Renewable Energy as a Source of Power Generation in Nigeria

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ABSTRACT

The aims of this study are to investigate and identify renewable energy sources and how they can be used (potentials) to ameliorate the energy crisis of Nigeria from the electricity generation point of view. Solar photovoltaic and wind energy is considered as a means to help tackle the shortage of electricity in the country. It is evident that solar and wind energy are viable alternative sources of energy for power generation in Nigeria. Port Harcourt is selected for the design because it is one of the cities with the highest rainfall in the country, and this will help in the assessment of solar PV potential for power generation in the country. The north has more solar resource compared to the south of the country. These locations are chosen because several studies have been carried out in order to investigate the pattern and characteristics of wind speed across the country with less consideration to the south-east zone. Based on the research and the analysis, it is found that solar and wind energy would be a solutionto the problem of electricity shortage and at the same time be a supportive energy source for the existing energy system in Nigeria.

Keywords: *Solar Photovoltaic, Wind Energy, Renewable Energy, Electricity Generation.*

INTRODUCTION

It is obvious that nation can develop without electricity. All sectors of the economy would be severely retarded because it is a necessary requirement for development. Electricity is the most commonly used and wanted form of energy throughout the world (Oyedepo, 2012). When the population of a nation grows and its economy expands, its demand for electrical energy multiplies. A shortage in supply is bound to occur when this demand is not met adequately (Ohunakin, 2010). Chiejina notes that the growth of any nation depends on the capability of its electricity supply industry (Business Day News, 2012). The various sectors of the economy such as agriculture, education, industry, tourism, health, etc depends on reliable, adequate and economic price of power for development. Renewable sources of energy like wind and solar can be replenished naturally on a daily basis when they are used. Hence, developing nations such as Nigeria should diversify her source of energy for electricity to renewable sources of energy.

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The aims of this study are:

i) To have a better understanding about the potential of renewable energy sources in Nigeria
ii) To investigate how renewable energy sources can be supported, promoted and encouraged in Nigeria in order to bridge the gap of Nigerians that did not have access to electricity.
iii) To show that renewable energy is strategically significant to the socio-economic well-being of the nation.
iv) To examine how sources of energy in Nigeria can contribute to economic growth and development of the nation.
v) To identify renewable energy potentials in different regions of the country
vi) To investigate the capability in the utilization of solar energy and wind energy in the rural and urban areas of the country

Renewable Energy Resources and its Potentials

The use of alternative energy resources (Renewable energy resources) and their development are of great importance because they prevent pollution of the environment and global warming which have constituted serious threats to the world. Energy resources have an important role to play in the world's future and this makes them very important and essential ingredients to economic and social development of any nation. There are many renewable energy resources in existence which can be used instead of conventional and fossil fuels. Sources of renewable energy are secure and inexhaustible. Hence, the problem of reserve depletion will not be encountered or experienced (Boyle, 1996).

Emissions from renewable energy are not detrimental to the environment like the fossil power stations. Hence, renewable energy is a climate friendly form of energy (Stiebler, 2008). Renewable energy has an impact on the environment but the impact is far lower than the fossil fuels and nuclear power (EREC, 2004). Several climate changes have been observed in the last century, in different regions all over the world. These climate changes are attributed to the rise of fossil fuel uses due to the important demographic and industrial development (Akella Sani and Sharma 2009). The following climate changes affect Nigeria, increased frequency and intensity of storms, droughts, floods, increased frequency of fires, sea-level rise, temperature rise, precipitation change, landslides (Thompson, 2011). Non-renewable energy sources are a resource of economic value that cannot be replaced readily through natural means on a level equal to their consumption, happen to be the most widely used and they are not environmentally friendly due to their harmful emissions and byproducts. The non-renewable energy sources deplete, meaning that the sources are exhaustible and their rate of usage will affect their availability in future because once they are used up, cannot be replenished in a short period of time. Their rate of power production is not consistent and adequate for national consumption as in the case of Nigeria because they belong to government who lack policy and legislation to address the situation.

Looking at the cost of maintenance also, it does not help developing countries in any way because of insufficient technological capabilities in the energy sector and energy financing. The energy requirements of developing nations like Africa are rapidly increasing with majority depending on traditional biomass for their cooking and heating (Ajayi, 2009). According to Bugaje (2004) and Haanyika (2006), over two billion people worldwide are recorded as people that do not have access to energy in commercial forms rather use traditional fuels in cooking. Similar figure was also recorded as people that do not have access to electricity.

