



ASSESSMENT OF WIND RESOURCE AND ENERGY POTENTIAL OVER AUCHI AND ENVIRONS, EDO NORTH, EDO STATE

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ABSTRACT

Wind energy is favored by areas with consistent and strong winds, stable financial investment, with strong policy for energy transition. As the country sets out programmes to sustainably transit from over dependence on fossil fuels to clean energy, there is need for preliminary assessment of energy resources of the country. Wind is an important source of renewable energy in Nigeria especially in the coastal, guinea savannah and sudano-sahel regions. Auchi town is a transition between savannah and tropical rainforest agro-climatic region of Nigeria, though more of savannah. This unique geographical feature coupled with ongoing energy transition initiatives of the Federal government aimed to tackle greenhouse gasses (GHGs) emission necessitated the need for the present study. The study aimed to evaluate the wind resources and energy potential of Auchi town and environs. Both field measurement, NUMET and NASA-SSE datasets were utilized. Regression analysis of field measurement with NIMET datasets yielded an R-Value (correlation factor) of 0.629 and an R² value of 0.39 for Jattu – Atte Road, 0.623 and 0.388 for Barthony Petrol Station along Okene Road, and 0.623 and 0.388 for Auchi-Jattu respectively. The corresponding values with SSE data yielded R-Value of 0.722 and an R² value of 0.521 for Jattu – Atte Road, 0.761 and 0.580 for Barthony Petrol Station along Okene Road, and 0.762 and 0.581 for Auchi-Jattu. These results indicated a better relationship between on-site and SSE historical data than those from NIMET. The annual average wind speed for Auchi data is 2.505 m/s using SSE data and 2.257 from NIMET data. The average wind speed recorded at Jattu – Atte Road, for the seven-day measurement period from is 2.268 m/s. In Barthony Petrol Station along Okene Road and Auchi-Jattu respectively sites the seven days averages were 2.268 m/s and 2.267 m/s respectively. Wind speed values were further subjected to Weibull distribution curve analysis to determine the power density. Result revealed that Power density, P (W/m²) area ranges from 164 W/m² to 177.4 W/m² at 10m and from 187.43 W/m² to 247.35 W/m² at 60m. This a good power density to support a hybrid wind energy project. However, there is need for more studies to determine the effects of other key parameters such as heights, turbulence on power yield as well as Land use and Land cover features that may affect wind projects in the study area.

Keywords: Wind, Energy, Speed, Distribution, Weibull curve, GHGs

INTRODUCTION

Electricity and heat generation are important source of Green House emission, as well as represent at least 24 percent of greenhouse gas (GHG) emissions (Barthelmie and Pryor, 2021). The result of these emissions including increasing global temperatures with associated environmental and health consequences. An increase of 1.5°C in the average global temperature over the next few decades (Herring, 2020) will lead to a climate “tipping point” with effects such as an increase in potentially dangerous heat waves and excessive precipitation that can lead extreme weather and hydrological-related events. Concern for climate change mitigation and the need for achieving key SGGs especially those that center on clean energy, climate action and poverty eradication has continued to drive research and development into renewable energy technologies, and one of promising area is wind energy. In Nigeria, the introduction of renewable energy such as wind into the energy mix by the Federal is expected to increase the generation capacity required to meet electricity demand for domestic, commercial and industrial use (Energy Commission of Nigeria, 2022). Wind energy is an essential component of renewable energy as well as viable step towards climate change



mitigation. The technology also offers several advantages, including being cost-effective, reliable, and environmentally friendly (Barra *et al.*, 2021, Sadorsky, 2021, Olabi *et al.*, 2023). Utilizing wind energy is also key towards achieving SDGs to expand the share of renewable energy in the global electricity mix to at least 70% by 2030. This is attainable as wind energy beside reducing CO₂ emissions, also create jobs, especially if some challenges, such as the potential to harm wildlife are properly managed.

In July, 2019, the federal government of Nigeria signed a power deal with power giant Siemens to deliver 25,000 MW by the end of 2025 and to fix the archaic transmission and distribution infrastructure in the power sector (Folabo and Adewale, 2019). This stride by the government is an indication of the nation's readiness to provide sustainable solutions to energy crisis in Nigeria, while at the same time promoting sustainable Environment.

