turbulence flow. As a result, a low wind speed wind turbine (LWSWT) is recommended, in order to harvest maximum energy output. Such low wind speed conditions may sometimes require a counter rotating or hybrid systems, etc. However, the HAWT is usually considered in situation where land resources are not an issue, so that each wind turbine could be separated from the adjacent turbine wakes. However, selecting the right technology available will have significant difference on energy output as well as costs i.e. initial investment costs, and shorter payback period can be expected. After all however, the future of wind power will depend on the ability of the industry to continue to achieve cost reductions.

ACKNOWLEDGEMENTS

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