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Energy Crisis in Nigeria: Need for Renewable Energy Mix

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Abstract Nigeria is endowed with oil and natural resources but the country cannot be said to have ever had adequate supply of electricity in the history of its electricity generation. This might get worse, as the country's population increases and economic development is calling for more demand of energy. The gradual diminishing of fossil fuels and the effort to save the eco-system from global warming has seen nations turning to alternative sources to meet their energy demands. It is therefore, imperative that renewable energy solutions be proffered to cater for Nigeria impending industrialization and its energy crisis which leaves many industries running at high cost and keeps many private homes in blackout. This paper discusses the potentials of renewable energy as an additional generation source to meet the energy demand of Nigerian populace. It focuses on the country's energy crisis and how its natural resources can be harnessed to meet the nation's energy demand while reducing global pollution. An analysis of projected energy capacities from the abundant renewable energy resources and how much of these resources are required to be harnessed in the proposed energy mix- to achieve over 60,000MW of power- was presented.

Keywords: *energy crisis, Nigeria, renewable energy*

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1. Energy Crisis in Nigeria: An Overview

The first electricity supply company in Nigeria was established in 1929, though history has it that electricity generation in Nigeria started around 1896. It was in 1972 that all isolated electricity generating corporations in Nigeria were merged with Niger Dams authority which was the only hydroelectric power station as at that time. The merger was named; National Electric Power Authority (NEPA). In 2005 the Federal government of Nigeria initiated the Electric Power Sector Reform Act (EPSRA) after amending the electricity and NEPA laws which were the prevailing laws as at 1998. The amendments were to remove NEPA's monopoly and encourage private sector participation, albeit there were no tangible results. The reform for the sector was revived in 2010 with the Power Sector Reform Roadmap, which is successfully being implemented despite some challenges. The Power Sector Reform has led to the unbundling of the Power holding Corporation of Nigeria (PHCN) into 18 different companies - 11 distribution companies, 6 generation companies and 1 transmission company [1].

The International Standard Industrial Classification [ISIC] is a United Nations system for classifying economic data, according to category E division 40. The electricity statistic includes generation, collection, transmission and distribution of electric energy for sale to all categories of consumers [2,3]. On the other hand, in Nigeria, this information can only be obtained from PHCN publication in its annual reports and accounts. Nigeria Electricity consumption per capita between the 2010 and 2014 is 149kWh which is less than half of Ghana and incomparable to United States with per capita of 13,246kWh [4].

Energy crisis in Nigeria has been a concern for both the Nigerian government and the people for the past four decades [1]. While other countries with similar problems have long overcome the predicament, Nigeria still looms in pitch darkness. Businesses have relocated from the country due to inability of the national power supply to meet their demand while homes have had to adapt to the epileptic power supply or in some cases total blackout [5].

The few companies operating in Nigeria largely depend on the off-grid supply using diesel/gas/petrol-powered electric generators thereby running at huge overhead costs and contributing to greenhouse gas pollution among other harmful environmental problems. According to the Director-General of Centre for Management Development, Dr Kabir Usman, at the launch of the National Power Training Institute of Nigeria graduate skills development programme in Abuja in 2012, 60 million Nigerians spend ₦1.6tn on generators annually.

In the world ranking of environmental pollution, Nigeria's category is low compared to world leaders like USA and Great Britain [6]. This could be attributed to low level of industrialization in the country owing to the energy crisis being discussed. The question raised in our minds is how the energy crisis in Nigeria can be solved whilst taking into consideration environmental conservation initiatives.

If renewable energy is added to the present energy supply, more than sixty thousand megawatts (60,000MW) or sixty Gigawatts (60GW) of power required to place Nigeria in the category of industrialized nation can be achieved without significant increase in environmental pollution.

The poor electricity production in Nigeria is a major contributor to the poor industrial development in the country who is renowned to have the lowest electrification per capita in Africa. In Nigeria, electricity generation, transmission and distribution account for less than one percent (< 1%) of its GDP but fifty-four percent (54%) of the share of utilities (e.g. electricity and water supply) [7]. The electrification rate in Nigeria is estimated at forty one percent (41%) [8], indicating that the demand far outweighs the supply. The Federal Government is deeply concerned about this problem and has made several concerted efforts to increase electricity production in Nigeria. The government has made it an objective to increase the current electrification rate from forty one percent, 41%, (5,500MW) to fifty percent, 50%, (8,000MW) by 2016. It has a target of increasing electricity production to 40,000MW by the year 2020 [9].

