PAPER • OPEN ACCESS

A review on the prospect of wind power as an alternative source of energy in Malaysia

To cite this article: S N Ashwindran et al 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1078 012017

View the article online for updates and enhancements.



This content was downloaded from IP address 175.136.34.169 on 27/09/2021 at 03:20

A review on the prospect of wind power as an alternative source of energy in Malaysia

S N Ashwindran¹, A A Azizuddin^{1,*}, A N Oumer² and M Z Sulaiman¹

¹ Faculty of Mechanical & Automotive Engineering Technology Universiti Malaysia Pahang, Pekan, Malaysia.

² College of Engineering, Universiti Malaysia Pahang, Pekan, Malaysia.

*Corresponding author's email: azizuddin@ump.edu.my

Abstract. Fossil fuels has dictated the energy sector for several decades, rising as the primary and prominent source of energy production for various sector of industries namely electricity (power), transportation, manufacturing and others. However, extensive usage of fossil fuels majorly contributed to pollution issues and degradation of the environment. Hence, governments and research agencies are providing supports and resources to facilitate the growth of renewable energy sector (RES). This manuscript provides a brief view of the challenges of wind renewable energy sector in Malaysia relative to geographical wind condition, government policies and challenges in initiation of wind technologies and global perspective of green energy in terms of RER. It is found that data presented by previous researchers on wind speed data are considered unreliable to be utilized for WT power density assessment and design. Notably, wind speed in Malaysia is seasonal based and highly inconsistent. The wind flow pattern and intensity experience by Malaysia are merely an aftereffect of weather change in neighbouring regions. Nevertheless, it is found that selected regions of east-coast peninsular Malaysia and selected region of Sabah and Sarawak is potential for harvesting wind power due to substantial and adequate wind pattern behavior during monsoon season. Therefore, it is evident that geographical wind condition of Malaysia is appropriate for wind power devices as a form of RER in green energy sector of Malaysia. However, it is also found that fundamental design modification is required on conventional design of WT in terms of blade morphology and configuration in order to adapt to unsteady monsoon wind speed pattern.

Keywords: Wind Engineering; Renewable Energy; Wind Speed Characteristic in Malaysia.

1. Introduction

Renewable energy (RE) is an alternative approach to depleting non-renewable energy resources. In response to increasing awareness to environmental issue such as rise of greenhouse gases (GHG), and high carbon lifecycle assessment (LCA) [1]. Governments and research agencies are providing supports and resources to facilitate the growth of renewable energy sector (RES) [2]. There are different types of RE namely on solar, wind, tidal or hydro motion, nuclear and biomass. Today wind turbines (WT) are the prominent form of renewable energy for direct energy harvesting. Joselin Herbert et al. [3] stated that wind power is an indirect form of solar energy, where the differential heat radiated by the sun on earth surface influence the wind potential. Considering in terms of yearly growth per installed energy harvesting technology, wind energy is considered as the fastest growing in

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1

IOP Conf. Series: Materials Science and Engineering 1078 (2021) 012017 doi:10.1088/1757-899X/1078/1/012017

comparison to other renewable energy resources (RER) [4,5]. Technologies on RER are sufficient and well developed. However, more extensive research and development is being conducted to improve the efficiency of the respective RE system [6]. Wind turbine technology has grown significantly as a prominent source of RE harvesting due to its zero emission, reliability and low cost [7–9]. Cognet et al. [10] stated that, conventional WT performs efficiently only at specific working condition (angle of attack and aerodynamic characteristic of blade) and environment (wind speed) in which makes wind energy conversion poor in general. Moreover, lack of development and research on wind power devices leads to energy and economic loses. Hence, different approach is required on convention WT blade design in order to improve the operating regime and power extraction performance. In comparison to between the two types of WT configuration, HAWT is widely preferred in wind power generation than VAWT [11,12]. However, there are disadvantages to HAWT type domains such as unstable physical structure, requires high material criteria for blade fabrication and low wind energy capturing area [13]. The wind energy capturing performance of VAWT is lower in comparison to HAWT [14,15]. However, research shows that VAWT framework indicated more substantial potential than HAWT for low wind speed condition regions and offshore application [16–18]. VAWT has received limited attention among researcher over the past decades due to the aerodynamic complexities relative to HAWT [19]. Lately, VAWT received attention among researcher on the aerodynamic performance properties and design mechanism [15].

Generally conventional WTs are design to operate at high wind speed ranging from 10-15 m/s [20]. This constrains the WT to harvest adequate power at low wind speed condition [21]. Sustainable amount of research is being conducted in effort of improving the conventional WT or in other words design reconfiguration such as blade configuration and morphology, rotor configuration, pitch angle variation and others [22]. Research shows that, design configuration adjustment and optimization has improve the efficiency in power extraction [23–26]. Currently, researcher is actively working on blade morphology and configuration for optimal wind interaction. Ikeda et al. [27] stated that conventional WTs work within the narrow zone center at different TSR at turbulent wind environment. Hence, limits the aerodynamic performance of the turbine. Li et al. [28] mentioned that WTs operates below atmospheric boundary layer, which is comparatively higher than inflow turbulence of aviation flight. The author also stated that interference pose by geographical obstacles in low wind speed region will further increase the turbulent intensity. Hence such environment creates unreliable wind flow condition for the blade. Bianchini et al. [16] stated that design optimization needs to be implement on conventional VAWT in order to improve the aerodynamic efficiency. Design improvement and optimization of WT is conducted at various level and aspects namely from blade morphology to rotor control system. The primary governing factor that influences the performance of the WT is the blade shape. Although, numerous concept and method emerged over the years, current research trend in WT blade modelling is smart blade [29] and biomimicry or bioinspiration [30]. Research shows that WT blade modelling via bioinspiration technique has improved the power extraction capabilities. Moreover, understanding the aerodynamic behavior of bio-elements helps to comprehend the complexity in flow behaviour exhibited by WT. Nonetheless, the geometrical properties of the blade morphology also play an important role in blade performance. The blade shape influences the flow field properties and the behaviour of flow response. Traditional WT design struggles with fundamental design error which consequently impacted the operational capabilities. Compounded structural design issues especially blade structure constitutes to the inefficiency of the WT [31]. Despite over 30 years of experience, manufacturers and engineers are adherently working to improve the efficiency of WT [31]. In spite of other improvements namely material structure, gearbox modification, turbine and control system enhancement in WT technology, less attention is paid to blade morphology design.

