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Assessment of Wind Energy Potential in Nigeria

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Abstract

In this paper, the assessment of wind energy potential for Nigeria is carried out. Average monthly wind speed data is obtained from NASA meteorological website for a period of forty (40) years (1981 - 2021) for forty-seven (47) study locations. The average annual and monthly wind speed estimated for the study locations varies from 1.38 - 3.89 m/s and 1.15 - 5.05 m/s, respectively, while, the overall average annual wind speed is estimated at 2.74 m/s and the average annual minimum and maximum wind speed ranges from 1.38 – 3.89 m/s. Wind speed is observed to increase from the southern to the northern region of Nigeria. Consequently, the prospect of the harvest of more wind energy in the northern region. Thirteen (13) study locations are identified as possible sites for the harvest of wind energy. Among these cities; Damaturu, Gasau, Katsina and Nguru are identified as possible locations for large harvest of wind energy in Nigeria.

Keywords: Electricity**,** Nigeria**,** renewable energy**,** wind energy**,** wind speed data

1. Introduction

The availability of energy sources, its efficient conversion and distribution is a vital recipe for economic growth, social development and political stability in any given society. Energy sufficiency is one of the major indicators of the level of prosperity of the citizens in a nation.

In spite of the huge capital investment claimed to have been made by various Nigerian governments into the power industry and the breath taking sources of energy generation (hydro-power, steam power (coal), gas power, solar energy, etc.) that abound within the country. Low generation and supply of electricity is still bedeviling the Nigerian citizens. Presently, in Nigeria, 92 million people are estimated to be living without electricity, while, where there is access to electricity, it is commonly characterized with erratic supply [1]. Though, Nigeria is African's largest crude oil producer and world ninth largest exporter [2]. The persistent unavailability of electric supply from national grid to meet the need of Nigerian growing population has apparently affected the economy and slowed down the growth of rural and sub-rural settlements [3]. This is also responsible for the massive migration of the youth population from rural communities to urban areas for better economic opportunities. Ref. [4], aptly reported that sustainable energy transition in rural areas will save households in Nigeria $60 annually. Therefore, there is need to access the availability of other forms of energy sources especially the renewable energy for generation of electricity.

For the last decade, renewable energy resources have experienced rapid growth. Among the renewable energy sources, wind energy is free, clean and inexhaustible. Wind energy conversion systems (WECS) are being considered by most countries as alternative energy source to further reduce the dependence on fossil fuel. This is necessary considering the rapid global depletion of crude oil, volatile prices and environmental effects associated with fossil fuels [5]. The energy of the wind can be harnessed to provide power for many useful tasks such as generation of electricity for domestic usage. Wind energy systems, generate power near load center and thereby eliminate energy losses associated with transmission network [6]. Although, this source of energy is not continuously available. The common environmental effects of wind energy system are visual impact, noise and wild life impacts [7].

Wind turbines are usually classified based on the axis about which the turbines rotate; Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). However, wind turbines that have rotor swept area of 200 m^2 or less [8] and a power rating range of 1 kW to 100 kW are classified as small wind turbine [9]. This type of wind turbines is supplied as standalone unit and install close to the place of use which may not be a windy location unlike large wind turbines in a wind farm. Small wind turbines can be used to power communities, homes, business, schools, clinics, farms and miscellaneous equipment to support unattended operation in developed and developing countries [10]. The application of small wind turbine in Nigeria, mostly in the rural communities can reduce the dwindling over-stretched grid connected electricity

Several researchers have carried out studies on wind energy potential for different locations in Nigeria. Among these studies, only Ref [11 - 13] carried out an extensive assessment of wind energy potential in Nigeria. Ref [11] used wind speed data measured from 1951 - 1975 by Nigeria Meteorological office that ranged between twelve and twenty-five years to survey wind energy potential in Nigeria for twenty-two cities. While, Ref [12] studied wind energy potential for thirty locations of Nigeria with the use of wind speed data obtained from the same source as Ref [11] for a period that range from eight to twenty-two years. In a separate study carried out by Ojosu and Salawu [13], statistical analysis method and cost benefit of the uses of wind energy for generation of electricity was carried out with the use of 15 years of wind data for twelve study locations in Nigeria. In this study, the assessment of wind speed and its associated characteristics for several study locations is carried out as to determine the visibility of the harvest of wind energy in Nigeria for electricity generation in the rural communities by the use of small WECS.

