Study and Analysis of Renewable Energy Technologies Status in Nigeria

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Abstract-- *The objective of this paper is to elucidate the status of renewable energy deployment in Nigeria. Energy is a vital commodity and is closely intertwined with development. Energy is also required to sustain and expand economic processes like agriculture, electricity production, industries, services and transport. It is commonly suggested that access to energy is closely linked with development and economic well-being. In Nigeria, the low level of economic development is in connection with the poor deployment of renewable energy technologies as their major sources of energy which translate to the high poverty index in the country. The non-renewable and conventional energy has been found to be epileptic therefore cannot contribute much too high energy demand due to increase in population, technological growth and industrialization.*

Index Terms- Renewable, Energy, Hydro, Biomas, Photovoltaic, Wind, Energy Deployment

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1.0 Introduction

Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. If poverty should be curbed in any nation the policy makers must place priority on electrical power generation and distribution. Uninterrupted energy supply is a vital issue for all countries today. Future economic growth crucially relies on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Security, climate change, and public health are closely interrelated with energy [1]. Energy is the back-bone of the technological advancement, industrial production, manufacturing, distribution and utilization of the throughput of the industry. Figure 1 is a diagrammatic display that shows how energy generation could provide support and enhance positively the throughput of its product of an industry, which in return helps in boosting the growth of national economy in totality, see Equation 1. It is convincingly clear to come to a conclusion that the economic development of a nation is directly proportional to her energy generation.

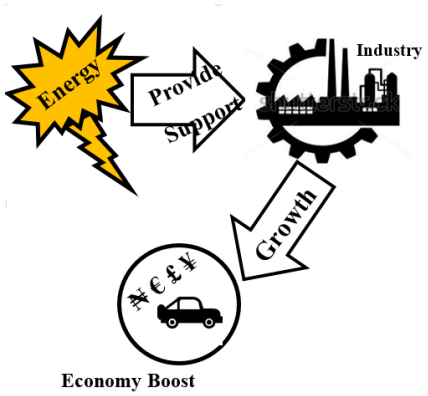

Figure 1: Energy Support Link in Industrial Development of National Economy

$$E_G \propto \sum_{\substack{0 \le g \le \infty \\ 0<d<\infty}} P_z(g,d) \qquad (1)$$

Where,

E_G, is the Economic growth of the economy.

P_z (g, d), is the power generated which that has to function with power generated 'g' and the power distributed'd'.

Developed countries in the world are trying to decrease their dependence to fossil energy by integrating renewable energy sources to their energy policies. Several projects in the field of Renewable Energy System (RES) are developed in some countries to maintain steady energy source. Growing evidence of global warming phenomena, rapid depletion of fossil fuel resources and fast escalation in world's population have caused widespread attention to seek energy from the RES [2].

However, availability of energy plays a major role in every aspect of our socio-economic life. Energy is, and will always be, a key component of the economic, social and political development of Nigeria [3]. Poor access to energy in Nigeria has been a major impediment to Nigeria's economic growth [4]. Increasing incidence of power shortages has been identified as responsible for the dwindling the growth in development of Nigeria and this is not unconnected with the inabilities to develop new generating capacity as hydropower has been the only source of power, thereby diminishing electricity supply severely during droughts [4]. Constant power availability needs to be taken as a vocal point in development planning, that is, the modern technologies needed to drive economic development. This is strictly tied to the use of energy. The standard of living of a given country can be directly related to the amount of energy consumption. The energy crisis, which has engulfed Nigeria for almost two decades, has been enormous and has largely contributed to the incidence of poverty by paralyzing industrial and commercial activities during this period. The Council for Renewable Energy of Nigeria estimates that power outages brought about a loss of 126 billion naira (US$ 984.38 million) annually [4][1]. Apart from the huge income loss, it has also resulted in health hazards due to the exposure to carbon emissions caused by constant use of backyard generators in different households and business enterprises, unemployment, low standard of living and high cost of living leading to a deterioration of living conditions. Furthermore, energy is an important contributing feature in the development of any country or region [5]. Indeed, energy is fundamental to the fulfillment of basic individual and community needs such as lighting, transportation, provision of water, food, health and education. Since all these services are the indices by which a nation's progress and development are measured, it follows that energy is a major determinant of every country's economic and social development.

