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CHALLENGES IN ARCHITECTURAL DESIGN TO SUPPORT WIND ENERGY HARVESTING IN MALAYSIA

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Abstract

The effect of global climatic change directly influences our built environment. With the depletion of current fossil fuel, there are several drives for sustainable solutions towards generating energy for future daily consumption. Apart from employing solar energy, wind energy is also considered as an environmentally friendly solution to produce electricity. Foremost, the current standard of living for better quality of life requires uninterrupted supply of daily basic resources such as food, water, and electricity. This paper discusses the expansion of knowledge in wind energy and its theoretical studies on building integrated wind turbines (BIWT). The conclusion outlines challenges in the architectural design process to evaluate criterias for low-rise residential buildings in a low wind speed region.

Keywords: *architectural design; conceptual design; residential building; wind energy harvesting*

1.0 INTRODUCTION

Generally, the available resources for electricity power are from fossil fuel, mini hydro, sun, wind, biomass, and biogas. Security of energy supply and environmental issues has stimulated a global shift towards renewable energy (RE). to encourage the uses of renewable energy sources (RES). The potential of RES is widely explored on large scale development and consumption. However, there are initiatives to harness it for small and micro scale uses.

The harness of wind energy is gaining momentum and one of the fastest growing renewable sources for generating electricity (Dabbaghiyan, Fazelpour, Abnavi, & Rosen, 2016; Bobrova, 2015; Tiwari & Kumar Mishra, 2012). It has limitless availability (Kaldellis & Zafirakis, 2011) and smaller carbon footprint than fossil fuels (Abbasi & Abbasi, 2016). The past 50 years has seen wind energy as a new emerging research field characterised by a high degree of interdisciplinary (Sørensen, 2016).

This paper discusses the expansion of knowledge in wind energy and its theoretical studies on building integrated wind turbines (BIWT). The conclusion outlines challenges in the architectural design process to evaluate criterias for low-rise residential buildings in a low wind speed region.

2.0 MALAYSIA FOR RENEWABLE ENERGY

In reducing the global warming effect Malaysia has made a voluntary pledge in 2009 to reduce CO_2 emissions by 2020 (Ho, 2016). Hence, the Ministry of Energy, Green Technology and Water (KeTTHA) has introduced the National Energy Efficiency Master Plan (NEEMP) in 2010 targeted to achieve reduction of CO_2 emissions, to reduce carbon footprint and to secure the energy supply for economic stability. Malaysia had recorded an increase in the country's final energy consumption, due to the shift in economic policy from agricultural based to industrialised based. Change in lifestyle and increase in population growth also contributed to an increase in energy consumption (Hussin, Abdullah, Ali, Hassan, & Hussin, 2014). The energy demand and consumption are set to increase significantly as the country strives to achieve high-income industrialised nation status (Energy Commission, 2015a). The government, in the Eleventh Malaysia Plan, has approved the National Energy Efficiency Action Plan (NEEAP) 2016-2025 and since 2017, it has initiated programmes to reduce energy consumption (Energy Commission, 2018).

2.1 Renewable Energy Initiatives

NEEAP also shifts towards increasing RE to secure energy demand for future usage (Hamdan, Mustapha, Ahmad, & Mohd Rafie, 2014: Bujang et al., 2016). Besides strenghthening the reliability of supply, RE also reduces the dependence on fossil fuels. Diversification of energy sources and achieving energy independence are key steps in ensuring stable economic and societal developments (Bujang, Bern, & Brumm, 2016). The Energy Commission (2018) reported the grid system in Peninsular has been operating with a reserve margin of 6,349MW (35.7%) with the electricity demand of 17, 790MW and the installed capacity of 24, 139 MW. Therefore, to ensure a continuous electricity supply with the increasing demand, several generation projects which could produce more than 10,000 MW of capacity are initiated.