In 2023, the Federal Government has signed the new Electricity Act, through the Nigerian Electricity Regulatory Commission. This Act marks a historic shift in Nigeria's electricity governance, from a centrally regulated structure to one where states are empowered to generate, transmit, distribute, and regulate electricity within their borders and only submit to national oversight by the NERC (Izuaka, 2023). With this new Act, about seven (7) states currently controlling their electricity markets in accordance with the Electricity Act 2023 (Aina, *et al.*, 2025). These include Enugu, Ondo, Ekiti, Imo, Oyo, Edo, and Kogi. Other states, including Lagos, Ogun, Niger, and Plateau, are expected to complete their transitions between June and September. One of the implications of this major shift from energy regulation structure will be increased drive into state-wide research and development into innovative renewable energy technologies. Edo State, has potentials for Wind energy in the northern part of the state which is essentially fall under the savannah agro-climatic region. In order to harness this resource and in line with international best practices, there is need for detailed feasibility studies leading to production of a world class bankable data on wind resource, which can enhance turbine selection and other economic analysis that will guide prospective investors. This present study is aimed to address this research need.

MATERIALS AND METHODS

Geographical Description of the Study Area

Auchi is in the northern part of Edo State, Nigeria, located within Latitude 7.07°N and Longitude 6.27°E of the Greenwich Meridian (Fig. 1). Auchi is a town in Edo State, Nigeria in Etsako West Local Government Area of Edo State. Auchi town serves as the Local Government headquarters. Other towns in the Etsako West local government area include: Uzairue, South Ibie, Agbede and The Anwain Clan (Dalil *et al.*, 2016). In the 2006 census, the study area had a population of 142,819 people. It has a total land area of 358 Km².

