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Estimation of Wind Energy Potential for Two Locations in North-East Region of Nigeria

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Abstract: This paper presents an estimation of wind power potential of North East, Nigeria (Bauchi and Maiduguri) on the basis of monthly wind speed data at 10m height from the ground. The data for the locations were collected from Nigeria metrological station, Abuja for the period of (2013-2017). Mean monthly values were used in calculation of Weibull distribution parameters c (scale factor ms^{-1}) and k (shape factor). The Weibull results shows that for Bauchi, the shape factor ranges from 2.86 – 5.96 and scale factor ranges from 2.32ms^{-1} – 2.54ms^{-1} while Maiduguri the shape factor ranges from 2.66 – 5.52 and values of scale factor ranges from 4.74ms^{-1} – 5.89ms^{-1}. It is evident that the maximum average monthly value of wind speed in Bauchi occurs in year 2017 with value of 3.8ms^{-1} in the month of May while the maximum average wind speed in Maiduguri occurs in year 2013 with value of 8.5ms^{-1} in the month of December. The probability distribution function f(V) of wind speed, together with the duration function T(V) was evaluated for the period under investigation. From the statistical analysis of distributions, the Weibull distribution was found to have better fittings in the probability distribution functions f(V) and T(V). The value of power density was computed to be 33.47W/m^2 (class I) & 374.62W/m^2 (class II) and energy density was also computed to be 24.9 kWh/m^2 & 278kWh/m^2 for both Bauchi and Maiduguri respectively.

Keywords: Weibull Distribution, Weibull Parameters, Duration Function, Wind Energy

1. Introduction

Wind energy is the energy that is extracted from the wind using mechanical turbines. Even though it is a renewable energy resource. The contribution of wind energy varies between different years. Hence an efficient power management technique is followed to harvest maximum energy when there is excess wind and it can be used to compensate when wind mill production is low. Wind energy can be harnessed for grid and non-grid electricity generation, water pumping, irrigation and milling [1].

Wind energy is currently the most economic renewable energy apart from hydropower. Its usage versatility and ability to use it as a decentralized energy form make its application possible in rural areas where it is technically and economically feasible in the country. The major challenge to using wind as a source of electricity generation is that wind is intermittent and does not always blow when electricity is needed [3].

The wind systems that exist over the earth's surface are as result of variation in the pressure. These are due to the variations in solar heating, warm air rises and cooler air rushes in to take its place. Wind is merely the movement of air from one place to another due to uneven heating of the earth's atmosphere which causes temperature difference between land and seas, or mountain and valleys [5].

Wind speed generally increase with height above the ground, this is due to roughness of ground features such as vegetation and house which results to slowing down the wind speed.

Wind energy has been used since earliest civilization to grind grain, pump water from deep wells and power sail boat. Wind mills in Europe pre-industrial were used for many applications. The utilization of wind energy has been increasing around the world at an accelerating pace [7]. However, the development of new wind projects continues to be hampered by lack of reliable and accurate wind resource data in many parts of the world. Such data are needed to enable governments, private developers and others to determine the priority that should be given to wind energy utilization and to identify potential areas that might be suitable for development. The distribution of wind speeds is important for the design of wind farms, power generators and agricultural applications; such as irrigation [2].

These sources of energy are inexhaustible, clean and free. They offer many environmental and economic benefits in contrast to conventional energy sources. Wind energy is considered as a cost effective energy and its technological advancements allow it to compete with conventional power generation technologies [3].

Today, wind analysis provides remarkable information to researchers and designers that are involved in renewable energy studies, a large number of studies have been published amongst which are: Akpinar [1] presented a work on statistical analysis of wind energy potential on the basis of the Weibull and Rayleigh distribution for Agin-Elazig, Turkey. The work studies 5 years measured wind speed data based on the Weibull and Rayleigh models. The Weibull distribution provides better power density estimation in all twelve months than the Rayleigh models. Emami [4] worked on the statistical evaluation of wind speed and power density in the Firouzkouh region in Iran. The work studies an hourly average wind data which was observed for one year (2003) at Firouzkouh meteorological station, from his result he found that the region is quite favorable for wind power generation.

