Econometric Analysis of Wind Power Generation in Five Selected Cities of South Western Nigeria

Nze-Esiaga Nnawuike, Okogbue Emmanuel C

Abstract— This study analysed the econometrics of wind electricity generation at five selected cities of south western Nigeria which are Abeokuta, Akure, Ikeja, Oshogbo and Ibadan using three wind turbine models of GE 1.5xle, AV 927 and AV 928. 51 years monthly mean wind speed data at 10m height obtained from the Nigeria Meteorological Agency. Results showed that potential exist for electricity generation of between 0.3 and 1.6GWh per month and between 1.5 and 16.8GWh per annum. It was also discovered that better potential exist for wind power generation in the wet season (0.3 - 1.7GWh) than in the dry season (0.2 – 1.5GWh). The minimum cost of generating 1kWh of wind electricity with the turbine models at the cities was estimated to be €0.01 with a maximum cost of €0.14.

Index Terms— Average wind speed, Cost, Electricity, South Western Nigeria, Turbine Model, Wind power density, Weibull parameter.

1.0 INTRODUCTION

THE quest to reduce environmental impacts of conventional energy resources and, more importantly, to meet the growing energy demand of the global population had motivated considerable research attention in a wide range of environmental and engineering application of renewable form of energy. It is recognized that wind energy, as a renewable energy source, has stood out as the most valuable and promising choice. Wind energy by nature is clean, abundant, affordable, inexhaustible and environmentally preferable. Due to its many advantages, wind energy has also become the fastest growing renewable source of energy in both developed and developing countries. For example, wind energy is widely used to produce electricity in countries like Denmark, Spain, Germany, USA, China and India. Interestingly, the global cumulative installed capacity of wind power had increased sharply from 6,100 MW in 1996 to about 237,669 MW in 2011 [1]. Africa, for example, Egypt, Morocco and Tunisia are the leading countries with installed capacities of 550, 291 and 114 MW, respectively, at the end of 2011 [1]. The increasing energy demand, the rapidly depleting fossil fuel reserves and the environmental problems associated with the use of fossil fuel have necessitated the development of alternative energy sources like wind energy for electricity generation in Nigeria. It is reported that the electricity production in Nigeria as of the end of 2010 is less than 4,000 MW due to fluctuations in the availability and maintenance of production sources, leading to a shortfall in supply [2].

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Although several studies have been performed to investigate the economics of generating electricity from wind across Nigeria, much attention has not been given to sites in the south-west region. The focus of this study is, therefore, to evaluate the economic viability of generating electricity from wind energy in five selected locations (Abeokuta, Akure, Ibadan, Ikeja and Oshogbo) in the south-west region. It is the authors' view that this information will be helpful to the government and any organization in making an informed decision with regard to investment in wind energy resource in this part of Nigeria.

2.0 MATERIALS AND METHODS

Fifty one years (1961 – 2011) monthly mean wind speed data measured over the stations (indicated in Table 1) employed for this study were obtained from the Nigeria meteorological department Agency. The data were measured continuously using three-cup generator anemometer at a height of 10 m above sea level but for purposes of this study wind at 80 m height was deduced (from Eq. 1.) because the turbine hub heights are at 80 m. The data were then analyzed to determine the monthly, seasonal and yearly wind resource potentials for power generation.

Table 1: Details of the selected cities

Station	Latitude (N)	Longitude (E)	Altitude (m)	Air Density (kg m^{-3})

ABEOKUTA	7.10	3.20	104.00	1.21
AKURE	7.17	5.18	375.00	1.18
IBADAN	7.26	3.54	227.20	1.20
IKEJA	6.35	3.20	39.40	1.22
OSHOGBO	7.47	4.29	302.00	1.19

The wind profile characteristics at 80 m height were estimated from [7]:

$$V_{ref} = V_{10}\left(\frac{h_{ref}}{h_{10}}\right)^{\alpha} = \left(\frac{80}{10}\right)^{\alpha} = V_{10}(8)^{\alpha} = V_{80} \qquad (1)$$

where: $V_{ref} = V_{80}$= wind speed at reference height of 80 m, V_{10} = wind speed at 10 m height, h_{ref} = reference height = 80 m, h_{10} = 10 m height, α = roughness factor for the sites. This was taken to be 0.3 according to [8], for small towns. With the wind speeds at 80 m height, the Weibull parameters for analyses at the new height were evaluated and used with Eqs.2 – 4.

2.1 Simulating the Electrical Power Output from a Wind Turbine Model

Three practical Wind Energy Conversion Systems (WECS) (turbine models) were employed with the Weibull results obtained the wind data at 80m height. One of the models was from General Electric (model GE 1.5xle), and the remaining two were from Avantis Group (models AV 927 and AV 928). Table 2 presents the technical details of the turbine models.