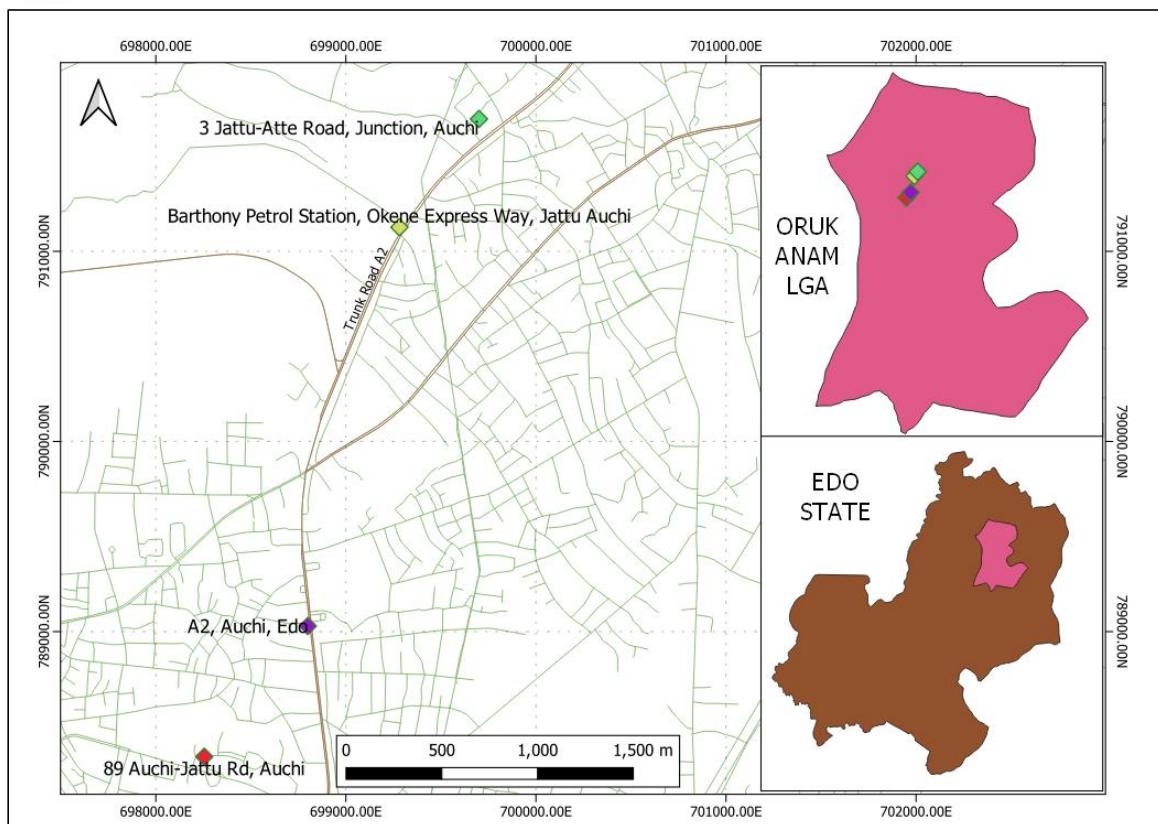


Figure. 1: Map of the Study Area

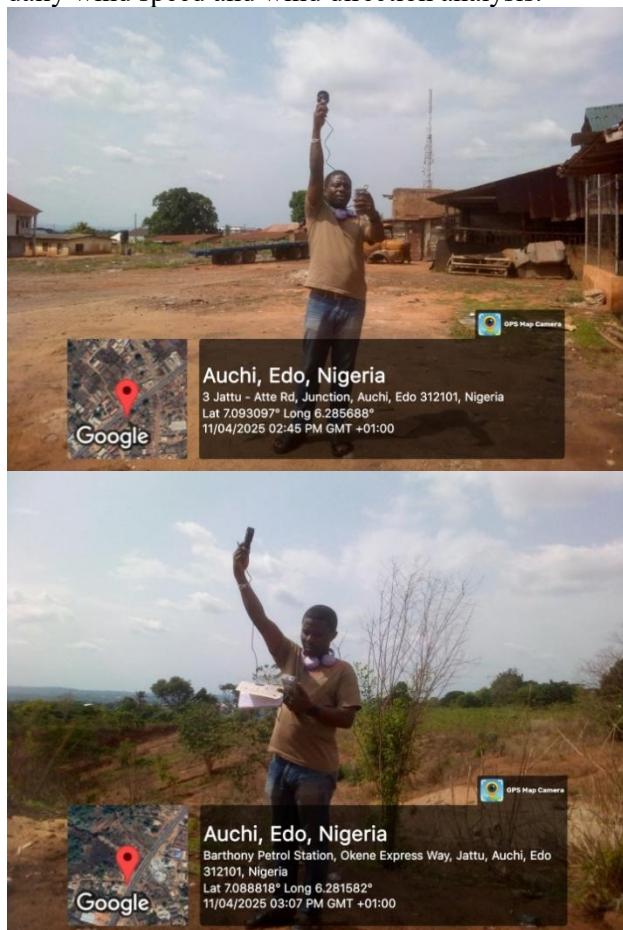
Auchi is drained by Orle River and few tributaries such as Omemi, Okami, and Awie River. These rivers have their source areas from both flanks of major water divide and contribute to the morphology of the gullies found within the region. The Auchi area lies within the tropical region characterized by two climatic conditions namely, the rainy season and dry season. Early rainfall in some cases starts from January / February with full commencement of rainy season in March and ends in November of each year. The dry season lasts between four to five months. While the rainy season is characterized by heavy thunderstorm that lasts from April to October, the dry season extends from November to March with high temperature and dusty atmosphere known as the harmattan. The mean annual rainfall is about 1952 mm. The temperature pattern has mean daily and annual temperature of 28°C and 27°C respectively. The high conventional rainfall intensity and the concomitant large volumes of runoff are of significant environmental issue and an important factor in formation of gully in the study area (Okeke, *et al.*, (2016). The study area and its environs fall into the Guinea savannah vegetation belt. The vegetation here is prominently made up of sparsely distributed trees, herbs, shrubs, and grasses. The vegetation in this area is mostly secondary i.e., the natural vegetation is being altered and replaced with agricultural crops such as Maize, Groundnut, Cassava, Cashew, Mango, and Sugar cane (Tekena *et al.*, 2016).

Historical Data Acquisition Methods

Historical Meteorological data was collected from the Nigeria Meteorological Agency, (NIMET), Lagos office and National Aeronautics and Space Administration – Surface Meteorology and Solar Energy database (NASA-SSE). Available wind data acquired include wind speed and wind direction data for 30 years (1986-2015) from NIMET for Benin City. The NASA-SSE spans 22 years data from 1982 – 2003 was also acquired to complement NIMET data. These data were subjected to various trend analyses to understand the variability in wind condition Auchi town.

On-site Data Acquisition

On-site collection of meteorological data was measured from March to April, 2025. This was done to validate secondary data from NIMET and NASA-SSE dataset. Three mobile/wireless micro weather stations equipped with wind anemometer and wind vane (Techno Line WS-2350) were mounted at Jattu – Atte Road, Barthony Petrol Station along Okene Road and Auchi-Jattu and at 10 metre height above ground level (Plate 1&2). The wireless weather station is designed to read meteorological data over a radius of 100-200 meters. The console component of the weather station provides the user interface, data display, such that data generated are downloadable in real time for daily wind speed and wind direction analysis.



