International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.4, July-Aug. 2012 pp-2434-2437 ISSN: 2249-6645

Nigeria's Wind Energy Potentials: the Path to a Diversified Electricity Generation-Mix

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ABSTRACT: *For many decades, conventional energy resources have continually remained major energy sources in Nigeria. This paper therefore looks at the enormous wind energy potentials in Nigeria. Available data on wind speed for some towns in Nigeria indicates very good prospects for wind energy development. This paper advocates the inclusion of wind energy in the nation's energy supply mix. This would diversify and reverse the current acute electricity deficit experienced in the country, as well as address environmental concerns and effect of climate change.*

Keywords: *Electricity, Energy, Nigeria, Potentials, Wind,*

I. INTRODUCTION

Nigeria is a well endowed country with abundant wind energy resources which can be used to generate electricity. However, despite the abundance of these energy resources, there is persistent electricity supply deficit, which may be attributed to under utilization of these potentials. Other major barriers to the deployment of wind energy technology in the country include high initial cost of wind power generation, systemic issues governing reliable transmission and system integration, social acceptance of technology and energy market structure. The non-proper coordination of activities in the energy sector largely because of lack of concrete policy and energy plan is also worth mentioning.

Wind energy has been widely used in Nigeria to power water supply for many decades now. In recent times efforts are largely geared towards its use for electricity generation, for example, the Federal Government of Nigeria is currently constructing 10 MW Wind Farm at Katsina and work has reached advanced stage of completion, although there are some issues with grid integration. In Nigeria, typical wind pattern occurs mostly from the east for inland areas and from the west over the coastal areas. During the harmattan period (December – March) strong winds appear covering the country especially in the northern parts where the main wind direction shifts to west / south western directions. A study on the wind energy potentials for a number of Nigerian cities shows high wind speeds in the Sokoto region, Jos, Gembu and Kano / Funtua. The stations at Maiduguri, Lagos and Enugu also indicated relatively strong wind speeds, sufficient for energy generation by wind farms. Apart from these sites, other promising regions with usable wind potentials are located at the Nigeria's shoreline [1].

The proper utilization of these wind energy potentials will ensure promotion of socio-economic development as well as quality of life of the citizenry. Expanding the use of renewable resources such as wind will reduce carbon dioxide emissions which contribute to global warming and lower long-term overdependence on fossil fuels. Further, wind energy like other power technologies based on renewable energy resources is fast evolving globally and widely available, thereby ensuring security of supply. Prior to construction of any wind farm, a detailed verification of the specific on-site wind conditions is necessary to come up with a suitable wind map in other to identify those areas which have favorable wind regimes and can therefore be selected for the development of wind energy projects.

This paper therefore attempts to give an overview of the nations wind energy potentials, enumerating the numerous challenges hindering its development and identify some measures that will possibly lead to inclusion of wind in the energy supply mix to satisfy our growing energy demand, diversify our supply sources to guarantee energy security and align with the new global trend of green energy growth.

II. GLOBAL TRENDS IN WIND ENERGY DEVELOPMENT

Today wind energy is one of the fastest developing renewable energy technologies in the world and mainly onshore. Wind is among the cheapest renewable sources per unit of electricity produced. Analysis indicates that a network of land-based 2.5MW wind turbines could supply over 40 times current worldwide electricity consumption [2].

Wind energy generation market is continuously growing worldwide. In 2009, 82 countries used wind to generate energy, and 49 countries increased their installed capacity [3]. Middle East and Africa also recorded a total of 230MW of newly installed capacity with almost 90% growth rate in Morocco and 170% growth in Tunisia. Although these values are small compared with wind energy producing regions like North America, Europe and Asia, the presence of wind energy in remote locations of the world simply highlights the continued rapid growth in global demand for emissions-free wind power, which can be installed virtually everywhere around the globe.

Wind energy had over 238GW of installed capacity at the end of 2011[4] and is expected to play a crucial role in mitigating future greenhouse gas emissions. The Global Wind Energy Council forecasted that global wind market will grow by over 155% to reach 240GW of total installed capacity by the end of 2012. According to recent projections, wind energy is expected to contribute some 12% of global electricity by 2050, with 57% of this energy produced by non – OECD economies. However, USD3.2 trillion will have to be invested over the next 40 years to realize this improvement [5].

