JOURNAL OF ELECTRONIC VOLTAGE AND APPLICATION
e-ISSN: 2716-6074

JEVA

Vol. 6 No. 2 (2025) 140-147
https://publisher.uthm.edu.my/ojs/index.php/jeva

Predictive Simulation of Wind Turbine Outputs at Mersing, Johor

Muhammad Adam Asyraf Salleh[1], Suriana Salimin[1]*

[1] *Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: suriana@uthm.edu.my
DOI: https://doi.org/10.30880/jeva.2025.06.02.013

Article Info

Received: 18 July 2025
Accepted: 21 October 2025
Available online: 9 December 2025

Keywords

Wind turbine power output, vertical-axis wind turbine, renewable energy in Malaysia

Abstract

Wind power potential in tropical nations such as Malaysia is typically having low and fluctuating wind speeds, rendering traditional Horizontal Axis Wind Turbines (HAWTs) not as effective. This project solves the dilemma of power output calculation of Vertical Axis Wind Turbines (VAWTs) confidently, which are more appropriate for low-wind regions but for which there are no applicable tools of assessment. This study tries to develop a simulation model that calculates power output of a VAWT based on real environmental readings for example, wind speed, temperature, and relative humidity. Dynamic estimation of power output and air density were included in a working mathematical block model and performed using ideal wind power equation. Environmental readings measured from two Malaysian sites, Batu Pahat and Mersing, were employed in order to explore and test the model. Outputs show that Mersing whose average wind speed met and exceeded that of turbine cut-in, held up maximum energy output of 34,930 Wh in February, in comparison to Batu Pahat which was likely to fall short of power delivery due to low wind speed. Simulation outcomes also concluded that temperature and humidity significantly influence air density, and hence, turbine efficiency. Lastly, aforesaid proposed model constitutes a certain tool in assessing VAWT viability on the basis of low-wind, high-humidity areas. It upholds early-stage planning, site selection, and early-stage feasibility determination because it provides credible simulations of wind energy output in compliance with changing tropical conditions.

1. Introduction

The global transition to clean energy has taken wind power as a leading clean energy source due to the minimal environmental impact and relatively minimal maintenance costs [1]. However, local wind patterns and turbine configuration significantly determine the operations of wind power systems. In Malaysia, where the wind speed is generally low and homogeneous, Horizontal Axis Wind Turbines (HAWTs) are limited by high cut-in speeds and directionality sensitivity [2]. Vertical Axis Wind Turbines (VAWTs) have advantages in turbulent and low-wind flow conditions and are omni-directional, maintenance-starved, and more adaptable for irregular terrain [3], [4].

VAWT studies employ experimental testing [5], computational fluid dynamics (CFD) simulation [6], and hybrid statistical–physical models [7]. Although these methods enhance performance understanding, they tend to be large-scale oriented or rely on idealized conditions and are therefore less applicable in small-scale tropical applications. Additionally, predictive models in general overlook the influence of temperature and relative humidity in air density, when these factors have great impacts on wind energy conversion in the tropics [8]. This oversight decreases the accuracy of existing forecasting tools for localized small-scale deployment.

This study addresses these limitations by establishing a MATLAB Simulink-based predictive model that dynamically uses wind speed, temperature, and relative humidity in real-time air density calculation. The novelty of this model is that it explicitly accounts for tropical atmospheric variability to produce a more precise and location-dependent prediction of VAWT power output compared to fixed-parameter or idealized models.
The objectives are to:

- Contrast wind energy potential at two Malaysian sites (Mersing and Batu Pahat)
- Examine the impact of time-variation in atmospheric conditions on air density
- Model the absorption by the corresponding turbine power using site-specific inputs. In applying tropical climate effects to forecasting modelling, this study presents a realistic approach to evaluating the absorption by small-scale VAWT applications in low-speed-wind regions.