Plates 1&2: On the site wind resources assessment

Estimation of Annual Energy Production

The mean wind speed derived from the Weibull distribution curve is then used to calculate the estimated annual energy production in Wh/year according to equation 2 shown below.

$$P_{el} = \frac{\rho C_p A_r V^3 \eta H_y}{2} \quad (1)$$

where:

P_{el} = Electrical power [W]

ρ = Air density [kg/m³]

C_p = Power Coefficient (<59%)

A_r = Rotor Swept Area (πr^2 [m²])

V = Wind Speed [m/s]



η = Efficiency

H_Y = Hours/year

This equation is the mathematical basis for the calculations but as can be seen from the equation a number of variables are determined for example by the turbine's characteristics such as the power coefficient and approximated running time in hours/year. The power coefficient even varies with varying wind speed and this complicates the calculations even further.

RESULTS AND DISCUSSION

Annual Mean Wind Speed

The estimated long-term wind resource for the site was acquired by the wind records for the period from year 1986 through to 2015 from NIMET office, Lagos. This provided a good long-term database by which to establish which years were good, bad or average wind years (see Figure 2). We compared the coincident wind speeds from NIMET and the site for the purpose of evaluating reliability of archival datasets. Hourly wind speed data for Auchi town was not available from NIMET, hence the Auto-Regression Average time series was done using daily average data. On-site hourly measurements at the three sites were averaged. To achieve better correlation, on-site daily averages of the three locations were regressed with monthly average wind speeds from NIMET and NASA-SSE datasets. These data were then imported to an Excel Worksheet and the Regression Data Analysis tool was used to determine the correlation coefficient. The monthly average, wind data from the three candidate sites were very close as shown in Table 1.

Table 1: Average Monthly Wind Speed for the Candidate Sites, SSE and NIMET

Month	12Hrs	12Hrs	12Hrs	NASA-SSE	NIMET
Feb	2.8328	2.8321	2.8316	2.69	2.17619
Mar	1.8807	1.8808	1.881	2.49	2.409524
Apr	2.036	2.0361	2.0357	2.19	2.552381
May	1.9745	1.9755	1.9742	2	2.185714
Jun	1.9471	1.9467	1.9468	2.43	2.242857
Jul	2.4869	2.4875	2.4866	2.83	2.142857
Aug	2.7192	2.7184	2.7194	2.91	2.095238

Regression analysis with NIMET data yielded an R-Value (correlation factor) of 0.629 and an R^2 value of 0.39 for Jattu – Atte Road, 0.623 and 0.388 for Barthony Petrol Station along Okene Road, and 0.623 and 0.388 for Auchi-Jattu respectively. The corresponding values with SSE data yielded R-Value of 0.722 and an R^2 value of 0.521 for Jattu – Atte Road, 0.761 and 0.580 for Barthony Petrol Station along Okene Road, and 0.762 and 0.581 for Auchi-Jattu. These results indicate a better relationship between on-site and SSE historical data than those from NIMET.

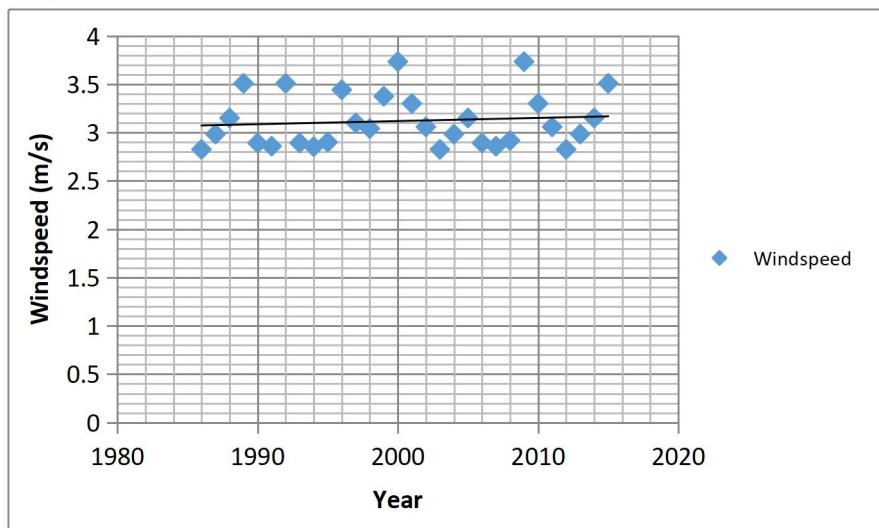


Figure 2: Average Annual Wind Speed Distribution.

