An Evaluation Of Offshore Wind Renewable Energy Performance In Malaysia

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Abstract

The effort in finding the potential of renewable energy in Malaysia is essential due to the problem of global warming and the rise of energy demand. As time passes, these problems become severe and start to create a significant concern. This study aims to evaluate the performance of wind energy in Malaysia as a step ahead for the application of renewable energy to overcome the problems mentioned above. A software simulation using ANSYS was performed to evaluate wind energy performance by adopting the wind speed profile data for offshore locations in Malaysia. Based on these data, the potential sites for offshore wind energy development were assessed and proposed by the criteria of wind pressure in the rotor, wind velocity in the rotor, and the total power generation. The results show that Kijal, Kuala Terengganu, Kudat and Kota Kinabalu measure the greatest wind energy by the high wind pressure and velocity.

Keywords: Offshore wind energy, Offshore Malaysia, Wind energy performance.

Introduction

The need for exploring and discovering new energy resources is essential due to the global warming issue caused by greenhouse gases (GHG) emission and the increment of the energy demand [1]. The world is facing a severe problem of global warming, which triggering climate change. According to the World Wildlife Fund (WWF), the global warming and the GHG emission are mainly caused by human activities [2]. The burning of fossil fuels for the generation of electricity has worsened the scenario. GHG is defined as any gas that absorbs the heat from the earth's surface and traps in the atmosphere [3]. The concern on the reduction of GHG emission leads to the Kyoto Protocol that setting up the limit of the GHG emission [4]. It is the first international agreement between nations to stabilise the GHG concentration at a level that would not be dangerous to the climate system. Statistics show that from 1990 to 2004 only, the emission of the carbon in Malaysia increased by 221% as results from the industrial and transportation industry [5], and critically rose up to 235.6% in 2009 [6].

The most recent and immediate issue affecting the power generation in Malaysia is the insecure gas supply, which leads to more dependent on coal and imported gas. The consumption of these resources has significantly contributed to global warming [7,8]. Besides the global warming issue, global energy demand shows significant increment over the years [9]. The usage of energy has increased as the world is now focusing on the Industry Revolution 4.0, which involves the automation technology that requires energy as the primary source of development. Despite depending on the existing energy resources, the discovery of renewable energy has given a good sign to overcome global warming and to satisfy the global demand of the energy.

The renewable energy resources that are available in Malaysia, including hydro, solar, wind, geothermal and tidal wave [10]. As for now, Malaysia is more focusing on the hydropower generation, followed by solar power [11]. Meanwhile, the remaining resources are still lacking in focus, and wind energy is yet in the radar of the Malaysia governmental policy. However, wind energy is one of the most promising solutions as the alternative resource for power generation which to reduce the GHG emission [12]. Few different wind energy technologies are available across a range of applications, but the primary use of wind energy of relevance to climate change mitigation is to generate electricity from a more substantial, grid-connected wind turbines. The offshore wind energy has considerable potential as a tremendous resource for delivering clean and abundant energy on a global scale.

Nowadays, wind energy is continuing to be one of the fast-growing industries for power generation with a worldwide installed capacity of 318 GW as of the year ending 2013 and 369.553 GW by the end of 2014. On top of that, many assessments, permits, and installations are underway [13,14]. Meanwhile, many countries are stepping into a bigger scale of wind energy development, e.g. Brazil [15], Morocco [16], China [17], the Caribbean [18], Turkey [19], Uzbekistan [20], Djibouti [21], Columbia [22], and New Zealand [23]. The potential of wind energy harvesting in terms of technical and economic investment is deeply discussed. The development of the wind energy policies for countries such as

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Poland [24], India [25], and Kenya [26] have also been outlined and reviewed. This has shown the potential of wind energy as a new energy resource in fulfilling the global demand.

Aforementioned, Malaysia has the potential to develop wind energy. However, the utilisation of offshore wind energy in generating the electricity in Malaysia is still showing zero statistics as it is not listed as an eligible renewable source in the Renewable Energy Act 2011 [1]. At present, there are no feed-in tariff rates for the development of the offshore wind energy projects available in Malaysia yet. Thus, a detailed study was conducted to determine the potential of wind energy in Malaysia as well to evaluate the performances.

