# WIND POTENTIAL IN LOCAL AREAS

**Muriel Matumba[1], Lufuno Takalani[12], Sophie Mulaudzi[1] , Tshifhiwa Ranwaha[1]and Eric Maluta[3]**

[1]Department of Physics, University of Venda, Thohoyandou, South Africa
[2]Vuwani Science Resource Centre, University of Venda, Thohoyandou, South Africa
[3]Green Technology Confucius Institute, University of Venda, Thohoyandou, South Africa

E-mail : rotondwamuriel@gmail.com

**Abstract :** Rural regions are largely reliant on non-renewable energy sources and frequently experience energy shortages. To lessen dependency on fossil fuels and advance sustainability in these areas, alternative renewable energy sources like wind energy must be investigated. By examining wind speed, direction, and flux data gathered using a weather station and eddy covariance flux tower, this study evaluates the wind energy potential in nearby locations. Determining the viability of small-scale wind energy plants is the aim. The demand for renewable energy sources increases, and has intensified global interest in wind energy as an effective alternative to fossil fuels. Wind energy is also environmentally beneficial, which makes it a very important component in the shift to sustainable energy systems. Wind energy has become an intense alternative to non-renewable energy systems. If wind energy is effectively used, it can supply a substantial amount of the world's electrical needs because it is abundant, renewable and not polluting.

The analysis shows that small-scale projects are possible and whether the local wind conditions are appropriate for wind energy generation. It might also draw attention to the seasons or environmental factors with the greatest potential for wind generation. The study recommends small-scale wind energy systems in appropriate locations, considering the findings. The best sites and wind turbine parameters should be investigated in further detail. To promote sustainable growth, policymakers must incorporate wind energy into regional energy planning. The need to minimize greenhouse gas emissions, the finite nature of fossil fuel resources, and growing concerns about environmental sustainability have all contributed to a change in the global energy landscape. Even though wind energy is becoming more popular, there are still few region-specific evaluations that consider both technical and meteorological considerations.

## 1 Introduction

Energy produced by naturally occurring sources is commonly referred to as renewable energy. Since it can be made use of without polluting or significantly affecting the environment, such energy sources are sustainable, which offers a clean energy source. Recently, wind energy has been a growing energy source in the world, and wind power is one of the most widely used alternative sources of energy. Wind energy has been used for centuries for navigation and agriculture. Today, the use and technology of wind energy has been developing very fast. Limited reserves of fossil fuels and their negative impacts on the environment lead institutions, organizations and governments to find out more efficient technologies and new and renewable energy resources to produce energy in the natural environment[1].

There is still a demand for sustainable, dependable electricity in many South African rural areas. Even though most cities are linked to the national grid, some isolated places still heavily rely on non-renewable resources like firewood and diesel generators, have limited access to clean energy, and experience frequent blackouts. In addition to posing environmental problems, this dependence restricts the area's capacity for economic growth, healthcare, and education. In South Africa's transition to a more sustainable and equitable energy future, renewable energy, especially solar and wind, is more crucial than ever.

Wind energy is frequently marketed as a cheap and environmentally friendly way to produce power, particularly in places where it might not be feasible to construct grid infrastructure. It's not as easy as just setting up wind turbines wherever the wind blows; there must be enough steady wind at a given location to produce electricity effectively for wind energy to be feasible. The absence of long-term data or access to sophisticated measurement equipment is the primary reason why the wind energy potential of many rural areas, including Vuwani, has not been fully evaluated.

## 2 Methodology

This study analyses publicly available wind data from the Southern African Universities Radiometric Network (SAURAN) to close that gap. The long-term, high-quality meteorological data provided by SAURAN is gathered from a network of stations located throughout Southern Africa [3]. With this information, we evaluated Vuwani's wind conditions to see if wind power, either alone or in combination with solar power, could be a viable option for the locals. We analyzed the daily and weekly wind patterns using simple statistical methods such as histograms and time series. We also computed Wind Power Density (WPD) to assess the energy present in the wind and used the Weibull distribution, a popular technique for modelling wind speed probabilities. We concluded by comparing our results with typical wind turbine performance curves to determine how well typical turbines would function under these circumstances [2].