2. Background of the Study.

The cry for power outage in Nigeria has been a serious issue for over three decades now. In large populated country like Nigeria, only approximately one-third of the country's population has access to commercial electricity, with around 10% in the rural areas[6]. Nigeria is blessed with abundant primary energy resources. These include non-renewable energy sources such as natural gas, crude oil, coal and tar sands; and renewable energy sources such as hydro,

biomass, solar and wind[3]. However, the economy has mainly depended on the consumption of oil and gas for commercial energy. The use of hydro-power plants, which entered the Nigerian energy scene in the 1960's, now accounts for the second largest energy resource for electricity generation in Nigeria, contributing approximately 26% of the total installed grid-connected generated energy[3]. Nigeria receives abundant solar energy that can be usefully harnessed with an annual average daily solar radiation of about 5250 Wh/m2/day. This varies between 3500 Wh/m2/day at the coastal areas and 7000 Wh/m^2/day at the northern boundary [7]. The average amount of sunshine hours all over the country is about 6.5 hours [7]. Nigeria is an energy resource rich country, endowed with abundance of renewable energy (RE) resources, providing her with great capacity to develop an effective national energy plan. However, Nigeria is yet to exploit these huge available energy potentials with less environmental and climatic impacts [8]. On the contrary, the National energy supply is at present almost entirely dependent on fossil fuels and firewood. And this energy is predominantly use in raw form. Substantial progress has taken place in the use of the major rivers in Nigeria and their tributaries to provide hydropower for the country. The total technically exploitable hydropower potential based on the country's river system is conservatively estimated to be about 10,000 MW of which only 19% is being tapped or developed [8]. Currently, solar, wind, biomass, etc. are in abundance all year round in Nigeria and largely untapped. For an energy source to be renewed, it means that its harvesting, conversion and use would occur in a sustainable manner and avoid any negative impacts on the people and natural environment. Renewable energy (RE) reality in Nigeria will be dependent on adequate government policy, financial and technical capability and public acceptance for their installation. Renewable energy (RE) resources abound in Nigeria but have not been fully exploited. This paper x-rays the state and level of renewable energy production and utilization. For a country like Nigeria, sole dependence on fossil fuel (petroleum) is not enough to meet the energy needs of the country. Interest in renewable energy development and dissemination in Nigeria is needed. This is the major cause of epileptic power sources associated with Nigeria, electricity supply.

3. Overview of Renewable Energy Status

This section reviews the different sources of power generation and distribution in Nigeria. Nigeria being advantaged as it is located at the tropic, this fact makes it very possible for green energy to be sourced via numerous means by nature. Below, subsections describe the overview of the power generated in the country.

3.1 Hydro Power

The country is reasonably endowed with large rivers and some few natural falls. Small rivers and streams also exist within the present split of the country into eleven River Basin Authorities, some of which maintain minimum discharges all the year round. Hydropower currently accounts for about 29% of the total electrical power supply in Nigeria [8]. In a study carried out in twelve states and four (4) river basins, over 278 unexploited Small Hydro-Power (SHP) sites with total potentials of 734.3 MW were identified. However, SHP potential sites exist in virtually all parts of Nigeria with an estimated total capacity of 3,500 MW. They indicate that Nigeria possesses potential renewable source of energy along her numerous river systems, a total of 70 micro dams, 126 mini dam and 86 small sites have been identified. A private company, the Nigerian Electricity Supply Company (NESCO) and the government have installed eight (8) SHP stations with aggregate

capacity of 37.0 MW in Nigeria. Most of these stations are found around Jos at Kwall and Kurra Falls[6]. The total technically exploitable hydropower potential based on the country's river system is conservatively estimated to be about 11,000 MW of which only 19% is currently being tapped or developed[8]. These rivers, waterfalls and streams with high potentials for Hydropower, if properly harnessed will lead to decentralized use and provide the most affordable and accessible option to off-grid electricity services especially to the rural communities. Currently, the hydroelectricity source in Nigeria is the only power source integrated to the national grid. Other form of renewable energy sources is yet to be discovered and integrated.