Table 1. Power Generation Companies in Nigeria with On-grid license from NERC and their installed capacities [10, 11]

Name	Site Location	Type	Installed Capacity (MW)	Available Capacity
AES Nigeria Barge Limited		Thermal	270	224
Afam Power PLC	Afam Rivers State	Thermal	987.2	60
Agbara Shoreline Power Limited	Agbara Ogun	Thermal	100	
Alaoji Generation Company Limited (NIPP)	Alaoji Abia State	Thermal	1074	
Anita Energy Limited	Agbara Lagos State	Thermal	90	
Azura Power West Africa Limited	Ihovbor Benin, Edo State	Thermal	450	
Benin Generation Company Limited	Ihonvbor Edo State	Thermal	450	
Calabar Generation Company Limited	Calabar Cross State	Thermal	561	
Century Power Generation Limited	Okija Anambra State	Thermal	495	
Enersys Nigeria Limited	Ado Ekiti State	Thermal	10	
Delta Electric Power Limited	Oghareki Etiope West LGA	Thermal	116	
DIL Power PLC	Obajana Kogi State	Thermal	135	
Egbema Generation Company Limited	Egbema Imo State	Thermal	338	
Egbin Power PLC	Egbin Lagos State	Thermal	1320	1100
Energy Company of Nigeria (NEGRIS)	Ikorodu, Lagos State	Thermal	140	
Enersys Nigeria Limited	Ado Ekiti Ekiti State	Thermal	10	
Ethiope Energy Limited	Ogorode, Sapele Delta State	Thermal	2800	300
Farm Electric Supply Limited	Ota-Ogun State	Thermal	150	
First Independent Power Company Limited	Omokun Rivers State	Thermal	150	60
First Independent Power Company Limited	Trans Amadi, Rivers State	Thermal	136	
First Independent Power Company Limited	Elewe, Rivers State	Thermal	95	
Fortune Electric Power Company Limited	Odukpari, Cross Rivers State	Thermal	500	
Gbarain Generation Company Limited	Gbarain, Bayelsa State	Thermal	225	
Geometric Power Limited	Aba, Abia State	Thermal	140	140
Geregu Power PLC (BPE)	Geregu Kogi State	Thermal	414	276
Hudson Power Ltd.	Warawa, Ogun State	Thermal	150	
Ibafo Power Station Ltd.	Ibafo, Ogun State	Thermal	200	
Ibom Power Ltd	Ikot Abasi Akwa Ibom State	Thermal	190	
ICS Power Ltd	Alaoji, Abia State	Thermal	624	
Isolo Power Generation Ltd.	Isolo, Lagos State	Thermal	20	
JBS Wind Power Ltd.	Maranban Pushit, Mangu, Plateau State	Wind	100	
Kainji Hydro Electric Plc (Kainji Station)	Kainji, Niger State	Hydro	760	450
Kainji Hydro Electric Plc (Kainji Station)	Jebba, Niger State	Hydro	540	450
Knox J&L Energy Solutions Ltd.	Ajaokuta, Kogi State	Thermal	1000	
Lotus & Bresson Nigeria Ltd.	Magboro Ogun State	Thermal	60	
MBH Ltd.	Ikorodu Lagos State	Thermal	300	
Minaj Holdings Ltd.	Agu-Amorji Nike Enugu East LGA, Enugu State	Thermal	115	
Nigeria Agip Oil Ltd.	Okpai Delta State	Thermal	480	361
Nigerian Electricity Supply Corporation (Nigeria) Ltd. (NESCO)	Bukuru, Plateau	Thermal	30	
Notore Power Ltd.	Onne, Rivers State	Thermal	50	
Ogorode Generation Company Ltd (NIPP)	Ogorode Delta State	Thermal	450	
Olorunsogo Generation Company Ltd (NIPP)	Olorunsogo, Ogun State	Thermal	750	
Olorunsogo Power Plc (BPE)	Olorunsogo, Ogun State	Thermal	335	76
Omoku Generation Company Ltd.	Omoku, Rivers State	Thermal	250	60
Omotosho Generation Company Ltd.	Omotosho II Ondo State	Thermal	500	76
Omotosho Power Plc (BPE)	Omotosho Ogun State	Thermal	335	35
Paras Energy & Natural Resources Development Ltd	Ogijo, Ogun State	Thermal	96	
Sapele Power Plc	Sapele, Delta State	Thermal	1020	90
Shell Petroleum Development Company Ltd.	Afam VI	Thermal	642	450
Shiroro Hydro Electric Plc	Shiroro, Niger State	Hydro	600	450
Supertek Electric Ltd.	Ajaokuta, Kogi State	Thermal	500	
Supertek Nigeria Ltd.	Akwete, Abia State	Thermal	1000	
Ughelli Power Plc.	Ughelli, Delta State	Thermal	942	320
Western Technologies & Energy Services Ltd.	Sagamu, Ogun State	Thermal	1000	
Zuma Energy Nigeria Ltd. (Gas Plant)	Ohaji Egbema, Owerri, Imo	Thermal	400	
Zuma Energy Ltd. (Coal Plant)	Itobe, Kogi State	Thermal	1200	
TOTAL			**25,255.2**	**4978**

The installed capacities of various power generation companies in Nigeria and the summary of a typical national daily operational report are shown in Table 1 and Figure 1 respectively.

