# Boosting Electricity Supply in Nigeria: Wind Energy to the Rescue?

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## ABSTRACT

Renewable energy sources are considered to be clean, but their large-scale use is hampered by the cost of generated energy and low utilization factor. Wind energy, however, has emerged as one of the most economical of them and there has been remarkable growth of wind power installations in the world. In this paper is presented the levels of wind energy potential in the 36 state capitals of Nigeria and the federal capital at Abuja. The "optimal sites" for wind energy utilization are Enugu in the Southeast, Yenegoa and Port-Harcourt in the South, and Ikeja in the Southwest which recorded a maximum wind speed of 3 m/s compared to that of Enugu which was 2.7 m/s in March and 2.6 m/s for Yenegoa in August. The seasonal signatures are also evident in the North-central zone with the high altitude Jos station (at elevation of 1295 meters) showing a clear pattern of having high wind speeds of up to 3.9 m/s in March. In the Northeast, Bauchi was the "leading site" for wind energy utilization with a maximum wind speed of 3.4 m/s in May. In the Northwest, we see a similar signature with the "leading site", Katsina having maximum wind speeds of 3.9 m/s in May-June. A case is made for offshore wind farms in the South and Southwest zone listing some environmental advantages and for cities in the vicinity of rivers and high altitude locations in the country since the wind speeds are generally low across the country.

(Keywords: renewable energy, Nigeria, offshore, wind speed, wind energy, electricity)

## INTRODUCTION

Two main challenges are facing the world in the 21st century (International Energy Outlook, 2006). One is to meet the exponentially growing demand for energy, particularly in the developing countries, where today 1.6 billion people do not have access to commercial energy. The other is to deal with the global, regional and local environmental impacts resulting from the supply and use of energy (Chineke and Igwiro, 2008).

Expanding the use of renewable fuels will lower the long-term price of crude oil and reduce carbon dioxide emissions that are contributing to global warming. Nigeria is richly endowed with both fossil energy resources such as crude oil, natural gas, coal, and renewable energy resources like solar, wind, biomass, biogas, etc. For many decades, fossil fuels and firewood (conventional energy resources) have continually remained the major energy sources which account over 90% of the national energy consumption (Archer and Jacobson, 2004). However, in recent times, there has been a continual decline in supply of conventional energy due to the depletion of the national reserve while the demand has continued to increase resulting in energy crisis with incessant power outages. The environmental pollution and health hazards associated with the use of fossil fuels are another driving force towards the global switch to renewable energy (Ojosu and Salawu, 1990; Jacobson, 2004; International Energy Outlook, 2008).

There is energy poverty in Nigeria irrespective of the huge energy potentials in the country and activities in the energy sector are not properly coordinated because of lack of an integrated and comprehensive energy policy. What we have on the ground are pieces of legislations, procedures and directives characterized by waste, corruption and obsolescence. The generation of electricity and its distribution is characterized by inefficiency, obsolescence, endemic corruption, poor maintenance and waste. As for the energy of the poor, biomass, there is complete misrepresentation in priority list of government successive energy plans, as if the problem never exists. The aim of this study is to showcase the wind energy potential over the 36 state capitals and the federal capital territory of Nigeria (Figure 1) which will guide international investors, advise governments and non-governmental and community-based organizations whose motive is to ensure the promotion of socio-economic development as well as improve the quality of life of urban and rural dwellers in Nigeria.