2.0 Material

Nigeria is one of the countries in the West Coast of African and lies between latitude 3°15' to 13°30'N and Longitude 2°59' to 15°00' [14]. It is bounded by Niger Republic to the north, by the Republic of Chad and Cameroun to the east, by Benin Republic on the west and Bright of Biafra on the south. The country is commonly divided into Northern and Southern regions with cities at the middle being equidistance from the influence of the Sahara Desert and Bright of Biafra called middle belt. In Nigeria, the seasonal period is commonly divided into two: Dry season which usually commence from November and end in April when cold dry and dusty north-east trade winds from Sahara Desert keep the atmosphere heavily overcast by dust for many days with characteristic hazy weather conditions and rainy (wet) seasons that start from May to October during which each part of the country experience different levels of rainfall. In this study, the average monthly wind speed data from 1981 - 2021 (40 years) for fourth-seven (47) study locations are sourced from National Aeronautics and Space Administration (NASA) website [15]. These study locations have been chosen to cover all the major cities in Nigeria as the values of the wind data can be applicable to nearby communities.

3.0 Methodology

3.1 Wind Speed Data

The available wind speed data of a site is the first parameter to be considered in the harvest of wind energy source in any location. Values of the monthly, average monthly, overall average monthly maximum and minimum and average annual maximum and minimum wind speed from 1981 - 2021 for forty-seven (47) study locations in Nigeria at wind speed of 10 m/s is presented in Table 1.

Table 1 average monthly wind speed for study locations at 10m/s from 1981-2021 (NASA)

Locations	*Lat. (°N)*	*Long. (°E)*	*Elev. (m)*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Ave*
Abakaliki	6.33	8.12	88.44	2.77	2.54	2.7	2.84	2.67	2.88	3.16	3.21	2.76	2.26	1.84	2.4	2.67
Abeokuta	7.15	3.37	80.92	2	2.23	2.44	2.44	2.26	2.42	2.84	2.94	2.45	1.99	1.65	1.73	2.28
Abuja	9.08	7.4	406.97	2.9	2.75	2.56	2.48	2.2	2.19	2.42	2.45	1.99	1.77	2.12	2.67	2.37
Ado-Ekiti	7.62	5.24	379.21	2.14	2.2	2.39	2.46	2.23	2.28	2.62	2.68	2.11	1.75	1.64	1.88	2.2
Akure	7.26	5.21	379.21	2.14	2.2	2.39	2.46	2.23	2.28	2.62	2.68	2.11	1.75	1.64	1.88	2.2
Asaba	6.21	6.7	103.94	2.53	2.43	2.56	2.64	2.5	2.79	3.19	3.28	2.81	2.3	1.86	2.14	2.59
Awka	6.23	7.09	103.94	2.53	2.43	2.56	2.64	2.5	2.79	3.19	3.28	2.81	2.3	1.86	2.14	2.59
Bauchi	10.31	9.83	518.79	4.11	4.18	3.83	3.47	3.28	3.01	2.59	2.3	2.3	2.63	3.28	3.82	3.23
Benin-City	6.34	5.61	93.92	1.76	1.71	1.74	1.74	1.64	1.8	2.06	2.13	1.83	1.5	1.29	1.5	1.73
Bida	9.08	6.01	126.59	2.26	2.21	2.23	2.35	2.17	2.14	2.34	2.36	1.89	1.66	1.71	2.05	2.11
Birinin Kebbi	12.44	4.2	241.96	3.64	3.64	3.24	3.08	3.27	2.99	2.43	1.96	1.75	1.89	2.54	3.29	2.81
Calabar	4.98	8.35	39.48	2.08	2.25	2.38	2.43	2.41	2.72	2.99	3.07	2.76	2.39	1.97	1.88	2.45
Damaturu	11.75	11.97	402.61	4.81	4.94	4.62	4.06	3.96	3.94	3.38	2.74	2.39	2.58	3.86	4.54	3.81
Duste	11.75	9.34	465.94	3.02	3.11	3.07	2.98	2.79	2.61	2.17	1.8	1.77	1.99	2.39	2.78	2.53
Enugu	6.46	7.55	151.33	2.78	2.61	2.74	2.85	2.67	2.91	3.28	3.32	2.81	2.3	1.88	2.37	2.71
Gombe	10.28	11.18	381.62	4.47	4.62	4.12	4	4.06	3.76	3.27	2.76	2.36	2.32	3.08	4.01	3.56
Gusau	12.17	6.68	529.87	4.92	4.82	4.28	3.84	3.61	3.51	3.08	2.61	2.31	2.68	3.74	4.53	3.66
Ibadan	7.38	3.95	188.89	2.17	2.31	2.6	2.71	2.52	2.65	3.08	3.16	2.53	2.03	1.71	1.89	2.45
Ijebu-Ode	6.83	3.92	90.82	1.77	1.94	2.12	2.14	2	2.17	2.54	2.63	2.2	1.78	1.46	1.54	2.02
Ikeja	6.61	3.36	25.49	2.48	2.9	3.24	3.21	2.98	3.36	3.92	4	3.54	2.88	2.29	2.15	3.08
Ikom	5.97	8.73	116.85	2.16	2.31	2.51	2.58	2.48	2.74	3.01	3.12	2.73	2.29	1.82	1.9	2.47
Ilorin	8.48	4.55	344.93	2.72	2.96	3.51	3.84	3.4	3.21	3.47	3.51	2.62	2.25	2.14	2.4	3
Jalingo	8.9	11.38	251.79	3.51	3.5	3.61	4.1	3.67	3.49	3.45	3.16	2.4	2.08	2.32	3.13	3.2
Jos	9.9	8.86	980.85	4.3	4.2	3.82	3.43	2.89	2.68	2.54	2.49	2.41	2.71	3.45	4.06	3.24
Kaduna	10.52	7.42	623.54	4.77	4.49	3.67	3.18	2.85	2.73	2.61	2.47	2.09	2.23	3.46	4.43	3.24
Kano	12.01	8.6	442.08	2.84	2.89	2.78	2.64	2.51	2.39	1.94	1.52	1.44	1.69	2.16	2.58	2.28
Katsina	12.97	7.63	474.54	5.05	4.93	4.54	4.03	3.77	3.85	3.46	2.72	2.45	2.94	4.02	4.7	3.86
Lafia	7.81	6.74	167.21	2.38	2.54	3.01	3.23	2.82	2.71	2.88	2.84	2.32	2.03	1.89	2.12	2.57
Lokoja	7.81	6.74	167.21	2.38	2.54	3.01	3.23	2.82	2.71	2.88	2.84	2.32	2.03	1.89	2.12	2.57
Maidugri	11.84	13.16	318.25	4.57	4.78	4.65	4	3.77	3.98	3.64	2.88	2.57	2.79	3.91	4.34	3.82
Makurdi	7.74	5.54	373.17	2.53	2.65	3.01	3.16	2.83	2.82	3.14	3.19	2.52	2.12	1.97	2.23	2.68

