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Utilizing Renewable Energy Resources to Solve Nigeria's Electricity Generation Problem

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Abstract

There is a paradigm shift in the way energy resources are utilized in today's world, the shift to renewable source is not only environmental friendly but it is almost available in every country. Most developed nations are increasingly doing away with traditional energy sources and embracing renewable energy to satisfy their energy needs, the case of Brazil and the use of ethanol in transportation is a vivid example. This paper considers the case of Nigeria which at the moment is grappling with a serious electrical power crisis. The paper reviews the state of the electrical industry in the country; considering the pattern of electricity generation and consumption over the last couple of decades and also delves into the renewable energy resources potential of Nigeria. The paper proposes how the renewable sources can be used to improve the power generation in the country. An estimate of major renewable energy resources specifically Hydropower, solar, wind and biomass was provided. One major observation of this paper is that Nigeria can adequately meet her energy demands and simultaneously export electrical power to her neighbours due to the vast amount of renewable energy resources she possesses (from hydropower sources alone Nigeria can source 11 GW which is almost double present installed electrical energy capacity).This paper also suggested practical insights on how to utilize these renewable energy resources in order to solve the country's long running electricity problem.

Keywords: *Renewable energy resources, Electricity generation, Nigeria, Energy demand, Hydropower, solar, wind, biomass.*

1. Introduction

The last decade witnessed massive debate on climate change and its consequences on the environment. However climate change has now been empirically verified and now attention is on how to mitigate and adapt to the consequences of climate change. In order to cut global carbon emissions by half in 2050 and to achieve a decline in emissions by 2020, various reduction measures are being implemented by many countries around the world. The two most promoted carbon emission reduction measures are energy efficiency (EE) and renewable energy (RE),the later being regarded as a better option as it is readily available in uniform proportion all over the world [1]. It is evident that a number of developed countries have demonstrated successes in the implementation of RE policies in electricity, transportation,agriculture, heating/cooling and in drying processes. The world's attention is mostly focused on the developed world leaving the developing countries at the trailing end of events. It is clear that most African nations (developing countries) are endowed with renewable energy (RE) more than the developed countries but their lack of expertise and poor management and policy have left them at the bottom of RE implementation. The increasingly acknowledgment of RE technologies as the future of energy and the speculation that crude oil will soon cease to be the driver in the energy sector have motivated RE research in Africa. Nigeria the 12th largest oil producing country in the world is repositioning itself for the future. The Nigerian economy is crude oil driven which contributes slightly over 30% to its GDP and accounts for about 90% of government income earning [2]. Despite the huge revenue from crude oil the government has failed in many areas to improve the living conditions of its people. One major area that needs intervention is the shortage of electricity supply for domestic and industrial use.Current efforts to mitigate the acute and epilectic supply of electricity neccesitates RE sources research in Nigeria. The current state of power generation and distribution in Nigeria does not truly represent the energy potential of the country. Table 1 shows the years and capacities of electricity generation plants in Nigeria, it will be observed from Table 1 that the most recent plant was commisioned in 1990 knowing that the average life cycle of generating plant is 30 years. The plants break down more often and huge funds goes into maintaining old plants that need to be replaced. The electricity sector managed by Power Holding Compnay of Nigeria (PHCN) received a sum of $10 billion between 1999 to 2007 from the office of the presidency of Nigeria without a substantial improvement in electricty generation [3]. The aim of this paper

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is to analyse the potential of RE resources in Nigeria and to suggest how they can be integrated to electricity generation to end the acute power shortage in the country.

Fig. 1. Map of Nigeria

Table 1: Existing and planned electricity plants in Nigeria, 2005[4]

	Type	capacity (MW)	Year commissioned
Existing plants			
Jebba	Hydro	578.4	1984
Kainji	Hydro	320	1968
Kainji	Hydro	200	1976
Kainji	Hydro	240	1978
Shiroro	Hydro	600	1990
Afam I	Gas	20.6	1963
Afam I	Gas	35	1965
Afam II	Gas	95.6	1976
Afam III	Gas	110	1978
Afam IV	Gas	450	1982
Ijora	Oil	6.7	1966
Ijora	Gas	60	1978
Delta I	Gas	72	1966
Delta II	Gas	120	1975
Delta III	Gas	120	1978
Delta IV	Gas	600	1990
Sapale GT	Gas	300	1981
Sapele ST	Gas	720	1978 & 1980
Oji	Coal	300	1956
Egbin	Gas	1320	1985
AES (Egbin-IPP[b])	Gas	270	2004
		Total existing	**6538.3**
Planned			
Papalanto	Gas	330	2007
Omotosho	Gas	330	2007
Guregu	Gas	414	2007
Alaoji	Gas	330	2007
IPP[a] (oil companies)	Gas	3909	2007–2008
IPP (Private, non-oil)	Gas	2584	2007–2008
		Total planned	**7897**

[a] Independent power producer.