2. Materials and Methods

This research work proposes simulation-based methodology for calculating the power output of a Vertical Axis Wind Turbine (VAWT) at Mersing, Malaysia. The simulation model has been created in MATLAB Simulink and incorporates several environmental conditions like wind speed, temperature, and relative humidity as well as turbine parameters for calculating air density and predicting power output. The model aims at assisting in the decision-making process of small-scale renewable energy installations by offering a useful and easy-to-use turbine performance prediction tool. As a matter of real-life applicability, environmental data were obtained from the Malaysian Meteorological Department (MET Malaysia) for two locations with polar opposite conditions: Batu Pahat and Mersing, both located in Johor.

Batu Pahat is an inland region with perpetually low wind activity, whereas Mersing, situated at the east coast, has high and variable wind speeds as it is a coastal area. The wind speed data from both regions were collected for several months of 2024, including the seasonal patterns that are essential to determine turbine feasibility. Aside from wind speed, the model also takes in temperature and relative humidity as the parameters that have a direct influence on air density and hence the kinetic energy carried by the wind. The parameters are employed as dynamic inputs in the simulation so that the model can more accurately compensate for the environmental variability of the tropics. By combining these data sets with theoretical wind energy equations and turbine properties, the model predicts real-time power output. This approach allows for location-specific examination of VAWT performance that can be used by planners and engineers to select appropriate locations for deployment and optimize system design according to the environmental properties of the area. Fig. 1 and Fig. 2 show the highest wind speed data collected per month at Batu Pahat and Mersing Johor respectively.

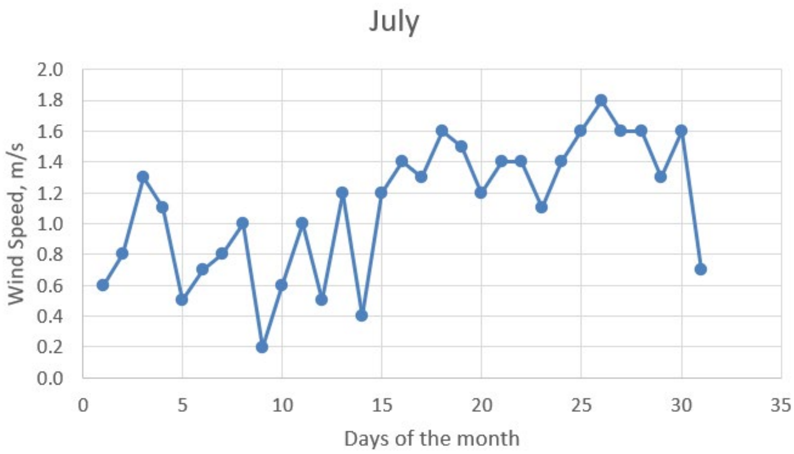

Fig. 1 *Wind speed of weather station in Batu Pahat, Johor taken on July 2024*

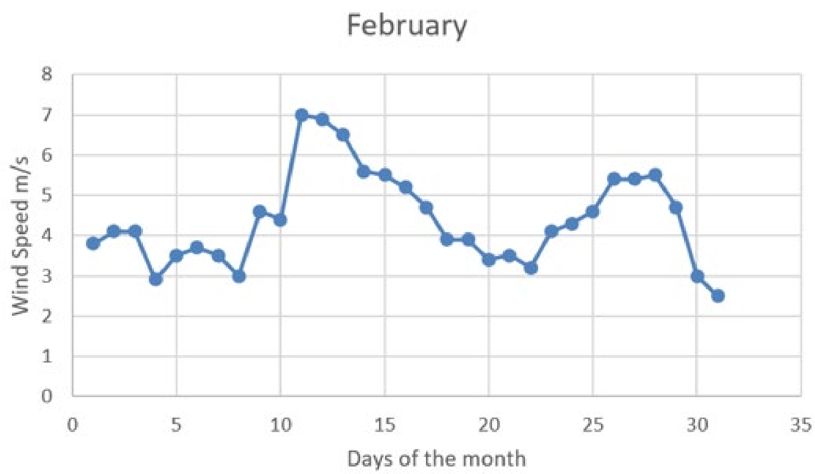

Fig. 2 *Wind speed of weather station in Mersing, Johor taken on February 2024*

Fig. 3 illustrates the functional flowchart of the wind turbine power output estimation process. It begins with acquiring wind data from sources like Jabatan Meteorologi Malaysia or on-site readings. The data is then analyzed to extract key information such as wind speed, temperature, and humidity, which are used to define the parameters for power estimation.