Mbaise	5.54	7.29	92.75	2.34	2.28	2.35	2.41	2.33	2.6	2.92	3.02	2.65	2.21	1.79	1.98	2.41
Minna	7.61	8.09	149.83	3.02	3	3.3	3.42	2.98	2.97	3.18	3.14	2.57	2.17	1.98	2.59	2.86
Nguru	12.88	10.46	345.61	4.94	4.95	4.75	4.07	3.57	3.62	3.39	2.7	2.52	3.1	4.33	4.75	3.89
Onitsha	6.14	6.8	103.94	2.53	2.43	2.56	2.64	2.5	2.79	3.19	3.28	2.81	2.3	1.86	2.14	2.59
Oshogbo	7.79	4.55	337.39	2.43	2.6	3.03	3.23	2.91	2.9	3.31	3.38	2.55	2.06	1.89	2.13	2.7
Owerri	5.47	7.02	62.54	2.26	2.18	2.22	2.25	2.16	2.44	2.77	2.87	2.52	2.1	1.72	1.9	2.28
Port-Harcourt	4.34	7.05	6.8	1.65	1.77	1.76	1.66	1.62	1.86	2.17	2.29	2.03	1.71	1.5	1.45	1.79
Potiskum	11.7	11.09	411.77	4.36	4.47	4.13	3.56	3.43	3.33	2.8	2.27	2.06	2.25	3.38	4.06	3.34
Sokoto	13.01	5.25	276.18	4.51	4.42	3.94	3.59	3.8	3.71	3.12	2.44	2.19	2.38	3.3	4.14	3.46
Umuahia	5.53	7.5	92.75	2.34	2.28	2.35	2.41	2.33	2.6	2.92	3.02	2.65	2.21	1.79	1.98	2.41
Uyo	5.04	7.92	39.48	2.08	2.25	2.38	2.43	2.41	2.72	2.99	3.07	2.76	2.39	1.97	1.88	2.45
Warri	5.55	5.57	9.6	1.36	1.41	1.4	1.3	1.2	1.36	1.64	1.79	1.58	1.28	1.07	1.15	1.38
Yelwa	10.84	4.75	257.74	3.94	3.89	3.36	3.35	3.15	2.9	2.65	2.48	2.07	2.05	2.81	3.54	3.01
Yenegoa	4.93	6.28	17.26	2.08	2.15	2.23	2.19	2.09	2.37	2.72	2.87	2.56	2.14	1.78	1.77	2.25
Yola	9.04	12.5	344.13	2.48	2.82	3.36	3.55	2.94	2.68	2.59	2.36	1.91	1.91	2.05	2.21	2.57
Zaria	11.13	7.73	646.9	4.86	4.67	3.97	3.5	3.23	3.11	2.82	2.53	2.2	2.39	3.51	4.45	3.43
			Ave	3.01	3.05	3.04	2.97	2.77	2.82	2.88	2.76	2.36	2.18	2.33	2.71	2.74
			Max	5.05	4.95	4.75	4.1	4.06	3.98	3.92	4	3.54	3.1	4.33	4.75	3.89
			Min	1.36	1.41	1.4	1.3	1.2	1.36	1.64	1.52	1.44	1.28	1.07	1.15	1.38