Interest in alternative energy source such as renewable energy is due to rising prices of oil, increasing global energy consumption and environmental concern. West Africa contributes about 25% of global large hydropower installed capacity. There is a general shortage of information in Africa regarding energy in terms of potential of energy resources, actual installed systems and current energy use when compared to the rest of the world (Monforti-Ferrario, 2011). Lack of this information is more apparent for renewable energies. It is also difficult to compare the potential for the different energy options because of the intermittent validated information (Monforti-Ferrario, 2011). Approximately 3 billion people worldwide was estimated in 2010 to rely on traditional biomass for cooking and heating, and a population of about 20% of the world, 1.4 billion people do not have access to electricity with 85% of these people living in the rural areas (Monforti-Ferrario, 2011). He also has it that more than a billion have access to unreliable electricity networks only. According to the Alliance for Rural Electrification elaboration of International Energy Agency (IEA) data (Monforti-Ferrario, 2011), it was estimated that the total amount of people with no access to electricity in the African continent has reached 589 millions in 2008, with an additional 9 million of people every year without access to electricity since 2002. (Monforti-Ferrario, 2011) says that 99.6% of the African population without access to electricity is concentrated in the Sub-Sahara Africa (SSA) countries according to IEA data. It is obvious that mankind cannot indefinitely continue to depend on the consumption of finite energy resources EREC, (2004).

Fossil fuels and nuclear power are currently supplying the world's energy. The needs for energy systems are necessary in order to meet the demands for a broad range of services such as commerce, industry, household and transportation needs. In the past decades, a well established source of electricity supplying 16% of the global electricity production in 2004 was the hydropower. Noticeably, Canada, China, Brazil, the United States and Russia were the top five producers of hydropower. It was a dominant source of power in countries such as Canada and Brazil, and considerable in countries such as China, Russia and Nigeria. It was said to be significant in large economies such as France, India, Germany, Italy, Japan, Indonesia, Iran, Mexico, Spain and the US (Krewitt, Simon and Pregger, 2008). Despite very high growth rates of solar photovoltaic, the generation of electricity from it is still barely noticeable in power production statistics in the world. Wind, geothermal and biomass capacity are said to be diversifying the

production of power from renewable sources in countries such as Germany, Italy, Mexico, Indonesia, Japan, UK, Spain and the US. Nigeria, the giant of Africa because she is the largest country with about 923,768 square kilometers of total area and about 150 million population and the richest country in Africa with abundant resources of fossil fuels and renewable energy resources, is suffering from chronic energy shortages/energy crisis despite its vast oil and gas reserves and an abundance of renewable energy potentials. The nation is not developed because the proportion of its population that has access to energy services is too low. The use of renewable energy such as photovoltaic and solar thermal systems is still in its technological infancy (Awogbemi and Komolafe, 2011).

As a prerequisite for economic development, public welfare and social security, electricity supply should be consistent and reliable (Ohunakin, 2010). The Energy Commission of Nigeria (ECN) states that by 2015, the country is expected to produce about 15903 MW of electricity from renewable energy sources according to its planning. The technical committee set up by the Federal Government to evaluate the country's renewable energy potentials states in its report that the nation has about 15 sources of renewable energy from which it can expand its existing power generation capacities. These include: wind, solar, hydropower, biomass, geothermal, tidal, wave, biogas, anaerobic digestion, etc. The Director-General of ECN, Prof. Abubakar Sambo while speaking at a workshop on renewable energy development organized by ECN in collaboration with the United Nations Development Program (UNDP) in Abuja, states that the Government is developing a master plan that would enable the exploitation of renewable energy sources in the areas of solar energy, small hydro, wind and biomass energy generating systems (This Day-African Views on Global News, 2005).

The Renewable Energy Master Plan targets 20MW and 40MW for 2015 and 2025 respectively for wind energy, 600MW and 2000MW for 2015 and 2025 respectively for small hydropower, and 75MW and 500MW for 2015 and 2025 respectively for PV solar energy Unimke (2011). In order to overcome Nigeria's current power shortages and achieve the objective of being among the twenty top economies in the world by 2020, Nigeria as a matter of urgency needs alternative sources of energy in order to achieve regular electricity supply for both domestic and industrial usage [8, 14]. It has been a great challenge for Nigeria and many other developing countries to provide energy for its rural and urban areas. About 60% of Nigeria's 150 million people have no access to reliable electricity from the national grid despite the country's huge natural resources. Lighting with kerosene lanterns, torches, candles etc is what most people rely on. Nigeria's energy mix is dominated by oil (57%), natural gas (36%) and hydroelectricity (7%) as at 2005 (Adegbulugbe and Adenikinju, 2009 and Oyedepo, 2012). Nigeria is fortunate to have huge energy resources that should have been utilized to transform its economy and the lives of its citizens (Adegbulugbe and Adenikinju, 2009) and these resources have not been exploited and harnessed due to inadequate infrastructures, finance and technical know-how. Nigeria is a nation reputed as the most populous black

