

## APPRAISAL OF THE WIND POTENTIAL AS AN ALTERNATIVE SOURCE OF ENERGY IN KASHERE, GOMBE STATE, NIGERIA.

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### ABSTRACT

The sources of energy we use in our day-day activities contributes significantly to the alarming global warming which the world is currently experiencing. A technical solution to the menace of an environmental friendly, sustainable and reliable energy is the peak of this research. Wind speed data from 2014 to 2017 measured at a height of 2 m were analyzed using the Weibull's distribution method. The results show that all through the studied years and seasons, the mean wind speed distribution for the rainy season is significantly stable as seen from the K-values. However, the dry season has the highest K-value of 2.08 signifying more stable winds during the season. The monthly averages, computed for height of 60 m above ground level ranges between 2.15 m/s and 6.42 m/s with the maximum wind speed in June while the minimum wind speed occurred in September. This implies that the wind velocity of the study area tends to be lower during the end of the rainy season. Nevertheless, the deviation in the mean wind speed was not significant, as such wind energy can serve as a reliable energy source for the area hence could be harvested.

**Keywords:** Renewable energy, wind energy, weibull distribution, wind speed.

### INTRODUCTION

Since its commercial advent in the 1970s, renewable energy has become increasingly popular to investors, government officials and the general public. The awakening of significant investments in renewable energy was motivated by a growing realization of the need for energy security. This need for energy security was visualized in the 1970s when there were oil shortages in the United State (Mark *et al.*, 2018). The oil shortages created an interest in developing ways to use alternative energy sources, such as wind energy, hydropower, geothermal power and so forth. Fortunately, the alternative means of tackling the menace of energy security was to harness renewable energy, for short wind energy. Since then, scholars, scientist and engineers developed kin interest in renewable energy.

The ever-growing need of energy has boost the usage and search for whatever form of energy. Unfortunately, some forms of energy have a lot of negative impacts on both the social, economic and physical environment. As suggested by many scholars, the way forward is to seek an energy source which will be; environmental friendly, a release from economic burden and socially acceptable. These make the problem which this research seek to provide a technical solution. Hence the aim of this research is to evaluate the possibility of a wind farm that will meet the energy requirement of Federal University of Kashere, Gombe State. To achieve this, two objectives are set which are to determine the average wind speed of the geographical ranges of Federal University of Kashere and to obtain the wind distribution all through the year and the seasons. The study area which is the Federal University of Kashere (FUK), is located in Akko Local Government Area of Gombe state, North-Eastern Nigeria and has a geographical coordinate; latitude: 9.9128°N, longitude: 11.0065°E. It is located on an elevation 431 meters above sea level.

Wind energy is the fastest growing source of energy and is getting worldwide attention due to technological advances for harnessing the wind power and its competitive cost of production as compared to other traditional means. Of these clean sources, the rapid development in wind energy conversion technology has made it an alternative to conventional energy system in recent years (Alam *et al.*, 2011). In order to conserve the conventional energy resources, and to address the environmental problems, the wind power utilization is the answer to these problems. Wind power has progressed from been a minor source of electricity to a technology that attracted many countries to it. In Nigeria, Oluseyi *et al.*, (2014) investigated the average wind speed in south western part of the country and the corresponding cost analysis showed that generation cost can be as low as 0.02 KW/h and as high as 5.03 KW/h. Ulan, (2013) analyzed wind power generation with a null hypothesis that "there is no significant difference in the wind velocity means" with the use of custom-constructed wind guide attachment. Unfortunately, the statistical analysis (ANOVA) rejected the null hypothesis which means the reverse might be the case.

Wind power apart from its reliability has several benefits such as industrial growth, clean fuel source, sustainability and many others. Wind power is recognized as an important contributor to renewable energy, climate, and energy security targets set by many countries across the globe. For this and many other related reasons, the use of wind energy has continued to expand, and will play an important role in the production of electricity in the future. Moreover, wind is a natural occurrence and harvesting its kinetic energy does not affect current and wind cycles in any way and the kinetic energy in the wind is a promising source of renewable energy with significant potentials in many parts of the world (Abdeen, 2011). Obviously, this form of energy seems to be the way forward and therefore serves as a technical solution of an effective remedy to fossil – fuel depletion, which satisfy the millennium Development Goals (MDGs).