Under the National Green Energy initiatives, the licensing of Large Scale Solar (LSS) projects has been approved since 2017, followed by other several generation projects utilizing different sources (Energy Commission, 2018). The Small Renewable Energy Power (SREP) program has encouraged private sectors to participate in small power generation projects utilizing biomass, biogas, mini-hydroelectric, solar and wind energy (Bujang et al., 2016). Another initiative includes the net energy metering (NEM), implementation by KeTTHA, for “everybody to be able to generate electricity for their own consumption, using renewable sources, which is also a plus for the environment” (Energy Commission, 2015b). Currently, NEM is available for solar energy since its technology is widely explored and used.

2.2 Wind Energy Initiatives

In 30 years of RE in Malaysia, from 1990s to 2014, Ho (2016) has identified 21 wind studies and developments conducted by several individuals and organisations. Many of these studies were on wind potential assessment for developments of on-shore and off-shore wind farms. However, based on inaccurate estimates of wind potential due to poor data and inadequate methodologies had resulted in many projects being abandoned (Ho, 2016).

Since 2012, Sustainable Energy Development Authority (SEDA) Malaysia has installed six wind masts at six different locations for future study on wind resource mapping. The identified six locations were based from previous studies; namely Bachok (Kelantan), Durian Tunggal (Melaka), Felda Chuping (Perlis) and Setiu (Terengganu), Kota Marudu and Pulau Banggi (Sabah). Hence, data collection for each site over a period of 12 months has begun since December 2014 (Tobergte & Curtis, 2013; SEDA, 2015). The energy potential analysis indicated only Kudat and Mersing display a promising potential to develop a medium capacity of wind turbine power, while the other sites may be suitable for small capacity (Albani & Ibrahim (2017).

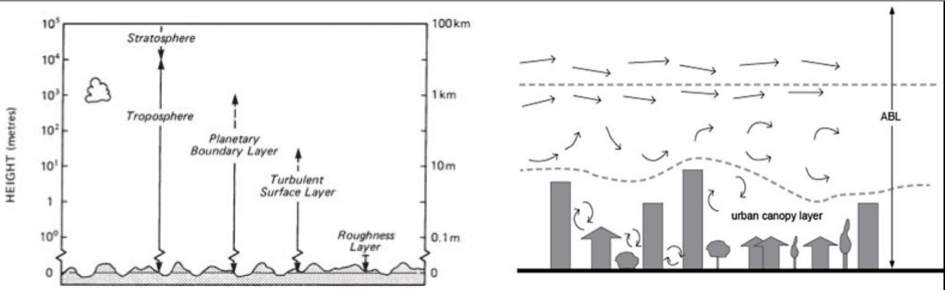
3.0 DEVELOPMENT OF WIND ENERGY

Both concepts of energy generation, and wind properties behaviour are significant to the study. Law of Conservation of Energy states energy cannot be created or destroyed but can be transferred from one form (mechanical, kinetic, chemical, etc.) into another. Thus, the basic principle of energy conversion or extraction from the environment can only be extracted from a flow system. Wind flow is the air movement, from areas of high pressure to low pressure, due to variations in temperature and pressure of earth’s surface (Ritter-Lopatowski, 2007; Roberts, 2013; Homes, 2015). The concept of wind energy states air in motion carries kinetic energy (KE) and can be transformed into mechanical energy using rotational energy from turbines to convert into electricity.

3.1 Atmospheric Boundary Layer

The atmospheric boundary layer (ABL) is the air layer directly above Earth's surface, within 1 km above the ground (refer Figure 1). Surface winds cause the movements of heat, vapour, pollutants and other airborne particles, hence their flow relates to regional climatology and play an important role in human life. Wind flow within 15 m above the ground, based on local terrain conditions, differs in turbulence intensity that will vary in speed and direction (Rao, 2011; Yang, Su, Wen, Juan, Wang and Cheng, 2016; Grayson, 2016). Hence, air turbulence is important in wind related studies.