Wind Speed Data and Sites Description

The present study was based on data source measured at a height of 10m above the ground level for Bauchi and Maiduguri North East, Nigeria. The wind speed data was collected from Nigerian meteorological station NIMET, Abuja for the period of (2013 - 2017). The geographical locations of Bauchi and Maiduguri North East, Nigeria are presented in Table 1 below. The locations have vegetation zone classified as Sudan zone and blessed with abundant vast land for agricultural activities.

However, the main objective of this present study is to estimate the wind energy potential for North-East region of Nigeria (Bauchi and Maiduguri) because the demand of power is increasing due to increase in human activities. It has been forecast that the present source of energy which if fossil fuel will gradually be depicted, hence the use wind energy for this locations have been found quite promising as an alternative energy source.

Table 1. *Geographical data for the selected location.*

Locations	State	Lat (N)	Long (E)	Alt (m)	Alt (ft)
Bauchi	Bauchi	10°18′57	9°50′39	615	2020
Maiduguri	Borno	11°50′.47	13°9′37	299	984

Source: http://www.fallingrain.com

2. Available Power and Extractable Power of the Wind

The power in wind is equal to energy per unit time. The energy available is the kinetic energy of the wind which is equal to the volume of air passing through an area (A) with wind speed in time (t). The power and energy density equation can be expressed as shown below [6];

Power density;

$$P = \frac{1}{2}\rho A {V_f}^3 \tag{1}$$

$$\frac{P}{A} = \frac{1}{2}\rho {V_f}^3 \tag{2}$$

The actual power that can be extracted from wind depend on several factors, such as type of machine and rotor used, sophistication of blade design, friction losses, and losses in the machine or other equipment connected to the wind machine.

The possible extract maximum theoretical efficiency of a wind machine is 59.3% of the wind power, this is known as Betz limit.

The maximum power a wind machine can extract can be expressed in the equation below [12];

$$Maximum\ Power = \frac{0.593}{2} * \rho * V^3 * A \tag{3}$$

In practice, a wind machine extracts substantially less power than this maximum. For example, the wind mill itself may capture only 70% of maximum power. Bearing will lose another few percentages to friction, generators, gears and other rotating machinery [8].

where; P is power density *(Watts)*, A is area *(m^2)*, ρ is density and V is velocity *(m/s)*.

3. Wind Speed Distribution

In order to evaluate the wind energy potential of any site, it is important to derive the expected probability distribution of the site's wind speed. Weibull distribution parameter has been widely used in analysis of wind speed because it gives good match with the experimental data [11].

The wind speed probability distribution is essential in wind energy studies. The probability distribution could be used to evaluate the following [7];

The capacity factor for a particular wind turbine generator used in producing any form of energy

The probability for the wind speed to lie in a certain interval especially when the speed is above cut in speed of the turbine.

The mean wind power density.

The probability density function for the wind velocity *v(m/s)* is given by [9, 14];

$$f_w(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{4}$$

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

$$T(v) = 8760 \exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{6}$$

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{7}$$

The Weibull parameters (scale and shape factors) can be calculated analytically from the available wind speed data using the relations below [10, 13];

$$c = v_m\left[\frac{k^{2.6674}}{0.184 + \left(0.816k^{2.73859}\right)}\right] \tag{8}$$

$$k = \left[\frac{\sigma}{v}\right]^{-1.090} \tag{9}$$

where; f_W is Weibull probability density function, F_W is the Weibull cumulative distribution function, *T(V)* is frequency distribution duration function, *c* is the scale factor (m/s) and *k* is the shape factor (dimensionless). $A = \pi r^2$

4. Results and Discussion

In this study, the wind speed data were recorded for two locations in North East (Bauchi and Maiduguri) for the period of (2013-2017) which have been statistically analyzed. The wind speed data of the two sites were obtained from Nigeria metrological station, Abuja. Based on these data, the wind speeds were analyzed and processed using spreadsheet and Wind Information System (WIS) software. The main results obtained are summarized as follows:

Wind Characteristics and Weibull Parameters

The average yearly wind speed values V_m and Weibull parameters k and c are presented in Table 2 and Table 8 for both locations for the period of (2013 – 2017). It can be seen from Table 2 that, the average wind speed values are between 2.07 - 2.31ms^{-1} for Bauchi while for Table 8, the values ranges from 4.30 – 5.27ms^{-1} for Maiduguri.