Simulation of Wave Energy Performance in Malaysia

Numerical simulation by ANSYS was performed to evaluate the performance of wind energy in Malaysia. The flow of the simulation processes as described in the following sections.

Model selection and geometry modelling

The simulation was initiated by designing the wind turbine, which was developed for wind energy harvesting. The wind turbine consisted of the tower, nacelle, and rotor. The geometry design of the wind turbine was developed by using DesignModeler Geometry. This modeller was used to create the 3D model of a 600 kW wind turbine, with a rotor diameter of 46 m and a hub height of 78 m as illustrated in Figure 1. The boundary condition was designed by referring to a wind farm model by Namiranian [27]. The boundary size of the wind farm was defined according to the diameter of the wind turbine, which is 6D x 2.8D x 4D. For this simulation, the wind farm was designed with the length, height, and breadth of 276 m, 129 m, and 184 m, respectively, as illustrated in Figure 2.

Selection of mesh

To ensure the reliability of the results, an appropriate meshing process must be carefully conducted. A high-quality meshing has to be produced to fulfil the quality criteria of the boundary

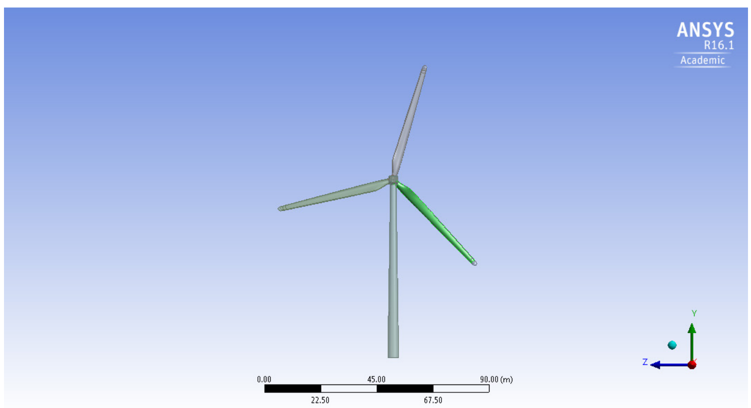


Figure 1 3D structural model of a 600kW wind turbine

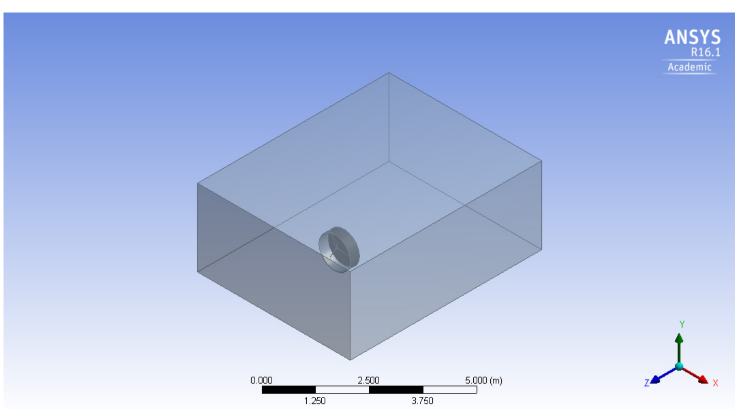
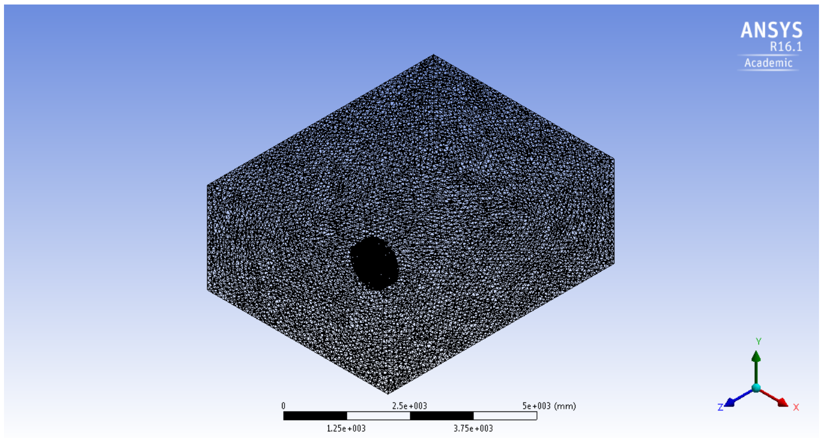
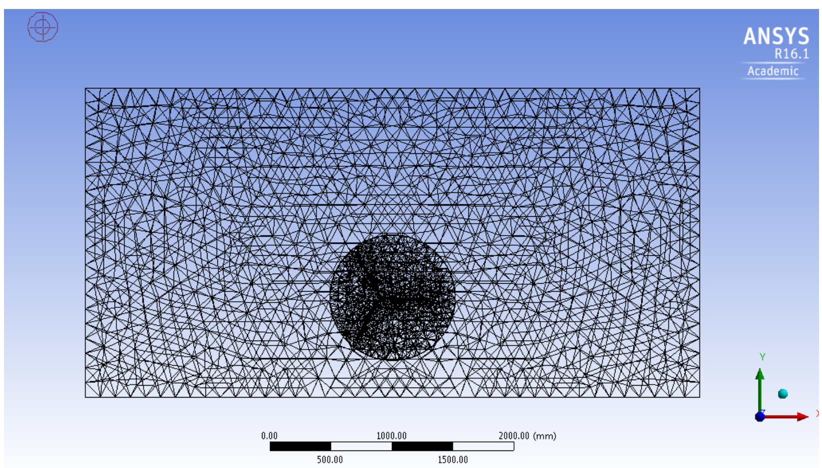