Figure 1. SAURAN station at University of Venda

The meteorological data used in this study came from the SAURAN open source, a public platform that provides high-resolution weather and solar data from a network of stations throughout Southern Africa. A weather station in the vicinity of Vuwani, Limpopo, was chosen for this case study. Data on a range of meteorological factors, such as wind direction and speed, are sent by the station every half hour. Acquiring wind data in CSV format over several weeks was the first step in the process to guarantee temporal representativeness. To fix outliers, missing values, and formatting errors, the dataset underwent preprocessing. For uniformity, all wind speed readings were standardized to meters per second (m/s), and timestamps were translated to a datetime format. To make sure the wind direction data matched the accurate timestamps and speed observations, they were also verified [3].

An exploratory analysis of the data was done to give a preliminary picture of the wind patterns in the area. Plots of time series were created to show how wind speed changed over the chosen time frame. The distribution of wind speeds was examined using histograms, and the predominant wind directions were identified using directional plots. We then fitted the wind speed data to the Weibull distribution. Wind energy studies frequently employ the Weibull distribution because it accurately captures the probabilistic behaviour of wind speeds. To estimate the scale parameter (λ) and shape parameter (k), the maximum likelihood estimation method was employed. The frequency and consistency of various wind speeds can be inferred from these factors. Based on the air density and wind speed data, the Wind Power Density (WPD) was computed using the following formula [5]:

$$\text{WPD}=\frac{1}{2}.\rho.V^3 \quad (1)$$

where V is the wind speed and ρ is the air density, which is taken to be 1.225 kg/m³. WPD is a crucial factor in assessing the feasibility of installing wind turbines since it gives an indication of the amount of wind energy that is available per unit area. Lastly, the calculated WPD values were contrasted with standardized wind turbine power curves, including those of larger commercial-scale 1.5 MW turbines and smaller 1–5 kW turbines. The anticipated energy yield and efficiency under local wind conditions could be evaluated due to this comparison [6].

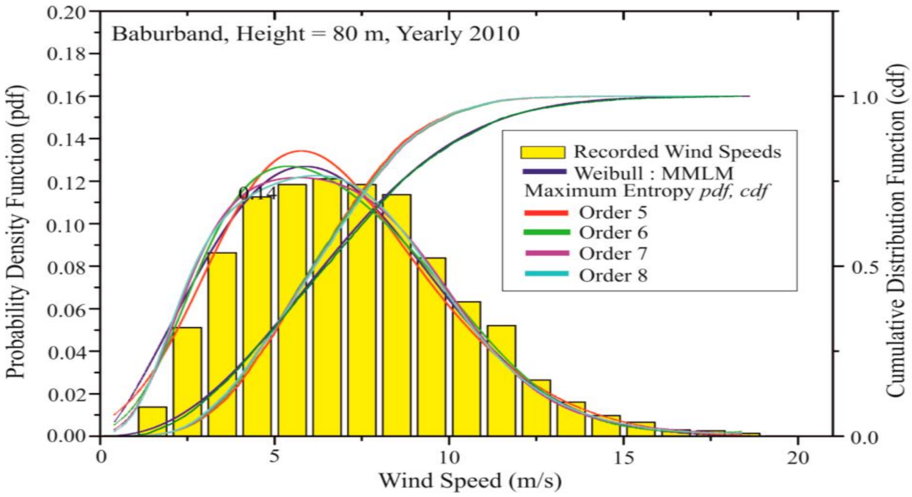


Figure 2. Comparison of wind energy using maximum entropy (https://www.mdpi.com/1996-1073/9/10/842)

Figure 2, shows the wind speed distribution at Baburband, located in Pakistan (height = 80 m) for the year 2010. The yellow bars represent recorded wind speed data, while various lines compare the fit of Weibull (MMLM) and Maximum Entropy models of different orders (5 to 8) to this data. The left y-axis shows the probability density function (PDF) and the right y-axis the cumulative distribution function (CDF).

