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Kazeem Olawale Babalola ✉; Ahmad Jais Alimin

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The Transition from Non-Renewable to Renewable Sources: A breakthrough to Solve Nigeria's Energy Crisis

Kazeem Olawale Babalola[a)] and Ahmad Jais Alimin

Centre for Energy and Industrial Environmental Studies, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat Johor, Malaysia.

[a)]Corresponding author: olawalebabalola896@gmail.com

Abstract. Considering the rising cost of petroleum products and the widespread demand for clean and renewable energy to lower carbon dioxide pollution to meet global emissions targets in developed and developing countries. For this reason, alternative energy sources such as solar, wind, and thermal have become crucial. This energy must be cheaper, and safer, and contribute significantly to energy development. Nigeria is faced with the problem of poor access to power supply, which contributes to retarded industrial growth, insecurity, and mass unemployment. Alternative sources, such as solar energy, bio-energy, etc are capable of solving the energy crisis in Nigeria with average solar insolation of $7.0 KWh/m^2$ per day in the north and $3.5 KWh/m^2$ per day) in the south. Biofuels such as bioethanol and biodiesel produced from biomass are also promising alternatives. They can reduce harmful emissions and give Nigeria hope for energy security and sustainable development. This paper reviews the potential of various renewable sources for energy generation in Nigeria. Presently, Nigeria requires thermal power plants from renewable sources capable of providing 13000MW, to meet the daily energy needs in Nigeria compared to the available 4000MW which is insufficient for over two hundred (200) million Nigerians. This study identifies biofuels as a major energy innovation for car engines, gas turbines, power plants, etc. In Nigeria and throughout sub-Saharan Africa, the use of biofuels could prevent energy shortages and promote more sustainable development. Challenges to widespread biofuel adoption in developing countries include deforestation, land scarcity, and the conflict between energy production and food security. It concludes that significant spending on energy research and the right institutional and governmental frameworks are needed to overcome the difficulties in order to realize the potential of alternative energy for sustainable development

INTRODUCTION

The energy crisis in Nigeria is the inability of the country's energy sector to supply adequate electricity to residential homes and businesses despite a rapidly expanding economy [1]. Nigeria is Africa's largest oil producer and one of the world's leading countries in terms of coal, oil, and gas deposits but only 45% of her population is connected to the electrical grid [2], and power outages occur at approximately 85% of the time, and are nearly nonexistent in some areas. The estimated daily power supply ranges from two to four hours, with days without power supply leading to retarded industrial growth, insecurity, and mass unemployment. Few businesses and households that can afford to run generators do so on very expensive and environmentally harmful fossil fuels like gasoline and diesel to supplement the intermittent power supply [2]. The literature reports found on the expansion of renewable energy sources in Nigeria are scanty and inconsistent. There were no comprehensive accounts of the potential of available renewable energy sources in each of the geopolitical zone of the country that could make them to be self-reliant on power generation. This study seeks to fill this gap by reviewing the current state of renewable energy in Nigeria, its prospects, and challenges. Electricity supply is a fundamental infrastructural requirement for a nation, economy, industrialization, productivity and growth, and enhancement of the quality of life. Consequently, a stable electricity supply is critical to a nation's long-term and rapid development, which translates into increased national productivity and economic prosperity. Therefore, a brief overview of power generation and distribution in Nigeria is essential to address this challenge.

Nigeria's power generation dated back to 1896 when electricity was first produced in Lagos, the then-federal capital territory of the country [3]. This came barely fifteen years after its existence in England. In 1896, the maximum electricity required in Nigeria was less than 60 kW. Thereafter, the Nigerian Government Electricity Corporation was created in