Figure 2 3D wind farm model

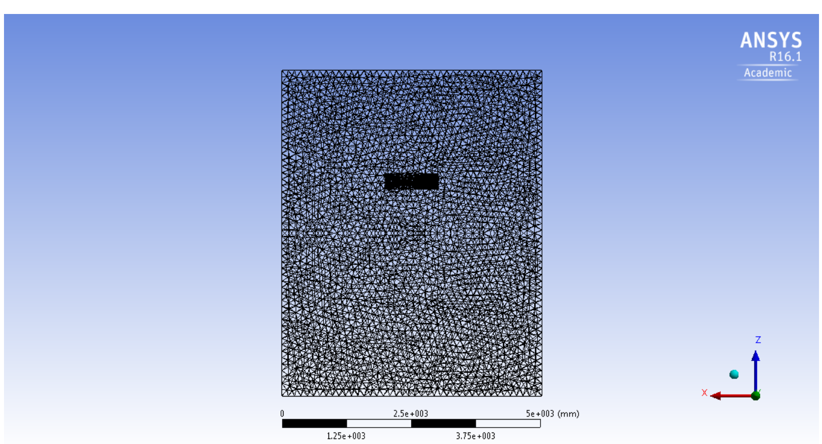
layer of the 3D model. In this study, the fine tetrahedral mesh with a minimum size of 1.234 mm and the growth rate of 1.20, was adopted due to the complexity of the 3D model. The mesh details of the 3D model and the boundary layer are illustrated in Figures 3(a)-(d) from different views.