nation in the world, the ninth populated country in the world and the world's sixth largest oil and leading gas exporter with the grid connecting less than 45% of the population. Only about 10% of the rural areas have access to the grid. The nation's major power sources are large hydro and thermal gas which are usually unreliable due to frequent and protracted outages. Iwayemi (2009) maintains that the country experienced 316 power outages in 2004, with an increase in 2005 by 26% followed by an explosive increase of 43% between 2006 and 2007. He also notes that the prolonged periods of time of power outages suggest that the number will also be very high in 2008. Foster and Pushak, (2011) also maintains that the country is affected by power outages more than 320 days a year according to the World Bank's Enterprise Surveys. This is a level many times higher than that found in other African countries. Distribution System Reliability (DSR) is defined as "the ability of the distribution of power system to perform its function under stated conditions for a period of time without failure" (Oyedepo, 2012). In the assessment of distribution performance, System Average Interruption Duration Index (SAIDI) is used and it is one of the DSR indices. This is the annual average total duration of electric power interruption to a customer and it is represented in minutes. SAIDI for some countries is given below on table 1.

Table 1: SAIDI for some countries in 2010

Country	**SAIDI (minute)**
Nigeria (PHCN)	900
Nigeria (MAN study)	>60,000
USA	88
France	52
Singapore	1.5

Source: Oyedepo, 2012

Analysis from table 1 above shows that Nigeria reliability index is very high (that is, a low reliability), 60,000 minutes or greater than as reported by the Manufacturers' Association of Nigeria (MAN) seems to be more realistic since it is in closer agreement with a figure obtained in another independent research of 87,639 minutes Oyedepo (2012). Nigeria was ranked 165 out of 179 countries by the International Monetary Fund (IMF) in terms of per capita income as at 2006. The United Nations classified Nigeria among countries with low Human Development Index with 0.461. The United States Central Intelligence Agency World Fact-Book reports on per capita electricity consumption in kilo-watt hours (kWh) for 2011 which ranks Nigeria 175th with 126.20kWh per head, far behind South Africa with 4380.04 (59th), Cameroon 248.83 (166th) and Ghana with 234.27 (168th) (CIA World Factbook 2011). Nigeria was ranked 3rd in Gross Domestic Product (GDP) of African countries in 2008 with 328100 GDP (USD millions) Africapedia (2012). The Global Competitiveness Index (GCI) rankings in its 2008-2009 report ranked Nigeria 94th in the world ranking and 11th in Africa ranking (Africapedia 2012 and World Economic Forum, 2008). Political and industrial interests in continuing to use fossil fuels were identified as the main

barrier to the uptake of renewable energy technologies. Droege, (2008); Foster and Pushak (2011) maintain that despite millions of dollars spent by the Federal government of Nigeria in resuscitating ailing power plants and constructing new ones, electricity generation from the Power Holding Company of Nigeria (PHCN) and the existing Independent Power Producing Plants (IPPs) still hovers between 3200 and 4000 megawatts (MW). For a modern society, energy is an essential component because all production and manufacturing activities rely on it (Tyler, 2002). Nigeria was described as the country with the biggest gap between supply and demand for electricity in the world as stated in the progress report on the roadmap for power sector reform. The Presidential Task Force on Power (PTFP) in its report released in 2010, put electricity supply in the country at 3,800MW for a population of 150 million people. It also said that the country supply was not adequate to stimulate economic growth. The roadmap implementation in its report stated that an additional 7,770MW of electricity from hydropower, thermal gas, solar and wind is expected to have been added to the current 3,800MW by the end of 2013. The National Independent Power Project (NIPP) is expected to add about 4,770MW to the national grid and the Independent Power Plants (IPPs) is to deliver an additional 3,000MW totaling 7,770MW by December 2013 (The Nigerian Voice, 2011). All these assumptions and predictions are mere paper work as there has not been anytime that targets were met especially in Nigeria.