Table 2: Technical Details of Wind Turbine Models [3, 4]

Wind Machine	v_c (m/s)	v_F (m/s)	v_R (m/s)	P_{eR} (kW)	Hub Height (m)	Rotor Diameter (m)
GE 1.5xle	3.5	20	11.5	1500	80	82.5
AV 928	3	25	11.6	2500	80	93.2
AV 927	3	25	13.1	3300	60-80	93.2

Eq.2 was used to simulate the magnitude of electrical output which the turbine models will generate if employed at the sites [5]:

$$P_e = \begin{cases} 0 & (v < v_c) \\ P_{eR}\,\frac{v^k - v^k{}_c}{v^k{}_R - v^k{}_c} & (v_c \le v \le v_R) \\ P_{eR} & (v_R \le v \le v_F) \\ 0 & (v > v_F) \end{cases} \qquad (2)$$

Where P_e is the magnitude of electrical output, v_c = cut in wind speed, v_R= rated wind speed, v_F = cut off wind speed and P_{eR} = rated electrical power.

A very important parameter of a practical wind turbine model is the average power output ($P_{e,ave}$) from the turbine. It can be used to determine the total energy production and by extension the total income/cost analysis and can be evaluated from [5]:

$$P_{e,ave} = P_{eR}\left\{\frac{e^{-(v_c/c)^k} - e^{-(v_R/c)^k}}{(v_R/c)^k - (v_c/c)^k} - e^{(v_F/c)^k}\right\} \qquad (3)$$

The capacity factor, CF, associated with using a wind turbine to generate electricity is given as [5, 6]:

$$CF = \left\{\frac{e^{-(V_C/c)^k} - e^{-(V_R/c)^k}}{(V_R/c)^k - (V_C/c)^k} - e^{(V_F/c)^k}\right\} \qquad (4)$$

2.2 Wind Turbine Electricity Generation and Econometrics Analyses

Installing a wind turbine at a site for electricity generation is capital intensive. More so, selecting the right wind turbine for the site will depend on the prevailing location's wind profile characteristics. Thus, preliminary analysis to determine and forecast the magnitude of electrical power that a particular wind turbine will likely generate is a necessity. This invariably involves the application of different turbine models to the site's wind profile data. In order to do this, Eqs.2 to 4 were used with the three turbine models (Table 2) to evaluate the electrical power output that can be generated from the turbine.

2.3 Econometrics Analysis of Electrical Generation from Practical Wind Turbines at the Sites

Based on the results obtained for $P_{e,ave}$, the total income/cost analysis of generating certain magnitude of electricity for a given life or period of the turbine were evaluated from [9].

$$C_{pv} = x(1 + R_c) + \frac{x}{t}R_{om}\left[\frac{1+I_R}{R_I - I_R}\right] \times \left[1 - \left(\frac{1+I_R}{1+R_I}\right)^t\right] - xR_{sc}(1 + R_c)\left(\frac{1+I_R}{1+R_I}\right)^t \qquad (5)$$

Furthermore, the specific cost per kWh of each of the three wind turbines were estimated from:

$$C_{sc/kWh} = \frac{C_{PV}}{Annual\ P_{e,ave} \times t} \qquad (6)$$

where: C_{pv} = present cost, x = turbine price, R_c = rate chargeable on turbine price to arrive at the cost for civil/structural works, R_{om} = rate chargeable on annual turbine price to arrive at the cost for Operation and Maintenance (O & M), R_I = prevailing interest rate, I_R = prevailing inflation rate, R_{sc} = rate chargeable on total investment cost, t = turbine life or period of operation of turbine availability, $C_{sc/kWh}$ = specific cost per kWh.

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Certain assumptions were made [10] in carrying out the econometrics analysis of wind electricity generation at these cities as presented in Table 3.

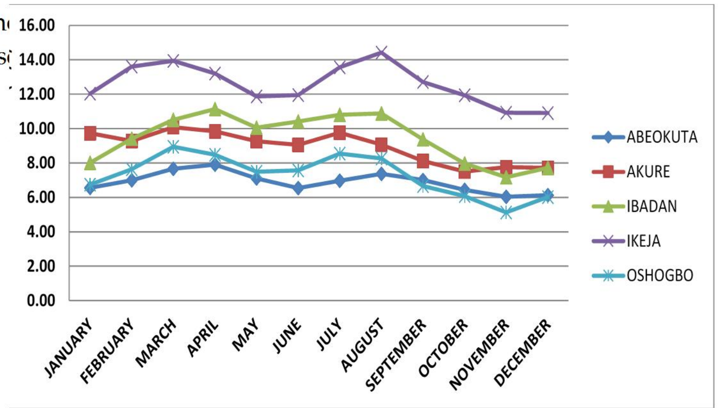

Fig. 1: Plot of 51 Years' Monthly Average Wind Speeds (at 80 m height)