Currently, Europe is the leading market for global wind power, and will probably remain so for the next decade. It is followed by the United States and then China as world leading wind power producers. China will probably overtake the United States and OECD Pacific countries as a major producer of wind energy by 2050, with projected figure of 1660 TWh. The rest of the world, including Africa and the Middle East, provide nearly one-fifth of wind electricity in 2050 [5].

III. NIGERIA'S WIND ENERGY POTENTIALS

Wind speed in Nigeria ranges from 1.4 - 3.0m/s in the southern areas and 4.0 - 5.12m/s in the extreme north. Wind speeds are generally weak in the southern part of the country except for the coastal regions and offshore location. Initial study has shown that total exploitable wind energy reserve at 10m height may vary from 8MWh/yr in Yola to 51MWh/yr in the mountainous areas of Jos Plateau and it is as high as 97MWh/yr in Sokoto [6].

Lahmeyer International's report [1] gives potential estimates for ten (10) selected sites in the country to be between 3.6 m/s to 5.4 m/s. These results when compared with the figures obtained from calculated wind speed using Climatic Model Mainz (KLIMM) gives difference of -4.3% to 4.1% which is within the acceptable limit of error. Table 1 presents the results for these ten (10) selected sites.

Table 1: Summary of measured data of annual Wind Speeds (Ten selected sites)

Site	Land -use Type	Altitude (m a.s.l.)	Height (m)	WIND SPEED (m/s) Measured	KLIMM	Difference (%)
Enugu	Complex landscape	466	30	4.6	4.4	-4.3
Jos	Complex landscape	1,344	30	5.2	5.1	-1.9
Pankshin	Complex landscape	1,355	40	4.9	4.7	-4.1
Sokoto	Plain surface	352	30	5.4	5.2	-3.7
Kano	Plain surface	340	30	4.9	5.1	4.1
Gumel	Plain surface	393	30	4.1	4.2	2.4
Maiduguri	Plain surface	373	30	4.7	4.6	-3
Ibi	River valley	300	30	3.6	3.3	-8.3
Gembu	Highly complex landscape	1,800	40	5	5.2	1
Lagos	Coastal Area	2	30	4.7	4.9	4.3

Source: Wind Energy Resources Mapping and Related Work Project: (LI/FMST, Nigeria, 2005)

The estimated gross energy yield of the sites by wind turbine types is shown in Table 2.

Table 2: Gross Energy Yield for the Measure

Measurement Station	Gross Energy Yield Measurement (MWh) FUHRLÄNDER FL 100	FUHRLÄNDER FL 250	VESTAS V52 850 52.0
	100/20	250/50	
Sok1	153.5	358.8	1,235.80
Jos01	129.6	299	1,025.80
Gem01	112.9	253.9	855.30
Pan01	117.1	272.1	936.60
Kan01	116.3	281.2	963.70
Mai01	102.7	262.2	906.10
Lag01	129.3	386.1	1,402.80
Enu01	92.9	217.9	734.20
Gum01	73.4	197.2	681.40
Ibi01	49.8	141.3	481.20

Source: Wind Energy Resources Mapping and Related Work Project (LI/FMST, Nigeria, 2005)

Table 3 [7] indicates high wind energy potentials for some selected states of the Federation. One percent of effective wind area of these 14 states has a potential to generate 50,046 MWh/y of electricity assuming 5MW/km^2 (a) and 30% capacity factor (b).

Table 3: Estimated Wind Energy Potentials for 14 Selected States

Selected State	Area (km^2)	Windy Area (%)	Effective Wind Area (km^2)	1% Area (km^2)	Potential capacity^{a} (MW)	Potential Generation^{b} (MWh/yr)
Adamawa	37,957	45%	17,080	170	854	2244
Bauchi	48,197	50%	24,098	240	1204	3166
Borno	72,767	100%	72,767	727	3638	9561
Gombe	17,428	100%	17,428	174	871	2290
Jigawa	23,415	100%	23,415	234	1170	3076
Kaduna	44,217	60%	26,530	265	1326	3486
Kano	20,389	90%	18,350	183	917	2411
Katsina	23,822	100%	23,822	238	1191	3130
Kebbi	36,320	25%	9,080	90	454	1193
Plateau	26,539	90%	23,885	238	1194	3138
Sokoto	32,146	90%	28,931	289	1446	3801
Taraba	59,180	40%	23,672	236	1183	3110
Yobe	44,880	100%	44,880	448	2244	5897
Zamfara	33,667	80%	26,933	269	1346	3539
Total				**3,808**	**19,043**	**50,046**