**Wind velocity (speed)**

Let the mean wind speed of the site be  $V_m$ , then it can be obtained from the equation;

$$V_m = \frac{1}{N} \sum_{i=1}^N v_i \tag{1}$$

Where  $v_i$  is the observed (recorded) wind speed and  $N$  is the data point. However, the root mean cube (RMC) speed  $V_{rmc}$  given by;

$$V_{rmc} = \sqrt[3]{\frac{1}{N} \sum_{i=1}^N V_i^3} \tag{2}$$

Fortunately, the wind power ( $P_w$ ) can be expressed in terms of wind speed

$$P_w = \frac{1}{2} \rho V_{rmc}^3 \tag{3}$$

Where  $\rho$  = observed air density.

**The weibull probability distribution function (pdf)**

Knowledge of the wind speed frequency distribution plays an important role for the estimation of wind potential in any location (Azad et al., 2014).

The two-parameter Weibull distribution is most commonly known for its high accuracy for wind speed data analysis (Zghal et al., 2011).

The Weibull PDF is given by

$$f(v) = \left(\frac{k}{c}\right) \left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} \tag{4}$$

And its corresponding cumulative distributive function

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^k} \tag{5}$$

Where  $c$  is the scale parameter and  $K$  is the shape parameter. The scale parameter indicates the wind regime at that location.

The mean and variance are respectively given by equations (6) and (7) below

$$\bar{V} = E(v) = c \Gamma\left(1 + \frac{1}{k}\right) \tag{6}$$

$$Var. (v) = c^2 \left[ \Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right) \right] \tag{7}$$

Where  $\Gamma$  is the gamma function.

There are other distributive functions used for wind analysis, however in this research analysis the Weibull distribution was used for analysis. Dikko and Yahaya, (2012) showed that for some cities in Nigeria, the Weibull Distribution Function produce better result for analysis. These cities are Gombe, Maiduguri and Yola.

**Variation of wind speed with height**

The wind speed as well as the Weibull parameters varies proportionally according to the Hub height (Khoulood et al., 2016). As wind turbines can be placed at different heights, the wind speed needs to be measured at such height by using the power law (Zekai

et al., 2012).

The law describes the vertical variation of wind speed as

$$V(h) = V_0 \left(\frac{h}{h_0}\right)^\alpha \tag{8}$$

Where  $V(h)$  is the wind speed at hub height  $h$ ,  $V_0$  is the wind speed at measured height and  $\alpha$  is wind shear power law exponent. The value for  $\alpha$  varies from 0.1 over the top of steep hills to 0.25 in sheltered locations. For flat coastal regions,  $\alpha$  is taken as 0.143 (1/7) which is the typical value used in most research (Youm et al., 2005). Similarly, the Weibull parameters also varies with the height as expressed by Oyedepo et al. (2012) in equation (9).

$$C(h) = C_0 \left(\frac{h}{h_0}\right)^\alpha \tag{9}$$

Where  $C_0$  is the scale factor at the measured height  $h_0$ .

The hub height mentioned above is a distance from the turbine platform to the rotor of an entailed wind turbine and indicates how high a turbine stands above the ground, not including the length of the turbine blades.

**MATERIALS AND METHODS**

The data for the analysis of this study were obtained from the weather station of Federal University of Kashere, Gombe state. The wind speed for the analysis of this study was collected up to four years (2014-2017) with the aid of an anemometer.

The wind speed was analyzed with the Weibull distribution which is explained in the equations (1) to (9). The analysis has two phases which are the seasonal and annual analysis. The major tools to be used for the analysis are graphs and bar charts.

This research utilises daily average wind data measured at 2 m above ground level. Data obtained were from October, 2014 to February, 2017. The data, at 2 m hub height were checked thoroughly for homogeneity, outliers and missing records before being processed for the study. Spurious and missing data as well as wind gusts and cyclonic winds (wind exceeding 20 m/s) were eliminated.