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1946 under the supervision of the Public Works Department (PWD) to assume leadership for power distribution in Lagos State. Subsequently, the Electricity Corporation of Nigeria (ECN) was established in 1959 as the central organization alongside the Nigerian Electricity Supply Company (NESCO) and the Niger Dams Authority (NDA) to generate, distribute, and sell voltages to the ECN. The functions of ECN and DAM were merged in April 1972 to form NEPA (National Electricity Power Authority) [3], with the aim of connecting the headquarters of all 774 Local Government Areas (LGAs) in Nigeria to the national grid. As of today, the local distribution of energy supplies within LGAs has not gone beyond the headquarters of the LGAs and their immediate surroundings. Villages and other smaller communities' hope for rural electrification have become a mirage. As a result, just 15% of Nigeria's two hundred (200) million people have access to power [4]. The formation of regulatory agencies such as NEPA was meant to increase electricity supply with the purpose of supplying power to the growing demand for it [5]. At the time, NEPA was abolished and a reform of the electricity sector was initiated, aimed at privatizing all electricity facilities to end the country's chronic electricity shortage and the state's long-existing monopoly of electricity utility. The reform, among other things, focused on establishing a regulatory agency to act as an arbiter of regulations in the energy sector and ensure strict adherence [6]. The reform aims to take away barriers to individual or company investment in the energy sector. It also aims to increase energy security and source diversification toward more environmentally friendly sources such as biomass, solar energy, geothermal energy, and wind. Power generation was expected to exceed 13,000 megawatts (MW) by 2015 and 40,000 MW by 2020.

METHODOLOGY

This study uses reports on relevant literature, policy frameworks, and publications from both government and private institutions as a policy document that provides insight into the past and present state of the energy sector in Nigeria and the way forward. The report shows the huge investments made by the various governments over the years and the price Nigerians are paying for high-level corruption in the sector by experiencing total blackouts and epileptic power supply considering the resources government is investing annually. Available statistics show that this sector receives the highest allocations and has nothing to show for it.

ENERGY CRISIS IN NIGERIA

The Nigerian energy problem has been a source of concern for both the government and the citizens for decades while other countries of the world faced with similar challenges have long since conquered their power shortages [7]. This crisis has caused many industries and businesses to vacate the country due to the inability of the national power supply to meet their needs, or where they are available, over 90% of businesses and companies run on generators or other independent power sources resulting in high production costs [7]. Households have had to adapt to epileptic power supply or in some cases complete darkness. Nigeria needs 1000 Watts of power per capita or 140,000 MW worth of power generation and handling capabilities, against the current delivery capacity of just 5,000 MW [8]. At 100 kilowatt-hours (kWh) annually, Nigeria has one of the lowest per capita energy consumption rates in the world. Only 4,000 MW of the 8,000 MW installed capacity is currently operational, and fewer than 2,000 MW is ready to produce energy [9]. Compared to other countries in the region, such as South Africa, which has 5,000 kWh percapita, it is clear that energy generation will be inadequate. Furthermore, even years after government power sector reforms and privatization of state-owned power generation and distribution companies, consistent power supply remains elusive due to disruptions in gas supply, weak transmission infrastructure, power theft, and poor grid extension due to low revenue generation, among other factors.

NIGERIA AND ITS ABUNDANT RENEWABLE ENERGY SOURCES

The five major renewable energy sources in Nigeria are; Solar energy. Nigeria nation's plentiful solar radiation is a significant source of renewable energy. The country experiences solar radiation on average of roughly 7.0$KWh/m2$ -day (25.2$MJ/m2$-day) in the far north and about 3.5$KWh/m2$-day (12.6$MJ/m2$-day) in the coastal latitudes [10]. With this resource, Nigeria would be able to generate 1850 x103 GWh of solar electricity annually, which is 100 times the amount of grid electricity the country now consumes [11]. With this capacity, rural electrification and application of solar energy in pumping water, clinic, schools, street light, and traffic lights are possible in the north-west zone of Nigeria such as Kaduna, Sokoto, Kano, Katsina, Jigawa and Kebbi; Bio-energy: Energy generated by living or formerly living organisms is called biomass energy. Plants such as corn, cassava, and bio-wastes such as forest waste, agricultural waste, and