Conventional WTs can be classified into two configurations in terms of rotor orientation that is vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT) [32–34]. HAWT is commonly used in large megawatt scale wind power application or known as large wind turbine (LWT). Where else VAWT is used for domestic and small wind power application (SWPA) or mini wind turbine (MWT). The propulsion of WT is governed by aerodynamic forces that is drag and lift

1078 (2021) 012017

doi:10.1088/1757-899X/1078/1/012017

[29]. Meanwhile, VAWT can be further classified into two types namely drag and lift type or commonly known as Savonius and Darrieus respectively [35-38]. Apart from generating power wind power devices is used for various applications such as wind power heating, seawater distillation, ship navigation and etc [39]. Moreover, WT are also classified based wind rotor performance with respect to power extraction coefficient (C_n) and tip speed ratio (TSR) and namely Savonius, horizontal axis three blade, vertical axis Darrieus [40], multi-blade [41], Dutch-four blade [42], high speed two blade [43,44] and single blade [45]. The minimal cut-in speed required for WTs to initiate rotation is from 3.5 m/s - 4 m/s [46], that is dependent on the configuration of blade type scale of turbine and propulsion configuration of wind turbine (lift or drag type). However, regions of South East Asia onshore sites have low wind speed potential, in which conventional wind power turbines can't produce sufficient power [47]. Hence design improvement and adaption are being implemented in the motive of obtaining a more efficient and reliable wind power device for low wind speed regions. The design adaption and improvement are mainly focused on propulsion aerodynamic load, blade configuration, blade morphology and etc. Researcher has proposed several innovative approaches to design optimization such surrogate modelling, parametric based optimization, specialized modified algorithm-based optimization, design adaptation and implementation and others. Based on the all the novel approach proposed by engineers and researchers on specialized WT, it might take years for the proposed design or mechanism to be considered feasible for commercial use [42]. Case in point, Musgrove rotor WT developed by Professor Musgrove is commercially available ranging from 25 kW to 1000 Mw [48]. However, Musgrove rotor is not prominent as other WT configuration counterparts. The aim of the manuscript is to provide a brief view of the challenges of wind renewable energy sector in Malaysia relative to geographical wind condition, government policies and challenges in initiation of wind technologies and global perspective of green energy in terms of RER.

2. Usage of fossil fuels

The alternative approach of discouraging the usage of fossil fuels as the source of power generation is on the investment and development of RE resources. The politics and policies revolving around fossil fuel has encourage greed among individuals on the control of power generation via fossil fuels [49]. Chances on harvesting electricity from thermal based fuel cheaper has decreased due to the extended learning process over the years on improving the harvesting process. The cost on fossil fuel has increase due to the rise of consumption and shortage of resources. Moreover, the cost of power plant has increased due to the rise of living standard in terms of minimizing pollution and enhanced safety standards [50]. Consequently, the rise in prices on non-renewable energy supply has impacted the development of economy. At the initial stage the initiation cost on renewables will be costly but as rise in knowledge on harvesting and enhancing technologies on RER, the energy cost will subsequently decrease. As in July 2016 in northern Europe, off-shore wind prices were reported at 70 EUR/MWh, the prices drop to 60 EUR/MWh in September and reach below 50 EUR/MWh by November [50]. Meanwhile in Malaysia, high consumption of fossil fuel led to high amount of carbon dioxide (CO_2) emission. Since 1980, there is continuous rise of carbon dioxide emission due to non-renewable fuel usage [51]. United States Energy Information Administration (EIA) reported that in 2017, Malaysia emitted 229 million metric tons of CO_2 due to high amount non-renewable fuel consumption [52]. Case in point, relative to Kyoto protocol in 2002, Prime minister of Malaysia made a promise in reducing the CO₂ by 40% by 2020 in United nations climate change conference (UNCCC) [53]. However, Malaysia government has not taken any serious steps in reducing the CO_2 index. This can be seen by the rise of CO_2 emission as shown in Figure 1 from 2002 till 2017.

1078 (2021) 012017

doi:10.1088/1757-899X/1078/1/012017



Figure 1. Carbon Dioxide Emissions by year in Malaysia. Source: United states.EIA 2020 Energy analysis of Malaysia [54].

Table 1. Countries examining "	100% renewable energy mechanism	(REM)'
--------------------------------	---------------------------------	--------

Countries	Analysis
Denmark [4]	The author stated that on global scale renewable energy constitutes less than 15 % of primary energy supply. The major key players are hydropower and fuel. The author concluded that with appropriate energy strategy it's possible for Denmark energy system to adapted 100% REM with the combination of biomass, wind power and photovoltaics RER.
Ireland [57]	Since the research were conducted in technical standpoint not economical perspective, the author stated that its technically feasible for Ireland to achieve 100% REM due to Ireland energy mix system. The author also mentions that there are several methods in achieving 100% REM apart from the presented methodology.
New Zeeland [58]	Researcher concluded that 32% of fossil fuel utilization for thermal generation can be replaced by 100% REM consisting renewable energy generation mix (REGM) of 53-60% hydro, 22-25% wind power, 0.2-0.3 bio-gas, 0.8-0.9 wood thermal and 12-14% geothermal.
Porto Santo island [59]	The authors developed a model for energy planning and optimization. The analysis was conducted at two different scenario which is peak shaving and 100% renewable power system. Results indicated that wind solar energy mix for peak shaving would be more effective than its counterpart. Where else, 100% renewable power system could be more cost effective.
Portugal [60]	The theoretical analysis conducted by the author indicated that Portugal could attain 100% REM energy system in 10 years with the assistance of suitable energy system strategy. The author utilized H ₂ RES software for energy plan system modelling. RER meteorological data such as wind speed and solar radiation were compared against the result obtained from H ₂ RES model.
Australia [61]	Proper and restructured planning on energy supply and demand makes it feasible for 100% REM to penetrate Australian National Energy Market (ANEM). Specific attention needed to be given to 100% REM with respect to wind and solar RER for balanced energy supply and demand. This is due to absence of wind and solar during winter evenings which demands high energy supply.
Croatia [62]	The author concluded that it requires for Croatia to carry out comprehensive planning on all economy sectors with regards to the implementation of 100% REM. The energy calculation was carried in EnergyPLAN software. Results illustrated that 2000 MW WTs could contribute to 10% total electricity demand granting that the new power plans operate at minimal load of 400 MW.

IPCME 2021		IOP Publishing
IOP Conf. Series: Materials Science and Engineering	1078 (2021) 012017	doi:10.1088/1757-899X/1078/1/012017

Unfortunately, at current status quo Malaysia is strongly dependent on fossil fuel by 90% for electrical power generation. Although solar energy supply is considered as the main contributor Malaysia's RE sector, the contribution only reached up to 2%. RE sector in Malaysia is targeted to reach 25% by the year 2025 [55]. Although other counties are rapidly evolving into RER, even as introducing the "100% renewable energy mechanism", where energy supply are entirely from RER. Several countries are involved in "100% renewable energy mechanism (REM)" where its being analyzed relative to their energy supply and demand [56]. Refer to Table 1 for details on counties that are examining on the concept of "100% renewable energy mechanism". Needless to say, 100% REM requires strategic energy planning in terms of technically and in economical perspective to maintain balance in energy demand and supply. Strategic energy planning would assist high penetration of RE to Malaysia energy supply chain. Relative to Malaysia, restructuring RE infrastructure and energy supply chain would displace the dependency of fossil fuel as main domain of electricity supply. However, Malaysia government is still struggling and reluctant in establishing a proper RE power supply. Therefore, Malaysia should carry out extensive and comprehensive research on RE power supply to cater for a sustainable and cleaner future.