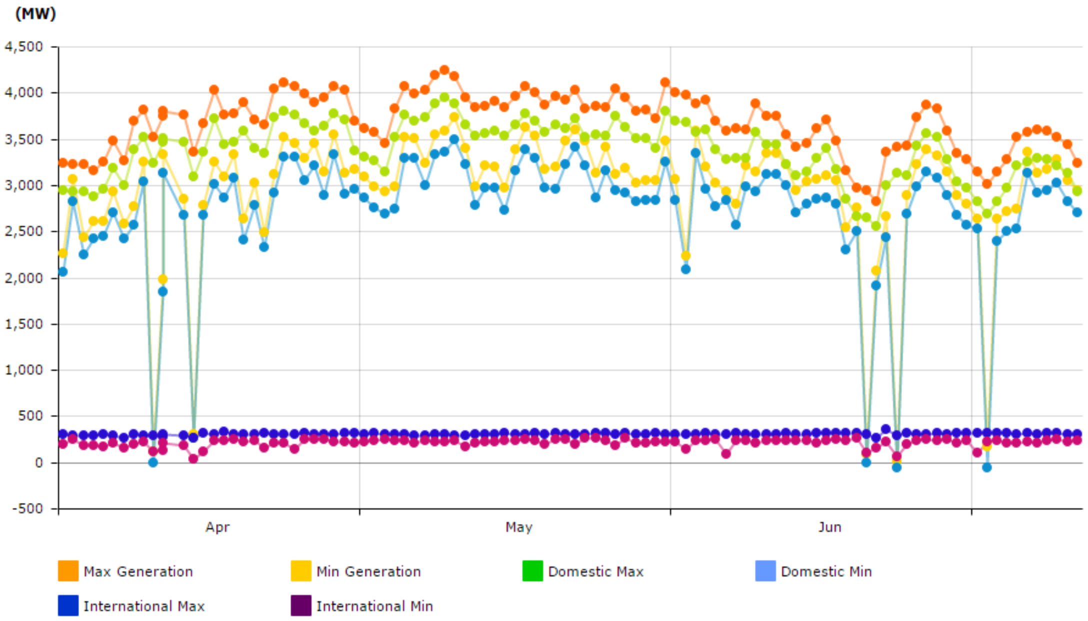

Figure 1. Summary of National Daily Operational Report of May 26, 2015 [12]

2. Renewable Energy Solutions

2.1. Solar Energy

Energy from the sun is the primary source of energy for all surface phenomena and life on earth. Solar energy is transferred to the earth through radiation and the energy reaching the top of the earth's atmosphere is estimated at 1400watts/m^2. It is used directly for a wide range of human life activities including simple domestic use - drying cloths, crop and providing hot water for home use; commercial generation of electricity using photovoltaic equipment; and heating water to drive turbines in thermal electric generators. The history of solar energy being used to generate electricity using photovoltaic cells can be traced back to 1876 when William Grylls Adam and his student Richard Evans Day discovered that solid material – selenium – produced electricity when exposed to light. Selenium photovoltaic cells were converting light to electricity at about 1 to 2 percent efficiency. In recent times photovoltaic cells are used to convert sunlight into electricity with 40 percent efficiency. Another method of using solar energy to generate electricity also used in recent times is to convert the sun's energy into heat which is then stored in thermal tanks. The thermal tanks contain molten salts or paraffin wax which can absorb tremendous amount of heat energy without changing state. The heat is then used as a heat source in steam engines to drive electric generators. Such thermal tanks usually have capacities of up to 1.44 Terajoules per 68m^3.

Grid – tie allows excess energy to be sent to the transmission grid, the rest of the electricity can either be stored or used directly with solar inverters for ac loads. Solar energy that falls on the earth in one hour can be approximated to the amount of energy that is needed on earth in a year. This energy source therefore holds a very great potential if properly harnessed.