municipal waste are the most commonly used biomass energy sources for electricity generation [12]. Agriculture is the economic backbone of Nigeria, About 70% of Nigeria's population is employed by agriculture, and it contributes 40% of the country's GDP, with crops accounting for 80%, livestock for 13% forest for 3%, and fisheries for 4% [12]. Although from the economic point of view, producing bioenergy from food crops is not a welcome development because of the competition between energy and food security in Nigeria. However, given the abundant wastes from the municipal and agriculture, the production of biofuel from biogas waste is economically feasible and sustainable in Nigeria"; Wind energy: Presently, Nigeria has not yet explored the potential of wind energy for power generation. However, the quest for a stable power supply has prompted energy researchers to consider the potential of wind energy as an alternative means of power generation. Jekayinfa and Scholz [13] investigated the potential for wind energy in Nigeria using data collected over four years from seven cities including Jos, Delta, Abuja, Enugu, Warri, Sokoto, and Calabar. It was found that locations along the ocean, have yearly wind speeds at 10 meters above the ground ranging from 2.3 to 3.4 m/s, while it was 3.9 m/s for high land areas and semi-arid regions. Sokoto in northwest Nigeria was found to have a wind power potential of up to $97 MW/h$. However, it was discovered that, except in the coastal and offshore areas such as Lagos, Delta, Ondo, Bayelsa, and Akwa Ibom, wind speeds were generally weak towards the south. The wind map in Figure 1 makes this point clear.

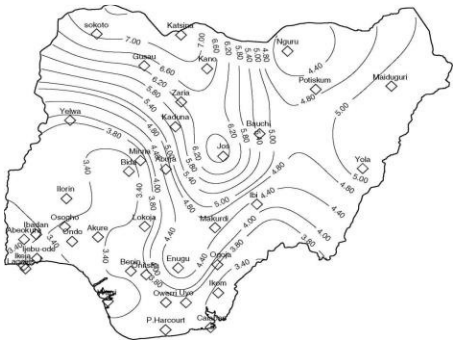

FIGURE 1. The wind map showing locations with enormous wind energy in Nigeria**.**

It can be seen that the North Central, and Southeast have demonstrated potential for wind speeds to generate energy. However, the North showed the greatest potential for wind energy harnessing in Nigeria. Therefore, government and private investors in the power sector should take this advantage and lead Nigeria out of the epileptic power supply situation; Hydropower: About two-thirds of Nigeria lies in the catchment area of the Niger River, which flows into the Atlantic Ocean in the Niger Delta, with its major tributaries: the Benue in the north-central, the Kaduna in the northwest, and Anambra in the southeast. The southern and Plateau regions of Nigeria have the most hydropower potential due to their consistent rainfall patterns and favorable topography [14]. Rainfall is sporadic in the northern regions, thus reservoirs may be necessary for the development of hydropower there, especially in the dry season. Given Nigeria's abundance of major rivers, waterfalls, and dams, hydropower may be considered the primary source of electricity generation and supply [15]. However, only 1930 MW, or 14% of Nigeria's total hydropower potential, is currently produced at Kanji, Shiroro, and Jebba, which accounts for around 30% of the country's total gross installed grid-connected production capacity which is an indication of underutilization of hydropower potentials [15]; Geothermal energy: This is the energy obtained from the natural heat of the earth. It is generated in the earth's core a few kilometers below the surface. The word geothermal is composed of the two Greek words "geo" (earth) and "thermos" (heat), so geothermal energy come from solar radiation and radioactive heat generation (alpha, beta, and gamma radiation) by radioactive decay minerals in the earth's core. There are a number of warm/hot springs and seepages in Nigeria, the majority of which are found within the sedimentary basin of the Benue Trough. These features are geological phenomena that act as visible manifestations of geothermal energy that exists beneath the surface of the earth. The Ikogosi in Southwest Nigeria is a good example of such a warm spring. Other potential warm springs capable of electricity generation are Rafin Reewa near Lere to the north-west Jos plateau, Kerang spring, Ngeji warm springs, Wikki warm springs.