3. Energy policies in Malaysia

Energy policies in Malaysia are regulated and overseen by Energy department of Economic Planning Unit (EPU) under the jurisdiction of the Prime Minister. Prior to 1979, there were several other energy policies, hence an overall energy policy was introduced known as National Energy Policies (NEP) 1979. The policy comprise of comprehensive guidelines on nation's energy objectives and strategies [63]. There are three main objectives to the 1979 energy policy, that is supply, utilization and environmental [64]. Later in 2000, Eight Malaysia Plan energy mix fuel policy were revised Four Fuel Policy to Five Fuel Policy by including RE [65]. In Five Fuel Policy, the target was set to 5% as for RE's contribution to energy mix. It is estimated that over the period of 5 year, it could save Malaysia RM 5 billion [66]. Electrification plans based on RE for 59,960 housing units was proposed in 9th Malaysian Plan (2006-2010) for rural areas specially Sabah and Sarawak region [67]. Besides, in 10th Malaysian Plan, the government suggested to increase the amount of electricity generation of RE from 1 % to 5.5 % of total energy by year 2010 [68]. Small Renewable Energy Power (SREP) program was initiated in May 2001 to motivate the utilization of small scale RER [69]. Concurrently, Special Committee on Renewable Energy (SCORE) under the supervision of Ministry of Energy, Green Technology and Water (KeTTA) were initiated to assist and coordinate SREP strategies in order to boost the development of RER [70]. The initial plan of SREP was to provide additional 500 MW via the installation of biomass, mini hydrokinetic turbine, biogas, solar photovoltaics and municipal solid waste from 2001 to 2005. Regrettably, wind energy was not included as one of the RER in SREP program. However, by the end of 2005, only 12 MW was able to be achieved. Nonetheless, the program was extended for another five years and reduced the target to 350 MW, yet only 61.7 MW was achieved [71]. Relentless, in 2010 National Renewable Energy Policy (NREP) were formulated, in which the principal objective of the policy is to attain 11 % from the total energy production via RER by 2020 [72]. Regardless of the initiatives done by the government, SREP program composed of complicated rules, regulation and legislation relative to project developers involved in SREP. Needless to say, this would be troublesome for companies to go through complicated procedures [71]. Government of Malaysia formed sustainable energy development authority (SEDA) to advise and assistance ministries and government entities on matters pertaining to RE policies law and to promote sustainable energy.

In 2011, Renewable Energy Act 2011 (Act 725) was formed, where the role of Act 725 is to stimulate the growth of RES, where the Act is composed of comprehensive implementation procedures and information pertaining to Feed in Tariffs mechanism [53],[54]. Although several countries managed to develop sturdy and stable FiT mechanism on wind energy, Malaysia do still struggle on developing a robust FiT framework for wind power technologies. Unreliable political policies such as unattractive energy tariff rates, hike in land prices and lake of financial support hinders the development of wind power sector [75]. Despite of the issues, based on the efforts and support given by several local parties it is evident that wind power harvesting is feasible in Malaysia. For an instance, realizing the

prospect of wind energy during monsoon season, in 2005 Malaysia government installed 150 kW WT at Pulau Terumbu Layang Layang, Sabah [76]. Other than that, in 2007 Tenaga Nasional Berhad (TNB) with Kuala Terengganu state government collaborated in Pulau Perhentian project solar-wind-diesel project [77]. The hybrid system is comprised of two 100 kW WT generator (WTG) [78], 100 kW solar-photovoltaic and 100 kW diesel generator [79]. The hybrid system is backed up with 480 kWh battery to store the energy [80]. Moreover, eight 5-10 kW MWT were installed in rural areas of Sabah and Sarawak by Ministry of rural and regional development [81,82].

4. Wind assessment in Malaysia

In order to assess wind power characteristic at particular region, comprehensive investigation is required relative to the location's topology. Therefore, information on wind speed dominance namely period (season), location and direction is crucial in wind energy potential assessment [83]. In Southeast Asia, Malaysia is located at 2° 30'N 112° 30'E near to equator on Sunda shelf. Consequently, the wind flow pattern and behavior is governed by monsoon seasons namely Southwest (SW) (June-September) and Northeast (NE) (November-March). Masseran & Razali, (2016) [83] investigated the behavior of wind speed direction in Peninsular Malaysia during monsoon seasons via finite von Mises-Fisher density function numerical model (FVMF). The author stated that monsoon seasons occurs due to the influence of change in pressure and temperature. Since the pressure above landmass is low in which causes to warm up the air faster in comparison to air over ocean. Due to the difference in gradient, this causes the wind over ocean to blow to shore landmass. Studies showed that during SW monsoon season air temperature at Asian continent is high from due to low pressure and in Australian continent has low air temperature and high-pressure environment. Consequently, this phenomenon causes the wind to advect and convect to Penisular Malaysia and South China Sea (SCS). During SW monsoon season, wind speed can reach to approximately 7.71 m/s. Meanwhile, Northwest monsoon season influence the wind speed to reach high speed margin due to the geographical region and weather phenomena. Wind speed during NE monsoon seasons can reach up to 15.4 m/s [83-85]. This indicates that wind speed during NE is higher than SW [86]. Moreover, Ocean and land breeze can achieve 5-7.5 m/s on sunny days. Nonetheless, valley breeze can exceed 9 m/s, while mountain breeze can rise to 11 m/s. Monthly average wind speed of Mersing passes 3 m/s. Annual wind speed of Mersing and Kuala Terengganu is 3.29 m/s and 2.67 m/s respectively [87].

Researchers in Malaysia carried out wind speed assessment at Kota Kinabalu, Melaka, Labuan, Alor Star, Kuala Terengganu, Tawau, Mersing, Cameron Highlands, and Kuching. The investigation was carried out to collect wind speed data from local metrological station using an anemometer at the height of 10 m [88]. The researcher found out that Mersing and Kuala Terengganu has the wind speed potential in comparison to other geographical locations. Industrias Metalurgicas Pescarmona S.A (IMPSA) and TNB collaborated in 2009 to investigate the wind speed potential in Malaysia to generate electricity at utility scale. IMPSA research indicated that Langkawi, Mersing, Kuala Terengganu and Kota Kinabalu are potential locations. The wind roses data were recorded using 80 m high mast. IMPSA stated that Malaysia has the credibility to produce 500 - 200 MW of power from wind [49]. Wind speed data from 18 m high were collected at Megabang Telipot indicated that maximum monthly arithmetic mean (AM) wind speed is 6.54 m/s and minimum monthly AM is 2.04 m/s. High AM wind speed occurs during the NE monsoon. Refer to Figure 2 on monthly AM wind speed at Megabang Telipot and Perhentian Island.





Figure 2. Monthly AM wind speed at Megabang Telipot and Perhentian Island. Source: Ho (2016) [49].

Between monsoon periods, at particular period selected area experience strong wind flow. Figure 3 illustrates real time Metrological terminal air report (METAR) wind speed on 18-April-2020. As manifested in the Figure 3, selected regions indicated wind speed of 6 knots, that is approximately 3.08 m/s. Strong and gustier windstorms take place at particular period between the two monsoon seasons (April-October) or otherwise known as inter-monsoon. Hence the windstorm exhibits potential treat, therefore being classified as metrological disaster subgroup [89]. Typhoons frequently occur across the Pacific West and move to westwards to Philippines. Consequently, Sabah and Sarawak experiences wind more than 10.3 m/s during the month from April to November [90]. Approximately, 6-7 tropical cyclones move across Philippines and SCS on yearly basis [91]. Refer to Table 2 for overview of wind speed potential and energy in Malaysia.



Figure 3. METAR wind speed mapping of Malaysia on 18-April-2020.