2. Electricity Production and Consumption

Africa's electricity consumption from 1980 to 2001 grew on the average of 3.1% per year, from 146 bkwh to 275 bkwh. If one is to compare with other regions, Africa's per capita demand for electricity declined relative to that in the MENA(Middle East and North Africa) region, making Africa the region with the smallest per capita consumption of electricity in the world [5]. The low demand of electricity in Africa only shows that the region is not industrialised when compared to other region like Europe or Asia. South Africa consumes an absolute majority of the electricity used in Africa and has a significantly higher per capita consumption rate than the region's other countries. Per capita power consumption in Nigeria is estimated at 82 KW whereas South Africa has a per capita consumption of 3793 KW. It is estaimated that just about 40% of Nigerians have access to electricity and out of this percentage 80 % reside in the urban areas. Most of the rural regions in Nigeria are not electrified,they depend on traditional sources of energy for lighting and cooking. The electricity sector in Nigeria is presently characterized by chronic power shortages and poor power quality supply. The nation has an installed capacity of approximately 6538.3 MW as shown in Table 2 . Out of the approximately 6538.3MW of installed capacity in Nigeria, not more than 4500 MW is ever produced.

Table 2. Electricity Generation and Consumption [4]

Year Installed	Capacity (MW)	Total Generation	Capacity Utilized (%)
1990	4548.0	1536.9	33.8
1991	4548.0	1647.2	35.6
1992	4548.0	1693.4	37.0
1993	4548.6	1655.8	36.4
1994	4548.6	1772.9	39.0
1995	4548.6	1810.1	39.8
1996	4548.6	1854.2	40.8
1997	4548.6	1839.8	40.4
1998	4548.6	1724.9	37.9
1999	5580.0	1859.8	33.3
2000	5580.0	1738.3	31.2
2001	6180.0	1689.9	27.5
2002	6180.0	2237.3	36.2
2003	6130.0	2378.4	38.8
2004	6130.0	2763.6	45.1
2005	6538.3	2494.4	40.5

Table 2 shows that electricity generation increased from 4548 MW in 1998 to 5580 MW in 1999 and later increased to 6538.3 MW in 2005. Electricity capacity utilized on the other hand decreased from 37.9% to 33.3%,31.2% and 27.5 % in 1999, 2000 and 2001 respectively before taking on an upward movement in the years that follow. It needs be pointed out that Nigeria has one of the lowest electricity prices worldwide. Even after the recent increase in electricity tariffs, electricity in Nigeria is still very cheap when compared to what obtains in many other countries in the world. The fluctuations of capacity utilization at different times in Table 2 is due to poor maintenance, fluctuations in water levels powering the hydro plants and the loss of electricity in transmission. This

inefficiency as well as inadequate facilities to boost electricity supply has been a major cause of the increasing gap between demand and supply of electricity coupled with about 33-40 % losses of electricty generated in transmission due to old transmission infrastructure belonging to Nigeria's Electric Utility: Power Holding Company of Nigeria (PHCN). The main generating power plants in Nigeria are located in different parts of the southern part of the country as shown in Table 1 and Fig.1 and a lot of these transmission losses occur when transmitting power to other parts of the country. It will be observed from Table 1 that most of the generating units are old and efficiency is an issue having spent more than half of their life span bearing in mind that a typical power plant equipment or machinery has a life span of about 30 years. New installed power generating plants are being installed in the country by private investors with most powering certain industrial areas. On the transmission scale,the transmission system comprises of 33KV lines and 132KV lines, a mixture of radial and ringed types, which transport electric energy from generating power stations to major grid substations from where 33KV and 11KV distribution network are supplied. There are over 114 major grid substations in the country; 23 of which are linked by 5000km of 330KV lines and 91 are linked by 6000km of 132KV lines, while on the distribution network there are hundreds of kilometers of 33KV and 11KV lines connected to various distribution substations all over the country. There are also over 1790 distribution transformers and 680 injection substations [6]. The following have been identified as major obstacles to stable electricty supplies in Nigeria:

1. Lack of preventive and routine maintenance of PHCN facilities which results in huge energy losses.
2. Frequent major breakdowns, arising from the use of out-dated and heavily overloaded equipments.
3. Lack of co-ordination between town planning authorities and PHCN, resulting in poor overall power system planning which in turn leads to over-loading of PHCN equipments.
4. Inadequate generation due to operational/technical problems arising from machine breakdown, low gas pressure and low water levels.
5. Poor funding of the organization (PHCN's sole source of revenue is from tarrifs which are the lowest in Africa).
6. Inadequate budgetary provision and undue delay in release of funds to PHCN.
7. PHCN's inefficient billing and collection system.
8. High indebtedness to PHCN by both public and private consumers who are reluctant to pay for electricity consumed as and at when due.
9. Vandalization and pilfering of PHCN equipments.
10. Inability to convert gas flares to a source of electricity.

The present efforts in Nigeria to solve the electricity problem have not utilized renewable technology despite her huge renewable energy endowment. The country is abundantly endowed not only in crude oil and gases but also in renewable energy. The challenges of the electricity industry in Nigeria is huge and complex but one way out is to employ renewable resources in power generation as proposed in this paper.

3. Nigeria's Renewable Energy Potentials

Nigeria is known as an oil producing state. The oil boom of the 1960 have deprived the country of tapping into other forms of energy on a commercial scale. The country's export capacity in Cocoa and other agricultural products witnessed a decline since the oil boom. The oil boom came at a point where the country was unstable politically and the resulting oil wealth was grossly mismanaged. The oil driven economiy is presently at a cross road of either a total collapse or conversion into a multi-resources driven ecomony. The present crises in the Niger Delta region of the country has reduced the daily oil production relegating Nigeria to second place in terms of oil production in Africa. The oil era ushered in corruption and other social vices that Nigeria as a country is still battling with. Only a few know that Nigeria is endowed with significant renewable energy resources that includes large and small hydroelectric power resources, solar energy, biomass, wind, potential for hydrogen utilization and development of geothermal and ocean energy. Table 3 presents estimated renewable energy resources in Nigeria, excluding potential hydrogen, ocean and geothermal energy.

Table 3. Nigeria's Renewable Resources [7]

Energy Sources	Capacity
Hydropower, large scale	10,000MW
Hydropower, small scale	734 MW
Fuelwood	13,071,464 hectares(forest land 1981)
Animal waste	61million tones/yr
Crop Residue	83million tones/yr
Solar Radiation	3.5-7.0kWh/m2-day
Wind	2-4 m/s (annual average)

The level of resource endowment, capacity to utilize certain technologies, government policies and the economics of the energy section are all issues that challenge the optimal utilization of the various sources of renewable energy in the country. About 60% of the Nigerian populace has no access to constant electricity, mostly in the rural areas. The lack of cheap electricity supply, mainly from PHCN, has enormous consequence on the economy. The prices of service and domestic product are on the high side, domestic industries struggle to survive thereby giving into imported finished products from developed countries.

Table 4. Non- Renewable Energy resources in Nigeria [8]

Energy Type	Reserves Estimates
Crude oil	36 billion barrels
Natural gas	185 trillion cubic feet
Coal	2.75 billion metric tons

3.1. Hydropower

The gross hydro potential for the country is approximately 11GW, enough to solely power the current electricity generation in the country. Current hydropower generation is about 10% of the nation's hydropower potential and represents some 50% of total installed grid-connected electricity generation capacity. The South-western and South- eastern regions of the country have higher precipitation with perennial streams and rivers, but it is unfortunate that there is not a single hydro system installed in these regions to ultilise these potentials over the years. The lifetime of small hydro facilities is around 20 – 30 years, compared with 8 – 10 years for diesel engine generators. Long service life is an important attraction of small hydro system. In Nigeria,a private company named Nigerian Electricity Supply Company projects (a small hydropower system) have some small hydropower in Nigeria which were completed between 1923 and 1964 and have not only continued to provide virtually uninterrupted power supply to the Jos metropolis, but have also continued to feed surplus energy into the national power grid till this day [8]. This demonstrates the long life span of an hydropower system. Although, small hydropower may require a moderately high capital cost, its low operation and maintenance (O & M) requirements coupled with long life span are its major advantage. Government and private sector investentment in the hydro system will raise current energy supply in the country. An acceptable 60% of hydro power potential utilization in Nigeria will raise power generation to around 12GW,a figure that will make electric power stable in Nigeria and increase industrial activities in the country.