**RESULTS AND DISCUSSION**

**Analysis of monthly mean wind velocity**

This study was restricted to flow of wind for normal days. The monthly averages of the filtered data, computed for heights of 2 m and 60 m above ground level are displayed in figure 1 and figure 2 respectively. It can be observed in figure 4.2 that the average wind speeds vary between 2.15 m/s and 6.42 m/s with the maximum wind speed in June (Winter season) while the minimum wind speed occurred in September. It can be inferred that the wind velocity tends to be lower during the end of the rainy season.

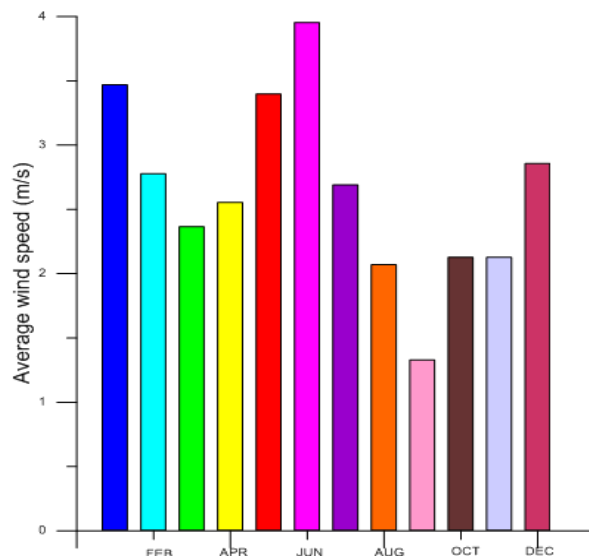


Figure 1: Monthly average wind speed at 2 meters from October, 2014 to February, 2017.

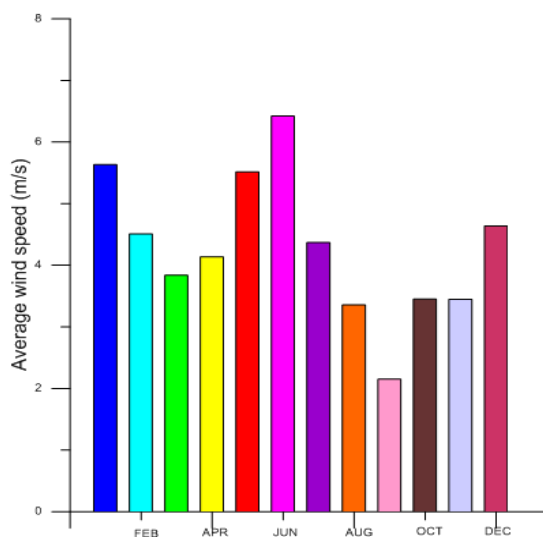


Figure 2: Monthly average wind speed at 60 meters from October, 2014 to February, 2017.

**Wind speed vertical profile**

A logarithmic wind profile was used according to equation (8) to estimate the mean wind speed values at various heights (Table 1).

**Table 1: Logarithmic wind profile of mean wind speeds and their corresponding heights.**

Height above ground (m)	Wind speed (m/s)
150	4.76
140	4.72
130	4.69
120	4.65
110	4.60
100	4.55
90	4.50
80	4.44
70	4.38
60	4.30
50	4.21
40	4.10
30	3.95
20	3.75
10	3.40

The modelled average wind speed value at 60 m which is good enough height for a turbine is 4.30 m/s (Figure 3). This is beyond the minimum standard of 12.6 km/h (3.5 m/s).