Similarly, values of the two Weibull parameters, the scale factor (ms^{-1}) and shape factor (dimensionless), calculated from the long term wind data for the sites studied with values of (shape factor) ranges from 2.86 - 5.96 and values of *(*scale factor) ranges from 2.32 ms^{-1} – 2.54ms^{-1} for Bauchi, while values of (shape factor) ranges from 2.66 - 5.52 and values of (scale factor) ranges from 4.74 ms^{-1} – 5.89 ms^{-1} for Maiduguri.

Table 2. *Values Obtained for Mean Yearly Wind Speed, Shape and Scale Factors for Bauchi.*

Year	2013	2014	2015	2016	2017
Average wind speed (V_m)	2.28	2.25	2.30	2.31	2.07
Shape factor (k)	5.96	4.17	3.94	4.42	2.86
Scale factor (c)	2.46	2.48	2.54	2.54	2.32

It can be seen from Tables 3 - 7 below, that the values of power and energy density increases with increase in the monthly average wind speed, while the duration function *T(V)* decreases with increase in wind speed. It is evident from the wind speed data, that the maximum average monthly value of wind speed in Bauchi from year (2013 -2017) occurs in year 2017 with value of 3.8ms^{-1} in the month of May. The highest power and energy density were obtained in year 2017 in the month of May with values of 33.47W/m^2 and 24.90kWh/m^2 respectively, while the lowest power and energy density occurred in year 2015 with values 101.49W/m^2 and 755.08kWh/m^2 respectively. From the Weibull probability distribution function, it is noticeable that the highest probability density function *F(V)* occurred in year 2016 in the month of August with value of 0.6509 and the lowest occurred in year 2013 in month of June with value of 0.0009. For the duration function *T(V)*, the highest value occurs in year 2016, in the month of December with value of 8444.45 while the lowest value occurs in year 2013 month of June with value of 70.10.

Table 3. *Bauchi power and energy density wind speed for year 2013.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.3	7.42	5.52	0.011	4461.54
Feb	1.7	3.00	2.01	0.004	7836.66
Mar	2.0	4.88	3.63	0.008	6532.75
Apr	2.4	8.43	6.07	0.011	3671.96
May	2.8	13.39	9.96	0.007	991.57
Jun	3.2	19.99	14.39	0.001	70.104
Jul	2.7	12.01	8.93	0.008	1515.92
Aug	2.3	7.42	5.52	0.011	4461.54
Sep	2.2	6.50	4.64	0.010	5220.03
Oct	1.8	3.56	2.65	0.006	7490.33
Nov	1.9	4.18	3.01	0.007	7057.49
Dec	2.1	5.65	4.20	0.008	5917.06

Table 4. *Bauchi power and energy density wind speed for year 2014.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.4	8.43	6.27	0.6339	3662.24
Feb	1.9	4.18	2.92	0.5200	6304.04
Mar	1.6	2.50	1.86	0.3567	7460.25
Apr	2.4	8.43	6.07	0.6339	3662.24
May	2.9	14.88	11.07	0.4048	1282.96
Jun	2.5	9.53	6.86	0.6137	3114.63
Jul	3.0	16.47	12.25	0.3367	958.15
Aug	2.6	10.72	7.98	0.5783	2591.48
Sep	2.9	14.88	10.71	0.6383	1282.96
Oct	2.2	6.50	4.83	0.6273	4776.06
Nov	1.4	1.67	1.21	0.2501	7990.07
Dec	1.2	1.05	0.78	0.1602	8346.52