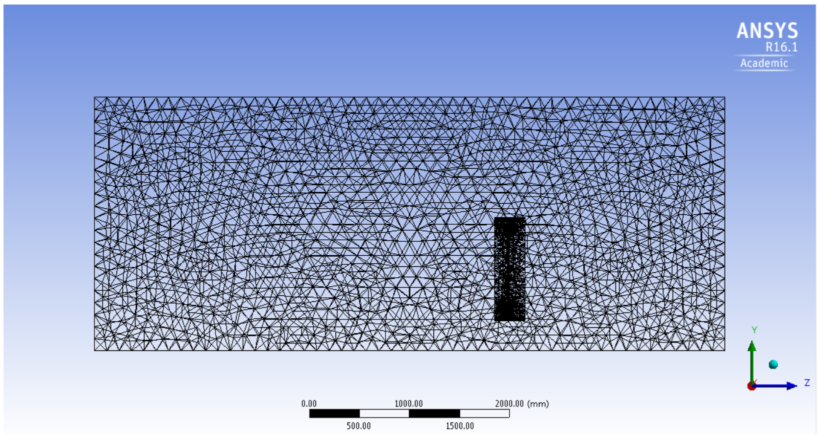
(a) Isometric view



(b) Front view



(c) Plan view



(d) Side view

Figure 3 Mesh details of the model and boundary layer

Numerical model setup

After creating the meshes that were suitable and appropriate for the 3D model, the next procedure was to specify the setup of the simulation analysis. The setup involved the specification of the domains, the boundary conditions, and the type of analysis.

Model Domains

In this study, two domains were created to describe the fix and movable parts, i.e. the stationary and rotating domains. For the fix parts such as the tower and the nacelle, both were placed in the stationary domain, while for the movable part such as the rotor, it was inserted in the rotating domain as shown in Figure 4.

Boundary Conditions

The boundary condition was defined by introducing a rectangular-shaped area. Each side of the boundary was defined as inlet, outlet, ground, and interfaces, as shown in Figure 5. During the simulation, the wind was generated into the wind farm model through the channel and dissipated through the outlets. The performance of the wind turbine was measured and evaluated as the wind exerted on the structure.

Figure 4 Domain set up

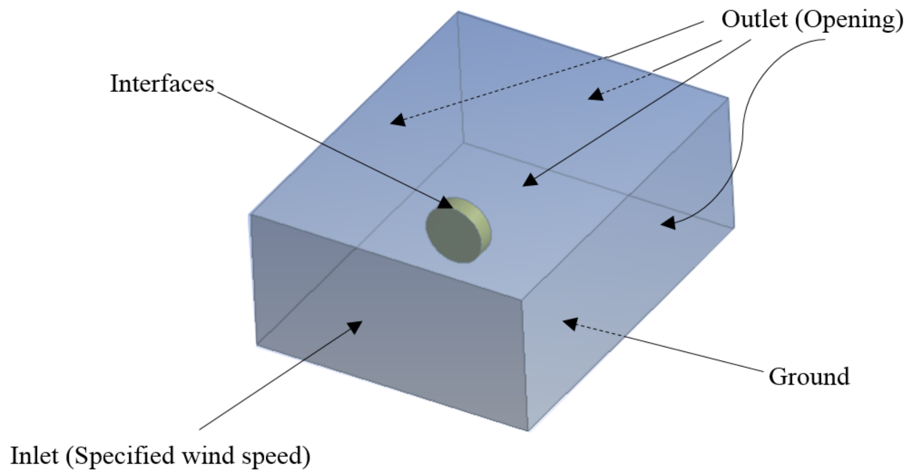


Figure 5 Boundary conditions

Simulation Analysis

Next, the transient analysis was adopted in the simulation to measure the variation of the airflow concerning time. Simulation duration of 80 sec with the time step of 0.1 sec was selected for the simulation.

Potential location identification

Darus et al. [28] highlighted that wind speed in the range of 5 m/s to 15 m/s is needed to generate 100 kW of electricity. Henceforth, by referring to wind speed data reported by the QuikSCAT [29] and WindSat [30], high potential locations for offshore wind energy development were further investigated. From the previous studies, Kijal, Tioman, Kudat, and Langkawi [31], also the waters of Kuala Terengganu, Mersing, and Kota Kinabalu [32] are reported to have wind speed more than 5 m/s. Detailed wind speeds for these locations in Malaysian water are tabulated in Table 1. The performance of a wind turbine subjected to offshore wind profile was further investigated.

Result and Discussion

Considering the generated wind profile, wind pressure and wind velocity in the rotor, as well the total power generation was evaluated based on the wind energy performance in Malaysia. Based on these measurements, the potential locations for the installation of the wind energy are then be proposed.