Renewable energy resource available in Nigeria

About 90% of the energy used by the rural population for cooking and heating is of traditional biomass energy sources such as wood, charcoal, manure, crop waste; candles and kerosene for lighting (Oyedepo, 2012). For Nigeria to advance in the standard of living for its citizens and stabilize its social, economic and political systems, it has to improve in its energy output and utilization by starting from the grassroots level. The natural and interconnected flow of energy of the planet earth is what the Renewable Energy Sources are based on. The solar energy the earth receives as radiation from the sun is far exceeding mankind's use in quantity. The sun generates wind by heating the planet. And wind creates waves. The evapotranspiration cycle is powered by the sun also, and this allows power to be generated by water in hydro schemes. This happens to be the largest source of renewable electricity in use currently in Nigeria and worldwide.

Wind energy: Oyedepo (2012) describes wind as a natural phenomenon that is related to the movement of air masses primarily caused by the differential solar heating of the earth's surface. Awogbemi and Komolafe (2011) also describes wind as movement of air caused by the uneven heating of the earth's surface by the sun. The sun's heat is absorbed at diverse rates due to the earth's surface being made of different types of water and land. The air above the land is heated up more quickly than the air above water during the day. Winds are created due to the rise of warm air over the land and the rush of heavier, cooler air to take its place. The winds are reversed at night because the air cools more rapidly over

land than over water. Oblack (2008) defines winds as "simply air that moves as a result of a pressure gradient". He goes further to explain "winds as a squeezed balloon". If one takes a balloon filled with air and squeezes it at one end, the air rushes from the end where one apply pressure and flows to the lower pressure zone. Similarly, wind works in the same way. When the earth is heated unequally by the sun, differences are created in air pressure all over the surface of the earth. In view of the fact that winds move from areas of high pressure to areas of low pressure (pressure gradient) the greater the difference in pressure, the higher the wind speed.

Generally, a wind farm is made up of a wind power station that is located in relatively high wind areas. And for a typical wind machine, it is made up of blades, cable, generator and a simple computer system. The blades capture the wind and spin, the generator converts the mechanical energy into electricity, the cable carries electricity to the transmission line and the computer system is responsible of controlling the direction of the blades. In Nigeria, annual wind speeds in some cities at 10m height are between 2.32m/s with 4.51 watts per square meter of blade area and 3.89m/s with 21.97 watts per square meter of blade area for Port Harcourt and Sokoto State respectively (Oyedepo, 2012). Recently, efforts have been made towards the use of wind power for electricity generation although wind energy has been used for water supply for hundreds of years (Sambo, 2005). Considering the duration of wind speeds greater than 3m/s, the energy per unit area works out as 168.63 and 1,556.35kWh per square meter of blade area for Port Harcourt and Sokoto respectively (Sambo, 2005).

Oyedepo, (2012) estimates that the maximum obtainable energy from a 25m diameter wind turbine of an efficiency of 30% and height of 25m is about 24.5MWh/year and 25.7MWh/year for Port Harcourt and Lagos respectively, while that of Sokoto and Kano is 97MWh/year and 50MWh/year respectively. Adegbulugbe and Adenikinju (2009) in their own studies show that the actual total wind energy reserve using a height of 10m may vary from 8MWh/year to 51MWh/year for Yola and the mountainous areas of Jos Plateau respectively, and rose to 97MWh/year for Sokoto. In the South of the country, wind speeds are generally weak except for the coastal regions and offshore locations. Generally, peak wind speeds in Nigeria occurs between April and August on most sites. Therefore, the country's wind conditions are within a moderate wind energy zone. Shown below is the map of Nigeria showing the 36 States of the Federation and the Federal Capital Territory (FCT), Abuja.

The only known and functional wind electricity project (wind pump) is the 5kWp Sayya Gidan Gada wind electricity in Sokoto (North West Nigeria). A 0.75kWp wind electricity project is run on an experimental basis to investigate the viability of wind farming in the area. Despite the huge amount of wind energy in the Northern part of the country and its coastal States, wind energy is still at zero in the Nigeria energy mix (Adegbulugbe and Adenikinju, 2009, Oyedepo 2012). That is, wind energy has not contributed to the energy mix of the country where it will be noticed.

Solar energy: In general, solar energy is the most promising of all the renewable energy sources due to its apparently limitless potential (Awogbeni and Komolafe, 2011, Oyedepo, 2012 and Sambo, 2005). Radiation of energy from the sun is at the rate of about 3.8 x 10^{23}kW per second (Awogbeni and Komolafe, 2011, Oyedepo, 2012 and Sambo, 2005). Most of this energy is radially transmitted as electromagnetic radiation that comes to about 1.3kW/m^2 at the atmosphere boundary. A square meter of the earth's surface can receive as much as 1kW of solar power after traversing the atmosphere and averages to about 0.5 kW over all hours of daylight in Nigeria. Nigeria is said to lie within a belt of high sunshine with enormous solar energy potentials distributed fairly well throughout the country.