Table 5. *Bauchi power and energy density wind speed for year 2015.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.7	12.01	8.93	0.5207	2469.63
Feb	1.8	3.56	2.38	0.4341	6778.89
Mar	1.4	1.67	1.25	0.2437	7963.90
Apr	2.6	10.72	7.72	0.5551	2941.62
May	3.2	19.99	14.87	0.2568	739.24
Jun	2.6	10.72	7.72	0.5551	2941.62
Jul	2.9	14.88	11.07	0.4257	1636.39
Aug	2.5	9.53	7.09	0.5783	3438.93
Sep	2.8	13.39	9.64	0.4768	2023.10
Oct	2.3	7.42	5.52	0.5881	4467.89
Nov	1.7	3.00	2.16	0.3865	7138.47
Dec	1.1	0.81	0.61	0.1272	8443.05

Table 6. *Bauchi power and energy density wind speed for year 2016.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.5	9.53	7.09	0.6483	3431.51
Feb	2.1	5.65	3.93	0.5912	5675.52
Mar	1.7	3.00	2.23	0.3738	7384.97
Apr	2.7	12.01	8.65	0.5771	2348.49
May	3.3	21.92	16.31	0.1754	359.68
Jun	2.7	12.01	8.65	0.5771	2348.49
Jul	2.6	10.72	7.98	0.6209	2874.33
Aug	2.3	7.42	5.52	0.6509	4579.69
Sep	2.8	13.39	9.64	0.5195	1867.29
Oct	2.2	6.50	4.83	0.6277	5140.77
Nov	1.6	2.50	1.80	0.3164	7687.11
Dec	1.2	1.05	0.78	0.1301	8444.45

Table 7. *Bauchi power and energy density wind speed for year 2017.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2	4.88	3.63	0.4853	4568.54
Feb	2.4	8.43	5.67	0.4363	2926.58
Mar	2.4	8.43	6.27	0.4363	2926.58
Apr	3.0	16.47	11.86	0.2483	1099.92
May	3.8	33.47	24.90	0.0520	148.32
Jun	2.9	14.88	10.71	0.2824	1332.30
Jul	2.4	8.43	6.27	0.4363	2926.58
Aug	1.9	4.18	3.11	0.4822	4992.76
Sep	1.9	4.18	3.01	0.4822	4992.76
Oct	1.7	3.00	2.23	0.4570	5818.98
Nov	1.3	1.34	0.97	0.3455	7244.27
Dec	1.0	0.61	0.45	0.2345	8008.15

Table 8. *Values Obtained for Mean Yearly Wind Speed, Shape and Scale Factors for Maiduguri.*

Year	2013	2014	2015	2016	2017
Average wind speed (V_m)	5.27	5.09	4.46	4.30	5.27
Shape factor (k)	3.34	4.25	2.66	4.11	5.52
Scale factor (c)	5.89	5.60	5.02	4.74	5.71

It can be seen from Tables 9 - 13, that the values of power and energy density increases with increase in the monthly average wind speed, while the duration function *T(V)* decreases with increase in wind speed. It is evident from the wind speed data, that the maximum average monthly value of wind speed in Maiduguri from year (2013 - 2017) occurs in year 2013 with value of 8.5m/s in the month of December. The highest power and energy density were obtained in year 2013 in the month of December with value of 374.62W/m^2 and 278.72kWh/m^2 respectively, while the lowest power and energy density occurred in year 2013 and 2015 in the month of January and October with values of 6.50W/m^2 and 4.83kWh/m^2 respectively. From the Weibull probability distribution function, it is noticeable that the highest probability density function *F(V)* occurred in year 2017 in the month of March with value of 0.3380 and the lowest occurred in year 2013 in months of January with value of 0.0548 respectively. For the duration function *T(V)*, the highest value occurs in year 2013, in the month of January with value of 8437.95 while the lowest value occur in year 2014 month of February with value of 147.30.