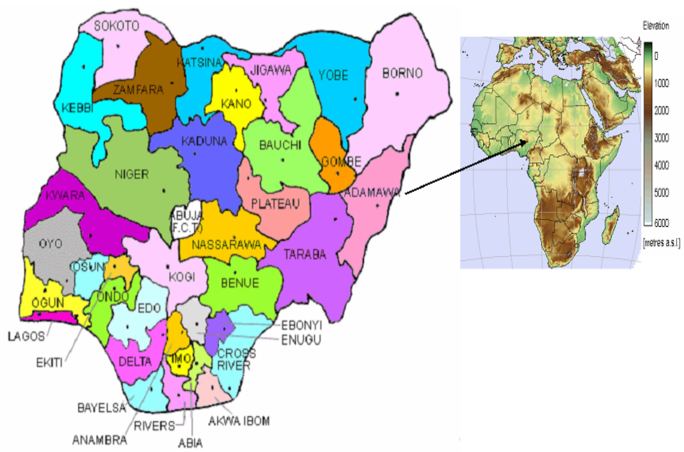


**Figure 1:** Map of the 36 States of Nigeria within Africa.

In the face of increased greenhouse gas emissions, climate change and pollution from the commonplace petrol and diesel generating sets and rising unemployment, the wind energy sector will help to create jobs to supplement that from other renewable energy sectors like solar and biomass. For project planning and siting, a reliable prediction of the wind resource is therefore crucial (Diab, 1988; Fagbenle and Karayiannis, 1994; Mohsen and Akash, 1998; Weisser and Foxon, 2003; Lavagnini et al., 2006).

## METADATA AND RESULTS

The monthly mean wind speed data (at 10 meters and measured in meters per second) used for this study is a subset of the International Water Management Institute (IWMI) http://dw.iwmi.cgiar.org/ World Water and Climate Atlas. This dataset spans from 1961 to 1990 and is in Arcview GRID® format. The IWMI World Water and Climate Atlas give irrigation and agricultural planners rapid access to accurate data on climate and moisture availability for agriculture. The IWMI World Water and Climate Atlas allow users to download data, organize data into common workable formats, view and manipulate that data according to specific needs, and analyze the results of the manipulation. The development of the data sets was commissioned by IWMI with financial support provided through the United States Assistance International Development (USAID) and the Official Development Assistance of the Government of Japan. These grids form the Global data set were produced by the Climatic Research Unit (CRU) of the University of East Anglia, Norwich, Norfolk, UK on behalf of the International Water Management Institute, Colombo, Sri Lanka. There are some other CRU data sets at http://www.cru.uea.ac.uk/cru/data/tmc.htm.

As in the other parts of West Africa, the climate of the area is determined by the interplay of three major airstreams: the tropical maritime (Tm) airmass, the tropical continental (Tc) air mass, and the equatorial easterlies (Omotosho, 1988; Adejuwom and Odekunle, 2006). The Tm air mass originates from the St. Helena anticyclone located off the coast of Namibia and in its trajectory, picks up moisture form over the South Atlantic Ocean, crosses the equator, and enters southwestern Nigeria. The Tc air mass originates from the Libyan anticyclone north of the tropic of Cancer. It picks up little moisture along its path and is thus dry. The two air masses (Tm and Tc) meet along a slanting surface called intertropical discontinuity (ITD) or intertropical convergence zone (ITCZ) over land (Balas et al., 2007). The equatorial easterlies represent a rather erratic cool air mass, which comes from the east and flows in the upper atmosphere along the climatic equator. Occasionally the air mass dives, and undercuts the Tm or Tc air mass and gives rise to line squalls or dust devils (Iloeje, 2002) during which time the wind speed will be higher.

The 36 states of Nigeria within Africa are shown in Figure 1. The results for the more “oil-rich” South geopolitical zone is listed in Figure 2.