Figure 2: Hydro Energy Status

3.2 Wind Energy

The average wind speed in Nigeria ranges between 2-4 m/s at 10m height mainland[9]. Windmills were used in Nigeria as early as the mid-1960s. In the northern regions of Sokoto and Garo, over 20 homes and a school used windmills to pump water. Research into the feasibility of wind power in certain regions has suggested the physical potential for this type of power generation is high in some regions of Nigeria. Three separate studies have measured the average wind speed in various parts of the country for periods ranging from three to ten years [9]. The regions where studies were conducted are: Sokoto in the northwest, Borno State in the northeast, and Owerri in the southeast. At wind speeds of 3.5 m/s or greater, wind power systems can provide energy at costs cheaper than photovoltaic, diesel, and grid extension, therefore making Sokoto and Borno State ideal locations for wind power systems. Also, the costs of wind power electricity generation would be less in the regions with high average wind speeds.

Figure 3: Wind Energy Status

3.3 Solar Energy

Nigeria is well endowed with solar energy resources as it is geographically located between latitudes of 4° and 14° North of the equator and longitude 3° and 14° East of the Greenwich Meridian. The annual mean solar energy recorded in Nigeria is 2,300Kwh/m2 and global radiations as high as 24Mj/m2/day have been recorded. Although the actual number of sunshine hours may be modulated by local weather conditions, the average sunshine hour for Nigeria is 3,000 hours per year [9]. This is sufficient to put terrestrial solar devices to use in any part of Nigeria. Solar energy is a renewable energy resource and is converted to electrical energy in two ways thus using a photovoltaic material which generates an electrical potential when exposed to light or using a thermal process which uses the energy from the sun to heat a working fluid in an electricity generating cycle [10].

Figure 4: Solar Energy Status

3.4 Biomass Energy

Population is certainly the primary reason for the increase in energy needs. However, use of biomass for cooking and heating activities in Nigeria is also influence by economic factors, particularly, poverty levels. Per capita income levels and increasing use of modern fuels are unequivocally correlated. Empirical evidence shows that when a country's per capita income is less more of the population uses fuel wood and dung for cooking, however, once incomes have increased most people switch to modern fuels, and substitution is nearly complete. According to World Bank report on poverty in 2012, over 70% of Nigerians are living below $2.0 per day (below internationally accepted minimum poverty line) [10]. Practically, they may not afford to switch from using traditional biomass to modern commercial energies. In fact, it has been suggested that the extensive use of biomass in traditional and inefficient ways and the limited.

The availability of modern fuels are manifestations of poverty. Based on the figure, we can classify Northern Nigeria as both energy and income poor in relation to South West and Southern-South. On the other hand, Southern Nigeria is relatively, energy poor but in terms of income they are relatively rich. The high use of biomass in that area is likely to be the problem of easy accessibility to modern energy. However, the rate of regeneration of the forest is very slow; this often creates wood fuel gap because wood is being harvested faster than it is being grown in these areas. Reliance on biomass (especially in the form of charcoal) also encourages land degradation. Another environment related problem of biomass energy is the emission of greenhouse gases and its consequence to global warming. Here this issue is bordered on efficiency and how the biomass is used. For example, many studies argue that biofuels are more environmentally friendly than fossil fuels like kerosene. The figure below shows the biomass energy level for heating. Deployment of Biomass is still crude in Nigeria while the biomass potential is exponentially increasing ranging from industrial waste, municipal waste, animal dung, food waste, Agricultural waste to forestry products.

Figure 5: Biomass Energy Level.