3.2. Solar Energy

The annual average of total solar radiation varies from about 12.6 MJ/m^2-day (3.5 kWh/ m^2-day) in the coastal latitudes to about 25.2 MJ/ m^2-day (7.0 kWh/ m^2-day) in the far north. This gives an average annual solar energy intensity of 1934.5 kWh/m^2-yr; thus over the course of a year, an average of 6,372,613 PJ/year (≈1,770 thousand TWh/year) of solar energy falls on the entire land area of Nigeria. This is about 120 thousand times the total annual average electrical energy generated by the PHCN. With a 10% conservative conversion efficiency, the available solar energy resource is about 23 times the Energy Commission of Nigeria's (ECN) projection of total final energy demand for Nigeria in the year 2030. [7]

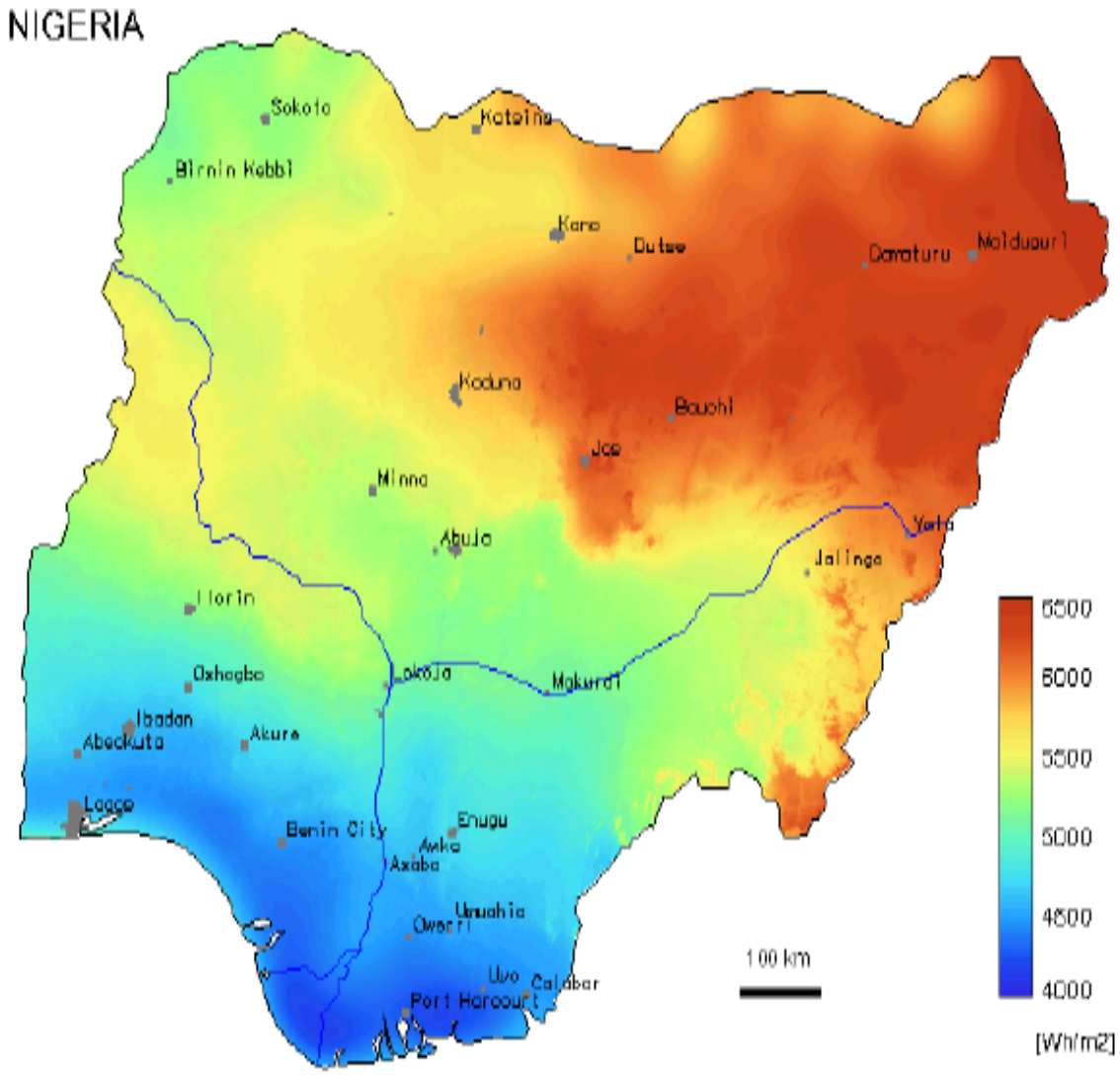

Fig. 2. Solar Radiation Map of Nigeria [9]

Figure 2 shows the solar radiation variation in Nigeria. If the players in the energy sector in Nigeria will concentrate investment on the region with high solar radiation,power transmission over a long distance will reduce and this will reduce transmission losses. Figure 1 shows the geographical land mass of Nigeria,where currently the power stations are located in the southern part of the country and need to be transmmitted to the Northern end of the country. Huge investment in solar technology will save the country from constant power shortage and will attract investment from foreign firms that want to do business in Africa.

Solar photovoltaic technologies are gaining increasing acceptance in Nigeria. However, despite improvements in local R&D efforts, the body of knowledge on these technologies and their market potentials is considerably inadequate. Launching major national initiatives on these technologies requires robust knowledge base and capacity. In all, PV technologies are showing increasing promise in terms of efficiency improvements and costs. The estimated lifetime of PV modules are 25 and 30 years making them exceptionally attractive for investors. Today, all the PV modules in the Nigerian market are imported. Solar PV systems can be extensively used for a wide range of electrical energy requirements, including; solar home systems, water pumping, refrigeration and telecommunications that will reduce the load curve of electricty demand. These applications have positive social and economic impact on the lives of individual users, businesses and communities.

3.3. Biomass