Fable 2. Overview on wind speed characteristic and power in N	Malaysia
--	----------

Authors	Overview	Wind speed characteristic
Siti Khadijah et al. [92]	Geographically Malaysia is situated at equatorial region in which the weather is influence by monsoon. Thus, making Malaysia a strategical venue for wind energy harvesting at selected location and time period. East coast (EC) regions namely Kelantan and Kuala Terengganu indicated great potential with high wind speed potential during monsoon season. Moreover, the author also added that wind energy offers great theoretical	East Coast state's average wind speed is 15.4 m/s during monsoon season.

	notantial as an alternative anamou resource	
	potential as an alternative energy resource.	
Daut et al.[93]	On 9 th March 2011, data on solar radiation and wind speed were collected over a period of 24 hours via weather station at Universiti Malaysia Perlis at 21.7 m height. Electrocorder were utilized to measure the output every per minute.	Over the period of 24 hours, it is found that the maximum and average wind speed is 7.61 m/s and 3.03 m/s respectively.
Daut et al. [94]	Since the 70's wind energy technology has evolved rapidly. Due to the advance in wind engineering, WTs are made available at reasonable cost. Where numerous new blade profile has been introduced with higher efficiency then the conventional blade, advanced control systems and turbine electronics has become easily accessible at low cost.	Maximum, arithmetic mean and minimum of daily wind speed (m/s) data of Perlis on month April 2011, are 3.2274, 1.7133 and 0.1992 respectively.
Masri et al. [95]	Two low speed wind speed were installed at USM Nibong Tebal. The turbines were placed at different heights in order to analyse the power extraction process relative to the wind speed at given height. At height 10 m, average monthly energy produced by 2 kW WT is approximately 163 Wh. The author utilized Davis instrument health weather link for data acquisition.	The maximum wind speed recorded at 10 m was 6 m/s is between 2 pm to 6 pm. However, at 30 m height the maximum wind speed is 18 m/s.
Masseran et al. [96]	In three-years period, 18.2 % of the time the wind speed exceeds 4 m/s at Mersing Station. Consequently, only selected period in a year, substantial amount of energy is harvested.	Although maximum wind speed (m/s) at Kuantan and Alor Setar is 11.8 and 11.5 respectively. However, the average wind speed did not exceed 3 m/s. Since the minimum cut in speed for WT power generation is 3 m/s. Therefore, it's not suitable to electricity generation. Nonetheless, wind speed lies between 6 -12 m/s, thus making it possible to harvest energy at selected period in a year.
Albani et al. [97]	Northern part of Kudat has potential for small scale wind farm based on wind speed data collected via Wind Atlas analysis and application program (WAsP). Based on the AM wind speed value, MWT installation has potential for energy harvesting due to cut-in speed of 4.0 m/s.	Based on interpolated wind speed data collected at Kudat, it is found that the peak wind speed value is 5.4 m/s and minimum value of 4.3 m/s.
Lawan et al. [98]	Due to Malaysia geographical properties, it is considered as light wind speed zone. Therefore, WTs need to be installed in the appropriate or at potential location with minimum cut in speed. Mini scale wind turbine would be suitable to electrical power generation.	Wind speed in Malaysia are inconsistent caused by variation in seasons and wind pattern. Wind speed potential in Malaysia ranges from 2.0- 8.93 m/s.
Ahmadian et al. [99]	Wind energy density investigation were conducted on Butterworth to asses wind harvesting feasibility. Five commercially available WTs were utilized for the development of turbine power curve. The analysis conducted using HOMER energy simulator will assist the engineers in the selection of WT to be installed in Butterworth.	Studies shows that, the average annual wind speed of Butterworth is 2.87 m/s and frequency of occurrence more than 3 m/s is 20.2 %. Hence, WTs with cut in speed of 3 m/s would be suitable for this site.

IPCME 2021

IOP Publishing

power

m hub tower height, maximum average

monthly wind speed resulted in 5.4 m/s.

Kuala Terengganu were considered as

production due to its 50 % probabilistic occurrence of wind speed more than 3

Southwest wind speed is below 7.5 m/s and steady wind speed of 5 - 10 m/s north-eastly wind. East coast states of Peninsular Malaysia can reach up to 15 m/s. Average valley breeze win speed is $V_m = 9$ m/s and mountain breeze can

Generally, SW wind speed is below 7

Annual AM wind speed in Mersing is

2.74 m/s with peak value of 3.97 m/s

Standard-2 RADAR-SAT SAR data

indicated that Langkawi experiences an

average yearly wind speed ranging

On 31 December 2017, Kota Bharu,

Kelantan recorded the highest daily

average wind speed of 7.1 m/s.

during mid of NE monsoon.

from 3-5 m/s.

potential site for wind

reach to $V_m = 11$ m/s.

m/s.

m/s.

IOP Conf. Series: Materials Science and Engineering		1078 (2021) 012017	doi:10.1088/1757-899X/1078/1/012017
Akorede et al.	In 2009 the Prime Minister	launched the green	At 70 m height, on month January
[100]	technology policy which resu	lted in launching of	Mersing recorded an average monthly
	FiT in 2011 to further encour	rage RES. However,	wind speed of 6.95 m/s. However, at 10

HOMER energy simulator was utilized to simulate the suggested WTs for the study in terms of energy production and capacity factor relative to wind speed data in Kuala Terengganu. Analysis relative to the performance WTs, it is found that LWT is not
suitable for Kuala Terengganu site.

scrutinized.

wind power sector is yet to be enrolled and

Ibrahim et al.	Malaysia is considered as mesoscale wind where the		
[102]	wind flow is influenced by local wind movement		
	Since Malaysia is maritime country, wind flow		
	pattern is governed by sea and land breeze.		
	Mountain and valley breeze also have an effect on		
	wind flow.		

- Daryabor et al. Due to monsoon current circulation properties of [103] Due to monsoon current circulation properties of SCS during SW, Penisular Malaysia experience strong western boundary current and eddies. Thus, making SCS an anti-cyclonic region. The eddies are generated due to temperature difference and baroclinic instabilities. Eddies formation are also caused by wind stress due to wind stratification resulted by wind shear.
- Belhamadia et al. [104] Wind speed data over the period of 2011-2012 from National Aeronautics and Space Administration (NASA) surface metrology database was verified against data from MMD for data reliability. Wind speed data of seven cities indicated that, highest annual average wind speed record was Mersing flowed by Kota Bharu, Miri and Kuala Terengganu. Wind turbines with cut in speed of 2.5 m/s are able to operate for 5084 hours in Mersing.
- Deros et al.,Data collected from RADAR-SAT SAR were[105]validated against QUICKSCAT wind vector data.
- MalaysiaMMD yearly report stated that, in 2017 MalaysiaMeteorologicalexperienced on average normal weather and climateDepartmentcondition.[106]Nonetheless, Kedah experiencedextreme weather resulting in drastic flooding. Thisis due to tropical depression which resulted in heavyrainfall and strong wind.
- Ahmad Zaman Malaysia territory is divided into regions; From month April to September, Sabah Peninsular Malaysia and Borneo facing SCS. and Sarawak experiences high wind et al. [107] Meanwhile, west cost of Peninsular Malaysia is face speed reaching up to 10 m/s due to the occurrence of typhoon at Philippines. by straits of Malacca. Since the conditions of the oceans surrounding Malaysia is less turbulent, Wind speed data shows below 7 m/s steadier wind with less wind shear. Thus, making it during SW monsoon and high wind more prospective to offshore wind power energy. speed of 15 m/s during NE monsoon. Studies were carried out to investigate the wind The AM wind speed of the six towns is Kubota &

Ahmad [108] speed potential of major towns in Malaysia. The from 1-3 m/s from 1988-2002. The AM major towns were Penang, Kuala Terengganu, Kuala Lumpur, Johor Bahru, Temerloh and Kota wind velocities between Kota Bharu and Kuala Terengganu town is 2.7 m/s Bharu. The local climate is influenced by the land-NE monsoon. Termerloh during sea breeze due to the continuous solar radiation indicated the weakest wind speed throughout the year. Penang has higher sea breeze strength due to its inland location. effect then Kuala Lumpur due to location of the Termerloh AM velocities is from 0.2island at south coast facing straits of Malacca. 0.3 m/s. Unlikely, Kuala Lumpur is situated far from the costal line.