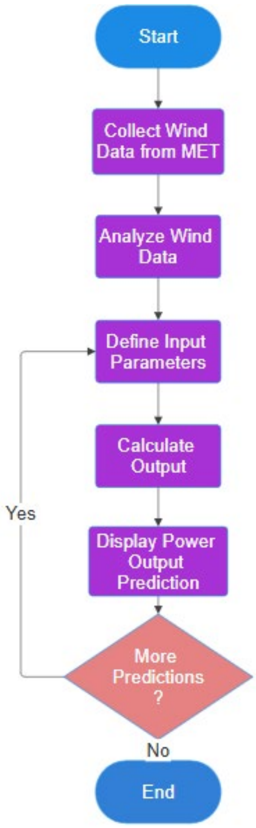

Fig. 3 *Flowchart of wind turbines power output estimation process*

2.1 Wind Power and Air Density Calculation

The model developed under this study forecasts the power production of a Vertical Axis Wind Turbine (VAWT) using both the turbine characteristics and environmental conditions using MATLAB platform. Key turbine parameters are the rotor diameter, height, and power coefficient, while wind speed, temperature, humidity, and altitude are variables used to calculate air density. Since power extracted from the wind is extremely sensitive to air density as well as wind speed, both must be accurately calculated to provide reliable simulation results.

For the sake of mimicking real atmospheric conditions, the model determines air density dynamically rather than with a standard constant. Air density will change according to altitude, temperature, and relative humidity, all of which change according to the place and climate. The model therefore includes computations for atmospheric pressure, saturation vapor pressure, and partial water vapor pressure. These are then used to compute the specific gas constant of humid air. In this way, the model is more accurate. Table 1 will show the formula that are used to develop the simulation model.

Table 1 *Formula for simulation model for power output of wind turbine*

Content	Formula	
Wind Power Output	$Pout = \frac{1}{2}\rho A v^3 Cp$	(1)
Swept Area of VAWT	$A = H \times D$	(2)
Air Density (ρ)	$\rho = \frac{P}{Rs \times T}$	(3)
Specific Gas Constant for Humid Air	$Rs = Rd\,\frac{1 + 0.61(\omega)}{1 + \omega}$	(4)
Mixing Ratio (ω)	$\omega = 0.622\,(\frac{e}{P - e})$	(5)
Partial Vapor Pressure (e)	$e = RH(es)$	(6)
Saturation Vapor Pressure (e_s)	$es = 6.112\,e^{(\frac{17.61(T)}{T+243.5})}$	(7)

2.2 Specification of Smart Energy Management System (SEMS) and Off-Grid Photovoltaic (OGPV)

The simulation is executed in MATLAB Simulink depending on parameters such as wind speed, temperature, relative humidity, and height. These are passed through the model subsystems to calculate air density, which the swept area of the turbine and power coefficient is calculated together to determine the power output. User input values are entered from a dedicated parameter block as shown in Fig 4.