Wind Pressure in Rotor

From the simulation, the wind pressure in the wind farm was measured, and the maximum pressure was found to be highest on the rotating body towards the tip of the blades. Table 2 shows the wind pressure simulated in the rotating body of the offshore wind turbine. Considering the maximum wind pressure inside the boundary, the wind turbine simulated for Kijal in Terengganu was found experiencing the highest wind pressure of 0.76 kPa as compared to the other locations. On the other hand, the performances simulated for Johor and Kedah offshore wind experienced the least wind pressure with the maximum pressure of 0.08 kPa.

Table 1 Offshore wind locations and speed

Location (offshore)	Wind speed (m/s)
Kijal, Terengganu	12.50
Kota Kinabalu, Sabah	11.50
Kudat, Sabah	8.00
Kuala Terengganu,	6.95
Tioman, Johor	5.14
Mersing, Johor	5.14
Langkawi, Kedah	5.14

Table 2 Wind pressure in the rotating body of the offshore wind turbine by location.

Location	Wind pressure (kPa)
Kijal, Terengganu	0.76
Kota Kinabalu, Sabah	0.27
Kuala Terengganu	0.19
Kudat, Sabah	0.09
Tioman, Johor	0.08
Mersing, Johor	0.08
Langkawi, Kedah	0.08

Wind Velocity in Rotor

Another measured criterion for the evaluation of the performance of wind energy is the wind velocity in the rotating domain. During the simulation, high-velocity changes around the rotor due to the rotation of the rotor were observed. The wind velocities in the rotor by location as a function of time are presented in Figure 6.

Power generation

The power generated is related to the velocity of the wind in the wind turbine and the radius of the rotor. The equation for the potential power generation, P, is given as [33]:

$$P = \frac{1}{2} \rho A v^3 Cp \quad (1)$$

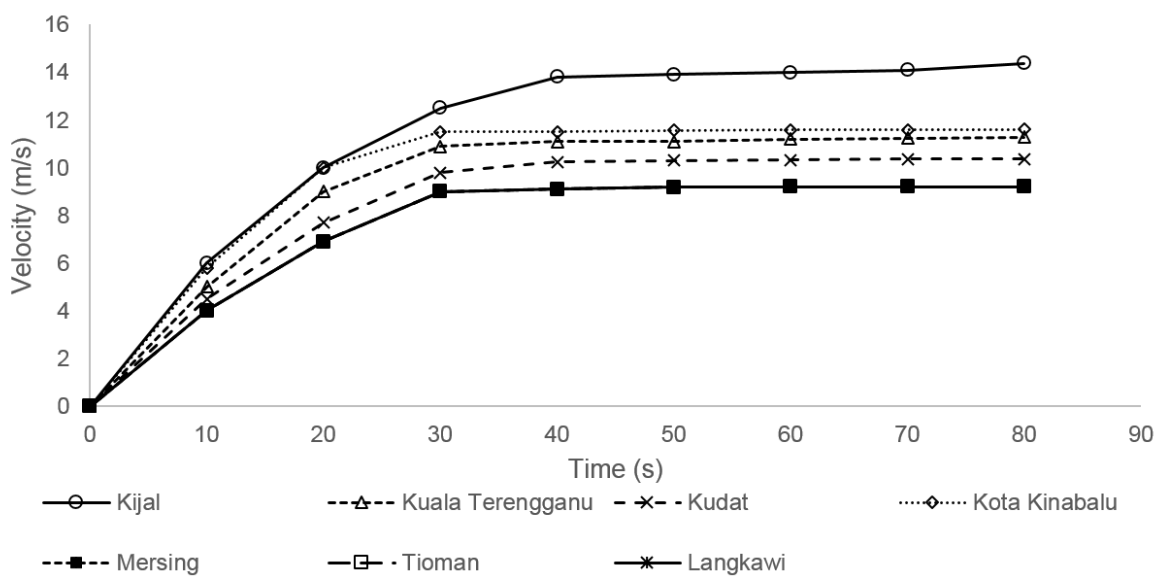


Figure 6 Wind velocity for all location

It is observed that the velocities of the wind in the rotating body vary by locations, which affected by the variable of wind speed profile. Offshore wind turbine at Kijal generates the highest wind velocity, followed by Kota Kinabalu and Kuala Terengganu. In the study, it was found that the maximum power generation is produced as the wind velocity in the wind turbine ranged between 10 m/s to 15 m/s. Hence, the potential locations that capable of generating maximum power output are identified as Kijal, Kota Kinabalu, Kudat, and Kuala Terengganu, which can harness the optimum power from 600 kW wind turbine.