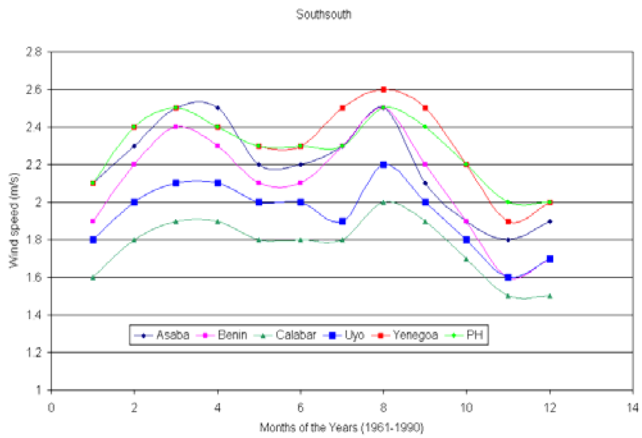


**Figure 2:** Monthly Mean Wind Speed in the South Geopolitical Zone of Nigeria.

Yenegoa (longitude 6.26 $^{o}$ E, latitude 4.92 $^{o}$ N) seems to have more wind energy potential for the months of June to October although the levels are the same with the nearby Port-Harcourt site (longitude 7.0 $^{o}$ E, latitude 4.75 $^{o}$ N) during January to March (see Table 1 and Figure 2). In Figure 3 we see the seasonal variation of the monthly mean wind speed (in meters per second) at 10-meter height for the state capitals in the southeast geopolitical zone of Nigeria.

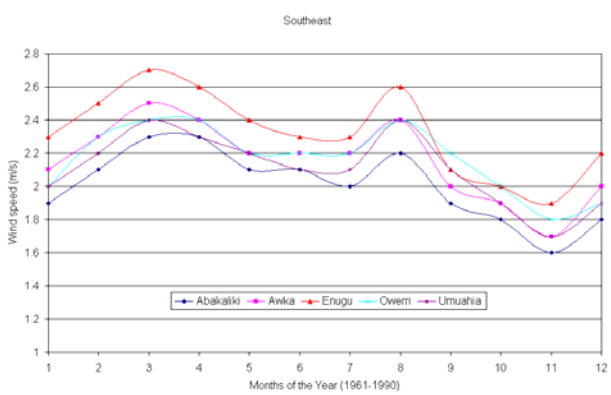


**Figure 3:** Monthly Mean Wind Speed in the Southeast Geopolitical Zone of Nigeria.

The Enugu (longitude 7.50$^{o}$ E, latitude 6.50 $^{o}$ N) and Awka (7.73 $^{o}$ E, 6.20 $^{o}$ N) sites had higher values of wind speed than others (Table 1). The maximum value of wind speed recorded at Enugu was 2.7 m/s in the month of March with the least value of wind speed for the region being 1.6 m/s at Abakaliki in the month of November. In the Southwest geopolitical zone, the coastal Ikeja longitude 3.33 $^{o}$ E, latitude 6.58 $^{o}$ N) had higher values of wind speed than the other sites of Ado-Ekiti, Akure, Ibadan, Osogbo and the nearby Abeokuta site (longitude 3.33 $^{o}$ E, latitude 6.58 $^{o}$ N). The potentials for wind energy utilization are higher for the months of July and August that coincides with the "little dry season" in the zone, a phenomenon that is modulated by the ITCZ (Balas et al., 2007). The maximum value of the wind speed is 3m/s for July and August at Ikeja (Figure 4).

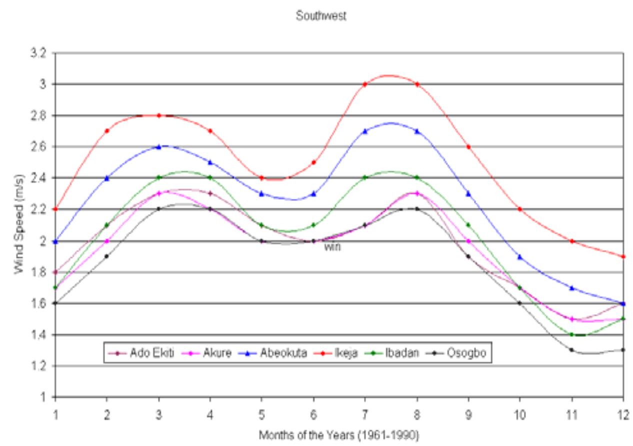


**Figure 4:** Monthly Mean Wind Speed in the Southwest Geopolitical Zone of Nigeria.

For the North-central geopolitical zone and the federal capital Abuja (longitude 10.0 $^{o}$ E, latitude 9.0 $^{o}$ N), we see that the high altitude Jos site (longitude 8.90 $^{o}$E, latitude 9.92 $^{o}$N) had consistently higher wind speed values for all months than others (Figure 5).