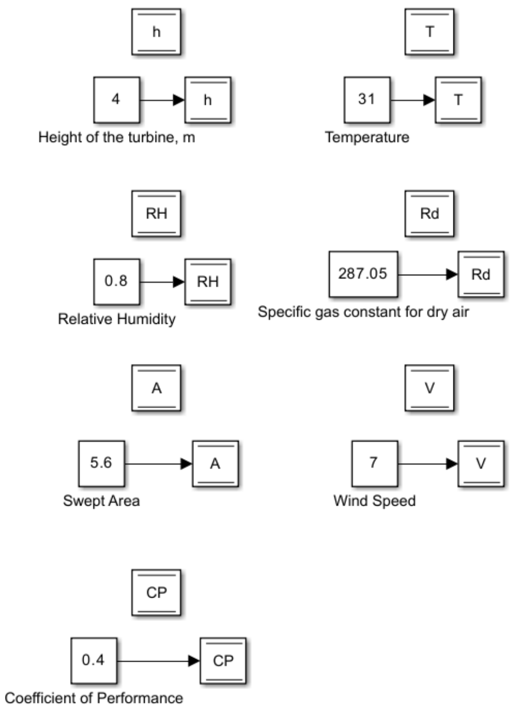

Fig. 4 *Input values parameters of the simulation model*

Allowing for immediate test scenarios. Results values like air density and power are displayed by Simulink display blocks. Trend analysis and performance monitoring are facilitated using waveform outputs when time-series wind data is used as the input, to facilitate trend analysis and performance monitoring. The system is modular, expandable, and poised for simulating different turbines or addition of real-time data in continued work.

3. Results and Discussion

Simulation results were analyzed for sites Batu Pahat and Mersing using monthly average wind speed data obtained from MET Malaysia. Batu Pahat had uniformly low wind speeds below 2 m/s, which fall short of the cut-in speed for the 10kW Aeolos-V turbine (2.5 m/s). This means Batu Pahat will not be appropriate for the installation of wind power using this specific model of turbine. Mersing, however, had increased levels of wind activity for months affected by the monsoon. Mean wind speeds were consistently above the cut-in value, having reached significantly in excess of 4 m/s. This makes Mersing a better site for the installation of small wind turbines.

3.1 Simulation Output from MATLAB

Simulations were run using site-specific conditions, such as wind speed for example, 3.4044 m/s, temperature (31°C), and relative humidity (81%). The model dynamically computed air density and determined the turbine power accordingly. Fig 5 shows the overall view of the prediction model, it was evident that small variations in environmental factors influenced the predicted power, which demonstrated the model's sensitivity and accuracy. In regular Mersing conditions, the power output was estimated as being in the acceptable range in which it can run in partial load, which confirms the feasibility of energy harvesting in favorable conditions.