4.0 Nigeria Energy Project Plan

In a bid to aggressively address the lingering energy crisis faced in the country, the International Atomic Energy Agency (IAEA) scenario based model was used to model the demand structure of Nigerian energy sector in four scenarios. The developed model is for the analysis of energy demand tagged Model for Analysis of Energy Demand (MAED). It evaluates future energy demands based on medium to long term scenarios of socioeconomic, technological and demographic development. These are combined to give an overall picture of future energy demand growth. Similarly, another model called MESSAGE i.e. the Model for Energy Supply Strategy Alternative and General Environmental impacts, also developed by IAEA was used to estimate the supply strategy for meeting the energy demand in Nigeria. MESSAGE combines technologies and fuels to map energy flows from supply to demand. The projected energy demand and corresponding electricity demand for the country from 2005 through 2030, using the previously mentioned MAED model, are depicted in Tables 1 and 2 respectively. While figures

Table 1: Target for Renewable Energy Contribution to Electricity Generation in Nigeria.

Resource	2010 (MW)	2015 (MW)	2030 (MW)
Large hydro	1,930	5,930	48,000
Small hydro	100	734	19,000
Solar PV	5	120	500
Solar Thermal	0	1	5
Biomass	0	100	800
Wind	1	20	40
Total RE	2,036	6,905	68,345
Total Energy Resources	16,00 0	30,00 0	192,00 0
Percentage of RE (%)	13	23	36

Source: Renewable Energy (RE) Master plan for Nigeria, ECN 2005

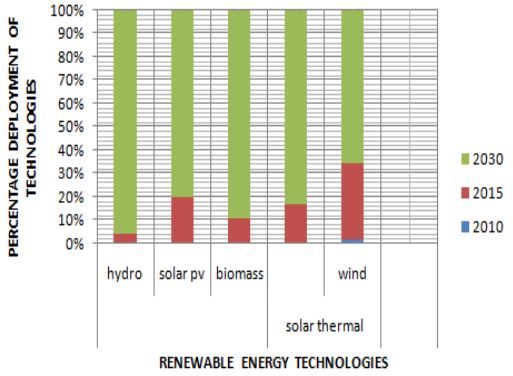

Figure 6: Graph of Expected Renewable Energy Percentage Contribution to Electricity Demand. Source: Renewable Energy Master plan for

Nigeria, ECN 2005

Table 2: Electricity supply projection Sources: Energy commission of Nigeria (2008).

Scenario	2010 (MW)	2015 (MW)	2020 (MW)	2025 (MW)	2030 (MW)
Coal	0	2,393	6,515	9,305	15,815
Gas	13,555	23,617	37,733	56,086	85,585
Hydro	3,702	4,962	6,479	9,479	11,479
Small hydro	40	90	140	227	701
Nuclear	0	0	3,530	7,005	11,872
Solar	5	10	34	75	302
Wind	0	126	1,471	3,019	5,369
Total Supply	17,303	31,197	55,903	85,196	131,122

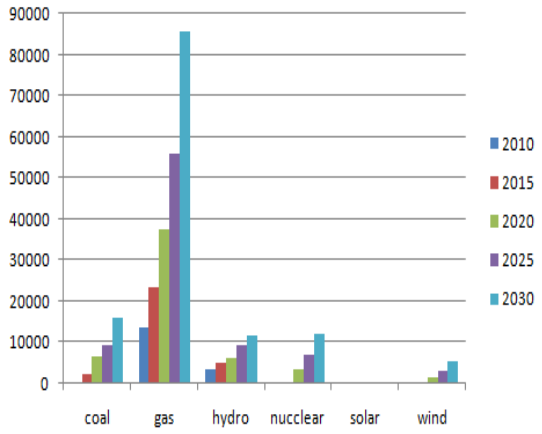

Figure 7: statistical presentation of energy commission of Nigeria projection. Source: Renewable Energy Master plan for Nigeria, ECN 2005

4.1. Statistical Review of Nigeria Power History

Transcorp thermal power was the first power station commissioned in 1966 in Ughelli Delta state which was under upgrade till 1990 with a power capacity of 972MW. In 1968 a hydro power station was commissioned in the Kainji from a dam in river Niger. Currently the country has three working hydro power station and twenty-five thermal power station with the total power generating capacity of 14379.8MW. The thermal plant is in no doubt the major source of power generation in the as it contributes 86.53% of the generated energy and hydroelectric-power contributing the remaining 13.47% of the generated power.