2.2. Wind Power

Wind power is the energy derived from wind to produce mechanical energy or electricity. Electricity is generated from wind energy using windmills or ship sails. The windmills provide the power for different purposes like pumping water, grinding grains, and so on. The windmills have evolved over the years into wind turbines which are used to convert the kinetic energy in wind into electric power. The effect of wind on the turbine blades produces a rotational force which is transferred to the gear train connected through a shaft arrangement. The output from the gear train is connected to the generator that produces electricity. The use of wind for electricity generation can be traced back to 1887 by Prof James Blyth and since then different improvements have been developed. Wind energy is a sustainable energy as the earth can never run out of wind. The quantitative measure of the wind energy available at a location is referred to as *wind power density* (WPD). It is a calculation of the mean annual power available per square meter of swept area of the turbine. A collection of wind turbines in a particular area is referred to as a wind farm. When it is erected on landed areas it is called On-shore wind energy electricity generation. If it is erected on bodies of water especially in the oceans to leverage on heavy wind generated by ocean currents; it is referred to as Off-shore wind energy electricity generation. Alta Wind Energy Centre (AWEC) in Tehachapi, California is currently the largest on-shore wind farm with operating capacity of 1,020MW and the largest Off-shore wind farm with generation capacity of 630MW is found in London array wind farm, UK [13]. Therefore, wind power potential cannot be underestimated in energy generation.

2.3. Biomass

Biomass is any organic material that has stored sunlight in the form of chemical energy; these include plants, agricultural crops or residues, municipal wastes and algae. It supplied far more renewable electricity than wind and solar power until recently [14].

Biomass resources of Nigeria can be identified as wood, forage grasses and shrubs, animal waste and waste arising from forestry, agricultural, municipal and industrial activities, as well as, Aquatic biomass [15]. As state by Achakpo, et al. (2015), biomass resources of the nation was estimated to be about 8 x 102 M.J. Plant biomass can be utilized as fuel for small-scale industries. It can also be fermented by anaerobic bacteria to produce a very versatile and cheap Fuel Gas i.e. biogas. If developed properly, biomass can and should supply increasing amounts of “biopower”. The common way to harness biomass to biopower is to burn it to make heat. Over the years, the technology for harvesting energy of biomass has developed into a more efficient and cleaner form (sustainable biopower). These technologies are Direct combustion- burning the materials to produce steam which turns the turbine that produces electricity; Co-firing- mixing it with coal and burn it at a power plant designed for coal or at natural gas-powered plants; Repowering- coal plants running entirely on biomass; Combined Heat and Power (CHP); Biomass gasification- heating biomass in an oxygen-controlled environment and under pressure, converts it into a mixture of hydrogen and carbon monoxide called syngas. This syngas is passed directly through turbine to generate electricity; and Anaerobic digestion- micro organism breakdown of the biomass.

Many versions of efficient wood-burning and charcoal stoves have been developed and are being used in many parts of Nigeria today with the overall objective of curtailing the amount of trees that are perennially cut to provide fuel wood and charcoal. Biogas digesters, which are capable of producing biogas that could be used for domestic and industrial uses, have been developed in many parts of the country for sustainability. The energy from biomass will go a long way as an alternative source for power generation in Nigeria if properly developed.

2.4. Geothermal Energy

Geothermal energy is heat energy generated and stored in the earth; it is generated from the radioactivity decay and continual heat loss from the earth’s formation. The temperature difference between the planet and the surface drives a continuous conduction of thermal energy in form of heat from the core to the surface. Rocks and water in the crust is sometimes heated up to 370^{o}C as the temperature at the core – mantle boundary may reach up to 4000^{o}C. This energy can be used for district heating, space heating, industrial processes, desalination, agricultural applications and most importantly to generate electricity. The history of geothermal energy for electricity can be traced to 1911 when the world first commercial power plant was built. To generate electricity using geothermal energy, a hole is dug into the ground or rock to depths of about 4 – 10 Km and water is allowed to flow into this hole and back to the surface. The water reaching the hotter earth crust is heated up and the steam travelling back up to the surface is used to drive turbines which in turn drive generators that produce electricity. Using emerging technology known as Enhanced Geothermal Systems (EGS) the heat in the earth’s crust can be harnessed for electricity generation on a large scale. In 2014, geothermal power installed capacity worldwide was up to 12,635 MW with United State currently leading with 3450MW installed capacity and 2542MW generating capacity [17]. Geothermal power is reliable and sustainable, as the earth’s internal heat content of 1031 joules is 100 billon times current worldwide energy consumption.

2.5. Nuclear Power

Nuclear Power generation for commercial use started in 1954 at Obninsk, Russia when the first nuclear powered station; APS-1 was established and connected to the power grid [18]. A nuclear power station is not much of a difference from fossil fuel-powered or steam-powered plants. The only difference is that the required heat energy to turn water to steam is generated in the nuclear reactor. It was discovered that certain isotopes of some elements can split and when this splitting occurs heat is generated. Uranium -235 is one of such isotopes. During fission, Uranium - 235 atoms become unstable and split into two light atoms called fission products. The instability of these atoms causes the atoms to collide with other atoms resulting into chain of reactions. In the process, a lot of heat energy is generated. In nuclear power plants the heat is passed through water and the steam generated from the boiling water turns turbines and generates electricity [18]. About 152T eU of Uranium reserve has been discovered in two locations in Nigeria by the defunct Nigerian Uranium Mining Company (NUMCO) [19,20,21]. This shows that Nigeria has the potential for a self sustaining nuclear power plant. At 392GW, nuclear power amounts for 11% of total electrical power generation in the world.