Source: Nigeria Climate Assessment, LCD Power Sector, preliminary report (WBG / Lumina Decision Systems, 2011)

Agbetuyi et al [8], estimates wind energy density at 25m height for some 22 selected sites across the country. Table 4 provides detailed potentials and wind energy densities of the sites.

Table 4: Wind Energy Density Estimates at 25m Height

S/N	Station	Mean wind speed at 25m level	Monthly mean wind Energy	Annual Wind Energy	Annual Wind Energy from a Wind Turbine (kWh)	
		m/s	kWh	kWh	10m Blade Diameter	25m Blade Diameter
1	Benin City	2.135	2.32	27.86	2,187.81	13,673.78
2	Calabar	1.702	1.12	13.42	1,053.69	6,587.53
3	Enugu	3.372	7.83	93.91	7,375.75	46,097.96
4	Ibadan	2.62	4.15	49.78	3,909.79	24,436.19
5	Ilorin	2.078	1.23	14.73	1,157.06	7,230.57
6	Jos	4.43	16.05	192.64	15,129.60	94,559.98
7	Kaduna	3.605	9.91	188.88	936.81	58,355.08
8	Kano	3.516	8.57	102.86	8,078.61	50,491.28
9	Lagos(Ikeja)	2.671	4.36	52.32	4,099.78	25,682.52
10	Lokoja	2.235	2.6	31.21	4,451.23	15,320.17
11	Maiduguri	3.486	8.42	101.01	7,933.61	49,583.17
12	Minna	1.589	1.05	12.6	989.60	6,185.01
13	Makurdi	2.689	4.44	53.27	4,183.51	26,148.85
14	Nguru	4.259	14.48	173.74	13,645.19	85,284.42
15	Oshogba	1.625	1.07	12.81	1,006.60	6,288.09
16	PH	2.64	4.17	49.98	3,925.48	24,533.88
17	Potiskum	3.636	9.44	113.25	8,894.35	55,591.46
18	Sokoto	4.476	16.47	197.68	15,525.75	97,035.94
19	Warri	2.027	2.02	24.2	1,900.66	11,879.15
20	Yelwa	3.36	7.76	93.13	7,314.88	45,714.59
21	Yola	1.824	1.45	17.34	1,361.88	8,511.75
22	Zaria	2.891	5.32	63.88	5,017.26	31,357.02
	Total		**134.23**	**1680.5**	**120,078.90**	**790,548.39**

Source: Wind energy Potential in Nigeria: (Agbetuyi et al, 2012)

IV. JUSTIFICATION FOR DEPLOYMENT

An analysis of the power generation capacity required to support the NV20:2020 economic vision shows that, Nigeria will need to generate electricity in the range of about 35,000 – 40,000MW by year 2020. To achieve this, there is need to aggressively pursue the harnessing of the nation's wind and other renewable energy resources.

Thus, Sambo (2012) [9], gives some of Nigeria's renewable energy resources as 14,750MW of hydro power potentials, 3.5 - 7.0 kWh/m^2/day of solar radiation (485.1 million MWh/day using 0.1% Nigeria land area), (2-4) m/s at 10m height of wind speed, 72 million hectares of arable land for energy crops and agricultural production. Other conventional energy resources include 180.57 trillion SCF of natural gas, 2.734 billion tonnes of coal and lignite, 37.2 billion barrels of light crude oil, and yet to be quantified nuclear element. Despite all these renewable and non-renewable resources, Nigeria is generating electricity from only two sources (gas and hydro), which are both poorly harnessed and mismanaged.