Using a simple ratio approach, we find that the average wind speed for the 7-days study period is 10 percent lower than what we consider to be the normal or long-term average. We used this adjustment (i.e., +10 percent) to create the long-term average wind speed for the sites. The result is presented in Figure 3.

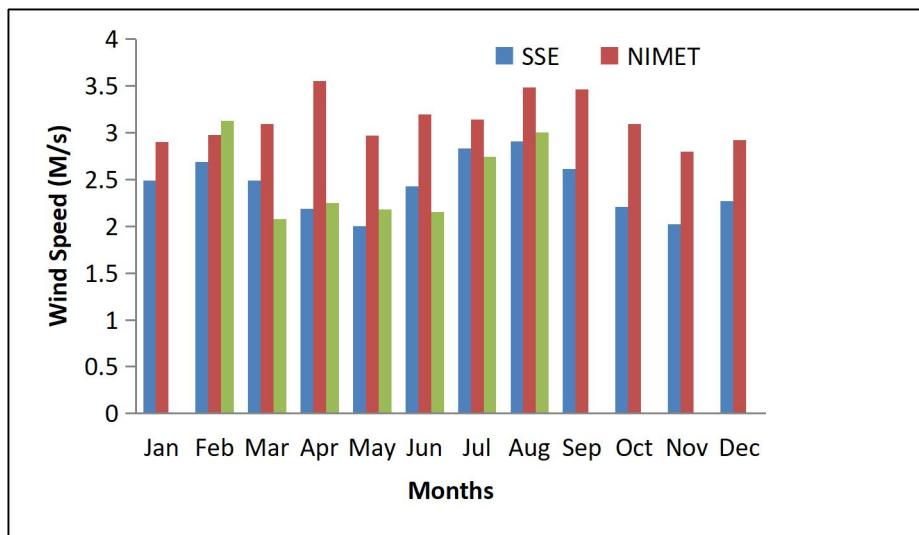


Figure 3: Average Monthly Wind Speed Distribution

The annual average wind speed for Auchi data is 2.505 m/s using SSE data and 2.257 from NIMET data. The average wind speed recorded at Jattu – Atte Road, for the seven-day measurement period from is 2.268 m/s. In Barthony Petrol Station along Okene Road and Auchi-Jattu respectively sites the seven days averages were 2.268 m/s and 2.267 m/s respectively.

Wind Speed Distribution

The Weibull distribution curve is used when calculating mean wind speed. The relative frequency of wind speeds on the y-axis is plotted against the wind speed in m/s on the x-axis. Two parameters derived from the Weibull distribution curve are given, Weibull-k and Weibull-A (m/s). A Weibull distribution curve has different looks depending on the distribution of wind speeds. The form of the curve will be more peaked if the wind speeds tend to be close to a certain value, on the other hand if the distribution of wind speed is large the curve's peak will be less marked. Weibull-k is a

shape parameter that describes the look of the curve and has a value between 1 and 3, and the higher the number the more peaked the curve is. A low k indicates increased presence of very high wind speeds that contain a lot of energy. Another parameter given in the Weibull distribution curve is Weibull-A and this is the calculated mean wind speed in m/s. Note that as the annual average wind speed at a site increase, the wind speed probability distribution shifts to the right. This results in more hours with wind speeds at higher wind turbine output levels and ultimately higher annual wind energy production levels.

Wind Direction Distribution

The percent of time that different wind speeds occur from different directions is portrayed as a plot called a wind rose. This chart displays both the fraction of the total annual wind energy that occurs in winds from the specific direction as well as the fraction of time each year when the wind blows from that sector. The results of wind analysis at 10m for each location are shown below in Figure 4-6. The wind rose is to the left, shaded areas show the relative frequency of wind blowing from that direction. To the right a Weibull distribution curve where measured wind speed, U , is used to calculate the wind power density, P . By using the Weibull distribution curve and its shape factor, k , the annual mean wind speed is estimated as A .