Figure 2, shows the diversification in wind related studies within ABL and they can be grouped into three main categories: namely regional scale, urban scale and building scale based on their scope of studies. Generally, under the urban and building scales, the studies emphasize on wind flows related to outdoor and indoor air ventilations for better human thermal comfort and safety measures in the built environment. Concerning harvesting wind for energy, wind flows studies under the regional scale are related to wind farm assessment and turbine technology advancement. In addition, studies under the building scale focus on wind turbine integration methods and building design parameters. Data on local wind climate and characteristics, over a longer period, will determine the local wind pattern. All studies had utilized data on wind speed, wind direction and wind turbulence within the ABL.



(a) Vertical structure of the atmosphere: Planetary Boundary Layer refers as ABL

(b) Wind flow and turbulence within ABL

Figure 1: Atmospheric boundary layer

(Source: Rao, 2011)

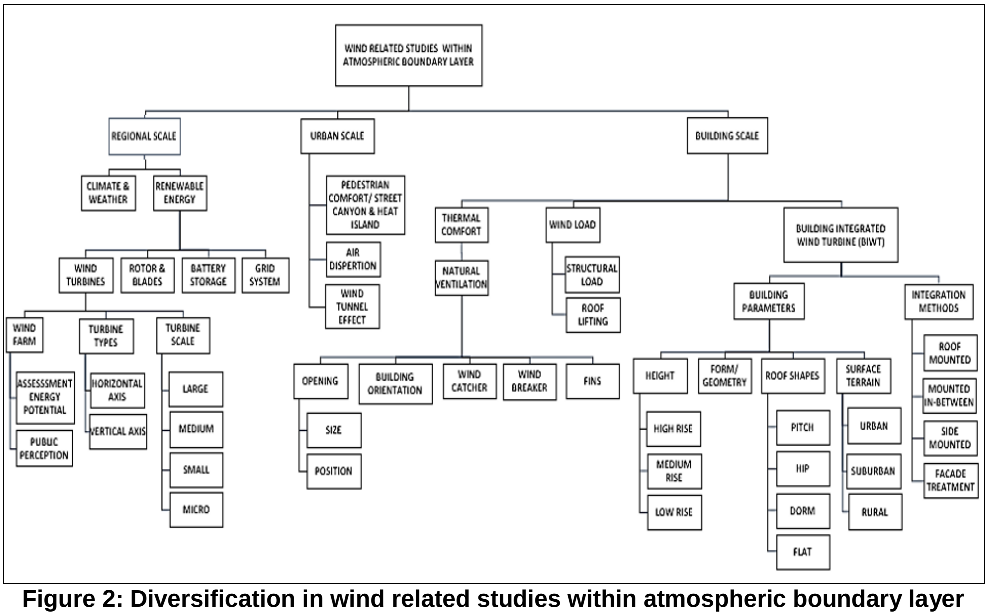


Figure 2: Diversification in wind related studies within atmospheric boundary layer

4.0 BUILDING INTEGRATED WIND TURBINE (BIWT)

Ancient civilization had utilised windmills to harvest wind energy, whereas the later decades used wind turbines in development of wind farms. However, the application of wind turbines (WTs) on buildings began in the late 20th century. The first high rise prototype for building an integrated wind turbine (BIWT) project was in the year 2000, named project WEB, by a research group under Wind Energy For The Built Environment (WEB) (Campbell & Stankovic, 2001). The focus was on the development of ideas to integrate WTs for areas with low and moderate wind speeds (2-5 m/s). The design ideas evolved on balancing and reconciling aesthetic, aerodynamic, architectural, environmental, and structural constraints for optimum energy yield. Rao (2011) suggested two types of approach for BIWT: designs that utilize the building form for amplifying wind flows for energy generation; and those that just utilize the building for mounting the turbines. Previous studies have identified potentials for BIWT were based on WT installation, and integration methods (refer to Table 1). Figure 3 shows BIWT with four possible locations for integration of WT, with the latest is into building's skin (Park et al., 2015; Hassanli et al., 2017).