As at 2009, the country's total generation capacity was 8,876MW but only 3,653MW was available, which is less than 41% of the total installed capacity [10]. It is instructive for Nigeria to learn from experiences of other countries and diversify its energy supply mix to achieve energy security. Harnessing wind power offers environmental advantages in terms of reducing carbon dioxide emissions and other pollutants such as oxides of Sulphur and Nitrogen mostly associated with burning of fossil fuels, thereby addressing global warming concerns.

V. WIND FOR ELECTRICITY GENERATION

For effective performance and maximum yield of wind power systems, project planning and siting as well as reliable prediction in terms of wind resource is a pre-requisite. Electricity is generated from wind through the use of wind turbines also known as wind energy converters (WEC). The main components of a WEC include rotor blade, generator, pitch, wind measurement system, brake, gear box, rotor hub, yaw mechanism, nacelle, transformer and tower.

The wind turbines convert the kinetic energy of wind into mechanical energy and then to electrical through the generator. The generator may be of fixed or variable speed. Due to changing wind speed and direction, the yaw mechanism is used to turn the blades of the wind turbines in line with wind direction to increase its output. The collection of wind turbines for purpose of electricity generation is called a wind farm and its planning involves series of processes.

Upon identification of the proposed site, wind data are collected for a period of at least 12 months on-site to ascertain general wind pattern for the whole year. Then, the data obtained is evaluated and analyzed with different wind turbines to determine the best for the site. The blade diameter, tower height and rated power all depends on wind data characteristics.

Other factors that need to be considered include accessibility and distance of the proposed site to the grid. Wind farm requires a considerable size of land area for its construction. In order to ensure efficiency, higher output and avoid wind theft, a minimum distance of 3D (3 times diameter of blade) between turbines and 5D to 7D in main wind direction is recommended [11].

Wind turbines are manufactured based on specification and are usually not off-shelf. Delivery may take up to a year and thus, setting up a wind farm from the scratch takes a period of at least 2 ½ years. WEC have maximum theoretical efficiency of 60% but only about 45% in practice.

Wind farms can be onshore or offshore. The offshore wind turbines need to have solid foundations and protection from corrosion. Hence, they are more expensive than onshore farms. The upside of offshore farms is the increase in yield. Load factor of onshore wind farms is usually 20-30% while that of offshore wind farms is 30-43% [5]. After about 20 years of operation wind turbines have to be decommissioned. Re-powering with a larger more efficient turbine is an economical choice.

VI. TARGET MARKETS AND COST ISSUES

Electricity from wind can be grid connected or off-grid with the latter being the most popular. Wind power is ideal for generating electricity at remote locations. Hence, clusters can be created with turbines generating electricity for remote villages or collection of thousands of households. With the low load factor of wind power plant, it can be used to boost the nation's electricity by targeting intermediate to peak load demand taking its advantage of quick start and stop.

The cost of setting up wind farms is very high. Electricity transmission infrastructure typically accounts for around 10 – 20% of the capital costs of constructing an offshore wind farm. Wind turbines are subject to economies of scale. For example, a building-mounted turbine with 2.5kW capacity generation would cost around £10,000 and may not payback in the equipment lifetime. Whereas a large scale turbine (1MW – 2.5MW) would cost £2 – £3.3 million and the payback period could range from five years to less than one year respectively. Hence, large capacity wind farms are more economical.

The average cost of generating electricity from large scale onshore wind is now around 3 - 4 pence per kilowatt hour, competitive with new coal (2.5 – 4.5 pence) and cheaper than new nuclear (4 – 7 pence). As gas prices increase and wind turbine costs fall further as the market grows, wind energy is also likely to become competitive with gas fired power generation [12].

VII. CHALLENGES OF DEPLOYMENT

There are a series of challenges affecting wind energy deployment in the country. These include lack of financing and other fiscal incentives, lack of skilled manpower and lack of indigenous manufacturing capabilities. Others include, lack of policy and institutional framework to encourage investment and deployment of wind energy technology. Low load factor of wind farms makes it unsuitable for base load power plants.

VIII. CONCLUSION

The use of wind power to generate and supply electricity will expand Nigeria's energy base and reduced environmental pollution. Hence, sites identified with superb wind energy potentials should be adequately harnessed. Effort should be made to address issues of integration to the national grid.

All necessary policies and institutional framework should be put in place to eliminate barriers to deployment of wind energy technology in the country.

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