Table 9. *Maiduguri power and energy density wind speed for year 2013.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.1	6.50	4.83	0.0548	8437.95
Feb	3.1	18.17	13.52	0.1129	7786.19
Mar	5.6	107.13	79.70	0.2169	3742.28
Apr	5.9	125.28	90.20	0.2084	3182.39
May	6.2	145.38	108.16	0.1950	2651.36
Jun	6.9	200.39	144.28	0.1499	1586.34
Jul	6.7	183.47	136.50	0.1642	1861.57
Aug	4.9	71.77	53.39	0.2154	5082.87
Sep	4.3	48.50	34.92	0.1923	6162.15
Oct	4.3	48.50	36.08	0.1923	6162.15
Nov	4.6	59.37	42.75	0.2061	5637.77
Dec	8.5	374.62	278.75	0.0437	283.51

Table 10. *Maiduguri power and energy density wind speed for year 2014.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	4.9	71.77	53.39	0.2789	4977.27
Feb	7.8	289.48	201.48	0.0375	147.30
Mar	6.2	145.38	108.16	0.2267	1880.98
Apr	5.8	119.02	85.69	0.2668	2750.62
May	4.3	48.50	36.08	0.2320	6333.77
Jun	6.1	138.46	99.69	0.2383	2084.69
Jul	6.3	152.53	113.48	0.2143	1687.79
Aug	4.3	48.50	36.08	0.2320	6333.77
Sep	4.0	39.04	28.11	0.1998	6901.83
Oct	3.9	36.19	26.92	0.1885	7071.92
Nov	3.2	19.99	14.39	0.1119	7987.94
Dec	4.3	48.50	36.08	0.2320	6333.77

Table 11. *Maiduguri power and energy density wind speed for year 2015.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	4.5	55.59	41.36	0.2095	4149.17
Feb	6.6	175.37	117.85	0.1053	1102.19
Mar	6.9	200.39	149.09	0.0874	849.34
Apr	5.7	112.97	81.34	0.1612	2154.33
May	5.9	125.28	93.21	0.1492	1882.33
Jun	5.8	119.02	85.69	0.1553	2015.69
Jul	5.3	90.81	67.57	0.1829	2758.35
Aug	3.5	26.15	19.46	0.1986	5975.11
Sep	2.3	7.42	5.34	0.1278	7730.47
Oct	2.2	6.5	4.83	0.1203	7839.16
Nov	2.7	12.01	8.65	0.1561	7232.23
Dec	2.1	5.65	4.20	0.1128	7941.30

Table 12. *Maiduguri power and energy density wind speed for year 2016.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	2.5	9.53	7.09	0.1099	8153.16
Feb	2.3	7.42	5.17	0.0866	8324.88
Mar	3.0	16.47	12.25	0.1790	7524.10
Apr	5.1	80.92	58.26	0.2824	2275.87
May	5.5	101.49	75.51	0.2187	1393.01
Jun	4.5	55.59	40.02	0.3290	3914.63
Jul	3.5	26.15	19.46	0.2528	6577.80
Aug	5.4	96.05	71.46	0.2361	1592.23
Sep	4.8	67.46	48.57	0.3149	3064.34
Oct	4.5	55.59	41.36	0.3290	3914.63
Nov	5.1	80.92	58.26	0.2824	2275.87
Dec	5.4	96.05	71.46	0.2361	1592.23

Table 13. *Maiduguri power and energy density wind speed for year 2017.*

Months	Wind speed (m/s)	Power density (W/m^2)	Energy density (kWh/m^2)	F(V)	T(V)
Jan	4.7	63.33	47.12	0.2857	6219.38
Feb	5.0	76.25	51.24	0.3285	5409.99
Mar	5.9	125.28	93.21	0.3380	2634.55
Apr	6.1	138.46	99.69	0.3083	2066.84
May	6.1	138.46	103.01	0.3083	2066.84
Jun	6.8	191.80	138.10	0.1538	631.23
Jul	6.9	200.39	149.09	0.1318	506.22
Aug	4.9	71.77	53.39	0.3155	5692.20
Sep	4.8	67.46	48.57	0.3011	5962.36
Oct	3.5	26.15	19.46	0.0992	8189.75
Nov	4.7	63.33	45.60	0.2856	6219.38
Dec	3.8	33.47	24.90	0.1384	7879.14

5. Conclusion

In this study, wind speed data for Bauchi and Maiduguri North East, Nigeria have been statistically analyzed. The Weibull probability distribution function have been derived from the wind speed data obtained from Nigeria metrological station, Abuja for the period of (2013-2017) and the probability function *F(V)* and duration function *T(V)* were evaluated.