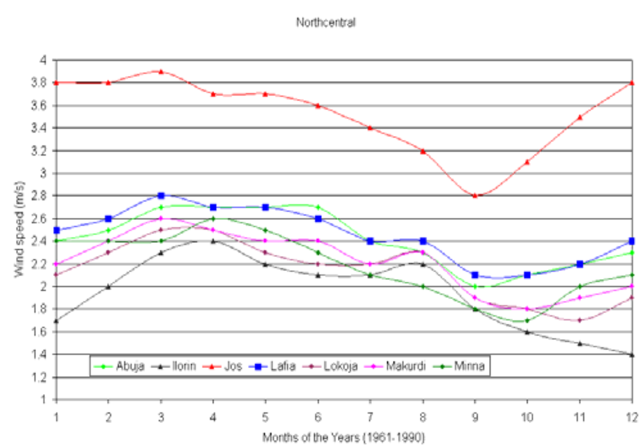


**Figure 5:** Monthly Mean Wind Speed in the North-Central Geopolitical Zone of Nigeria.

**Table 1:** The States of Nigeria, their Coordinates and the Maximum and Minimum Values of the Windspeeds with the Corresponding Months Indicated.

| State | Capital | Longitude | Latitude | Maximum | Minimum | Elevation |
|---|---|---|---|---|---|---|
| **South Zone** | | | | | | |
| Akwa-Ibom | Uyo | 7.93 | 5.05 | 2.2 (H) | 1.6 (K) | 68.0 |
| Bayelsa | Yenegoa | 6.26 | 4.92 | 2.6 (H) | 1.9 (K) | |
| Cross River | Calabar | 8.32 | 4.95 | 2.0 (H) | 1.5 (K,L) | 13.0 |
| Delta | Asaba | 6.18 | 6.75 | 2.5 (C,D) | 1.8 (K) | 43.0 |
| Edo | Benin | 5.60 | 6.32 | 2.8 (H) | 1.6 (K) | 375.0 |
| Rivers | Port-Harcourt | 7.00 | 4.75 | 2.5 (C,H) | 2.0 (K,L) | 19.5 |
| **Southeast Zone** | | | | | | |
| Abia | Umuahia | 7.48 | 5.53 | 2.4 (C) | 1.7 (K) | 121.0 |
| Anambra | Awka | 7.73 | 6.20 | 2.5 (C) | 1.7 (K) | 72.0 |
| Ebonyi | Abakaliki | 8.10 | 6.33 | 2.3 (C,D) | 1.6 (K) | |
| Enugu | Enugu | 7.50 | 6.50 | 2.7 (C) | 1.9 (K) | 141.8 |
| Imo | Owerri | 7.02 | 5.48 | 2.4 (C,D) | 1.8 (K) | 91.0 |
| **Southwest** | | | | | | |
| Ekiti | Ado Ekiti | 5.22 | 7.62 | 2.3 (C,D,H) | 1.5 (K) | |
| Lagos | Ikeja | 3.33 | 6.58 | 3.0 (G,H) | 1.9 (L) | 39.4 |
| Ogun | Abeokuta | 3.33 | 7.15 | 2.7 (G,H) | 1.6 (L) | 104.0 |
| Ondo | Akure | 5.20 | 7.25 | 2.3 (C,H) | 1.5 (K,L) | 375.0 |
| Osun | Osogbo | 4.57 | 7.77 | 2.2 (C,D,H) | 1.3 (K,L) | 305.0 |