Where is the air density of 1.23 kg/m^3, is the swept area, is the wind speed, and is the power coefficient, which is defined as 0.4. The generation of power for all potential locations are presented in Figure 7.

The finding indicates that the offshore wind at Kijal has the highest potential to generate the most significant power output as compared to the other locations as it is predicted to generate 921 kW of power. Meanwhile, the offshore wind speed in Kuala Terengganu and Kota Kinabalu can generate 445 kW and 483 kW of power, respectively. Nevertheless, the low wind speeds in Tioman, Mersing and Langkawi generate only 242 kW of power. It could be summarised that the power generation increases as the wind velocity of the vicinity of the rotor increases. Considering the offshore locations in Malaysia, which generating the wind speed in the range of 9 m/s to 14 m/s, 200 kW to 900 kW of electrical power is expected to produce and generated.

Acknowledgement

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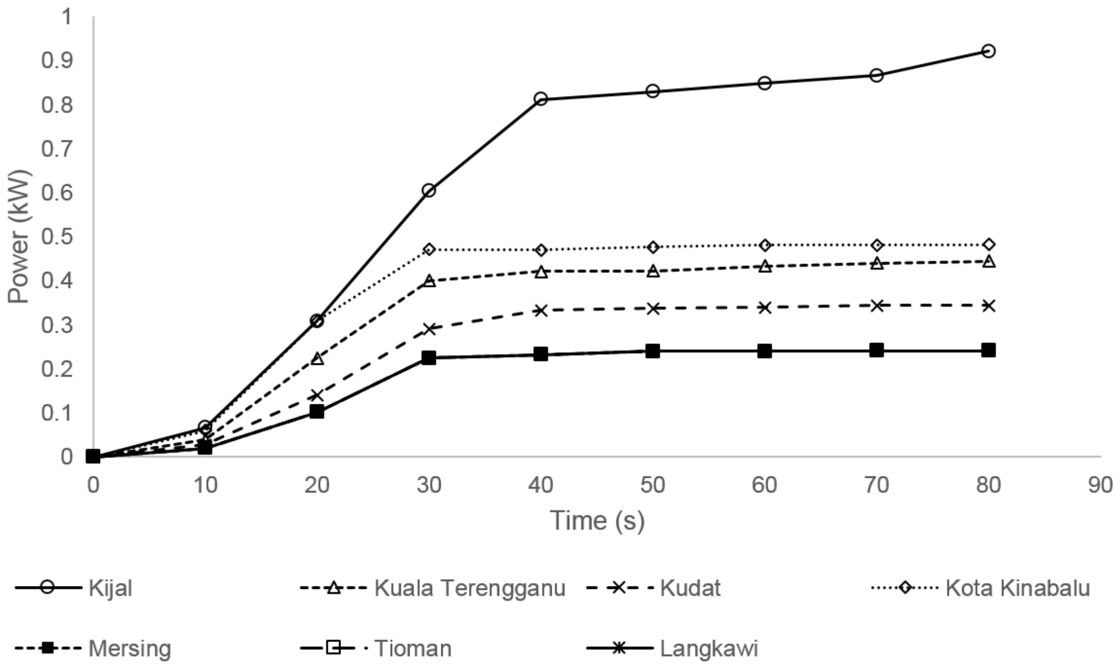

Figure 7 Power output for all locations

Conclusion

This research explores the wind energy potential at seven coastal and offshore locations in Malaysia. A software simulation using commercial software ANSYS was conducted to evaluate the wind energy performance by considering three criteria, i.e. wind pressure in the rotor, wind velocity in the rotor, the total power generation. The results show that Kijal, Kuala Terengganu, Kudat and Kota Kinabalu are the most promising locations for the offshore wind energy with the high performance in producing wind energy. The other locations seem to be not feasible as the generation of the power energy is classified marginal. The results of this study can be used for selecting a suitable and attractive site for Malaysian offshore water. However, further investigation must be conducted to study the impact of wind energy development on the industry and nation, and also to identify the technical and cost of capital for wind energy investment.