2.6. Thermal Energy

Thermal energy is the internal energy of a system due to the movement of particles by virtue of its temperature. Thermal power stations make use of this principle to heat water into steam which turns a steam turbine to generate electricity. The steam is thereafter condensed and recycled. Heat for steam production can be produced by burning coal, fuel oil or natural gas, nuclear reactors, geothermal and solar thermal. Steam engines for electricity generation started in 1882 and since then, different power stations has been established using improved technology to generate electricity; an example is the Mohave generating station near Laughlin in Nevada that is fuelled by coal with capacity of 1580 MW.

3. Renewable Energy Potentials

Table 2. Maximum possible power outcome per unit land or water area of renewable energy sources [5]

Energy Source	Power per unit land or water area
On shore Wind	2W/m^2
Offshore Wind	3W/m^2
Solar PV panels	5 - 20W/m^2
Geothermal	0.017W/m^2
Rain water {highlands}	0.24W/m^2
Hydroelectric facility	11W/m^2

According to Mackay (2008), the estimation of the various renewable energy sources can be carried out with reference to power per unit area of land or water. Based on the methods and equations used by Mackay (2008), the estimated power per unit area of various renewable energy sources is shown in Table 2.

3.1. Wind Farm for Nigeria

Onshore wind potential: Nigeria is one of the largest countries in Africa by land mass which is about 923,000 square kilometers [9]. The country only licensed “JBS Wind Power Ltd” which has generation capacity of 100MW but it has no contribution yet into the national grid. The challenges in setting up a wind farm in Nigeria ranges from lack of technical know-how, to government policy on renewable energy to little study on its energy potential among others. Since wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth’s surface, therefore the seasonal variations in the energy received from the sun affects its strength and direction. In Sambo (1987) study, wind energy potentials for a number of Nigerian cities shows that the annual wind speed ranges from 2.32 m/s for Port Harcourt to a figure of 3.89 m/s for Sokoto. The maximum extractable power per unit area, for the same two sites was estimated at 4.51 and 21.97 watts per square metre of blade area, respectively. And when the duration of wind speeds greater than 3 m/s is considered than the energy per unit area works out as 168.63 and 1,556.35 kWh per square metre of blade area for both cities respectively. Improved wind turbines now have more generating capacity per square meter of blade.

Therefore, establishing ten (10) wind farms each equipped with 100 units of 1MW capacity wind turbines will give a cumulative of 1000MW of power. Considering also that one million homes in Nigeria own a 600W wind turbine suitable for lighting and entertainment electronics, an additional 600MW of power could be included to the energy mix for the country. Such projects can be funded by constituency development funds available to members of the House of Representatives and Senators in Nigeria.

Offshore wind potential: The Nigerian continental shelf is about 42,285Km^2 [22]. Establishing two wind farms with 200 units of 2MW wind turbines will give a cumulative of 800MW in total capacity with enough space for all marine activities. It should be noted that off shore wind power has higher potentials due to strong ocean currents.

3.2. Solar Farm for Nigeria

The wind energy situation of the country has been researched into by the government and individual research bodies over time. The result of one of the studies is shown in Figure 2. From the wind map, it can be concluded that Nigeria indeed has the potential for huge wind energy development and will need to invest in this renewable source starting from the North, as wind speed is highest in the region including Sokoto, Jos, Bauchi and Kebbi States.

Mass-produced solar panels have at best efficiencies between 10 – 30%. The efficiency means the capacity of the photovoltaic cell to convert the sun irradiance into electric power. Solar energy resource is available in all parts of the country with an average sunshine hour of 5.535KWh/m^2/day. The vast expanse of Sahel Savanna in the Northern region of Nigeria provides more than enough land space for this kind of project. According to Mackay (2008), a yield of 5 – 20W/m^2 is estimated for solar power. Assuming an area of about 300Km^2 and at 10% solar panel efficiency;

The power achievable

$$= \left(5W/m^2 X\ 30\ X\ 10^6 m^2\right) \text{ to } \left(20W/m^2 X\ 30\ X\ 10^6 m^2\right)$$

$$= 150MW - 600MW \text{ is achievable.}$$

This land space accounts for only about 0.03% of Nigeria’s total land mass. Multiplying this land space by a factor of 10 gives a geometric feasibility of up to 6000MW of power. In addition, if one million homes in Nigeria own a 1000W solar power system on their rooftops, the cumulative power production will be 7000MW of power which can add notably 45% to the present electricity consumption per capita.