5. Classification of wind turbine

The description on the intensity of the wind speed with regards to a region is indecisive and complicated. Since wind speed intensity is a qualitative description, which varies according to benchmarks defined by local standards and geographical location. Moreover, this predicament has pondered manufactures on WT classification for product marketing purpose. Hence, for the purpose of WT design classification manufactures adapted an international technical standard, documented and proposed by International Electrotechnical Commission (IEC) which is IEC 61400: 2019 [109–111]. Table 3 reports the parametric description of WT classes complying to IEC 61400-1:2019. As illustrated in Table 3, WT are classified in to three types namely type I (up to 10 m/s), type II (up to 8.5 m/s) and type III (up to 7.5 m/s) based on V_m. Meanwhile, V_{ref} is used as reference for 10 min average wind speed with 50-year period. As for V_{ref,T}, Selamat et al. (2013) [112] stated that the 50year return period wind speed is 64.6 knots which is approximately 33.23 m/s. The prefixes A+, A, B and C is used to represent the turbulent intensity (I) of the wind. Since, actual or experimental data on turbulent parameters are unavailable, therefore value of I is defined according to class A which is I =0.16. In regards to literature survey on wind speed assessment in Malaysia, the adapted wind speed range is from 5.5 m/s to 7.5 m/s. Hence, for this study the proposed design is defined as IIIA WT with regards to IEC 61400: 2019 standard. Moreover, IIIA class WT is considered as low wind speed WT.

Wind turbine classes	Description	Ι	II	III
V _m (Max)	Annual average wind speed.	10 m/s	8.5 m/s	7.5 m/s
$\mathbf{V}_{\mathrm{ref}}$	10 min average wind speed with 50-year return period.	50 m/s	42.5 m/s	37.5 m/s
$V_{\text{ref},T}$	10 min average wind speed with 50-year return period in typhoon condition	57 m/s	57 m/s	57 m/s
A+	Turbulent intensity	0.18	0.18	0.18
А	Turbulent intensity	0.16	0.16	0.16
В	Turbulent intensity	0.14	0.14	0.14
С	Turbulent intensity	0.12	0.12	0.12

6. Discussion

Although Malaysian researchers presented an attractive form of investigation on wind speed potential assessment. However, the methodology presented by the authors are highly doubtful and questionable. This is due to the lack of crucial information on the methodology adapted for wind speed assessment. Conventionally, surface wind gust is measured by mast at standard height of 10 m above ground [113]. However, several authors did not present the height of the measurement were taken or did not comply to the standards. For an instance, several authors relied on wind speed data collected by Sopian et al. [88]. Meanwhile, Sopian et al. [88] gather the data from 10 MMD stations through Malaysia. Unfortunately, the height at which the data were collected varies by station. Although, Sopian et al. [88] corrected the data to standard height of 10 m via numerical mode. Factors such as location where the reading via MMD's anemometer were collected at different environment and condition namely near open sea, at airport and flat area. Data gather from MMD facilities are near or from airports that is considered bias due to influence of airplanes on anemometer reading and airports are located at low wind speed regions [49,80,87,114,115]. Masseran et al. [96] stated that location that faces the sea and with low surface roughness would be an ideal location for 10 m height wind speed data logging. Moreover, researcher also did not present information on instrumentations utilized for measurement such as hardware specification, sensor calibration parameters and techniques. Uncalibrated or inappropriate calibration of anemometer may establish bias data collection [116]. Nonetheless, this does not imply that the data provided by MMD is inadequate because the role of MMD is to gather wind speed data relative to weather forecasting and meteorological study not for WT wind density assessment. Since wind speed assessment techniques for WT power performance need to comply international standard IEC 61400-12-2 [117]. Hence, it is found that data collected by previous researchers on wind speed data are considered unreliable to be utilized for WT power density assessment and design. Notably, wind speed in Malaysia is seasonal based and highly inconsistent. The wind flow pattern and intensity experience by Malaysia are merely an aftereffect of weather change in neighbouring regions. Nevertheless, it is found that selected regions of east coast peninsular Malaysia and selected region of Sabah and Sarawak is potential for harvesting wind power due to substantial and adequate wind pattern behavior during monsoon season. Therefore, it is evident that geographical wind condition of Malaysia is appropriate for wind power devices as a form of RER in green energy sector of Malaysia. However, it is also found that fundamental design modification is required on conventional design of WT in terms of blade morphology and configuration in order to adapt to unsteady monsoon wind speed pattern regions.

Acknowledgments

This research work was conducted under Grant number FRGS/1/2019/TK10/UMP/02/4. We would like to thank Ministry of Higher Education, Malaysia for making this research possible.

References

- [1] Cheng M-Y, Wu Y-F, Wu Y-W and Ndure S 2019 Fuzzy Bayesian schedule risk network for offshore wind turbine installation *Ocean Eng.* **188** 106238
- [2] Arvizu D, Bruckner T, Christensen J, Devernay J-M, Faaij A, Fischedick M, Goldstein B, Hansen G, Huckerby J, Jager-Waldau A, Kadner S, Kammen D, Krey V, Kumar A, Lewis A, Lucon O, Matschoss P, Maurice L, Mitchell C, Moomaw W, Moreira J, Nadai A, Nilsson L J, Nyboer J, Rahman A, Sathaye J, Sawin J, Schaeffer R, Schei T, Schlomer S, Sims R, von Stechow C, Verbruggen A, Urama K, Wiser R, Yamba F and Zwickel T 2011 Summary for Policy Makers: Intergovernmental Panel on Climate Change Special Report Renewable Energy Sources (SRREN) (United States)
- [3] Joselin Herbert G M, Iniyan S, Sreevalsan E and Rajapandian S 2007 A review of wind energy technologies *Renew. Sustain. Energy Rev.* **11** 1117–45
- [4] Lund H 2007 Renewable energy strategies for sustainable development *Energy* **32** 912–9
- [5] Ackermann T and Söder L 2002 An overview of wind energy-status 2002 Renew. Sustain.