The mean annual average of total solar radiation of the country varies from about 12.6MJ/m^2/day (equivalent to 3.5kWh/m^2/day) in the coastal latitudes to about 25.2MJ/m^2/day (equivalent to 7.0kWh/m^2/day) along the semi arid areas in the far North of Nigeria. An annual average solar energy intensity of 1,934.5kWh/m^2/day and the solar radiation received by the country is at the level of 19.8MJ/m^2/day on the average. Hence, an average of 6,372,613PJ/year (1,770,000TWh/year) of solar energy falls on the entire land area of the country over a whole year. An average solar radiation level of about 5.5kWh/m^2/day is given and the average value for sunshine hours (average solar radiation time) is 6 hours/day. And this is considered favorable conditions for PV power generation (Adeggbulugbe and Adenikinju, 2009, Oyedepo 2012 and Sambo 2005).

Considering the huge increase of wind and photovoltaic solar in a short period as stated by the Renewable Energy Master Plan in its targets, renewable energy would be playing a great role in the electricity generation of the country. And the issue of frequent shortage of electricity would be a thing of the past provided that this is achieved. If the solar resource in the country is adequately harnessed, the target of 75MW of photovoltaic solar energy for 2015 would be achieved because the country would be generating about 50.7MWh (50730kWh) of energy from solar photovoltaic in a year provided the plan is successfully implemented. The Power Holding Company of Nigeria (PHCN) and the existing Independent Power Plants (IPPs) that are hovering between 3200 and 4000MW of electricity generation in the country can diversify and go for renewable energy such as solar photovoltaic and wind energy rather than wasting the millions of dollars in resuscitating ailing power plants and constructing new ones.

The projected 12000MW energy demand of the country would be achieved if only solar PV and wind energy sources are exploited, harnessed and used as source of power generation in order to include these alternative/renewable resources and technologies into the country's energy mix. The solar energy resource in the country for domestic and industrial uses is viable. This will in no small measure enhance the energy security of the country and sustainable energy supply system will also be established because conventional energy has an extinction risk and is depletable.

CONCLUSION AND RECOMMENDATIONS

Nigeria is really facing a serious energy crisis and ironically, this is not due to lack of energy resources but rather due to inappropriate technology and the poor state of infrastructural support to harness these resources most especially the renewable. For Nigeria not to be left out on the economic growth and trade liberalization that the world attention is focused on, its energy needs must be addressed with an utmost sense of urgency. The country has a vast energy resource based on both conventional and renewable resources but these are not harnessed adequately due to inappropriate framework. The shortage of electricity supply in Nigeria will be a thing of the past if the three tiers of government (federal, state and local governmentS) in Nigeria can commit political and financial support by establishing pilot projects in each of the rural and urban communities of the country. The nation's renewable energy resources should be utilized to increase access to electricity for sustainable development. Renewable energy is the best way to go in terms of strategy in order to maximize the advantage of the country location on the equator, reduce global warming and undesirable climate change by ensuring that the economy of the country is placed on a robust standing.

The recognition of renewable energy such as solar and wind energy as a great source of power generation and its usage will grant an answer to the concern of electricity shortage and one of the most effective solutions to sustainable development for the developing countries such as Nigeria. As a result of the analysis, it was revealed that urban areas of Nigeria have the potentials to attain access to electricity. In the course of this research, the wind energy potential and wind speed of the three locations selected in the south east zone of the country was examined. The annual mean wind speeds for Enugu is 5.42m/s, Owerri 3.36m/s and Onitsha 3.59m/s. The annual values of the wind speed carrying maximum energy for Enugu is 6.48m/s, Owerri 3.90m/s and Onitsha 4.33m/s. The annual mean wind power density for Enugu is 96.98 W/m^2, Owerri 23.23 W/m^2 and Onitsha 28.34W/m^2. Hence, based on the wind data used in this research, the resource of wind energy in the south east of the country might be classified into class one generally.

It can be concluded that the three sites would be suitable for the utilization of wind energy. And for the south east of the country to have this much of wind potential, the northern part of the country would demonstrate higher potential for the harvest of wind energy. If the three cities considered alone can generate about 1.49 X 10^{-7} MWh of power and 1170 MWh of energy in a year, then the National plan target of 20MW of wind for 2015 would be achieved. This has also proven the viability of wind energy as a source of power generation for Nigeria in general. Individuals and other researchers intending to carry out a study on this area should endeavour to extend to other cities of the country to identify the potential of other renewable sources of energy. Finally, the study should be carried out at regular intervals to know if there would be changes in the findings for necessary improvement.

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