In BIWT, the design parameters for both high-rise and low rise buildings are the building form and building orientation, while the annual production of energy yield is determined by wind power density, and wind turbine types. Most studies on high rise and medium rise buildings explored aerodynamic building shapes (Ritter-Lopatowski. 2007; Rao, 2011; Babsail, 2011; Grayson, 2016). The earlier studies on BIWT for low rise buldings, especially residential buildings, focused on roof forms (Abohela, Hamza & Dudek, 2013; Sari, 2015; Chong et al., 2016; Ozmen, Baydar & van Beeck, 2016). However, recent studies have explored the building shapes (Coma & Jones, 2015; Zhou et al., 2017) to accelerate wind flows for energy yield.

Table 1: Methods of building integrated wind turbines (BIWT)

	Brobrova. (2015) Campbell et al. (2001)	Rao (2011)	Babsail (2011)	Müller, Jentsch and Stoddart (2009)	Mertens (2006)	Hassanli et al. (2017)
1	Siting stand-alone wind turbines	Building amplified wind turbines	Top Installation	Building integrated horizontal axis wind turbines	At the roof or sides	On roof top
2	Retrofitting wind turbines onto existing buildings	Building mounted wind turbines	Side Installation	Building integrated vertical axis wind turbines	Between two airfoil-shaped buildings	In between Two Buildings
3	Full integration of wind turbines together with architecture		Duct Installation	Building augmented wind turbines	In ducts through buildings	Inside through-Building Openings
4			Between the Towers			Integration into Building's skin

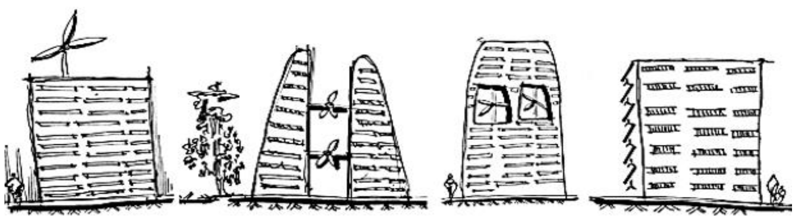


Figure 3: Possible locations for wind turbine integration
(Source: Hassanli et. al., 2017)

5.0 CHALLENGES IN ARCHITECTURAL DESIGN FOR LOW RISE BUILDING

Generating small scale power from wind, as per solar, requires minimal land area as compared to the other small power generation projects. Therefore, the generation of wind energy in BIWT has a higher potential than in wind farms (Park, Chung & Park, 2016). There are challenges when buildings are designed with wind energy in mind, as power active buildings, especially as an integral part of the house (Bobrova, 2015). Therefore, a special approach to an architectural shaping at the early stages of the design process is required (Babsail, 2011; Pour (2014); Bobrova, 2015; ELMokadem, Megahed, & Noaman, 2016). The challenges comprise of three main aspects as follows:

1. **Determining site suitability**. Collection of site data to include regulation and surrounding obstacles and general wind climate such as characteristics of wind environment: namely local annual wind speed, direction, turbulence intensities, wind shear and wind power density.
2. **Determining building form.** Consideration on proper building design with the ability to accelerate wind.flow and embrace integration methods for higher performance. The design criterias comprise the building orientation, dimensions, shape, height, volume, materials and constructive structure.
3. **Determining program priority**. Selection of tools to analyse the design for wind performance at early stages of design, namely Wind Tunnel Testing (WTT) and

Computational Fluid Dynamic (CFD). Evaluation is inclusive of suitable WTs for turbine power curves and comparing energy production with consumption.

The challenge for BIWT in architectural design for low rise is to accommodate the wind flows with high turbulence intensities due to surrounding obstacles within the lower part of ABL. This paper does not cover advanced technology of wind energy harvesting utilizing piezoceramic flag harvester and vibro-wind based on air vibration, which has high potential for BIWT.

6.0 CONCLUSIONS

Uninterrupted supply of daily basic resources such as food, water, and electricity is important to uplift the quality standard of living. Integrating the wind power into domestic buildings is beneficial to the occupants, as they will be less dependable on conventional sources of energy. Since most of the home appliances today operate using electricity, integration of renewable energy will help reduce the electricity bill for the household. BIWT has the potential to include wind energy in NEM because it can be initiated by individual homeowners.

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