Table 3: Assumptions for Cost Benefit Analysis [10]:

ITEM	Assumed value (%)
R_C (Rate chargeable on turbine price to arrive at the cost for civil/structural works)	20%
R_{OM} (Rate chargeable on annual turbine price to arrive at the cost for Operation and Maintenance)	25%
R_I (Prevailing Interest Rate)	6%
I_R (Prevailing Inflation Rate)	12%
R_{SC} (Rate Chargeable On Total Investment Cost)	10%
T (Turbine Life)	20 years

Table 4: Monthly and Seasonal Weibull Results (at 80 m height)

	ABEOKUTA			AKURE			IBADAN			IKEJA			OSHOGBO		
PERIOD	V(m/s)	C(m/s)	K(-)	V(m/s)	C(m/s)	K(-)	V(m/s)	C(m/s)	K(-)	V(m/s)	C(m/s)	K(-)	V(m/s)	C(m/s)	K(-)
JAN	6.6	7.3	3.8	9.7	10.9	3.3	8.0	8.8	4.2	12.0	13.2	4.1	6.7	7.5	3.0
FEB	7.0	7.7	4.2	9.3	10.2	3.9	9.4	10.3	4.2	13.6	15.0	4.0	7.6	8.4	4.1
MAR	7.7	8.5	3.4	10.1	11.1	3.8	10.5	11.5	4.5	13.9	15.4	3.7	8.9	9.8	4.1
APR	7.9	8.8	3.6	9.8	10.8	4.2	11.1	12.2	4.3	13.2	14.6	3.8	8.5	9.3	3.8
MAY	7.1	7.9	3.2	9.3	10.2	3.9	10.1	11.0	4.1	11.9	13.2	3.3	7.5	8.3	3.3
JUN	6.5	7.3	3.6	9.1	9.9	4.5	10.4	11.5	3.5	11.9	13.2	3.9	7.6	8.4	3.4
JUL	7.0	7.8	3.0	9.8	10.7	4.0	10.8	11.9	4.2	13.6	15.1	3.5	8.5	9.5	3.5
AUG	7.4	8.2	3.5	9.1	9.9	4.4	10.9	12.0	3.8	14.4	16.0	3.7	8.3	9.2	3.7
SEP	7.0	7.9	3.1	8.1	8.9	4.8	9.4	10.3	4.2	12.7	14.1	3.7	6.7	7.4	4.0
OCT	6.4	7.1	4.0	7.5	8.3	3.9	8.0	8.6	5.4	11.9	13.1	4.2	6.1	6.8	3.4
NOV	6.0	6.7	3.7	7.8	8.7	3.2	7.2	7.8	4.8	10.9	12.1	3.9	5.1	5.7	3.6
DEC	6.1	6.9	3.0	7.7	8.5	3.6	7.7	8.5	4.1	10.9	12.1	3.9	6.0	6.7	3.3
Dry Season	7.2	8.0	3.3	9.2	10.1	4.3	10.4	11.5	4.0	13.0	14.4	3.6	7.8	8.7	3.6
Wet Season	6.6	7.4	3.7	8.7	9.6	3.6	8.5	9.3	4.5	12.2	13.5	4.0	6.8	7.5	3.6
Whole Year	6.9	7.7	3.5	8.9	9.9	4.0	9.5	10.4	4.3	12.6	13.9	3.8	7.3	8.1	3.6

3.0 RESULTS AND DISCUSSIONS

Figs. 1 and 2 show the monthly and annual wind averages for the five cities. Clearly, the minimum and maximum monthly mean wind speed values for the five cities lay between 5.1 and 14.4 m/s respectively (Table 5). It can also be seen that the months with highest and lowest wind energy potential for Abeokuta are March and November respectively, for Akure, March and October; for Ibadan, April and November; for Ikeja, August and December; and for Oshogbo, March and November respectively.