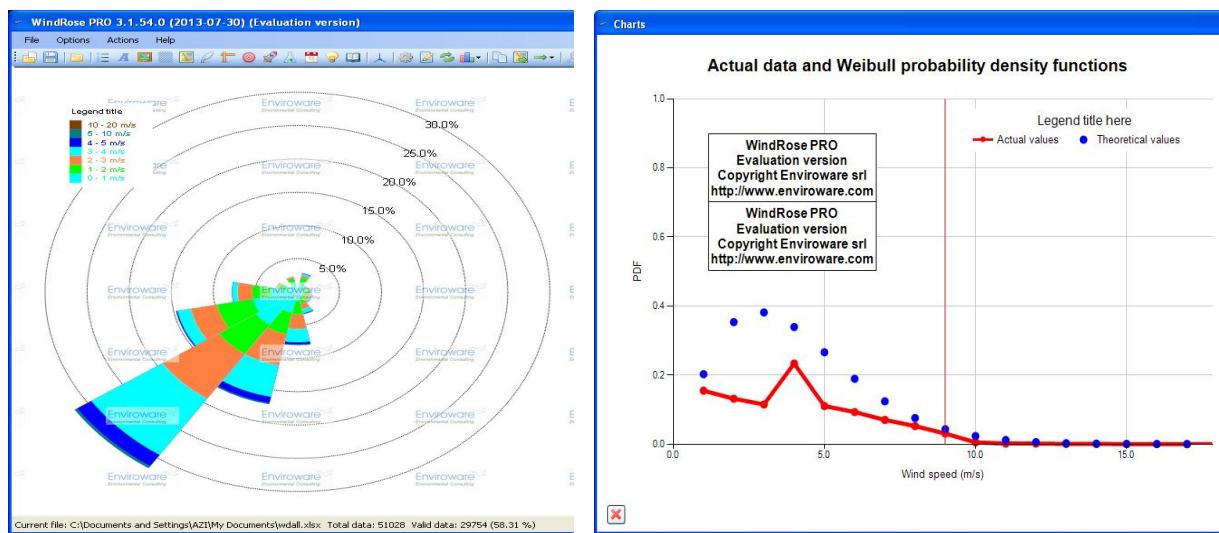


Figure 4: Wind Rose Graphs and Weibull Curve for Jattu – Atte Road

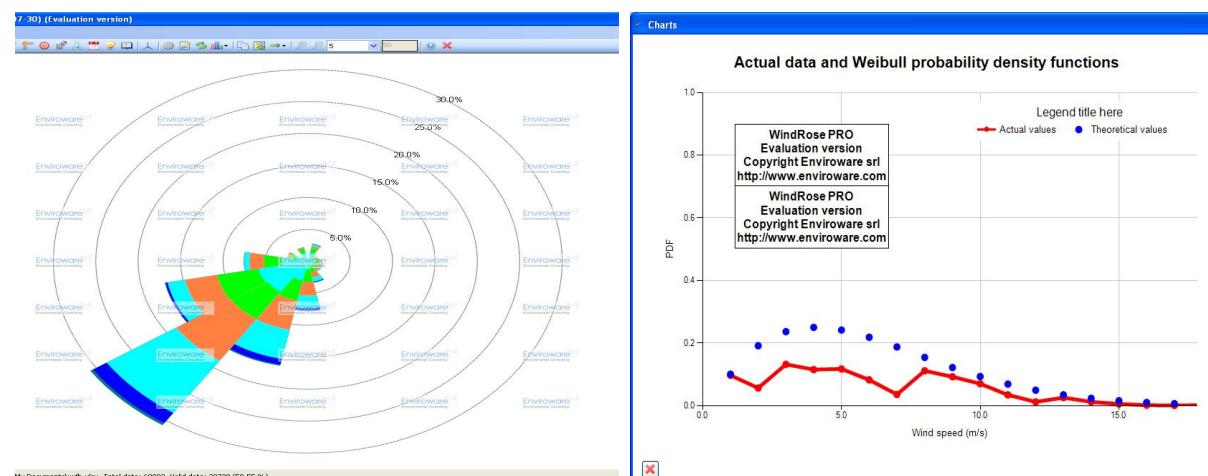


Figure 5: Wind Rose Graphs and Weibull curve for Barthony Petrol Station along Okene Road