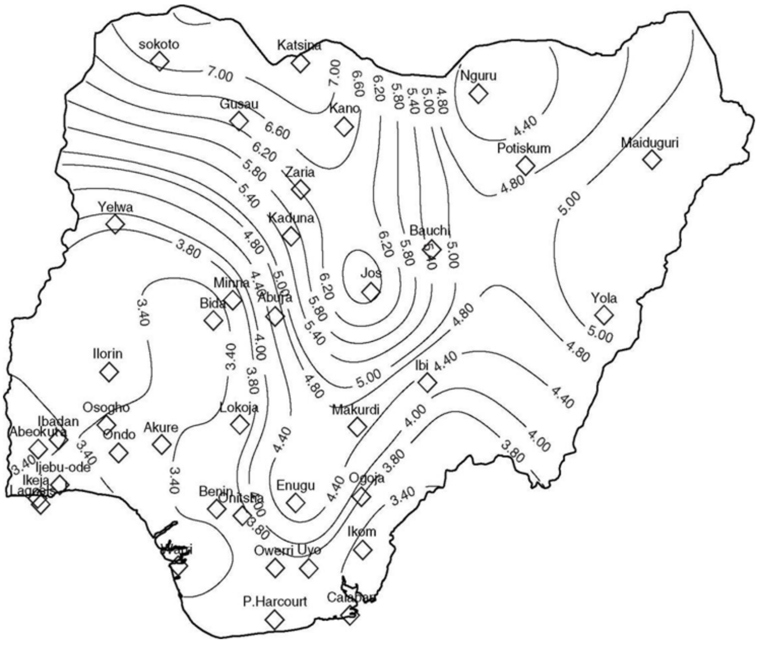

Figure 2. Nigeria wind map in m/s determined from 40 year's measurements at 10m height, obtained from Nigeria Meteorological Department, Oshodi, Lagos State, Nigeria (NIMET) [23]

3.3. Small Hydro Power (SHP)

The Jebba and Kainji dams have capacities of 570 MW and 760 MW respectively while; the Shiroro dam has a capacity of 600 MW. These make the total existing capacity for hydro power in Nigeria 1,930 MW. To complement the existing capacity, small and mini hydro power schemes with established potentials between 5kW to 20MW can be introduced around rivers and run off streams in Nigeria [24]. There are several dams around the country used for portable water supply which can further be exploited with small hydro turbines. Given that 63% of Nigeria land space is occupied by water [25], and at $11W/m^2$ potential of hydro power, Nigeria has a potential of generating 6,396,390MW of hydro power.

$$\text{i.e } 63\% \text{ x land mass x } 11W/m^2$$
$$= 0.63 \text{ x } 923{,}000Km^2 \text{ x } 11W/m^2$$
$$= 6{,}396{,}390MW.$$

If only 1% of this is harnessed for large, small and mini hydro, a potential of 64,000MW (1% of 6,396,390MW) can still be realized from hydropower in Nigeria. This will give significant improvement over a survey of 12 old states of the Federation carried out in 1980 (i.e Sokoto, Katsina, Niger, Kaduna, Borno, Bauchi, Gongola, Plateau, Benue and Cross River), which showed that 964MW of SHP can be harnessed from 277 sites and another research by the Federal Ministry of Power and Steel in 2006 which showed 12,220MW capacity hydro power sites exploitable in Nigeria [3].

3.4. Geothermal Power Potential

The potentials of geothermal power in Nigeria are high but the required technology is in the developing stage globally. It requires drilling deep down into rocks and earth's crust to gain access to the heat under the earth crust. Offshore drilling is common in the exploration of crude oil or fossil fuel in Nigeria's oil rich Niger delta region. Geothermal power was after wide researches found to be cost effective, reliable, sustainable and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries.