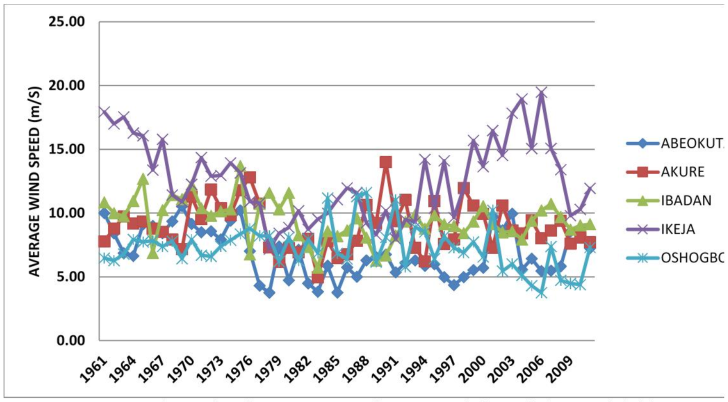

Fig. 2: Plot of 51 Years' Annual Average Wind Speeds (at 80 m height)

Figs. 1 and 2 also reveal that average monthly wind speed values for the period lay between 3.2 and 4.3 m/s for Abeokuta, 4.0 and 5.4m/s for Akure, 3.8 and 6.0m/s for Ibadan, 5.8 and 7.7m/s for Ikeja and 2.7 and 4.7m/s for Oshogbo for the period of study. The annual range for each of the stations lay between 2.0 and 5.7m/s for Abeokuta, 2.7 and 7.5 m/s for Akure, 3.1 and 7.3 for Ibadan, 3.8 and 10.4 m/s for Ikeja and between 2.0 and 6.2 m/s for Oshogbo, thus showing that Ikeja has the highest range and Oshogbo having the lowest.

Table 5: Frequency of Occurrence of Wind Speed Data

WIND SPEED	FREQUENCY OF OCCURANCE (%)				
RANGE	ABEOKUTA	AKURE	IBADAN	IKEJA	OSHOGBO
2<v≤3	2.1	0.2	0.2	0.0	2.3
3<V≤4	6.9	1.0	1.0	0.0	5.2
4<V≤5	11.1	2.6	2.8	0.3	10.0
5<V≤6	20.9	9.6	5.6	1.6	14.4
6<V≤7	16.3	10.9	7.4	2.9	15.7
7<V≤8	10.8	14.5	12.1	4.4	16.3
8<V≤9	12.6	16.7	19.3	7.5	15.0
9<V≤10	9.0	12.6	14.5	10.3	8.2
10<V≤11	6.0	10.8	12.1	10.5	4.4
11<V≤12	2.6	7.8	9.0	11.1	4.2
12<V≤13	1.1	5.6	6.5	9.2	1.6
13<V≤14	0.5	2.8	3.4	10.6	1.3
14<V≤15	0.0	2.1	1.8	5.7	1.0
15<V≤16	0.0	1.8	1.6	7.7	0.3
16<V≤17	0.0	0.8	1.3	4.7	0.0
17<V≤18	0.0	0.2	1.0	3.8	0.0
18<V≤19	0.0	0.0	0.2	4.1	0.0
19<V≤20	0.0	0.0	0.2	2.3	0.0
20<V≤21	0.0	0.0	0.2	0.7	0.0
21<V≤22	0.0	0.0	0.0	0.3	0.0
22<V≤23	0.0	0.0	0.0	1.6	0.0
23<V≤24	0.0	0.0	0.0	0.3	0.0
24<V≤25	0.0	0.0	0.0	0.3	0.0

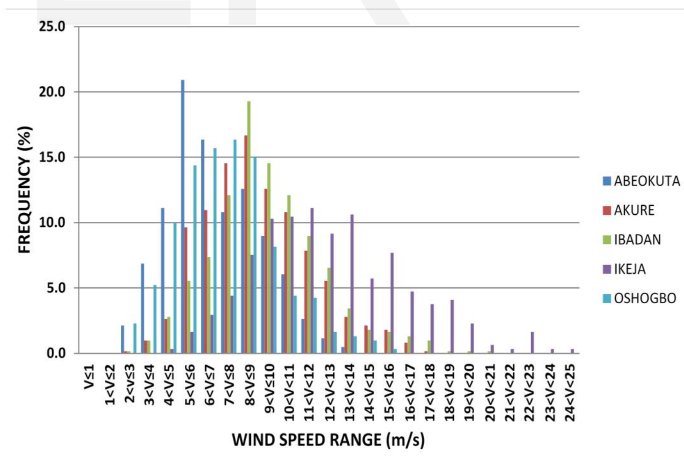

Fig 3: Plot of Frequency of occurrence of Wind Speed Data at 10 m height

It can also be seen that the frequency of occurrence of wind speed data 3.0 m/s and above for Abeokuta, Akure, Ibadan, Ikeja and Oshogbo were respectively 65.4%, 90.2%, 93%, 98.7% and 70.8. This is encouraging and means that wind turbines installed at these sites will work for most of the time since most new wind turbines are designed to operate with cut-in wind speed of 3.0 m/s [10], Tables' 6a-e and Figs. 4, 5 and 6 shows the output of simulation from the three wind turbines using Eqs. 2- 4.