### 3 Results and Discussion

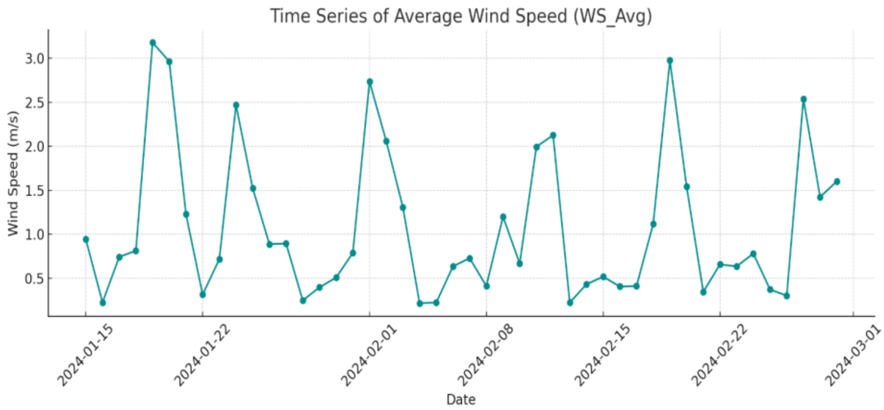


Figure 3. Time Series Plot (WS_Avg)

According to Figure 3, the time series plot, Vuwani's wind speeds changed greatly from day to day. The speeds varied from 0.2 m/s to 3.2 m/s at their lowest points. There were a few days with comparatively strong wind activity, most notably January 19 and 20. Wind speeds during most of the period, however, were less than 2 m/s, showing a lack of kinetic energy for conversion. These results show the region's wind resources' temporal fluctuation.

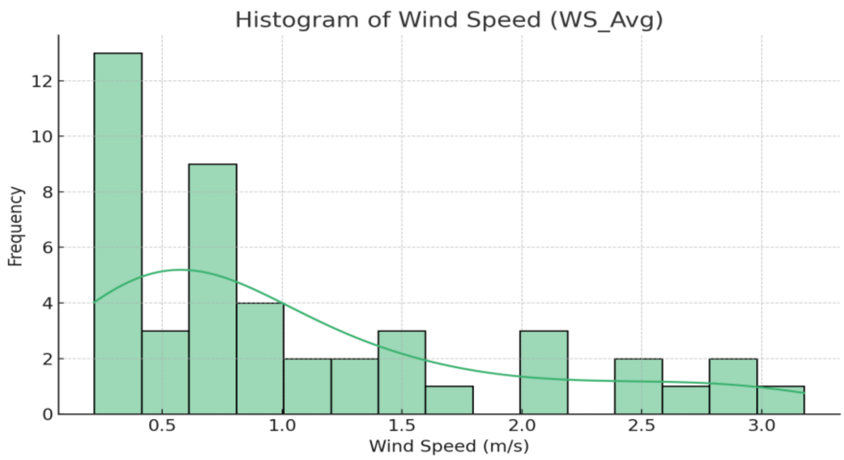


Figure 4. Histogram of Wind Speeds distribution

The wind speed histogram, Figure 4, showed a distribution that was skewed to the right, with many observations concentrated at lower speeds. Very few wind speeds were higher than 3 m/s, and the majority were below 1.5 m/s. Inland rural regions where vegetation, height, and terrain may impede airflow are likely to show this distribution pattern.

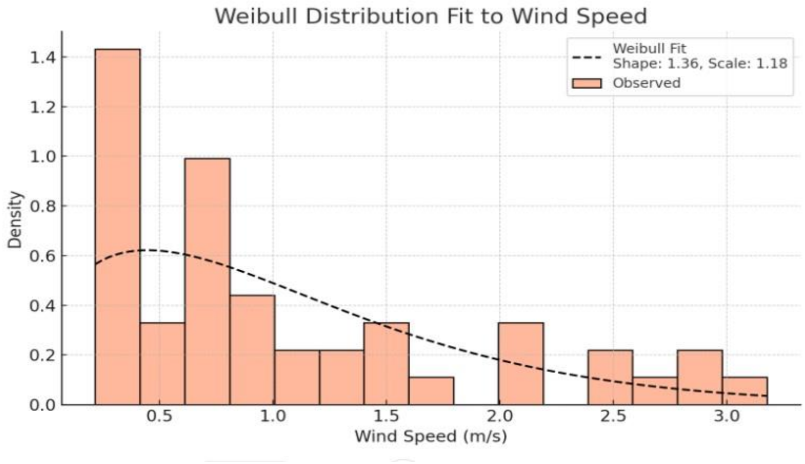


Figure 5. Weibull Distribution Fit

According to Figure 5, the fitted Weibull parameters, the wind regime is extremely variable and unpredictable, with a shape parameter (k) less than 2. Confirming the overall weakness of wind speeds in the area, the scale parameter (λ) was likewise rather low. According to these results, Vuwani does not have the regular, strong winds needed for the best wind turbine performance.