Table 3: Statistical analytical Table of Thermal and Fossil Fuel Power Station with their Location, Energy Capacity and Year of Commissioning

S/N	Thermal/Fossil Fuel Power Station	City/State of Location	Year Commissioned	Capacity (MW)
1	Egbin	Egbin/Lagos	1985 & 1986	1320
2	Sapele	Sapele/Delta	1981	1020
3	transcorp-Ughelli	Ughelli/Delta	1966, 1975, 1978 & 1990	972
4	Afam i-iv & v	Afam/Rivers	1982 & 2000	977
5	Geregu i	Ajaokuta/Kogi	2007	414
6	Omotosho i	Omotosho/Ondo	2006	335
7	Papalanto (Olorunsogo)	Papalanto/Ogun	2007	335
8	Kwale Okpai	Okpai/Delta	2005	480
9	Afam vi	Afam/Rivers	2010	642
10	Ibom	Ikot-Abasi/Akwa-Ibom	2009	190
11	Aes barge	Egbin/Lagos	2001	270
12	Omoku	Omoku/Rivers	2005	150
13	Trans-Amadi	Port-Hercourt/Rivers	2016	136
14	Revers	Port-Hercourt/Rivers	2013	180
15	Aba	Aba/Abia	2012	140
16	Geregu ii	Ajaokuta/Kogi	2012	434
17	Sapele	Sapele/Delta	2012	450
18	Alaoji	Alaoji/Abia	2015	1074
19	Olorunsogo ii	Olorunsogo/Ogun	2014	675
20	Omotosho ii	Omotosho/Ondo	2012	450
21	Omoku ii	Omoku/Rivers	2016	225
22	Ihavbor	Ihavbor/Benin	2013	450
23	Egbema	Egbema/Imo	2013	338
24	Calabar	Calabar/Cross River	2014	561
25	Gbarain	Gbarain/Bayelsa	2014	225
Total Capacity by Fossil power				**12443**

Tables 3 and 4 shows Statistical Display of Hydro-Power Station and Thermal Power Station respectively with their year of commissioning and generating capacity. From the review it was discovered that as at the May 2018 only thirteen states has electric power generating stations out of the 36 states in the federation and the FCT (that is about 35.14% of the states and FCT). In Nigeria power outage is that takes so many industries already existing into extinction and scares others

at the corridor of investing to settle in her sister countries like Ghana who has relatively better power supply. Nigeria in June, 2018 experienced a power drop of 1087MW which is about 7.56% drop of the total generating capacity

Table 4: Statistical Display of Thermal-Power Station in Nigeria showing Location, Capacity and Year of Commissioning

S/N	Name of Hydro-Power Station	City/State of Location	Year Commissioned	Capacity (MW)
1	Kainji	Kainji/Niger	1968	760
2	Jebba	Jebba/Niger	1985	576.8
3	Shiroro	Shiroro/Niger	1990	600
Total Capacity by hydro power				**1936.8**

Table 5: Showing States with their power generated, Number of power stations and Generated Power per Station In each of the Power Generating State.

State	Generated Power (MW)	No of Power Stations	Power Generation/ Station (ψ)(MW)
Lagos	1590	2	795
Delta	2922	4	730.5
Rivers	2310	6	385
Kogi	848	2	424
Ondo	785	2	392.5
Ogun	1010	2	505
Akwa-Ibom	190	1	190
Abia	1214	2	607
Benin	450	1	450
Imo	338	1	338
Cross River	561	1	561
Bayelsa	225	1	225
Niger	1936	3	645.3

4.1.2. Statistical Review of Power and Commerce of the States in Nigeria

About 14379.8MW of electricity power is generated to over 200 million (United Nation World Population Estimate 2019) Nigerians which translates to about 72 Watts/person which

cannot light-up a 100 Watt electric lamp per person.