Table 6a: Results from Simulating Electrical Power Output with the Wind Turbine Models for ABEOKUTA

	GE1.5xle			AV 928			AV 927		
PERIOD	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)
JAN	0.12	0.18	16.50	0.20	0.30	16.34	0.17	0.25	10.31
FEB	0.12	0.18	18.09	0.20	0.30	17.71	0.16	0.24	10.68
MAR	0.26	0.36	32.50	0.43	0.59	32.14	0.37	0.54	22.06
APR	0.27	0.37	34.38	0.44	0.61	33.89	0.38	0.55	23.06
MAY	0.22	0.31	27.97	0.37	0.52	27.89	0.34	0.49	19.49
JUN	0.13	0.20	18.07	0.21	0.32	17.97	0.18	0.28	11.62
JUL	0.22	0.31	28.03	0.37	0.52	28.04	0.34	0.49	19.89
AUG	0.23	0.32	28.82	0.37	0.53	28.52	0.32	0.47	19.26
SEP	0.21	0.30	27.37	0.34	0.49	27.32	0.31	0.45	19.07
OCT	0.10	0.16	13.92	0.17	0.26	13.76	0.14	0.21	8.45
NOV	0.86	0.13	12.24	0.14	0.22	12.26	0.12	0.18	7.77
DEC	0.14	0.21	18.94	0.24	0.35	19.19	0.22	0.32	13.33

Table 6b: Results from Simulating Electrical Power Output with the Wind Turbine Models for AKURE

	GE1.5xle			AV 928			AV 927		
PERIOD	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%
JAN	0.64	0.64	57.30	1.04	1.05	56.91	0.92	1.11	45.32
FEB	0.43	0.50	49.86	0.70	0.82	49.07	0.63	0.78	35.13
MAR	0.67	0.66	59.48	1.09	1.09	58.77	0.90	1.11	45.24
APR	0.56	0.60	56.01	0.90	0.99	55.13	0.74	0.96	40.23
MAY	0.47	0.55	49.66	0.76	0.91	48.86	0.62	0.86	34.86
JUN	0.36	0.47	43.97	0.58	0.77	42.95	0.46	0.66	24.81
JUL	0.57	0.62	55.17	0.93	1.01	54.35	0.75	0.98	39.97
AUG	0.39	0.50	44.69	0.63	0.81	43.72	0.49	0.71	28.89
SEP	0.20	0.30	27.70	0.33	0.48	26.80	0.25	0.37	15.41
OCT	0.20	0.29	26.29	0.33	0.47	25.80	0.27	0.40	16.37
NOV	0.29	0.39	35.79	0.48	0.63	35.54	0.44	0.61	25.51
DEC	0.25	0.35	31.33	0.41	0.57	30.88	0.35	0.51	20.65

Table 6c: Results from Simulating Electrical Power Output with the Wind Turbine Models for IBADAN

	GE1.5xle			AV 928			AV 927		
PERIOD	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)
JAN	0.24	0.35	30.98	0.39	0.56	30.25	0.24	0.31	18.89
FEB	0.43	0.50	49.94	0.69	0.82	49.01	0.47	0.54	33.96
MAR	0.74	0.70	62.81	1.19	1.15	61.87	0.74	0.91	46.15
APR	0.94	0.75	69.36	1.51	1.23	68.59	0.97	1.18	54.68
MAY	0.64	0.65	58.40	1.03	1.07	57.55	0.64	0.83	42.94
JUN	0.75	0.68	62.78	1.22	1.12	62.28	0.78	1.05	50.09
JUL	0.86	0.74	66.33	1.38	1.21	65.55	0.86	1.09	51.49
AUG	0.90	0.75	66.80	1.48	1.23	66.26	0.90	1.21	53.76
SEP	0.45	0.53	49.21	0.73	0.87	48.29	0.47	0.58	33.42
OCT	0.15	0.24	21.20	0.25	0.38	20.35	0.15	0.17	10.69
NOV	0.11	0.16	14.88	0.17	0.26	14.40	0.11	0.13	7.99
DEC	0.21	0.31	27.66	0.35	0.50	27.04	0.21	0.28	16.86

Table 6d: Results from Simulating Electrical Power Output with the Wind Turbine Models for IKEJA