Studies have shown that a geothermal power farm is potentially viable in many cities of the country. From the records of the geothermal gradient, it shows that many sites in Nigeria are good for geothermal system which is subject to confirmation with geophysical methods. As reported by Avbovbo (1978), the normal geothermal gradient of the earth is between 2-3°C/100m and geothermal gradient above this range is considered to be a good site for geothermal system. The geothermal gradient of Niger Delta region of Nigeria ranges from 1.3 to 5.5°C/100m. The geothermal gradient of Anambra Basin ranges from 2.5 to 4.9°C /100m [26]. A similar study of the geothermal gradient of Bida Basin shows that it ranges from 2 to 2.5°C/100m. The Borno Basin temperature gradient ranges from 1.1 to 5.9°C/100m. The study of Sokoto Basin has revealed its geothermal gradient to range from 0.9 to 7.6°C/100m [27]. The hot and warn springs is another indicator that shows the possibility of geothermal system in Nigeria. The following areas have springs that indicate the leakage of geothermal system from the crust: Akiri in Benue State with a hot spring at about 53.5°C, Wikki in Yankari Game Reserve, Bauchi State has a warm spring of about 32°C and Ruwan Zafi in Adamawa State located in Lamurde generate a temperature of 54°C. These surveys show the feasibility of 500MW geothermal power in Nigeria.

3.5. Biomass Potential

The country can utilize plant biomass as fuel for small-scale industries which could also be fermented by anaerobic bacteria to produce a cheap fuel gas (biogases). It is worth noting that, biogas production from municipal waste, agricultural residues and industrial does not compete for land, water and fertilizers with food crops like is the case with bioethanol and biodiesel production. This will also reduce the danger posed by these wastes. It has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily. Since 1 kg of fresh animal waste produces about $0.03m^3$ biogas, then Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only. Although biogas technology is not common in Nigeria, various research works on the technology and policy aspects of biogas production has been carried by various scientists in the country. Some significant research has been done on reactor design that would lead to process optimization in the development of anaerobic digesters [28]. Wood wastes and sawdust are other important biomass resources associated with the lumber industry. Biomass utilization as energy resources is currently limited to thermal application as fuel for cooking and crop drying.

There has been consensus in Nigeria now that renewable energy can play tremendous role in the overall energy development of the nation. The views have been strengthened by the Renewable energy Master Plan (REMP) of the country as developed by the Energy Commission of Nigeria (ECN), in conjunction with the United Nations Development Programme (UNDP) in November 2005 [29]. The objective among many is to accelerate the exploitation of renewable energy and development of the frame works for targets achievement. Going by the potential of biomass, the REMP has projected biomass to contribute 50MW of electricity in the medium term set at year 2015 and 450MW by 2025. As reported by Sambo (2007), significant research results have been achieved by relevant agencies in the public and private sector in biogas production, among which are the development of improved wood stoves and biomass briquetting technologies. This goes to show, a very high potential of biomass development for electricity generation in Nigeria.

3.6. Nuclear Power Potential

A 1000MW nuclear power plant is estimated to consume 162Ton of uranium in a year using the once-through type of nuclear reactors which burn up only the 0.7% Uranium-235 and discards the remaining uranium-238 as waste. Recent development in technology now makes use of fast breeder reactors which converts the Uranium-238 into fissionable plutonium and requires about 3Ton of Uranium/year to produce 1000MW of nuclear power if well optimized. In the worst case scenario if uranium exploration is not feasible and Nigeria needs to import from other countries. The cost of installing a fast breeder nuclear is high but the cost benefit ration makes it economical for power generation. Considering the capacity of Uranium deposits in Nigeria 20,000MW capacity nuclear power can be run sustainably in Nigeria.

3.7. Thermal Power Potential

Currently about 69% of power generation in Nigeria is thermal. The potential for thermal power is huge considering the abundance of fossil fuel and gases in Nigeria. A 17,000MW thermal plant being proposed will add significantly to the existing installations. In Table 1, 52 out of the 56 power projects are thermal, but thermal power comes with high environmental pollution in the form of carbon footprint. Hence this study discourages further construction of thermal stations in Nigeria.

4. Results

The estimated energy from the renewable energy potentials that are feasible in Nigeria is shown in Table 3. Going by this estimate, a total of 93,950MW can be conveniently generated in the country which translates to about 5,000KwHr/capita. Going by Figure 3, Nigeria energy mix perspective will place the country close to the top 20 highest electricity consumption per capita in the world.

The analysis shows that small and large hydro power generation has the highest energy potential in Nigeria. Electrification rate- percentage of households with an electricity connection- in Nigeria is estimated to be about 41% and 149KwHr/capita [10], and from the CBN report of 2013, the Federal Government has a projection of 8000MW in order to achieve 50% electrification. It therefore means that, 16,000MW energy capacity will achieve 100% electrification rate in Nigeria but it is grossly inadequate to position the country as an industrialized nation.