References

[1] F. Ghazali & A. H. Ansari, "The Renewable Energy Act 2011: A Study on renewable energy development in Malaysia,". *International Journal of Law, Government and Communication*, vol. 3, no. 7, pp. 143-151, Jan. 2018.

[2] J. K. Swim, S. Clayton and G. S. Howard, "Human behavioral contributions to climate change - psychological and contextual drivers," *American Psychologist*, vol. 66, no. 4, pp. 251–264, May. 2011.

[3] D. W. Kweku, O. Bismark, A. Maxwell, K. A. Desmond, K. B. Danso, E. A. Oti-Mensah, A. T. Quachie, B. B. Adormaa "Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming," *Journal of Scientific Research and Reports,* vol. 17, no. 6, Feb. 2018.

[4] M. Rhomberg, "Kyoto Protocol," in *Encyclopedia of Globalization*, Hoboken, NJ: Wiley-Blackwell, 2012, pp.1244-1254.

[5] K. Watkins, *Human development report 2007/2008. Fighting climate change: Human solidarity in a divided world*. London, UK: Palgrave Macmillan, 2007.

[6] Energy Commission (2012, May). National energy balance 2012. Malaysian Energy Information Hub (MEIH), Energy Commission Malaysia, Putrajaya, Malaysia. [Online]. Available: https://meih.st.gov.my/documents/10620/717f207d-1308-4d2c-b5e1-9f84b24d2e0b

[7] EIA. (2015, Sep.). Analysis & Projections: World Shale Resource Assessments, Washington, DC. [Online]. Available: https://www.eia.gov/analysis/studies/worldshalegas/

[8] A. Y. Azman, A. A. Rahman, N. A. Bakar, F. Hanaffi, A. Khamis, "Study of renewable energy potential in Malaysia," presented at 2011 IEEE Conference on Clean Energy and Technology (CET), Kuala Lumpur, Malaysia, Jun. 2011.

[9] S. M. Zaid, N. E. Myeda, N. Mahyuddin and R. Sulaiman, "Malaysia's rising GHG emissions and carbon 'lock-in' risk: a review of Malaysian building sector legislation and policy," *Journal of Surveying, Construction and Property*, vol. 6, no. 1, Jun. 2015.

[10] A. H. Shamsuddin, "Development of renewable energy in Malaysia-strategic initiatives for carbon reduction in the power generation sector," *Procedia Engineering*, vol. 49, pp. 384–391, Jul. 2012.

[11] M. D. Esteban, J. J. Diez, J. S. López, V. Negro, "Why offshore wind energy?," *Renewable Energy*, vol. 36, No. 2, pp. 444–450, Feb. 2011.

[12] M. Granovskii, I. Dincer, and M. A. Rosen, "Greenhouse gas emissions reduction by use of wind and solar energies for hydrogen and electricity production: Economic factors," *International Journal of Hydrogen Energy*. vol. 32, no. 8, pp. 927-931, Nov. 2006.

[13] S. Mathew, *Wind energy: fundamentals, resource analysis and economics*. Berlin, Germany: Springer-Verlag, 2006.

[14] L. Meid, (2014, Dec.). REN21 Publishes 2014 Annual Report, International Institute for Sustainable Development (IISD), Winnipeg, MB. [Online]. Available: http://sdg.iisd.org/news/ren21-publishes-2014-annual-report/.

[15] M. S. S. Gomes, J. M. F. Paiva, V. A. S. Moris, A. O. Nunes, "Proposal of a methodology to use offshore wind energy on the southeast coast of Brazil," *Energy*. vol. 185, pp. 327-336, Oct. 2019.

[16] Y. E. Khchine, M. Sriti, N. E. E. K. Elyamani, "Evaluation of wind energy potential and trends in Morocco," *Heliyon*, vol. 5, no. 6, Jun. 2019.