	GE1.5xle			AV 928			AV 927		
PERIOD	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)
JAN	1.12	0.85	76.09	1.86	1.41	75.87	1.73	1.58	64.30
FEB	1.00	0.81	79.91	1.68	1.41	83.82	2.22	1.68	75.61
MAR	1.12	0.86	77.35	1.86	1.56	84.08	2.46	1.88	76.70
APR	1.08	0.85	78.63	1.80	1.47	81.67	2.38	1.73	73.00
MAY	1.11	0.80	71.73	1.86	1.36	73.36	1.77	1.57	63.89
JUN	1.08	0.81	74.60	1.80	1.34	74.71	1.66	1.51	63.74
JUL	1.12	0.84	75.49	1.86	1.52	81.75	2.46	1.82	74.15
AUG	1.12	0.85	76.32	1.86	1.59	85.59	2.46	1.94	78.89
SEP	1.08	0.83	77.11	1.80	1.43	79.12	2.12	1.65	69.84
OCT	1.12	0.84	75.70	1.86	1.40	75.38	1.66	1.56	63.55
NOV	0.88	0.73	67.75	1.42	1.21	67.17	1.17	1.29	54.50
DEC	0.91	0.75	67.58	1.46	1.25	66.99	1.21	1.33	54.27

Table 6e: Results from Simulating Electrical Power Output with the Wind Turbine Models for OSHOGBO

	GE1.5xle			AV 928			AV 927		
PERIOD	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)	P_r(GWh)	$P_{E,ave}$(GWh)	CF(%)
JAN	0.19	0.28	25.5	0.34	0.48	25.60	0.31	0.44	18.10
FEB	0.18	0.27	26.53	0.30	0.44	25.94	0.24	0.36	16.11
MAR	0.39	0.50	44.58	0.64	0.81	43.72	0.51	0.73	29.74
APR	0.33	0.43	39.49	0.54	0.70	38.80	0.44	0.63	26.37
MAY	0.26	0.35	31.29	0.43	0.58	31.07	0.37	0.53	21.67
JUN	0.25	0.34	31.38	0.41	0.56	31.07	0.35	0.51	21.36
JUL	0.39	0.48	43.39	0.64	0.80	42.87	0.54	0.76	31.00
AUG	0.32	0.43	38.48	0.53	0.70	37.90	0.44	0.64	26.09
SEP	0.11	0.17	15.98	0.19	0.28	15.75	0.15	0.23	9.68
OCT	0.11	0.17	15.14	0.19	0.28	15.26	0.16	0.25	10.11
NOV	0.04	0.07	6.69	0.08	0.12	6.94	0.07	0.11	4.46
DEC	0.11	0.17	15.57	0.20	0.29	15.74	0.17	0.26	10.55

Clearly from figs. 4-6, it is obvious that the turbines can be employed in all the sites, however they produced higher average power output at the Ikeja than any other site and this is due to the fact that Ikeja is a coastal city.

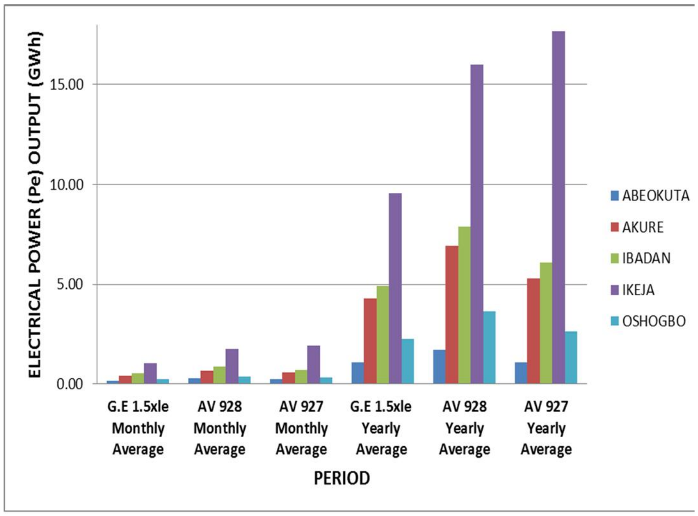

Fig 4: Plot of the Electrical Power (*Pe*) Output.