Table 3. Estimates of Renewable Energy potential in Nigeria (MW)

Energy Source	Power (MW)
On shore Wind	1600
Offshore Wind	800
Solar PV panels	7000
Geothermal	500
Biomass	50
Small and large Hydro	64,000
Nuclear Power	20,000
Total	**93,950**

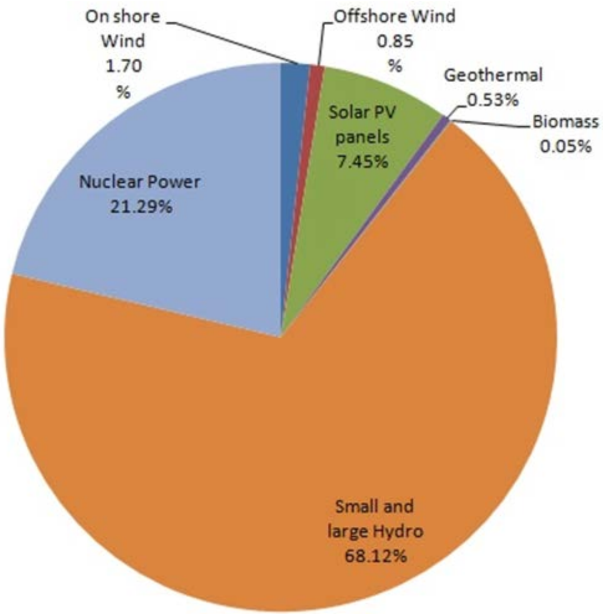

Figure 3. Pie chart of percentage estimates of renewable energy potential in Nigeria

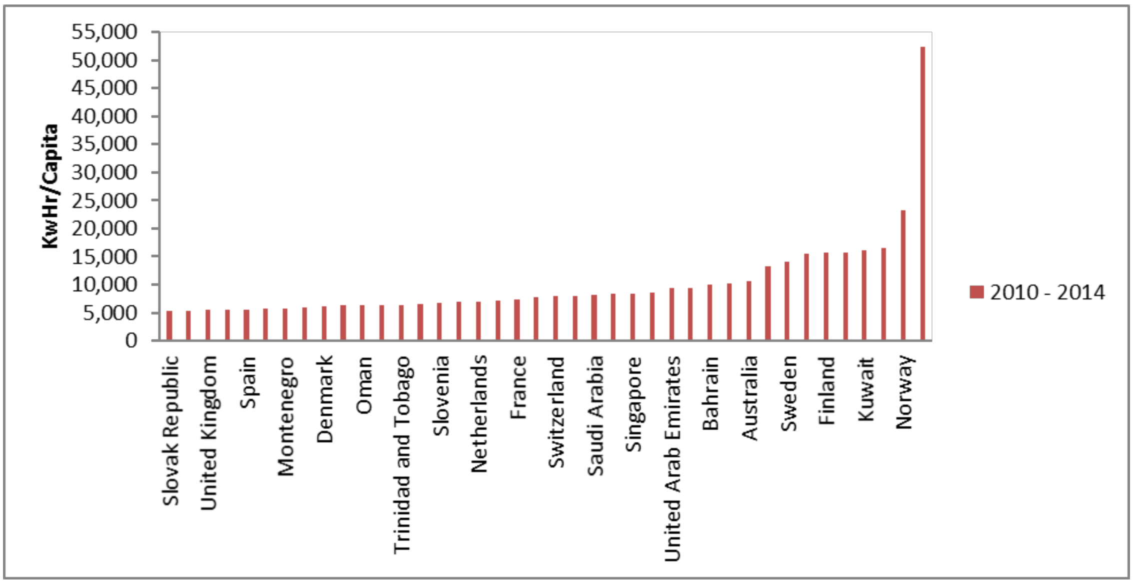

Figure 4. Top 20 Electric power consumption (kWh per capita) in the world

5. Conclusion

This study has been used to address the issues of Nigeria energy crises and suggested energy mix as solution. Although Nigeria is blessed with abundant energy resources with great potential for energy generation yet it's still engrossed with high level of energy deficiency. This has invariably affected development and impinged negatively on the economic growth with some parts of the country, especially the rural areas, lacking access to modern resources which come with availability of electric power. There is a great prospect for power generation through the abundant renewable resources as describes in this study if the associated challenges hampering the technological advancement are surmounted. Currently, hydro power which contributes about 20% of power generation in Nigeria is the only renewable energy source of power and its potential is yet to be fully exploited. Small hydro power can be coupled with several existing potable water supply schemes in the country at low cost in addition to the power supply from large hydro power schemes of the Nation. Nuclear power plant is another area with great potential for high capacity power generation (about 21.29%) if properly harnessed. The inclination towards gas-fired thermal plants will only create more environmental problems by depleting the ozone layer through the emission of CO_2 gases, it is therefore not considered as a prospect. The estimated result put solar energy as the third highest energy harvest potential in Nigeria. These analyses clearly show the potentials of managing the country's natural resources to cater for its growing energy demand and consequently its economic development. The estimates are feasible and the economic involved in executing the projects is highly objective.

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