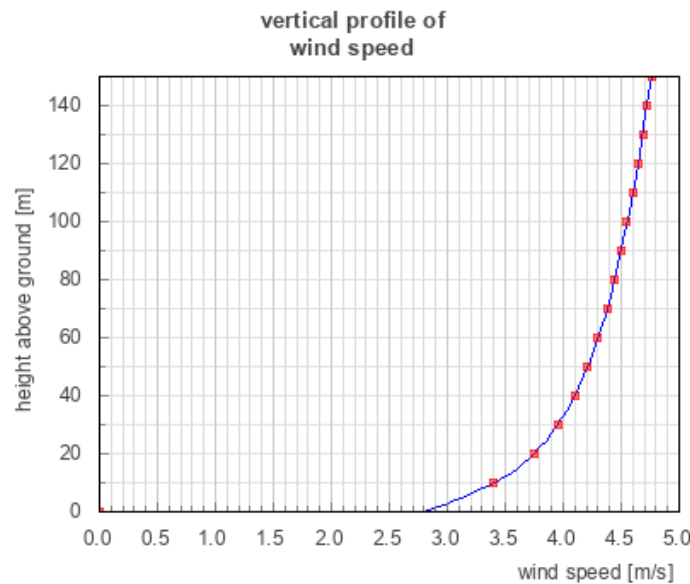


Figure 3: Logarithmic wind profile plot of the mean wind speeds against their corresponding heights.

**Wind speed distribution**

Naturally, the wind's speed constantly varies. In order to be able to predict a wind turbine's production it is necessary to know exactly how often the wind blows strongly. Normally, the wind is measured with an anemometer and the mean wind speed is recorded every day. This data was sorted into wind speed classes of 1 m/s each (Table 2). The energy contained in the wind was then expressed by the frequency (Weibull) distribution as in equation (4).

**Table 2: Wind speed frequency distribution**

All seasons Range	All seasons		Raining Season			Dry Season		
	Freq	% Freq	Range	Freq	% Freq	Range	Freq	% Freq
0-1	73.00	12.18698	0-1	50	14.45087	0-1	23	9.090909
1-2	136.00	22.70451	1-2	73	21.09827	1-2	63	24.90119
2-3	182.00	30.38397	2-3	113	32.65896	2-3	69	27.27273
3-4	129.00	21.53589	3-4	67	19.36416	3-4	62	24.50593
4-5	52.00	8.681135	4-5	26	7.514451	4-5	26	10.27668
5-6	15.00	2.504174	5-6	11	3.179191	5-6	4	1.581028
6-7	6.00	1.001669	6-7	3	0.867052	6-7	3	1.185771
7-8	5.00	0.834725	7-8	3	0.867052	7-8	2	0.790514
8-9	0.00	0	8-9	0	0	8-9	0	0
9-10	1.00	0.166945	9-10	0	0	9-10	1	0.395257

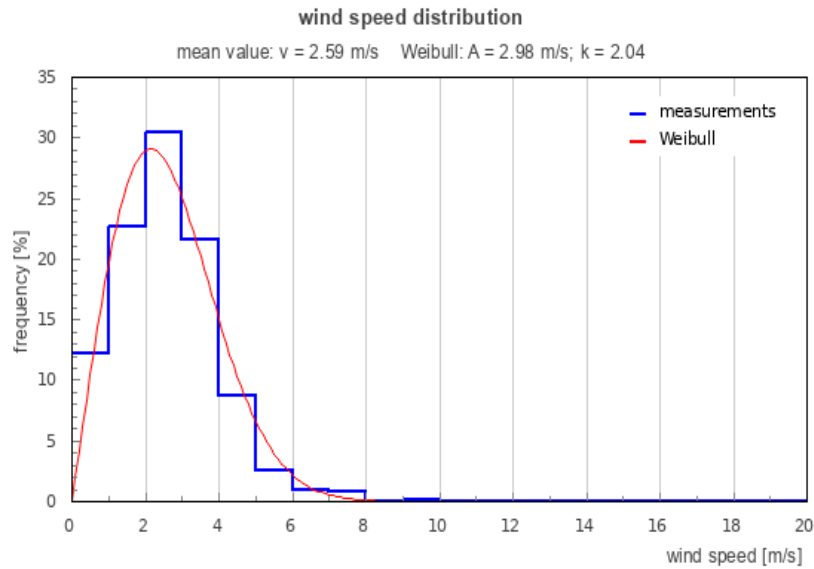


Figure: 4 Wind speed distribution for all seasons.