Nigeria's biomass resources include wood, forage grasses and shrubs, animal waste, and other wastes from forestry, agriculture, municipal and industrial activities as well as aquatic biomass. Biomass is similar to fossil fuels as it is made up of hydrocarbons that readily burn to release heat. Current efforts by the Nigerian government to improve biomass utilization is majorly in the transportation industry. The 2007 bioethanol policy birthed the 10% ethanol inclusion into petroleum products in the country. Present estimates show that around 61 millions tonnes/year of animal waste can be achived and that about 83 million tonnes/year of crop residue can be obtained. The use of staple crops like cassava,surgacane and sorghum for the production of ethanol in Nigeira has been highly criticized as these are staple meals for a majority of the country's citizenry. The government can extend the use of bioethanol into power generation which will produce significant effect since the feedstock for bioethanol are renewable. The estimate of biomass contribution to power generation in Nigeria is not available. We intend to do a comprehesive analysis of biomass for power generation in Nigeria.

3.4. Wind Energy

Wind speeds in Nigeria range from a low 1.4 to 3.0m/s in the southern areas and 4.0 to 5.12m/s in the extreme North. Wind speeds in Nigeria are generally weak in the South except for the coastal regions and offshore locations. In Nigeria, peak wind speeds generally occur between April and August for most sites. Initial study has shown that total actual exploitable wind energy reserve at 10m height, may vary from 8 MWh/yr in Yola to 51 MWh/yr in the mountain areas of Jos Plateau and as high as 97 MWh/yr in Sokoto[7]. Hence, Nigeria falls into the poor/moderate wind regime. Wind energy utilization in Nigeria is practically minimal. The hundreds of wind pumps scattered all over the country are ill maintained and some have been abandoned. Some state governments, like Jigawa and Kano, are making efforts to install new wind pumps. There is a pilot wind electricity project in existence which is the 5 kWp Sayya Gidan Gada wind electricity project at Sokoto. In addition, a 0.75 kWp wind electricity project in the center of the town is being run on an experimental basis to prove the viability of wind farming in the area. Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 4-6 cents per kilowatt-hour, depending on the wind resource base and financing of the particular project. The construction time of wind energy technology is less than other energy technologies, it uses cost-free fuel, the operation and maintenance (O & M) cost is very low, and capacity addition can be in modular form, making it adaptable to increasing demand. However, several economic, policy, technical and market barriers militate against the rapid adoption of wind power in Nigeria. These barriers must be addressed if the potentials identified and the targets set for electricity from wind power are to be realized.