It is quite evident that the wind energy in Maiduguri North East, Nigeria can provide up a maximum power and energy density of 374.62W/m^2 and 278.72kWh/m^2 respectively, which is significant in generating electricity since the power density is above 100W/m^2 which is classified as class I while for Bauchi the maximum power and energy density was obtained as 33.47W/m^2 and 24.90kWh/m^2 which can be used for battery charging, water pumping and smaller electrical appliances since the power density is less than 100W/m^2 which is classified as class II.

It can be concluded that the Weibull distribution is suitable to represent the actual probability of wind speed data for the North East region of Nigeria.

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References

[1] E. K. Akinpar, S. Akinpar, "Determination of the wind energy potential for Maden, Turkey", Energy Conversion and Management, Vol. 45 (18) pp. 2901-2914 (2004).

[2] A. S. Ahmed, R. Shata Hanitsch, "Evaluation of wind energy potential and electricity generation on the coast of Mediterranean Sea Egypt", Renewable Energy, Vol. 31 (7) pp. 183-202 (2006).

[3] A. N Celik, "On the distributional parameters used in assessment of the suitability of wind speed probability density functions", Energy Conversion and Management, Vol. 45 (13) pp. 1735-1747 (2004).

[4] N. Emmani, H. Behbahani-Nia, "The statistical evaluation of wind speed and power density in the Firouzkouh region in Iran". Taylor and Francis, Vol. 34 (12) pp. 1076-1083 (2013).

[5] A. N. Celik, "A statistical analysis of wind power density based on the Weibull and Rayleigh Models at the southern region of Turkey". Renewable Energy, Vol. 29 (5) pp. 593-604 (2004).

[6] M. J. Stevens, P. T. Smulders, "The estimation of the parameters of the Weibull wind speed distribution for wind energy utilization purposes" Wind Engineering, Vol. 3 (2) pp. 132-84 (1979).

[7] S. A. Ahmed "Investigation of wind characteristics and wind energy potential at Ras Ghareb, Egypt" Renewable and Sustainable, Energy Reviews, Vol. 5 (2) pp. 2750-2755 (2003).

[8] Z. Durisic, J. Mikulovic, “Assessment of the wind energy resource in the south Banat region Serbia”, Renewable and Sustainable Energy Reviews, Vol. 16 (4) pp. 3014-3023 (2012).

[9] M. A Alsaad, “Wind energy potential in selected areas of Jordan”, Energy Conversion and Management, Vol. 65 (10) pp. 704-708 (2013).

[10] J. O. Ojosu, R. I. Salawu, “A statistical analysis of wind energy potential for power generation in Nigeria”, Solar and Wind Technology, Vol. 7 (2) pp. 155-167 (1990).

[11] K. Ulgen, A. Hepbasli, “Determination of Weibull parameter for wind energy analysis of Izmir, Turkey”, International Journal of Energy Research, Vol. 26 (4) pp. 495-506 (2002).

[12] D. Watts, D. Jara, “Statistical analysis of wind energy in Chile”, Renewable Energy, Vol. 36 (7) pp. 1603-1613 (2011).

[13] A. Ahmed “Estimation of wind energy potential for two locations in north west region of Nigeria”, International Journal of Advanced Trends in Engineering, Science and Technology, Vol 1 (5) pp. 6-10 (2018).

[14] A. Ahmed “Investigation of wind energy resource on the basis of Weibull and Rayleigh models in north eastern and western Nigeria” American Journal of Aerospace Engineering, Vol 1 (6) pp. 27-32 (2019).