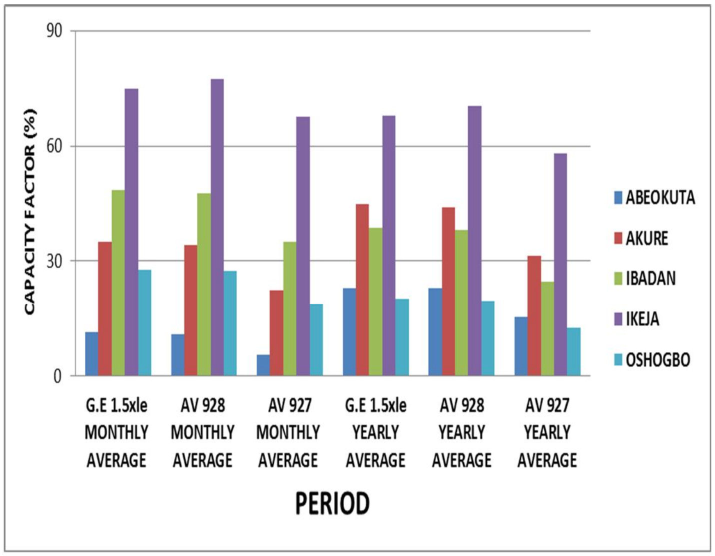

Fig 6: Plot of the Capacity Factor (C.F)

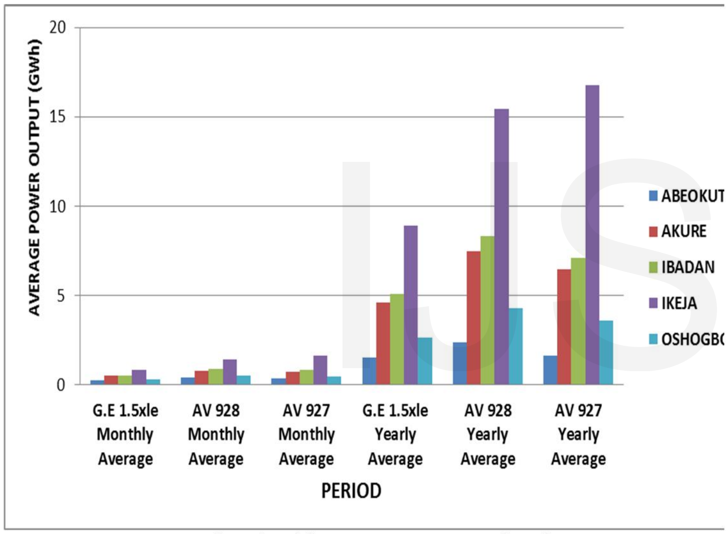

Fig 5: Plot of the Average Power Output ($P_{e,ave}$)

Figure 5 shows that turbine model AV 928 will produce at the highest CF across the months and years. This was due to the fact that, the speed rating of the model fell adequately within the site's wind speed data range at 80 m height (Table 4) . The AV 927 wind turbine model has the lowest CF. However, in terms of the average power output, model AV 927 which has the average power of 16.67 MWh, was the best and closely followed by AV 928 with an average power output of 15.44 MWh. This was partly due to the wind speed range at the hub height being close to the model's speed rating. Another reason is the fact that, for every speed value greater than the cut-in wind speed, it has higher potential of producing better magnitude of wind power than AV 928. As a result of the speed rating of model GE 1.5xle, it gave the lowest average power across the months and years.

3.1 Econometrics Analysis

The cost benefit analysis was estimated from Eqs.5 and 6 based on the assumptions presented in Tables 3 and 7. Substituting the assumptions of Table 3 into Eq. 5 gives:

$$C_{PV}=1.30755x \qquad (7)$$

Table 7: Assumed Turbine Model Price Analysis [10]:

Turbine Model	Assumed price (€)
GE 1.5xle	1,500,000
AV 928	2,500,000
AV 927	3,500,000

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Eq. 7 was used with the turbine prices [10] to determine the present value cost. The outcome of the analysis is presented in Table 8. Further to this, the specific cost of generating 1kWh of electricity was evaluated from present value cost of each turbine and average annual power output. The result is also presented in Tables 8A-E.

TABLE 8A: **ABEOKUTA**'S COST BENEFIT ANALYSIS FOR WIND ELECTRICITY PRODU

Turbine Model	Present Cost(€)	Average Pe,ave per annum×10^6kWh	20 Years Average $P_{e,ave}(t×P_{e,ave})×10^6$kWh	Specific Cost per kWh(€)	Speci per l
GE 1.5xle	1,961,325.00	1.49	29.80	0.07	
AV928	3,268,875.00	2.38	47.60	0.07	
AV927	4,576,425.00	1.62	32.40	0.14	

TABLE 8B: **AKURE**'S COST BENEFIT ANALYSIS FOR WIND ELECTRICITY PRODUC

Turbine Model	Present Cost(€)	Average Pe,ave per annum×10^6kWh	20 Years Average $P_{e,ave}(t×P_{e,ave})×10^6$kWh	Specific Cost per kWh(€)	Specif per k
GE 1.5xle	1,961,325.00	4.61	92.20	0.02	4.
AV928	3,268,875.00	7.49	149.80	0.02	4.
AV927	4,576,425.00	6.47	129.40	0.04	7.