Energy Rev. 6 67–127

- [6] Xia L, Ma Z, Kokogiannakis G, Wang Z and Wang S 2018 A model-based design optimization strategy for ground source heat pump systems with integrated photovoltaic thermal collectors *Appl. Energy* **214** 178–90
- [7] Azad A K, Rasul M G, Islam R and Shishir I R 2015 Analysis of Wind Energy Prospect for Power Generation by Three Weibull Distribution Methods *Energy Procedia* **75** 722–7
- [8] Suresh A and Rajakumar S 2019 Design of small horizontal axis wind turbine for low wind speed rural applications *Mater. Today Proc.*
- [9] Wizelius T 2012 Design and Implementation of a Wind Power Project *Comprehensive Renewable Energy* ed A B T-C R E Sayigh (Oxford: Elsevier) pp 391–430
- [10] Cognet V, Courrech du Pont S, Dobrev I, Massouh F and Thiria B 2017 Bioinspired turbine blades offer new perspectives for wind energy Proc. R. Soc. A Math. Phys. Eng. Sci. 473 20160726
- [11] Nayar C V, Islam S M, Dehbonei H, Tan K and Sharma H 2011 Power Electronics for Renewable Energy Sources Alternative Energy in Power Electronics ed M H B T-A E in P E Rashid (Boston: Elsevier) pp 1–79
- [12] Qin N, Howell R, Durrani N, Hamada K and Smith T 2011 Unsteady Flow Simulation and Dynamic Stall Behaviour of Vertical Axis Wind Turbine Blades *Wind Eng.* **35** 511–27
- [13] Peng Z, Chen B, Qin F G F, Jiang R, He Q, Tao S, Xiao H, Chen Y and Yang M 2019 Numerical simulation of aerodynamic performance of an airfoil combined lift and drag *Energy Procedia* 158 6282–7
- [14] Chong W T, Muzammil W K, Wong K H, Wang C T, Gwani M, Chu Y J and Poh S C 2017 Cross axis wind turbine: Pushing the limit of wind turbine technology with complementary design *Appl. Energy* 207 78–95
- [15] Eriksson S, Bernhoff H and Leijon M 2008 Evaluation of different turbine concepts for wind power *Renew. Sustain. Energy Rev.* **12** 1419–34
- [16] Bianchini A, Balduzzi F, Bachant P, Ferrara G and Ferrari L 2017 Effectiveness of twodimensional CFD simulations for Darrieus VAWTs: a combined numerical and experimental assessment *Energy Convers. Manag.* 136 318–28
- [17] Shahizare B, Nik-Ghazali N, Chong W T, Tabatabaeikia S, Izadyar N and Esmaeilzadeh A 2016 Novel investigation of the different Omni-direction-guide-vane angles effects on the urban vertical axis wind turbine output power via three-dimensional numerical simulation *Energy Convers. Manag.* **117** 206–17
- [18] Wang Y, Sun X, Dong X, Zhu B, Huang D and Zheng Z 2016 Numerical investigation on aerodynamic performance of a novel vertical axis wind turbine with adaptive blades *Energy Convers. Manag.* 108 275–86
- [19] Joselin Herbert G M, Iniyan S, Sreevalsan E and Rajapandian S 2007 A review of wind energy technologies *Renew. Sustain. Energy Rev.* **11** 1117–45
- [20] Akour S N, Al-Heymari M, Ahmed T and Khalil K A 2018 Experimental and theoretical investigation of micro wind turbine for low wind speed regions *Renew. Energy* **116** 215–23
- [21] Riyanto, Pambudi N A, Febriyanto R, Wibowo K M, Setyawan N D, Wardani N S, Saw L H and Rudiyanto B 2019 The Performance of Shrouded Wind Turbine at Low Wind Speed Condition *Energy Procedia* 158 260–5
- [22] Pambudi N A, Pristiandaru D L, Basori, Wijayanto D S, Sriwardani N, Rahman N, Bugis H, Wahyudi B D, Sudibyo C, Karno M W and Subagsono 2017 Experimental Investigation of Wind Turbine Using Nozzle-lens at Low Wind Speed Condition *Energy Procedia* 105 1063–9
- [23] Butbul J, MacPhee D and Beyene A 2015 The impact of inertial forces on morphing wind turbine blade in vertical axis configuration *Energy Convers. Manag.* **91** 54–62
- [24] Kosasih B and Saleh Hudin H 2016 Influence of inflow turbulence intensity on the performance of bare and diffuser-augmented micro wind turbine model *Renew. Energy* 87 154–67

IOP Conf. Series: Materials Science and Engineering 1078 (2021) 012017 do

doi:10.1088/1757-899X/1078/1/012017

- [25] Sotoudeh F, Kamali R and Mousavi S M 2019 Field tests and numerical modeling of INVELOX wind turbine application in low wind speed region *Energy* **181** 745–59
- [26] Vaz J R P and Wood D H 2016 Aerodynamic optimization of the blades of diffuseraugmented wind turbines *Energy Convers. Manag.* **123** 35–45
- [27] Ikeda T, Tanaka H, Yoshimura R, Noda R, Fujii T and Liu H 2018 A robust biomimetic blade design for micro wind turbines *Renew. Energy* **125** 155–65
- [28] Li X, Zhang L, Song J, Bian F and Yang K 2019 Airfoil design for large horizontal axis wind turbines in low wind speed regions *Renew. Energy* **145** 2345–57
- [29] Schubel P J and Crossley R J 2014 Wind turbine blade design *Wind Turbine Technol. Princ. Des.* 1–34
- [30] Seidel C, Jayaram S, Kunkel L and Mackowski A 2017 Structural Analysis of Biologically Inspired Small Wind Turbine Blades *Int. J. Mech. Mater. Eng.* **12** 19
- [31] Papaelias M and Márquez F P G 2020 Wind turbine inspection and condition monitoring Non-Destructive Testing and Condition Monitoring Techniques for Renewable Energy Industrial Assets ed M Papaelias, F P G Márquez and A B T-N-D T and C M T for R E I A Karyotakis (Boston: Elsevier) pp 19–29
- [32] Kaldellis J K and Zafirakis D 2011 The wind energy (r)evolution: A short review of a long history *Renew*. *Energy* **36** 1887–901
- [33] Wenehenubun F, Saputra A and Sutanto H 2015 An Experimental Study on the Performance of Savonius Wind Turbines Related With The Number Of Blades *Energy Procedia* **68** 297–304
- [34] Zhao D, Han N, Goh E, Cater J and Reinecke A 2019 Chapter 1 General introduction to wind turbines ed D Zhao, N Han, E Goh, J Cater and A B T-W T and A E H Reinecke (Academic Press) pp 1–20
- [35] Ahire R, Gawli S, Geedh3 K, Gade A and Patil S S 2017 Review on Vertical Axis Wind Turbine *Int. J. Adv. Sci. Res. Eng.* **03** 5–9
- [36] Moh Saad M M and Asmuin N 2014 Comparison of Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines *IOSR J. Eng. www.iosrjen.org ISSN* **04** 2250–3021
- [37] Ramadan A, Yousef K, Said M and Mohamed M H 2018 Shape optimization and experimental validation of a drag vertical axis wind turbine *Energy* **151** 839–53
- [38] Yang W, Hou Y, Jia H, Liu B and Xiao R 2019 Lift-type and drag-type hydro turbine with vertical axis for power generation from water pipelines *Energy* **188** 116070
- [39] Zheng C wei, Li C yin and Xu J jun 2019 Micro-scale classification of offshore wind energy resource ——A case study of the New Zealand *J. Clean. Prod.* **226** 133–41
- [40] Möllerström E, Gipe P, Beurskens J and Ottermo F 2019 A historical review of vertical axis wind turbines rated 100 kW and above *Renew. Sustain. Energy Rev.* **105** 1–13
- [41] Yoon S-H, Lim H-C and Kim D-K 2013 Study of several design parameters on multi-blade vertical axis wind turbine *Int. J. Precis. Eng. Manuf.* **14** 831–7
- [42] Schubel P J and Crossley R J 2012 Wind Turbine Blade Design Energies 5 3425–49
- [43] Clark R N 2014 Wind Turbine Components and Descriptions Small Wind ed R N B T-S W Clark (Boston: Elsevier) pp 39–67
- [44] Yoshida S 2016 In-plane self-excitation of two-bladed horizontal axis wind turbine rotors due to blade elasticity and gravity *Wind Eng.* **40** 343–59
- [45] Bangga G, Hutomo G, Wiranegara R and Sasongko H 2017 Numerical study on a single bladed vertical axis wind turbine under dynamic stall *J. Mech. Sci. Technol.* **31** 261–7
- [46] Misaran M S, Rahman M M, Muzammil W K and Ismail M A 2017 Assessment of C-Type Darrieus Wind Turbine Under Low Wind Speed Condition *IOP Conference Series: Materials Science and Engineering* vol 217 p 012019
- [47] Gitano-Briggs H 2012 Low Speed Wind Turbine Design Advances in Wind Power (InTech)
- [48] Mathew S 2006 *Wind Energy* (Berlin, Heidelberg: Springer Berlin Heidelberg)
- [49] Ho L-W 2016 Wind energy in Malaysia: Past, present and future *Renew. Sustain. Energy Rev.* 53 279–95