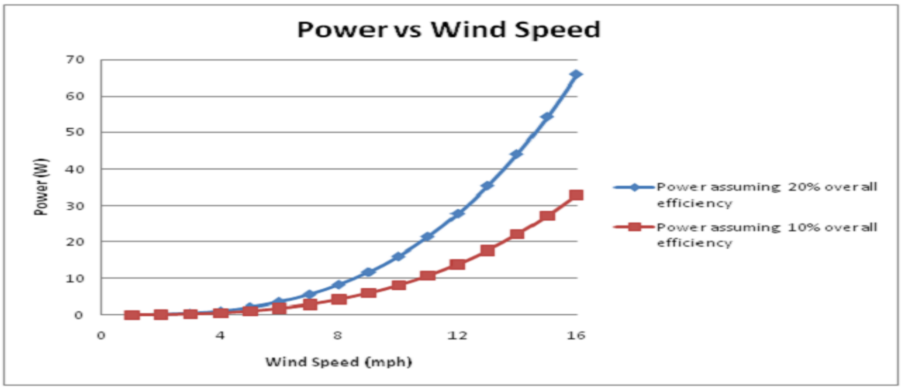


Figure 6. Wind cycle- Wind power density

Vuwani's energy potential is categorized as poor by international standards based on the computed WPD and measured wind speeds. The smallest criterion (~200 W/m²) suggested for utility-scale wind turbines was far higher than the average WPD. Under these circumstances, conventional commercial turbines would function inefficiently, if at all. The study revealed limited but potential use for very low-power (<1 kW) systems meant for off-grid homes when compared to small-scale turbine power curves. In hybrid energy systems, these might work well in conjunction with solar panels to boost total system output and dependability [4].

For the planning of renewable energy in Vuwani and other rural locations, the study's findings carry several implications. First off, this area is not a good place for large wind turbines due to the low wind speeds and poor WPD. Investing in such infrastructure would probably lead to economic inefficiencies and poor performance. This does not, however, completely rule out Vuwani using wind energy. Small wind turbines can supply extra energy for electronic device charging, water pumping, and lighting when combined with solar photovoltaic (PV) systems in hybrid configurations. These systems are particularly important for outlying residences, educational institutions, or medical facilities that are not wired into the national grid.

Furthermore, the research's methodology, which makes use of publicly accessible SAURAN data and basic statistical tools, shows a scalable strategy that may be duplicated in other rural regions. Before investing in more costly feasibility studies or installations, policymakers, engineers, and community planners can utilize this approach to conduct initial assessments. The significance of incorporating regional weather information into national energy plans is further emphasized by this study. Localized opportunities or limits may be overlooked by centralized planning that is exclusively focused on generic datasets or regional averages. More specialized and efficient energy solutions can be created by integrating site-specific data.

## 4 Conclusion

Using SAURAN weather data and statistical modelling methods, this study aimed to assess the wind energy potential of Vuwani, a rural location in South Africa. According to the research, the area's wind speeds are low, erratic, and insufficient for producing wind energy on a large scale. Estimates of wind power density confirm that only tiny turbines may be practical, and even these would benefit from solar energy system integration. However, the research offers important new information about South Africa's rural renewable energy environment. It shows how useful open-access data and simple statistical techniques are for performing first-site evaluations. Underserved areas may benefit greatly from hybrid renewable systems if proper planning and technology selection are made.

## References


[1] Carta, J. A., Ramirez, P., & Velazquez, S. (2009). A review of wind speed probability distributions used in wind energy analysis. Renewable and Sustainable Energy Reviews.

[2] Mathew, S. (2006). Wind Energy: Fundamentals, Resource Analysis and Economics.

[3] SAURAN. (2023). Southern African Universities Radiometric Network. [Online]. Available: SAURAN - Southern African Universities Radiometric Network

[4] Manwell, J.F., McGowan, J.G., & Rogers, A.L. (2009). *Wind Energy Explained: Theory, Design and Application*. 2nd ed. John Wiley & Sons.

[5] Weibull, W. (1951). A Statistical Distribution Function of Wide Applicability. *Journal of Applied Mechanics*, 18(3), 293–297.

[6] Saidur, R., Rahim, N.A., Islam, M.R., & Solangi, K.H. (2011). Environmental Impact of Wind Energy. *Renewable and Sustainable Energy Reviews*, 15(5), 2423–2430. https://doi.org/10.1016/j.rser.2011.02.024