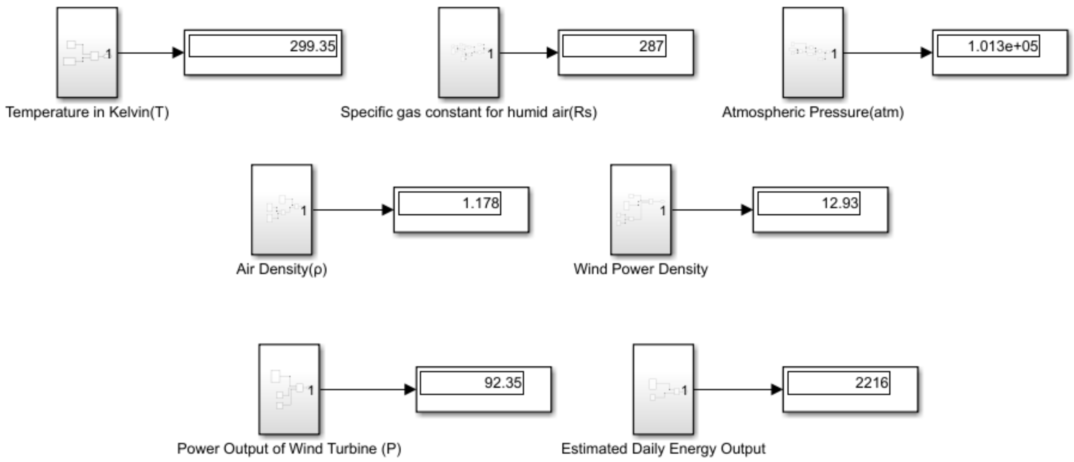

Fig. 5 *Overall view of the prediction model*

3.2 Effect of Mean Wind Speed on Wind Turbine Power Output

The simulation outputs indicate the correlation between turbine energy output and mean wind speed. Three months, namely February, December, and October, were taken into account using Mersing data. February, which recorded the highest mean wind speed in the months, demonstrated the best performance with 34,930 Wh during Day 11. December, though with moderate winds, yet gave consistent output, especially towards the end of the month, with most of the days registering above 9,000 Wh. October gave the least amount of energy due to the sharp drops below the 2.5 m/s cut-in speed of the turbine. Fig. 6, show the exponential relationship between power output and wind speed. Power output increases rapidly with the increase in wind speed according to the cubic relationship in power equation in wind. This demands the presence of sites and wind speed ranges ever greater than the cut-in speed in achieving maximum and steady operation of the turbine, particularly in the tropics where seasonal wind variation occurs.

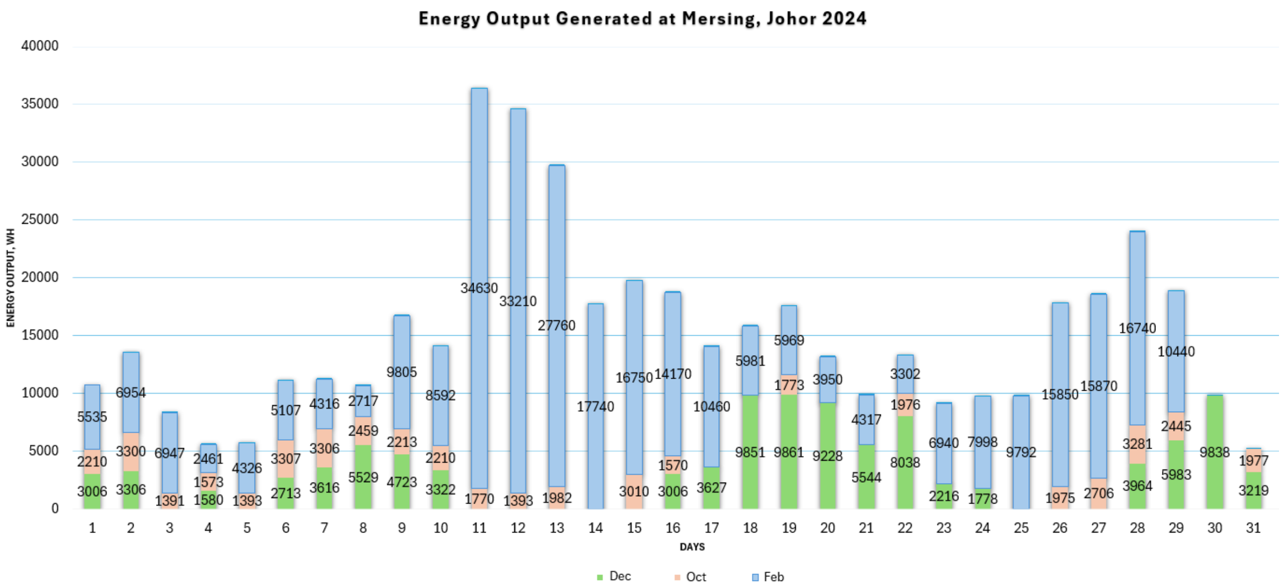

Fig. 6 *Daily wind energy production in watt-hours (Wh) for three months of different wind conditions*

3.3 Effect of Temperature and Relative Humidity on Power Output

The simulation tested the effect of temperature and relative humidity on power generation of wind turbines by keeping wind speed constant and varying the two factors. Power output was observed to be reduced by raising temperature because it reduces air density, as hot air is lighter and contains fewer air molecules to transfer kinetic energy to the turbine. In the tropical countries like Malaysia where temperatures are usually high, this effect can considerably reduce energy output.