| Oyo | Ibadan | 3.90 | 7.38 | 2.4 (C,D,G,H) | 1.4 (K) | 227.8 |
| **North-Central Zone** | | | | | | |
| Benue | Makurdi | 8.53 | 7.73 | 2.6 (C) | 1.8 (K) | 112.0 |
| Kogi | Lokoja | 6.82 | 7.75 | 2.5 (C,D) | 1.7 (K) | 41.0 |
| Kwara | Ilorin | 4.55 | 8.50 | 2.4 (D) | 1.4 (L) | 307.4 |
| Nasarawa | Lafia | 8.52 | 8.48 | 2.8 (C) | 2.1 (I,J) | |
| Niger | Minna | 6.55 | 9.62 | 2.6 (D) | 1.7 (J) | 256.4 |
| Plateau | Jos | 8.90 | 9.92 | 3.9 (C) | 2.8 (I) | 1295 |
| Abuja | Abuja | 10.00 | 9.00 | 2.7 (D-F) | 2.0 (I) | 344.0 |
| **Northeast Zone** | | | | | | |
| Adamawa | Yola | 11.93 | 9.91 | 2.7 (C-E) | 1.9 (I) | 186.1 |
| Bauchi | Bauchi | 9.83 | 10.32 | 3.4 (C,E) | 2.5 (I) | 609.7 |
| Borno | Maiduguri | 13.15 | 11.83 | 3.1 (B,C) | 2.2 (H,I) | 353.8 |
| Gombe | Gombe | 11.17 | 10.28 | 3.0 (E) | 2.2 (I,J) | |
| Taraba | Jalingo | 11.37 | 8.90 | 2.5 (C,D) | 1.8 (I) | 207.0 |
| Yobe | Damaturu | 11.95 | 11.73 | 3.3 (C) | 2.4 (I) | 382.0 |
| **Northwest Zone** | | | | | | |
| Kaduna | Kaduna | 7.43 | 10.52 | 3.3 (C-E) | 2.3 (I,J) | 645.0 |
| Kano | Kano | 8.50 | 11.50 | 3.7 (E,F) | 2.6 (J) | 472.5 |
| Katsina | Katsina | 7.60 | 12.98 | 3.9 (E,F) | 2.5 (J) | 427.0 |
| Kebbi | Birni kebbi | 4.20 | 12.45 | 3.1 (E,F) | 1.9 (I,J) | 199.0 |
| Jigawa | Dutse | 9.28 | 11.73 | 3.7 (E,F) | 3.1 (K) | 404.0 |
| Sokoto | Sokoto | 5.23 | 13.07 | 3.7 (F) | 2.1 (J) | 351.0 |
| Zamfara | Gusau | 6.67 | 12.17 | 3.7 (A,E,F) | 2.2 (J) | |