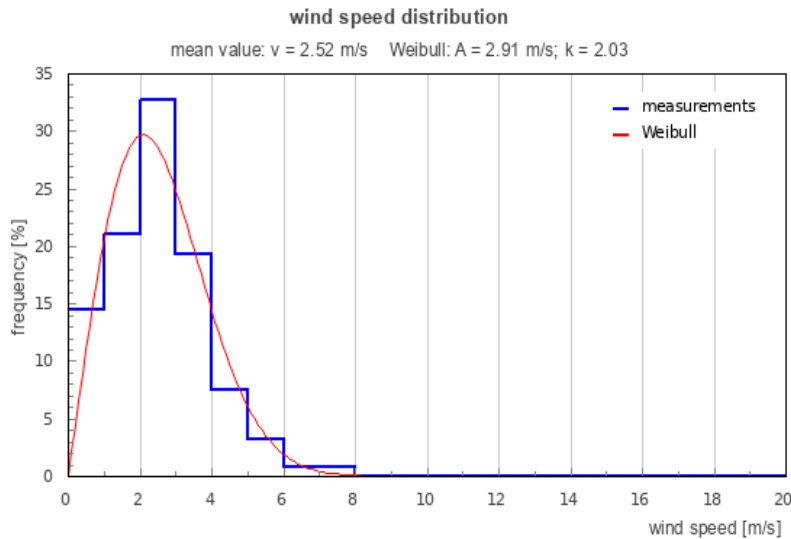


Figure: 5 Wind speed distribution for the rainy season.

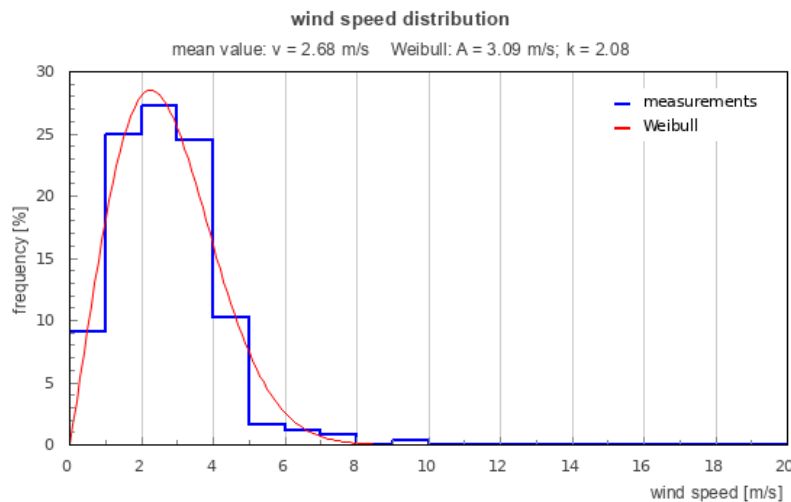


Figure: 6 Wind speed distribution for the dry season.

A is the Weibull scale parameter in m/s; a measure for the characteristic wind speed of the distribution. A is proportional to the mean wind speed. k is the Weibull form parameter. It specifies the shape of a Weibull distribution and takes on a value of between 1 and 3. A small value for k signifies very variable winds, while constant winds are characterized by a larger k. The Weibull curves peak near the average values of the wind speeds in all cases. The similarity of the trends shows a good representation given by the Weibull model when compared to the actual data.

All through the studied years and seasons the wind speed distribution showed significant stability as seen from the (above 2) K-values (figures 4 to 6). Nevertheless, the dry season has the highest K-value of 2.08 signifying more stable winds during the season (figure 6).

**CONCLUSION**

Based on the interpretation of wind speed data, the wind speed for rainy season in the results showed that through the studied years, from 2014-2017, which was restricted to flow of wind for normal

days, the monthly averages showed significant stability as observed from their k-values. It also showed that the average wind speed of 4.30 m/s with the maximum wind speed in June (winter season) and the minimum wind speed occurring in the end of the rainy season, suggesting stable wind during the season. The study area shows good wind energy potential hence part of the energy requirements can potentially be obtained from the wind throughout the year. The average wind speed of 4.30 m/s is beyond the minimum value of 3.5 m/s suggesting that it is very good to start a turbine. Also, the k-value of 2.08 is good since it falls beyond 69% of the required maximum.

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