Relative humidity also affects air density. With rising humidity, air contains more water vapor, reducing air density and, subsequently, power output. Coupled with high temperature, it reduces the efficiency of wind energy conversion further. The simulation also validated that both parameters though secondary to wind speed do have a measurable impact on turbine efficiency and need to be accounted for when output projections are made for humid, equatorial climates. Figures 7 and 8 illustrate the variation of power output with different temperature and humidity levels.

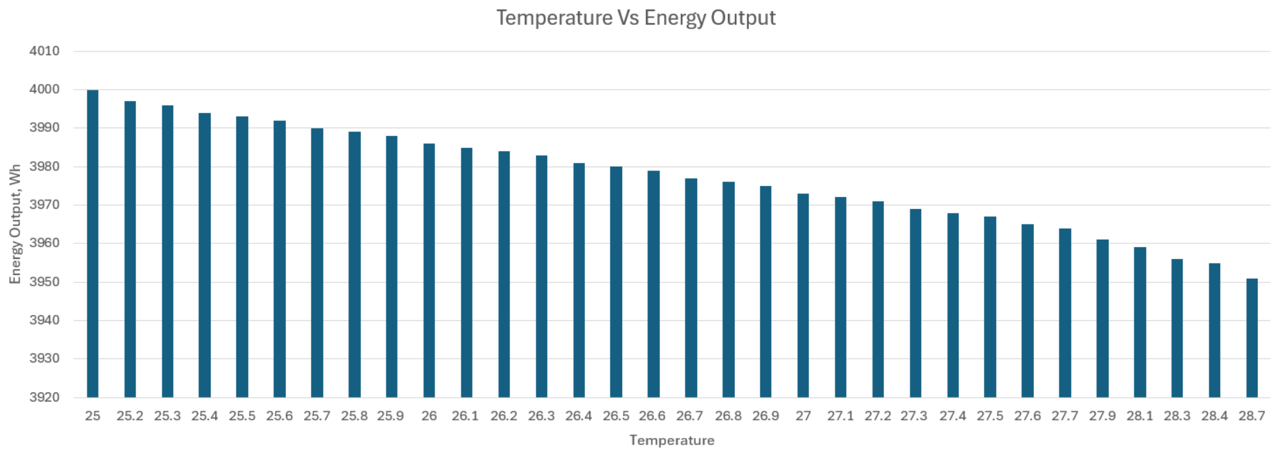

Fig. 7 *Relationship between temperature and energy output*

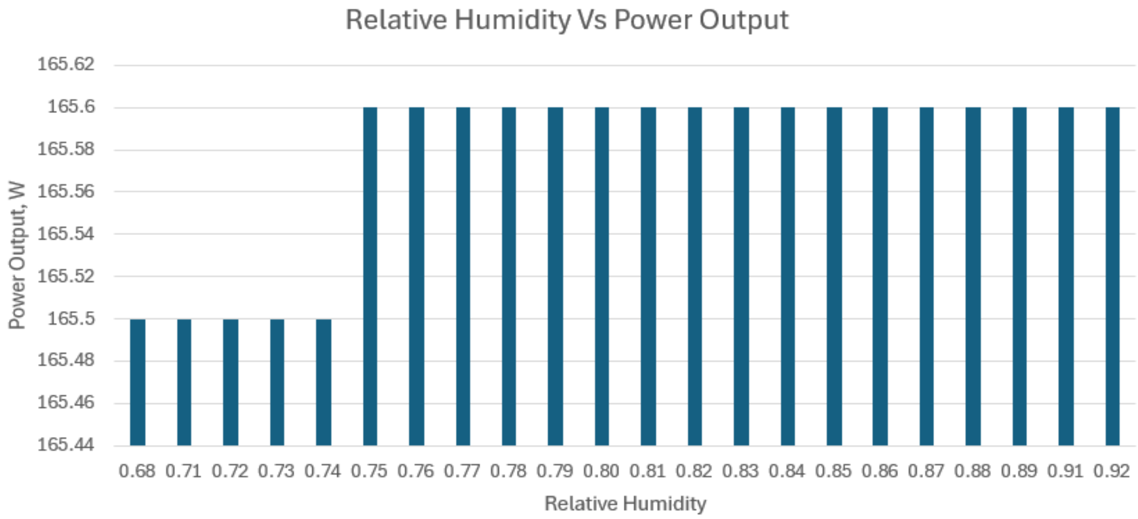

Fig. 8 *Relationship between relative humidity and energy output*

4. Conclusion

This study has been able to develop a MATLAB Simulink-based simulation model for the prediction of the power output of a Vertical Axis Wind Turbine (VAWT) in Malaysia for various environmental conditions. The model employs wind speed, temperature, and relative humidity as inputs to predict air density and simulate energy production with good accuracy. Simulation results validated that Mersing with its relatively higher average wind speed is a possible location for the installation of turbines, while Batu Pahat is not an apt location because of low winds throughout the year. The model is a good tool for the initial wind energy feasibility study, particularly for tropical, low-wind climates.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering in Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Adam Asyraf, Suriana*, ***data collection: analysis and interpretation of results: draft manuscript preparation:*** *Muhammad Adam Asyraf. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). *Wind Energy Explained: Theory, Design, and Application*. John Wiley & Sons.

[2] Gipe, P. (2004). *Wind Power: Renewable Energy for Home, Farm, and Business*. Chelsea Green Publishing.