Legend: A=January; B=February; C=March; D=April; E=May; F=June; G=July; H=August; I=September; J=October; K=November; L=December

It recorded a maximum wind speed of 3.9 m/s in the month of March (Table 1). Since the data used in this study was obtained at a height of 10 meters, an implication is that at the expected windmill height of 80 meters (Acker and Jacobson, 2004), the wind energy to be derived at this site will help to boost the electricity supply in this state and geopolitical zone (Medugu and Malgwi, 2005; Fadare, 2008). In the Northeast geopolitical zone, we observe that the Bauchi site (longitude 9.83 °E, latitude 10.32 °N) had higher values of wind speed than Damaturu, Gombe, Jalingo, Yola, and Maiduguri. It had a maximum value of 3.4 m/s in March and May (Figure 6).

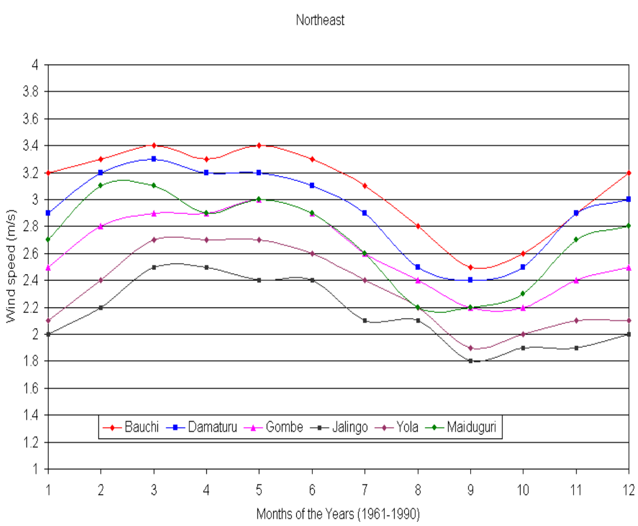


**Figure 6:** Monthly Mean Wind Speed in the Northeast Geopolitical Zone of Nigeria.

The wind speed in this northern zone, just like in others were lower at the onset of the dry season (September – October), a period when the air is laden with dust aerosols from the Sahara desert (Chiemeka et al., 2007). This is also the case for the Northwest geopolitical zone (Figure 7). The maximum values of wind speed of 3.9 m/s is observed in the months of May and June for the Katsina site (longitude 7.60 °E, latitude 12.98 °N) which were higher than at the other sites in the zone (Figure 7). The elevational pattern of most of Nigeria consists of a gradual rise from the coastal plains to the northern savanna regions, generally reaching an elevation of 600 to 700 meters (Figure 7).

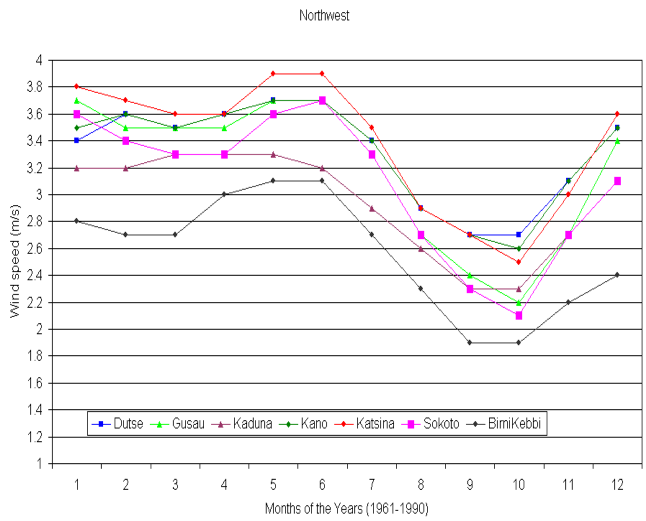


**Figure 7:** Monthly Mean Wind Speed in the Northwest Geopolitical Zone of Nigeria.

Higher altitudes, reaching more than 1,200 meters in elevation, are found only in isolated areas of the Jos Plateau and in parts of the eastern highlands along the Cameroon border. The elevation data was not available for all the study sites in Table 1. We all know that the wind blows faster at higher altitudes because of the drag of the surface (sea or land) and the viscosity of the air. Nevertheless, the potentials of the wind energy can be used to remedy the fluctuation or near-absence of electricity supply in this part of the country and others (Medugu and Malgwi, 2005).

## WHY NIGERIAN GOVERNMENT SHOULD EXPLORE THE WIND ENERGY OPTIONS

The first reason is greater fuel diversity and less dependence on fossil fuels, which are often subject to rapid price fluctuations and supply problems. This is a significant issue around the world today, with many countries rushing to install gas-fired electric generating capacity because of its low capital cost. As world gas demand increases, the prospect of supply interruptions and fluctuations will grow, making further reliance on it unwise and increasing the value of diversity. In Nigeria, the economy and politics revolves around the exploitation and exploration of fossil fuels.

The present restiveness in the Niger Delta area of the nation which is having a spiral effect on the world oil market would have been flagged if the wind energy option is developed (Fagbenle and Karayiannis, 1994; Medugu and Malgwi, 2005; Lavagninni et al., 2006; International Energy Outlook, 2008).