It is necessary to determine the adjusted average wind speeds at a raise wind turbine hub height. This is essential as wind speed significantly increases with height above the earth surface with respect to terrain roughness. To access stronger and less turbulent wind energy that occur at greater height, the global trend is to employ the use of long tower to raise the wind turbine. Actual wind turbine hub height is usually in the ranges of 50 m to 65 m [16]. The estimation of wind speed at different heights from that at which it is measured at the metrological station is carried out by the use of the power law equation given as [17].

$$\frac{v_1}{v_2} = \left(\frac{H_1}{H_2}\right)^{\alpha} \quad (1)$$

Where v_2 is the mean wind speed at heights H_2 recorded at the station, v_1 is the mean speed at the wind turbine hub height H_1 and α is the wind shear power index and its value is estimated from [18]

$$\alpha = (0.37 - 0.008\, In\, v_2)/\left(1.0 - 0.008\, In\, \left(\frac{H_2}{10}\right)\right) \quad (2)$$

The value of the wind shear power index depends on specific site-characteristics such as roughness of the terrain, the time of the day, the wind stability and speed intensity [11, 17]. For big cities that have land with big and non-uniform obstacles, the value of wind shear power index ranges from 0.28 - 0.40 [19]. The lowest wind speed value at which small wind turbine produce a net positive power output is approximately 3 – 4 m/s [20]. For optimum wind energy site selection which is aimed at extraction of maximum wind power, average annual wind speed of 3 m/s is used as the lower limit in this study.

3.2 Turbulence Intensity

The turbulence intensity is an important characteristic for the selection of wind energy source site. Its values represent the disturbances or irregularities in the wind speed, direction and vertical components [16]. High value of turbulence intensity causes extreme loading on wind turbines components, thus, a reduction in the power output. The values of turbulence intensity frequency ranges from 0.1 - 0.4 and it is given as [21]

$$TI = \frac{\sigma}{\bar{U}} \quad (3)$$

Where σ is the standard deviation. It is estimated from [22]

$$\sigma = \left[\frac{1}{N-1}\sum_{i=1}^{N}(u_i - \bar{U})^1\right]^{1/2} \quad (4)$$

Where N is the total number of months of data available, u_i is the individual average monthly wind speed and $\bar{U}$ is the annual average wind speed. The annual average wind speed is estimated from [22].

$$\bar{U} = \frac{1}{N}\sum_{i=1}^{N} u_i \quad (5)$$

3.3 Wind Power Density Estimate

The wind power density is a more viable parameter for the selection of wind energy site than the wind speed. Its value is a combination of the effects of a site's wind speed distribution, air density and wind speed. The available power flux possessed by a stream of flowing wind across a cross-sectional area is

$$P_a = \frac{1}{2}\dot{m}v^2 \quad (6)$$

Where v is the wind velocity (m/s) and $\dot{m}$ is the mass flow rate estimate from

$$\dot{m} = \rho A v \quad (7)$$

Where ρ is the site air density (kg/m^3) and A is cross sectional area of turbine blade (m^2). Hence, the available power in the wind stream can be written as