TABLE 8C: **IBADAN**'S COST BENEFIT ANALYSIS FOR WIND ELECTRICITY PRODUC

Turbine Model	Present Cost(€)	Average Pe,ave per annum×10^6kWh	20 Years Average $P_{e,ave}(t×P_{e,ave})×10^6$kWh	Specific Cost per kWh(€)	Speci per k
GE 1.5xle	1,961,325.00	5.08	101.60	0.02	4
AV928	3,268,875.00	8.33	166.60	0.02	4
AV927	4,576,425.00	7.12	142.40	0.03	6

TABLE 8D: **IKEJA**'S COST BENEFIT ANALYSIS FOR WIND ELECTRICITY PRODUCTION

Turbine Model	Present Cost(€)	Average Pe,ave per annum×10^6kWh	20 Years Average $P_{e,ave}(t×P_{e,ave})×10^6$kWh	Specific Cost per kWh(€)	Specific Cost per kWh(₦)
GE 1.5xle	1,961,325.00	8.92	178.40	0.01	2.32
AV928	3,268,875.00	15.44	308.80	0.01	2.23
AV927	4,576,425.00	16.76	335.20	0.01	2.88

TABLE 8E: **OSHOGBO**'S COST BENEFIT ANALYSIS FOR WIND ELECTRICITY PRODUCTION

Turbine Model	Present Cost(€)	Average Pe,ave per annum×10^6kWh	20 Years Average $P_{e,ave}(t×P_{e,ave})×10^6$kWh	Specific Cost per kWh(€)	Specific Cost per kWh(₦)
GE 1.5 xle	1,961,325.00	2.64	52.80	0.04	7.84
AV928	3,268,875.00	4.30	86.00	0.04	8.02
AV927	4,576,425.00	3.62	72.40	0.06	13.34

Tables' 8A-E shows that the turbine model that can produce the cheapest electricity for the sites is model GE 1.5xle. However, considering the advantage model AV 928 has in terms of its potential for higher power output, economic decision would need to be made before conclusion is reached. Such decision would be based on either to compromise the potential for higher power output and embrace the choice of lowest cost of power and vice versa.

Based on the Presidential task force on power set up by the Federal Government of Nigeria [11], which indicated that majority of power users spend between 50 and 70 NGN per kW h on self-power generation while the less privileged (mostly rural dwellers) spend more than 80 NGN per kW h in burning candles, kerosene and firewood, it can be concluded from Tables 5A-E that the cost of producing wind electricity in all the sites is more economical than self-power generation. Moreover, considering the environmental friendliness of wind electricity and the progression of its technology advancement, the cost of wind electricity is expected to decline in the near future.

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4.0 CONCLUSION

The study has assessed the economic viability of wind energy resources for power generation at five cities of south western Nigeria which are Abeokuta, Akure, Ibadan, Ikeja and Oshogbo. Monthly mean wind speed data for the study were obtained from the Nigerian meteorological agency, Oshodi, Lagos State. Since the turbine hub heights of turbine models that were used are at 80 m, the wind profile characteristics at this height were determined.

Adapting the results to three practical wind turbine models revealed that the sites are capable of generating megawatts of electricity, while turbine model AV 927 appeared to be the most suitable of the three used in the study. Thus, the sites are good enough for small scale wind farm projects. The econometrics analysis showed that it is possible to generate a kWh of wind electricity with at least ₦2.23 in Ikeja and at most with ₦29.80 in Abeokuta as compared to the cost of generating kWh of electricity which the Presidential Task Force on Power placed at between N50 and N80.

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NOMENCLATURE

c (m/s)	The Weibull scale parameter
k(-)	Weibull shape parameter or factor
v(m/s)	Wind speed
$V_{ref} = V_{80}$	Wind speed at reference height of 80 m
V_{10}	Wind speed at 10 m height
h_{ref}	Reference height = 80 m
h_{10}	10 m height,
α	Roughness factor for the sites
P_e	Magnitude of Electrical Output
v_c	Cut in wind speed
v_R	Rated wind speed,
v_F	Cut off wind speed
P_{eR}	Rated electrical power
C_{pv}	Present cost
x	Turbine price
R_I	Prevailing interest rate
I_R	Prevailing inflation rate
R_{sc}	Rate chargeable on total investment cost
t	Turbine life
$C_{sc/kWh}$	Specific cost per kWh

R_c Rate chargeable on turbine price to arrive at the cost for civil/structural works

R_{om} Rate chargeable on annual turbine price to arrive at the cost for Operation and Maintenance.