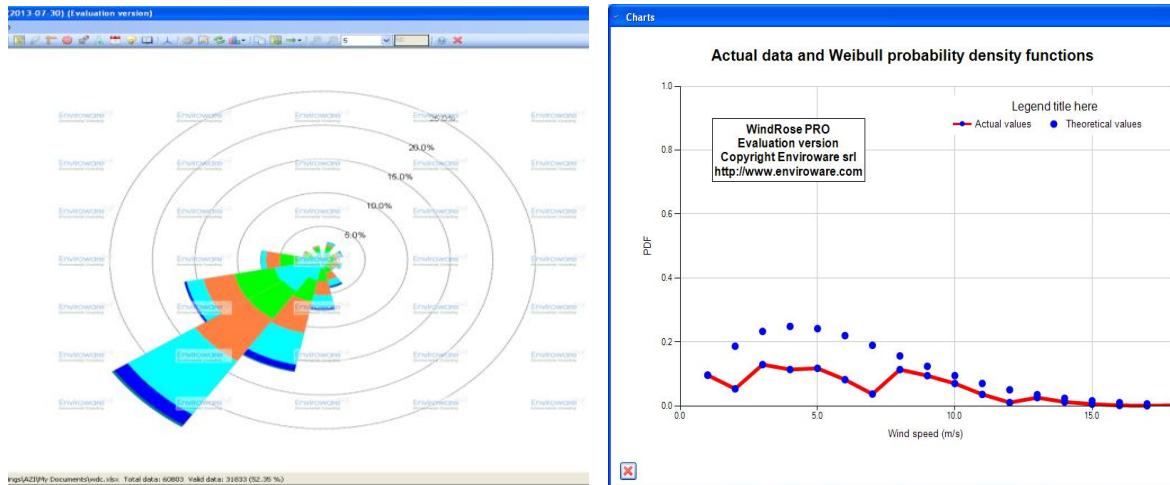


Figure 6: Wind Rose Graphs and Weibull Curve for Auchi-Jattu

Table 2 shows the results from all three locations. The values in the table are based on the 660 kW turbine Vestas V47 with hub height 45 meters.

Table 2. Mean Wind Speed and Power Density at 10m and 60m Heights.

Component	Auchi-Jattu	Jattu – Atte Road	Barthony	Petrol Station along Okene Road
Weibull-A (m/s)	3.088	3.094	3.122	
Weibull-k (m/s)	1.654	1.660	1.677	
Mean wind speed (m/s)	2.761	2.765	2.788	
Power density, P (W/m ²) – 10m	164.37	170.3	177.4	
Power density, P (W/m ²) – 60m	187.43	247.35	219.17	

Annual Energy Production

Theoretically the maximum power yield from a wind turbine is less than 59%, in reality this figure is always lower, for large turbines around 45%. The efficiency, η , is the difference between input and output power or P_{el}/P_{mec} . The losses in the generator system that converts mechanical power into electrical power are estimated to give $\eta \approx 0.9$. It should be highlighted that the power produced varies with the mean wind speed, V , at a factor of three, as can be seen in the equation (1), thus doubling the wind speed increases the power output at a factor of eight. Because of the complexity of the power equation and many of the extraneous factors not accounted for a wind analysis software (WindRose PRO 3.1.54.0) was used to compute power density for the selected candidate sites (see Table 2). It is important to notice that the power density is highest at Barthony Petrol Station along Okene at 10m but because of the high value of Weibull-k, indicating relatively frequent very high wind speeds, this does not necessarily mean that power production at this site will be the largest. Average monthly distribution of 24-hour and 12-hour wind speeds for each site at 10m height is presented in Figure 7 (a), (b), and (c). The average monthly wind speed decreases from a high in March, at the onset of the rainy season, to a low in June and rises to a peak in August.