IOP Conf. Series: Materials Science and Engineering 1078 (2021) 012017 doi:10.1088/1757-899X/1078/1/012017

IOP Publishing

- [50] Kåberger T 2018 Progress of renewable electricity replacing fossil fuels *Glob. Energy Interconnect.* **1** 48–52
- [51] Administration U S E I 2013 United States Energy Information Administration (USEIA)
- [52] Administration U S E I 2017 United States Energy Information Administration
- [53] Anon 2012 IEA International CCS Regulatory Network (Network): 4th CCS Regulatory Network Meeting Workshop Report 2012 (International Energy Agency (IEA) Paris, France.)
- [54] United states.EIA 2020 Energy analysis of Malaysia
- [55] Abdullah W S W, Osman M, Kadir M Z A A and Verayiah R 2019 The potential and status of renewable energy development in Malaysia *Energies* **12** 2437
- [56] Cosi B and Kraja G 2012 A 100 % renewable energy system in the year 2050: The case of Macedonia 48 80–7
- [57] Connolly D, Lund H, Mathiesen B V. and Leahy M 2011 The first step towards a 100% renewable energy-system for Ireland *Appl. Energy* **88** 502–7
- [58] Mason I G, Page S C and Williamson A G 2010 A 100% renewable electricity generation system for New Zealand utilising hydro, wind, geothermal and biomass resources *Energy Policy* 38 3973–84
- [59] Duić N and Da Graça Carvalho M 2004 Increasing renewable energy sources in island energy supply: Case study Porto Santo *Renew. Sustain. Energy Rev.* **8** 383–99
- [60] Krajačić G, Duić N and Carvalho M da G 2011 How to achieve a 100% RES electricity supply for Portugal? *Appl. Energy* **88** 508–17
- [61] Elliston B, Diesendorf M and MacGill I 2012 Simulations of scenarios with 100% renewable electricity in the Australian National Electricity Market *Energy Policy* **45** 606–13
- [62] Krajačić G, Duić N, Zmijarević Z, Mathiesen B V, Vučinić A A and Da Graa Carvalho M 2011 Planning for a 100% independent energy system based on smart energy storage for integration of renewables and CO2 emissions reduction *Appl. Therm. Eng.* **31** 2073–83
- [63] Jalal T S and Bodger P 2009 National Energy Policies and the electricity sector in Malaysia 2009 3rd International Conference on Energy and Environment (ICEE) (Malacca: IEEE) pp 385–92
- [64] Lim C H and Elias S 2006 Current and Future Trends of Renewable Energy In Malaysia *Int'l J. Sustain. Trop. Des. Res. Pract.* **1** 32–9
- [65] Economic Planning Unit 2001 *Eighth Malaysia Plan, 2001-2005* (Economic Planning Unit, Prime Minister's Department)
- [66] Rahman Mohamed A and Lee K T 2006 Energy for sustainable development in Malaysia: Energy policy and alternative energy *Energy Policy* **34** 2388–97
- [67] Economic Planning Unit 2006 *The Ninth Malaysia Plan 2006–2010*
- [68] Economic Planning Unit 2010 *Tenth Malaysia Plan 2011-2015* (Economic Planning Unit, Prime Minister's Department)
- [69] Shamsuddin A H 2012 Development of renewable energy in Malaysia strategic initiatives for carbon reduction in the power generation sector *Procedia Eng.* **49** 384–91
- [70] Mekhilef S, Barimani M, Safari A and Salam Z 2014 Malaysia's renewable energy policies and programs with green aspects *Renew. Sustain. Energy Rev.* **40** 497–504
- [71] Sovacool B K and Drupady I M 2011 Examining the small renewable energy power (SREP) program in Malaysia *Energy Policy* **39** 7244–56
- [72] Kardooni R, Yusoff S B, Kari F B and Moeenizadeh L 2018 Public opinion on renewable energy technologies and climate change in Peninsular Malaysia *Renew. Energy* **116** 659–68
- [73] Hashim H and Ho W S 2011 Renewable energy policies and initiatives for a sustainable energy future in Malaysia *Renew. Sustain. Energy Rev.* **15** 4780–7
- [74] Khor C S and Lalchand G 2014 A review on sustainable power generation in Malaysia to 2030: Historical perspective, current assessment, and future strategies *Renew. Sustain. Energy Rev.* 29 952–60
- [75] Irena and Iea-etsap 2016 Wind Power Technology Brief