$$P_a = \frac{1}{2}\rho A v^3 \quad (8)$$

Since wind turbines cannot completely extract this available power from the wind, the maximum extractable power is 0.593 of the available power. This power coefficient is called the Betz limit. Thus, the maximum power can be written as

$$P_m = 0.297\rho A v^3 \quad (9)$$

The maximum power per unit cross sectional area (W/m^2) can be expressed by taking site air density equal to 1.225 kg/m^3 for all the study locations as

$$\frac{P_m}{A} = 0.364v^3 \quad (10)$$

4.0 Results and Discussion

The overall average monthly maximum and minimum wind speed for the study locations are shown in Figure 1. Figures 2, 3, 4 and 5, shows the variation of average monthly wind speed distribution for latitudes 4.34 – 4.98ºN, 5.04 – 5.97ºN, 6.14 - 6.83ºN and 7.15 - 7.81ºN, respectively, while, Figures 6, 7, 8 and 9 shows those of latitude 8.48 - 9.9ºN, 10.28 - 10.84ºN, 11.13 - 11.84ºN and 12.01 - 13.01ºN, respectively.

It is observed from Table 1 that the overall average annual wind speed ranges from 1.38 – 3.89 m/s, with an overall annual average wind speed of 2.74 m/s. It is seen in Figure 1 that the overall average monthly wind speed varies from 1.15 – 5.05 m/s.

Figures 2, 3, and 4 are observed to consist of study locations in the southern part of Nigeria within the latitude of 4.34 – 6.83ºN. It is observed that the curves of this study locations followed the same line pattern. August is seen to record the highest level of wind speed for all the study locations within these latitudes. In Nigeria, August is one of the months of the rain season and usually characterized with the highest level of rainfall. The average monthly and annual wind speed within this latitude ranges from 1.07 – 4.00 m/s and 1.38 – 3.08 m/s, respectively. Among these study locations only Ikeja recorded the acceptable wind turbine cut-in speed of 3.08 m/s. This is of interest as Ikaja is a built-up area with lots of high rise buildings.

Figures 5 and 6 is observed to consist of admixture of both southern and northern cities within the latitude of 7.15 – 9.9ºN. Thus, this region is classified as middle belt. The range of average monthly and annual wind speed in this region is 1.64 – 4.3 m/s and 2.11 - 3.24 m/s, respectively. Within the mid belt region, only llorin recorded wind turbine cut-in speed of 3.00 m/s. The wind distribution curves in this region is observed to follow almost similar curve pattern with a relatively constant level from January to August and a notable depression from September through November before a raise in December.

Figures 7, 8 and 9 consist of study locations in the northern region of Nigeria within latitude 10.28 – 13.01ºN. The curves are observed to follow almost the same pattern with lowest depression in September for the study locations in this region. In Nigeria, September is among the months of the rainy season. While a relatively large increase in average monthly wind speed is observed during December, January and February. These are months of dry season in Nigeria. During this months, the Harmattan period has set in, when cold and dust-laden north-east trade winds from the Sahara Desert transverse into the country through the northern region. This reveals that in September WECS will produce less power output in this region. Among the study locations in the northern region, Kano recorded the lowest minimum and maximum average monthly wind speed of 1.44 and 2.57 m/s, respectively in September and the lowest annual average wind speed of 2.28 m/s. This reveal that within this region Kano is the worst location and September is the worst month for the harvest of wind energy. This is expected as the city of Kano is a built-up area with relative good numbers of high rise building. The average monthly and annual wind speed in the northern region varies from 1.44 – 5.05 m/s and 2.28 – 3.89 m/s, respectively. In this region, the following cities recorded wind turbine cut-in speed above 3.00 m/s; Zaria, Potiskum, Damaturu, Gombe, Bauch, Kadunna, Yelwa, Gusau, Nguru, Katsina and Sokoto.

From the forgoing wind speed data analysis, it is observed that more wind energy harvest is possible in the northern region of Nigeria as compared to the southern part annually. This may be attributed to high solar radiation intensity in the northern part of Nigeria. This translates to more electricity generation in the northern region for the rural communities through the use of small wind turbines.