[17] P. Zhang, "Do energy intensity targets matter for wind energy development? Identifying their heterogeneous effects in Chinese provinces with different wind resources," *Renewable Energy*. Volume 139, pp. 968-975, Aug. 2019.

[18] X. Costoya, M. deCastro, F. Santos, M. C. Sousa, M. Gómez-Gesteira, "Projections of wind energy resources in the Caribbean for the 21st century," *Energy*. vol. 178, pp. 356-367, Jul. 2019.

[19] S. Tagliapietra, G. Zachmann, G. Fredriksson, "Estimating the cost of capital for wind energy investments in Turkey," *Energy Policy*. vol. 131, pp. 295-301, Aug. 2019.

[20] A. Bahrami, A. Teimourian, C. O. Okoye, H. Shiri, "Technical and economic analysis of wind energy potential in Uzbekistan," *Journal of Cleaner Production*, vol. 223, pp. 801-814, Jun. 2019.

[21] A. I. Idriss, R. A. Ahmed, A. I. Omar, R. K. Said, T. C. Akinci, "Wind energy potential and micro-turbine performance analysis in Djibouti-city, Djibouti," *Engineering Science and Technology, an International Journal*, In Press, Jul. 2019.

[22] J. G. Rueda-Bayona, A. Guzmán, J. J. Cabello Eras, R. Silva-Casarín, J. Horrillo-Caraballo, "Renewables energies in Colombia and the opportunity for the offshore wind technology," *Journal of Cleaner Production*. vol. 220, pp. 529-543, May. 2019.

[23] C. Zheng, C. Li, J. Xu, "Micro-scale classification of offshore wind energy resource —A case study of the New Zealand," *Journal of Cleaner Production*. vol. 226, pp. 133-141, Jul. 2019.

[24] R. Gnatowska, E. Moryń-Kucharczyk, "Current status of wind energy policy in Poland," *Renewable Energy*, vol. 135, pp. 232-237, May. 2019.

[25] P. K. Chaurasiya, V. Warudkar, S. Ahmed, "Wind energy development and policy in India: A review," *Energy Strategy Reviews*, vol. 24, pp. 342-357, Apr. 2019.

[26] A. H. Kazimierczuk, "Wind energy in Kenya: A status and policy framework review," *Renewable and Sustainable Energy Reviews*, vol. 107, pp. 434-445, Jun. 2019.

[27] A. Namiranian, "3D Simulation of a 5MW Wind Turbine - DiVA portal." MSc dissertation, Dept. Mech. Eng., Blekinge Institute of Technology, Sweden, 2011.

[28] Z. M. Darus, N. A. Hashim, S. N. A. Manan, M. A. A. Rahman, K. N. Abdul Maulud, O. A. Karim, "The development of hybrid integrated renewable energy system (wind and solar) for sustainable living at Perhentian Island, Malaysia," *European Journal of Social Sciences,* vol. 11, no. 2, pp. 198-204, Nov. 2009.

[29] Jet Propulsion Laboratory. (2019, Jul.). Missions. California Institute of Technology. Pasadena, CA. [Online]. Available: https://winds.jpl.nasa.gov/missions/quikscat/

[30] WindSat. (2019, Jul.). Data Products. U.S. Naval Research Laboratory, Washington, DC. [Online]. Available: https://www.nrl.navy.mil/WindSat/DataProducts.php

[31] A. Albani and M. Z. Ibrahim, "Wind Energy Potential and Power Law Indexes Assessment for Selected Near-Coastal Sites in Malaysia". *Energies*. vol. 10, no. 3, Mar. 2017.

[32] S. Mekhilef, A. Safari, D. Chandrasegaran, "Feasibility study of off-shore wind farms in Malaysia," *Energy Science and Research*. vol. 28, no. 2, pp. 877-888, Jan. 2012.

[33] A. Sarkar and D. K. Behera, "Wind turbine blade efficiency and power calculation with electrical analogy," *International Journal of Scientific and Research Publications*. vol. 2, no. 2, Feb. 2012.