doi:10.1088/1757-899X/1078/1/012017

- [76] Farriz M B, Azmi A N, Said N A M, Ahmad A and Baharin K A 2010 A study on the wind as a potential of renewable energy sources in Malaysia ECTI-CON2010: The 2010 ECTI International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology pp 651–5
- [77] Ibrahim H N 2011 Towards Renewable Energy *Tenaga Link Malaysia* **1** 1–20
- [78] Ong H C, Mahlia T M I and Masjuki H H 2011 A review on energy scenario and sustainable energy in Malaysia *Renew. Sustain. Energy Rev.* **15** 639–47
- [79] Karim O A, Zuhairuse M D, Nor Atikah H, Siti Nurhidayah A M, Mohd Azhar A R and Khairul Nizam A M 2009 The Development of Hybrid Integrated Renewable Energy System (Wind and Solar) for Sustainable Living at Perhentian *Eur. J. Soc. Sci.* **9** 557–63
- [80] Albani A and Ibrahim M Z 2017 Wind energy potential and power law indexes assessment for selected near-coastal sites in Malaysia *Energies* **10**
- [81] Borhanazad H, Mekhilef S, Saidur R and Boroumandjazi G 2013 Potential application of renewable energy for rural electrification in Malaysia *Renew. Energy* **59** 210–9
- [82] Liang T S 2016 Rural Electrification in East Malaysia Achieving optimal power generation system and sustainability of rural electrification projects (KTH School of Industrial Engineering and Management)
- [83] Masseran N and Razali A M 2016 Modeling the wind direction behaviors during the monsoon seasons in Peninsular Malaysia *Renew. Sustain. Energy Rev.* **56** 1419–30
- [84] Satari S Z, Zubairi Y Z, Hussin A G and Hassan S F 2015 Some Statistical Characteristic of Malaysian Wind Direction Recorded at Maximum Wind Speed: 1999-2008 Sains Malaysiana 44 1521–30
- [85] Anon 2020 Asia wind energy association: Malaysia wind market overview
- [86] Saberi Z, Fudholi A and Sopian K 2019 Potential Evaluation of Wind Energy in Kuala Terengganu, Malaysia through Weibull Distribution Method *IOP Conf. Ser. Earth Environ. Sci.* **268**
- [87] Wen T W, Palanichamy C and Ramasamy G 2019 Small wind turbines as partial solution for energy sustainability of Malaysia *Int. J. Energy Econ. Policy* **9** 257–66
- [88] Sopian K, Othman M Y H and Wirsat A 1995 The wind energy potential of Malaysia *Renew*. *Energy* **6** 1005–16
- [89] Sabah S H A, Ramli N I, Majid T A and Zaini S S 2020 Development of site-specific wind hazard map for peninsular Malaysia via spatial modeling *Energies* **13**
- [90] Islam M R, Saidur R and Rahim N A 2011 Assessment of wind energy potentiality at Kudat and Labuan, Malaysia using Weibull distribution function *Energy* **36** 985–92
- [91] Pacheco B M, Rosaria N E, Aquino R E R and Garciano L E O 2007 Historical review of wind speed maps in the Philippines for various purposes: toward further development and use as typhoon hazard maps *Proceedings of the 4th Civil Engineering Conference in the Asian Region* (4CECAR)
- [92] Siti Khadijah N, Azami Z, Ahmad Mahir R, Mohd Said Z, Kamarulzaman I and Kamaruzzaman S 2009 Analyzing the East Coast Malaysia Wind Speed Data Int. J. Energy Environ. 3
- [93] Daut I, Irwanto M, Irwan Y M, Gomesh N, Rosnazri and Ahmad N S 2011 Potential of solar radiation and wind speed for photovoltaic and wind power hybrid generation in Perlis, Northern Malaysia 2011 5th Int. Power Eng. Optim. Conf. PEOCO 2011 - Progr. Abstr. 148– 53
- [94] Daut I, Razliana A R N, Irwan Y M and Farhana Z 2012 A study on the wind as renewable energy in perlis, northern Malaysia *Energy Procedia* **18** 1428–33
- [95] Masri S, Mohamad N and Hariri M H M 2012 Wind speed analysis at Nibong Tebal 2012 Int. Conf. Power Eng. Renew. Energy, ICPERE 2012 1–4
- [96] Masseran N, Razali A M, Ibrahim K and Wan Zin W Z 2012 Evaluating the wind speed persistence for several wind stations in Peninsular Malaysia *Energy* **37** 649–56

1078 (2021) 012017 doi:10.1088/1757-899X/1078/1/012017

- [97] Albani A, Ibrahim M Z, Yong K H and Terengganu K 2013 Wind Energy Investigation In Northern Part Of Kudat , Malaysia *Int. J. Eng. Appl. Sci.* **2** 14–22
- [98] Lawan S, Abidin W, Chai W, Baharun a and Masri T 2013 Reviewing Wind Speed and Energy Distribution in Malaysia *Eur. Acad. Res.* I 2104–22
- [99] Ahmadian J, Ghorbanian M J, Shams S, Goodarzvand F and Selvaraj J 2013 Butterworth, Malaysia wind energy potential assessment *CEAT 2013 - 2013 IEEE Conf. Clean Energy Technol.* 13–8
- [100] Akorede M F, Mohd Rashid M I, Sulaiman M H, Mohamed N B and Ab Ghani S B 2013 Appraising the viability of wind energy conversion system in the Peninsular Malaysia *Energy Convers. Manag.* **76** 801–10
- [101] Ahmadian J, Ghorbanian M J, Shams S, Goodarzvand F and Selvaraj J 2013 Kuala Terengganu, Malaysia wind energy assessment CEAT 2013 - 2013 IEEE Conf. Clean Energy Technol. 214–9
- [102] Ibrahim M Z, Yong K H, Ismail M and Albani A 2014 Wind speed modeling for Malaysia *Int. J. Renew. Energy Res.* **4** 912–23
- [103] Daryabor F, Tangang F and Juneng L 2014 Simulation of southwest monsoon current circulation and temperature in the east coast of peninsular Malaysia Sains Malaysiana 43 389– 98
- [104] Belhamadia A, Mansor M and Younis M A 2014 A study on wind and solar energy potentials in Malaysia *Int. J. Renew. Energy Res.* **4** 1042–8
- [105] Deros S N M, Asmat A and Mansor S 2015 Low wind speed direction extraction using wavelet transform technique *Int. Conf. Sp. Sci. Commun. Iconsp.* **2015-Septe** 358–61
- [106] Meteorological Malaysia Department 2017 Meteorological Malaysia Department: Annual Report 2017
- [107] Ahmad Zaman A A, Hashim F E and Yaakob O 2019 Satellite-Based Offshore Wind Energy Resource Mapping in Malaysia *J. Mar. Sci. Appl.* **18** 114–21
- [108] Kubota T and Ahmad S 2006 Wind Environment Evaluation of Neighborhood Areas in Major Towns of Malaysia *J. Asian Archit. Build. Eng.* **5** 199–206
- [109] Katsigiannis Y A, Stavrakakis G S and Pharconides C 2013 Effect of Wind Turbine Classes on the Electricity Production of Wind Farms in Cyprus Island *Conference Papers in Energy* vol 2013, ed C Sourkounis, A Poullikkas, P Demokritou and Y Al-Assaf (Hindawi Publishing Corporation) p 750958
- [110] Zhang M H 2015 Wind Resource Assessment and Micro-siting: Science and Engineering (John Wiley & Sons)
- [111] International Electrotechnical Commission 2019 International Standard: IEC 61400-1
- [112] Selamat I M, Liew M S, Nasir M and John K V 2013 Extreme Value Analysis and Joint Density of Metocean Loads for Malaysian Water *Malaysian J. Civ. Eng.* 52 40–52
- [113] Suomi I, Vihma T, Gryning S-E and Fortelius C 2013 Wind-gust parametrizations at heights relevant for wind energy: a study based on mast observations Q. J. R. Meteorol. Soc. 139 1298–310
- [114] Kadir E A, Miskon M T, Rashid N A and Yunus M Y 2018 A Study of Vertical Wind Turbine for Application in Low Wind Speed Condition in UiTM Terengganu, Malaysia J. Power Energy Eng. 06 38–48
- [115] Uti M N, Din A H M and Omar A H 2017 Reliability of wind speed data from satellite altimeter to support wind turbine energy *ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* XLII-4/W5 215–24
- [116] Demurtas G, Pedersen T F and Zahle F 2016 Calibration of a spinner anemometer for wind speed measurements *Wind Energy* **19** 2003–21
- [117] International Electrotechnical Commission 2005 *Iec 61400-12-1* vol 2005