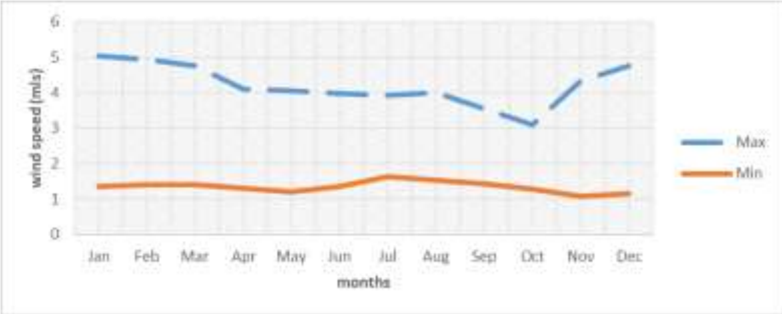

Fig. 1-month average maximum and minimum wind speed for the study locations

Fig. 2 variation of average monthly wind speed distribution for latitude 4.34 - 4.98ºN

Fig. 3 variation of average monthly wind speed distribution for latitude 5.04 - 5.97ºN

Fig. 4 variation of average monthly wind speed distribution for latitude 6.14 - 6.83ºN

Fig. 5 variation of average monthly wind speed distribution for latitude 7.15 - 7.81ºN

Fig. 6 variation of average monthly wind speed distribution for latitude 8.48 – 9.9ºN

Fig. 7 variation of average monthly wind speed distribution for latitude 10.28 – 10.84ºN

Fig. 8 variation of average monthly wind speed distribution for latitude 11.13 – 11.84ºN

Fig. 9 variation of average monthly wind speed distribution for latitude 12.01 – 13.01ºN

Table 2 Study locations with average annual wind speed ≥ 3

Locations	*Average Annual*	α	σ	TI	V_1@ 50 m	$\frac{P_m}{A}$ @ 50 m	V_1@ 65 m	$\frac{P_m}{A}$@ 65 m
Bauchi	3.23	0.36	0.67	0.21	5.77	69.97	6.34	92.93
Damaturu	3.81	0.36	0.88	0.23	6.79	114.10	7.46	151.40
Gombe	3.56	0.36	0.79	0.22	6.35	93.33	6.98	123.88
Gusau	3.66	0.36	0.98	0.27	6.53	101.31	7.17	134.45
Ikeja	3.08	0.36	0.59	0.19	5.51	60.78	6.05	80.75
Ilorin	3.00	0.36	0.57	0.19	5.37	56.22	5.90	74.71
Kaduna	3.24	0.36	0.92	0.28	5.79	70.61	6.36	93.79
Katisna	3.86	0.36	0.86	0.22	6.88	118.59	7.56	157.34
Nguru	3.89	0.37	0.86	0.22	6.93	121.34	7.62	160.98
Potiskum	3.34	0.36	0.84	0.25	5.97	77.26	6.56	102.60
Sokoto	3.46	0.36	0.79	0.22	6.18	85.78	6.79	113.88
Yelwa	3.01	0.36	0.67	0.22	5.38	56.78	5.92	75.45
Zaria	3.42	0.36	0.87	0.26	6.11	82.87	6.71	110.03

Table 2 presents study locations that have average annual wind speed ≥ 3. Among these study loactions, Ikeja and IIorin are located in the southern and middle belt region, respectively, while the remaining eleven cities are found in the northern region. The average annual wind speed varies from 3.0 - 3.89 m/s for these study locations. The wind shear power for these study location ranges from 0.36 - 0.37. This is expected as these cities are built-up areas. Thus, the building will cause obstruction to flow of wind. The values of standard deviation estimated for these set of study location ranges from 0.57 - 098. Turbulence intensity with large amplitude of gust speed in these study locations will be minimal. This is so because the turbulence intensity obtained for the study locations ranges from 0.19 - 0.28 which is an acceptable range for build-up areas. It is also observed that as the height of wind turbine hub increases, wind speed increase for the study locations. This have also resulted in an increase in the power density for the study locations. The choice of a higher tower for installation of WECS for generation of more electricity will be in consideration of available financial budget. The average annual wind speed and power density is observed to be higher in Damaturu, Gasau, Katsina and Nguru. Thus, the possibility of the harvest of more wind energy source in these Nigerian cities.

5.0 Conclusion

The result presented in this study reveals that in Nigeria, wind speed is relatively small but not negligible, mostly, in the northern region of Nigeria. Wind speed is observed to increase from the southern to the northern region. In the northern region, within the latitudes of 10.28 – 13.01ºN, harvest of wind energy has a good prospect mostly in Damaturu, Gusau, Katsina and Nguru. The harness of wind energy in northern Nigeria can be profitably useful for small scale applications such as individual home electrification and/or agricultural purpose such as water pumping for irrigation and provision of water for animals.

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