In addition, there will be greatly reduced environmental impacts per unit of energy produced, compared with conventional power plants. Environmental costs are becoming an increasingly important factor in utility resource planning decisions. There are a lot of sabotages in the oil sector-driven economy of Nigeria with cases of pipeline vandalization and oil spillage being commonplace. It is also worthy of mention that more jobs per unit of energy produced is possible from wind energy than from other forms of energy (International Energy Outlook, 2006). Selection of a suitable site is a key to the economics of wind energy. The power available from the wind is a function of the cube of the wind speed, which means that, all other things being equal, a turbine at a site with 5 meters/second (m/s) winds will produce nearly twice as much power as a turbine at a location where the wind averages 4 m/s. In the electric power business, where technology options often hinge on very small economic differences, good wind resource assessment and siting is critical.

There are several factors which therefore suggest the development of an offshore wind energy industry in Nigeria for large scale wind energy applications. The resource is extremely large along the coastal areas, the energy costs, although initially higher than for onshore, are cheaper than other renewable technologies and the risks are low, as several demonstration projects elsewhere have shown(Diab, 1988; Mohsen and Akash, 1998). Many people, while agreeing that wind turbines are a useful strategy, may not be happy to see them in their area. Siting wind turbines at sea however will reduce the constraints that can be found on land, such as the visual impact and planning challenges but definitely, the wind farms will have to be larger to provide economies of scale to cover these costs (Lavagnini et al., 2006). The Asaba, Port-Harcourt, Yenegoa, Calabar, Ikeja and Lokoja coastal sites are locations in Nigeria that can have optimal wind energy utilization using the offshore option. Kaduna that has a river is another suggested location (see Table 1 and Figure 7).

## CONCLUSIONS

Power sector institutions in Africa are characterized by inability to provide adequate levels of electricity services to the majority of the population, especially to the rural poor (Jacobson, 2004; Ex-Im Bank, 2008). In Uganda and Tanzania, only about 6.6 and 7 percent respectively of the total population has access to electricity. In the Democratic Republic of Congo, only 5 percent of the population benefits from electricity supply (karekezi and Kithyoma, 2003). As of 2008, the Nigerian power grid serviced 34% of the population, including 19% of the rural population (Akinbanmi, 2001; Ex-Im Bank, 2008).

The average electricity consumption per capita in Nigeria is about 168 kWh per capita/yr. If this is compared with industrialized countries, the per capita electricity consumption in Nigeria is less than 1 percent (Chineke and Igwiro, 2008; Ex-Im Bank, 2008). Since there is the need to take into consideration diurnal variations of wind velocity for wind energy resources assessment, we are continuing in this work by looking at wind power density, capacity factors, environmental and socio-political implications of wind energy utilization especially in the “restive” Niger Delta region. Although the wind speed measured at 10 meters is generally low over the Nigerian environment, the situation can be ameliorated by linking multiple wind farms together. Such approach can virtually eliminate low wind speed events and thus substantially minimize wind power intermittency (Archer and Jacobson, 2005).

Another option is by integrating several windmills and connecting them over a grid or better still, with other renewable energy technologies like solar and tide (BWEA, 2005; Chineke and Nwofor, 2007). Windiness varies, and an average value for a given location does not alone indicate the amount of energy that a wind turbine could produce. To make wind power more consistent requires that storage technologies must be used to retain the large amount of power generated in the bursts for later use.

A strong case is advocated for offshore small wind generation systems with capacities of 100 kW or less in the coastal areas of Nigeria to power homes, farms, and small businesses. Isolated communities that otherwise rely on petrol or diesel generators may use wind turbines to displace diesel fuel consumption. In urban locations, where it is difficult to obtain predictable or large amounts of wind energy, smaller systems may still be used to run low power equipment. Equipment such as parking meters or wireless internet gateways may be powered by a wind turbine that charges a small battery, replacing the need for a connection to the power grid. On the long-run, the lives of both rural and urban dwellers will be improved with a multiplier effect, thanks to wind energy, on reducing crime, unemployment, restiveness and enhancing sustainable development. Boosting the electricity supply in Nigeria using wind energy and other renewable energy technologies is one sure way of ameliorating the effects of climate change in addition to reducing the dependence, with the unnecessary "restiveness", on electricity and energy from fossil-fuels (International Energy Outlook, 2008).


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