4. Discussion

It is obvious that Nigeria presents an array of varied energy mix, from natual to renewable resources. The common guestion is why is the Country still in darkness?. We have seen the case of countries like South Africa and Egypt with very encouraging models of renewable energy utilizations. Nigeria's energy system is laced with poor infrastructural support coupled with weak and unstable policies. One important economic growth catalyst is energy and a lack of it puts a lot of constraint to development in many strata of life from domestic, agricultural, educational, health to foreign investment opportunities. Nigeria ability to optimally put into use its renewable energy potential will invoke the emergence of renewable energy markets in other African countries. The country has missed massive industrial expansion that can be easily translated into huge economic gain for the country due to her unstable power supply . The recent relocation of Unilever headquaters in Nigeria to Ghana is an example of finanacial losses that unstable power supply can cause. Many more industries have relocated to other African countries with better electricty supply.

The cost of maintaining personal power generating sets as is the case in Nigeria has skyrocketed the price of most locally manufactured goods and makes them much more costly that similarly imported goods. The abundant energy resources available in Nigeria should guarantee her a place of pride among other nations not only in Africa but in the wider comity of nations but her incompetence and poor managment policies have deprived her of that role. In other words if Nigeria gets it right, Africa is sure to get it right. In this respect, the following are suggested framework in the harnessing and optimising of renewable energy resources in Nigeria:

- Since solar radiation in Nigeria is fairly well distributed,a rural electrification drive based on Photovoltaic power systems should be pursued for supplying energy to homes, schools, clinics, small and medium scale farms, and small businesses.
- The Law that prohibits a state from developing its own electricity generation should be reviewed and if possible repealed

- The Univeristies of technology across the country should be empowered financailly to act as renewable energy R&D centres for the country
- The government should partner with leading countries in the area of renewable technology
- Development of workable strategies to integrate energy and sustainable development concerns into decision making in Nigeria

5. Conclusion

Electricity is a known catalyst for economic growth and development. Therefore proper provision of adequate, affordable, accessible and sustainable electricity supply is critical to development in Nigeria. Almost five decades after independence, Nigeria is still grappling with problems of generating enough electricity to meet demand, with average electricity consumption still approximately 100 kWh/capita. The lack of electricity over the years has resulted in economic lossess and entrenchement of poverty. Poverty reduction efforts in Nigeria will only be meaningful if the electricity problem is solved. The high unemployment rate in the country can be traced to the epileptic supply of electricty.This paper reviewed the electric industry in Nigeria specifically the electricity production and consumption pattern. Furthermore this paper explored the vast renewable energy potentials that Nigeria possesses and came to this irrefutable conclusion : The solution to energizing Nigeria lies solely in integrating renewable resources into her streams of non- renewable sources of power generation.

References

[1] John Sheffield. The role of efficiency and renewable in the future world energy market, Renewable Energy, Vol. 10, No. 213, pp. 315-318, 1997.

[2] Central Bank of Nigeria Annual Statistical bulletin, volume 16, 2005.

[3] National Electric Power Authority. Power reform and power-generation plans in the public and private sector. Abuja, Nigeria, November 2004.

[4] National Electric Power Authority. Annual Technical Report. National Control Centre, Osogbo,Nigeria; various editions (1985-1992).

[5] Bugaje, I.M. Renewable energy for sustainable development in Africa: a review. Renewable and Sustainable Energy Reviews 10 (2006) 603–612

[6] Energy Commission of Nigeria (2002) National Energy Policy. Abuja.

[7] Energy Commission of Nigeria (2005) Renewable Energy Master Plan. Abuja.

[8] Sambo, A. S., 2008. Paper presented at the "National Workshop on the Participation of State Governments in the Power Sector: Matching Supply with Demand", 29 July 2008, Ladi Kwali Hall, Sheraton Hotel and Towers, Abuja.

[9] Sambo A.S. Renewable development in Nigeria. World Future Council and strategy Workshop on renewable Energy, Accra, Ghana, 21-24 June, 2010