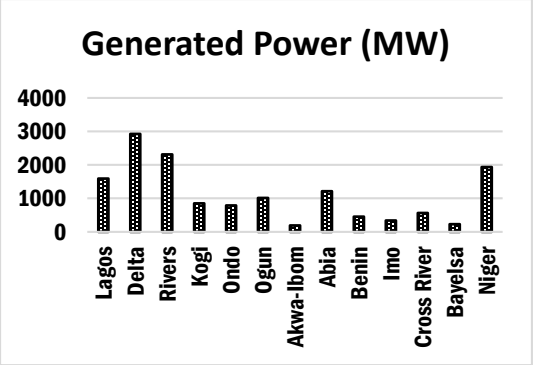

Figure 8: Graphical display showing the power generated in each of the power generating state

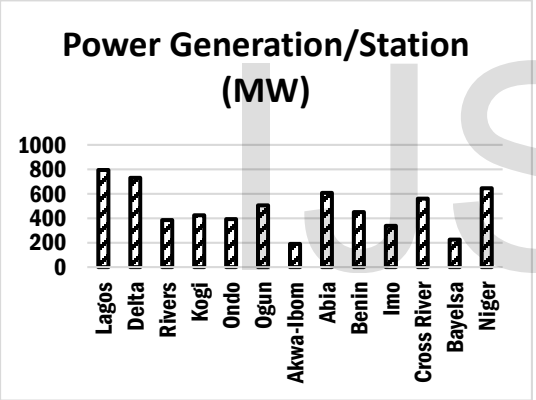

Figure 9: Chart showing the power generation strength of a unit power station in each of the states

Delta state has four power stations which generates the highest amount of power-per-state of about 27.27% of the total power generated for the country though rated second in terms of number of power stations in each state, coming behind Rivers state which happens to have more infrastructure on ground. Rivers state has six power stations that generates 16.06% of the country's total generated power. The power generation per station is estimated to see the average power in Mega-Watt of each station in a particular state also known (Power Generated density) with a symbol ψ. mathematically we have,

$$\psi = \frac{\text{Generated Power}}{\text{No of Power Stations}} \qquad (2)$$

Figure 10 is a is a statistical bar chart that shows the power generated in each of the thirteen power generating states with Delta state standing tallest of the rest of the bars indicating the most significant power generation state in the country. Figure 9 is a chart showing the state and the power generated density. Figure 10 is the map of Nigeria showing geographical location of the power stations.

1. EGBIN 1320MW
2. AES BARGE 270MW
3. SAPELE 1020MW
4. UGHELLI 972MW
5. OKPAI 480MW
6. SAPELE(II) 450MW
7. AFAM(I-IV & V) 977MW
8. AFAM(VI) 642MW
9. OMOKU 150MW
10. PORT HERCOURT 136MW
11. PORT HERCOURT 180MW
12. OMOKU(II) 225MW
13. GEREGU (I) 411MW
14. GEREGU (II) 434MW
15. OMOTOSHO(I) 335MW
16. OMOTOSHO(II) 450MW
17. PAPALANTO 335MW
18. OLORUNSOGO 675MW
19. IBOM 190MW
20. ABA 140MW
21. ALAOJI 1074MW
22. IHAVBOR 450MW
23. EGBEMA 338M
24. CALABAR 561MW
25. GBERAIN 225MW
26. KAINJI 760MW
27. JEBBA 576.8MW
28. SHIRORO 600MW

Figure 11: Nigeria Map Showing Locations of Power Stations

5. Conclusion

The forecast on the renewable energy cannot be realized due to some certain reasons. Corruption, unpatriotic and selfishness of those piloting the affairs of Nigeria economy has so much underdeveloped and stunted the growth and deployment of renewable energy over the years. This has, as well, stagnated the growth and development of the Nigeria economy thus unemployment and underemployment rate is on the rapid increment. From the statistical analysis in Figure 6, it was predicted that by 2030 renewable energy deployment must have gained ground and contribute to central energy sources in Nigeria but up till date there is no significant change in deployment of renewable energy as at when the forecast was made and the present.

With the trend of deployment, it could be inferred that Nigeria can only see maximum energy from 2025 to 2030. This could be seen clearly in Figure 7 with gas giving a total energy of 85585MW from Table 2. Gas energy source is not even renewable so the chance of Nigeria operating below her energy projection in 2030 is still high.

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