Yuan, X., Zhao, Y., Ma, C., Hu, F., & Shao, Z. (2017). "A review of prediction methods for wind-speed for wind-energy generation." *Renewable and Sustainable Energy Reviews*

[3] Battisti, L., Brighenti, A., Benini, E., & Zardin, B. (2011). "Vertical axis wind turbine design for low-speed wind regions." *Journal of Wind Engineering and Industrial Aerodynamics*

[4] Duran, H. S., & Crăciunescu, A. (2017). "Wind energy production estimation based on a hybrid predictive model." *Energy Procedia*

[5] Carta, J. A., Velázquez, S., & Cabrera, P. (2013). "A review of measure-correlate-predict (MCP) methods used to estimate long-term wind characteristics at a target site." *Renewable and Sustainable Energy Reviews*

[6] Aliyu, M., Ramli, A. T., & Saleh, M. A. (2013). "Nigeria electricity crisis: Power generation capacity expansion and environmental ramifications." *Energy*

[7] Bilgili, M., Yasar, A., & Simsek, E. (2011). Wind energy potential and utilization in Turkey. *Renewable and Sustainable Energy Reviews, 15*(8), 3493–3501. https://doi.org/10.1016/j.rser.2011.06.006

[8] Troen, I., & Petersen, E. L. (1989). *European Wind Atlas*. Risø National Laboratory.

[9] Jiménez, P. A., González-Rouco, J. F., et al. (2007). Surface wind regionalization in complex terrain. *Journal of Applied Meteorology and Climatology, 46*(4), 606–624. https://doi.org/10.1175/JAM2486.1

[10] Clifton, A., & Lundquist, J. K. (2012). Data clustering reveals climate impacts on local wind phenomena. *Journal of Applied Meteorology and Climatology, 51*(9), 1547–1557. https://doi.org/10.1175/JAMC-D-11-0252.1

[11] Bechrakis, D., & Sparis, P. (2000). Simulation of wind speed data for wind energy estimation. *Renewable Energy, 19*(1-2), 37–63. https://doi.org/10.1016/S0960-1481(99)00039-0

[12] Ackermann, T., & Söder, L. (2000). Wind energy technology and current status: A review. *Renewable and Sustainable Energy Reviews, 4*(4), 315–374. https://doi.org/10.1016/S1364-0321(00)00005-4

[13] Burton, T., Sharpe, D., Jenkins, N., & Bossanyi, E. (2011). *Wind Energy Handbook*. Wiley.