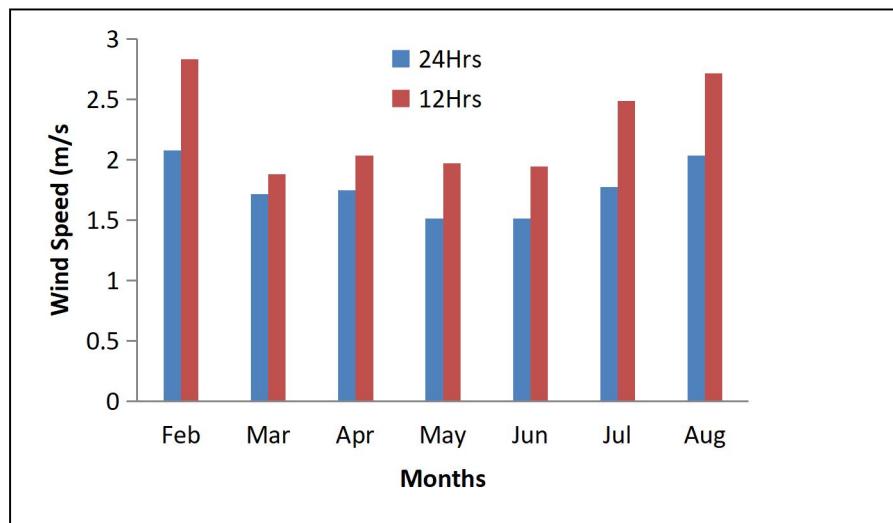


Figure 7a: Average Monthly Wind Speed at Jattu – Atte Road

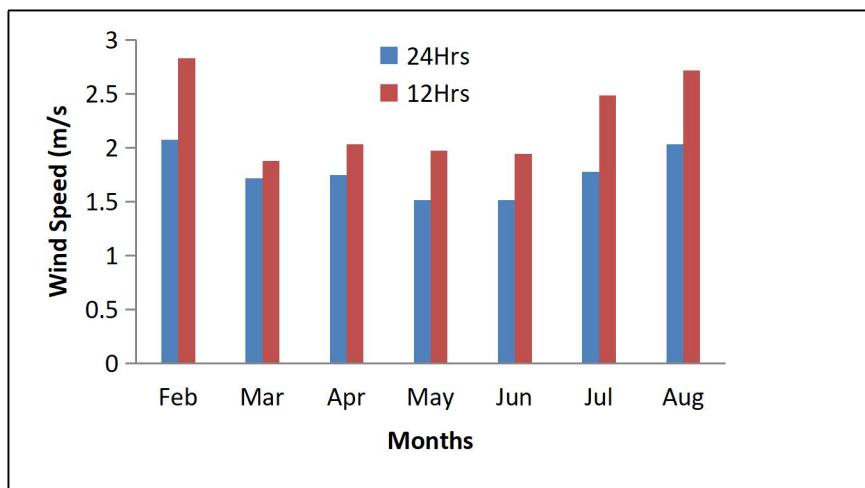


Figure 7b: Average Monthly Wind Speed at Barthony Petrol Station along Okene Road

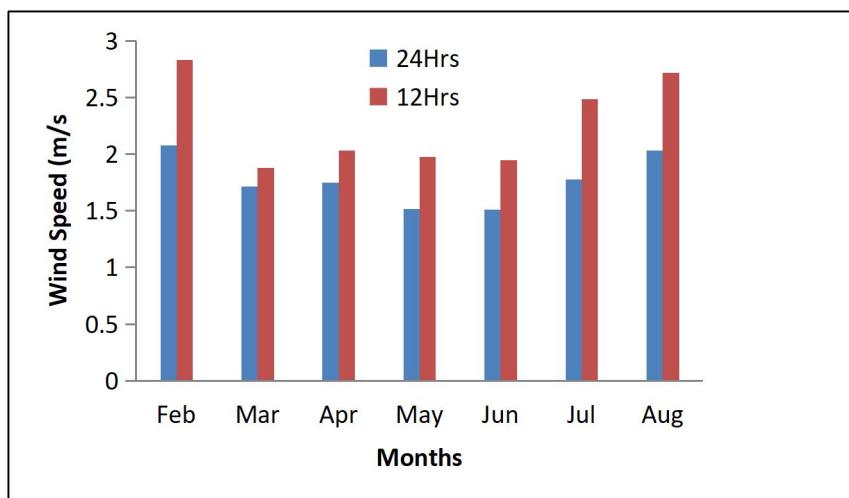


Figure 7c: Average Monthly Wind Speed at . Auchi-Jattu Environ



CONCLUSION AND RECOMMENDATIONS

Like most countries of the world, Nigeria is driving initiatives and policies to promote renewable energy hence meet its targets of net zero emission by 2060. wind energy will serve as an important mix of this energy transition. However, an important step towards a sustainable utilization of this resource is developing bankable data on wind speed, hence energy potential. The present study aimed to evaluate the wind resource of Auchi town in order to determine its viability for wind energy project. Auchi is on the intersection of latitude 7°N and longitude 6°E, in a hilly area with valleys and flat plains, at a meeting point between rainforest and guinea savannah. These geographical features favours wind project in the state. Secondly, the over dependence on fossil fuels with associated implications for global warming, instability in the price of oil products, coupled with energy insecurity and gross shortage of grid-based electricity power supply are another strong driver for transitioning to renewable energy sources like wind. The annual average wind speed for Auchi town is 2.505 m/s using SSE data and 2.257 from NIMET data. The average wind speed recorded at Jattu – Atte Road, for the seven-day field measurement period from is 2.268 m/s. In Barthony Petrol Station along Okene Road and Auchi-Jattu respectively sites the seven days averages were 2.268 m/s and 2.267 m/s respectively. These values were further subjected to Weibull distribution curve to determine the energy potential and results revealed that power density in the study area ranges from 164 W/m² to 177.4 W/m² at 10m and from 187.43 W/m² to 247.35 W/m² at 60m. There is need for more studies to determine the effects of turbulent on power yield as well as Land use and Land cover features that may affect wind projects in the study area.

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