EXPANSION OF RENEWABLE ENERGY IN SUB-SAHARA AFRICA

Ghana's renewable energy policy is designed to harness and explore abundant renewable energy sources with the

intent to maximize renewable energy potential capable of business and industrial growth in the country among other objectives. The policy identified potential renewable energy sources and classified them into different groups [16]. Ghana is among the countries in the region that have commendable access to improved electricity supply compared to its neighbors [17]. However, Ghana's urbanization has increased the country's energy intensity and efforts are being made to reduce this intensity [18]. They suggest that government should promote policies aimed at favoring less energy-intensive products, while high energy efficiency should be implemented and renewable energy couldbe an important driver of the economy and urbanization. Ghana has abundant biomass resources that might be used as a feedstock for the manufacture of biogas, reducing the nation's dependence on fossil fuels and fuel wood [19]; Senegal: About 85% of the rural population in Senegal lacks access to the power supply which contributes tothe country's energy crisis, despite huge sources of potential renewable energy for power generation [20]. According to Youm et al. [21] Senegal has the potential to address its energy crisis in both rural and urban areas if the available renewable sources are completely utilized. solar, wind, hydro, and biomass energy can be used in the country to provide both on and off-grid electricity generation. Among these sources, solar energy is a potential alternative with solar irradiation of $200 KWh/m^2$ and $1800 KWh/m^2$ for global horizontal and direct normal radiation. Biomass is the largest renewable energy source in Senegal, accounting for over 50% of the national energy balance, making it the dominant energy source. Due to the country's excellent agricultural conditions, crop species such as palm oil, jatropha, sunflower, castor, and sorghum are potential candidates for the production of biofuels used to generate grid and off-grid electricity [20]; South Africa: South Africa is one of the most determined countries in achieving renewable energy on the continent, as evidenced by its 1998 energy policy, which mandated that the country obtain 15% of its electricity supply from renewable sources [22]. The question now is whether this goal has been achieved. A study conducted by Pagels [23] indicates that in 2008, the energy mix in South Africa was 86% coal and 5% nuclear, while hydropower and gas together accounted for 9% of the energy mix. Similarly, Krupa and Burch [24] noted that despite the abundant renewable energy resources in the country, there has been little growth in their use. This challenge is related to South Africa's energy innovation system and the economics of renewable energy technologies. The South African government has spent enormous research funds on fossil fuel resources, dating back to the apartheid regime. This situation is also similar to Nigeria's energy crisis where the tradition is that the federal government is the sole financier of power supply which was inherited from the long military government in Nigeria. Urbanization and industrialization in South Africa depend largely on the available capacity of 42000 MW generated from fossil fuels, which has led to an increase in greenhouse gas emissions in the country. Renewable resources capable of solving the energy crisis in the country include solar and wind energy with an estimated supply capacity of 184Twh [24].

PROBLEMS CONFRONTING EXPLOITATION OF RENEWABLE ENERGY IN NIGERIA

Poor funding: Inadequate finance has been a significant hindrance to Nigeria's development of renewable energy technology. The federal government's annual budgetary contribution to the ministries of education and research and technology has not been encouraging. With the pitiful amount given to these ministries, extensive, fruitful research and development may not be possible. Foreign investors and other corporate entities should be encouraged to work with research institutions to finance projects like solar installation, geothermal power plants, and wind power, among others, in order to advance national growth; Neglect of the renewable energy master plan: Renewable energy master plan has received little attention considering the energy policy under ECN-UNDP 2005, which focused on increasing energy generation from 5000MW to 15000MW by 2020 through the exploration of renewable energy resources. To this effect, there hasn't been a single grid extension let alone electricity generation from a renewable energy source outside the conventional hydropower. If significant growth is to occur, the government must implement this policy and lead the country out of power shortage. The recommendations made in alternative energy policy must be strictly adhered to, this will be a crucial tool to achieve all the objectives of the policy. One of these policy recommendations urges the removal of import taxes on renewable energy sources, the establishment of a national renewable energy developmental agency, and the standardization of RE products are among the focus of this policy; Major problems facing the potential of biofuels as an alternative energy source in Nigeria include deforestation, land scarcity, and rivalry between food and energy generation; In Nigeria, there is no continuity in projects by any succeeding government. Every new administration prefers to start on a fresh note not minding the state of completion of existing projects. The government does not encourage the adoption of renewable energy in the power sector in Nigeria, this is clearly shown in the government's failure in enacting laws backing the utilization of renewable energy as well as its inability to build a renewable energy power plant for

power generation; The challenges that also prevent the full use of renewable energy sources include a lack of trained manpower and local production capability, security concerns for foreign investors, and a poor revenue-collecting culture.

CONCLUSION

The switch to renewable energy is intended to lessen Nigeria's reliance on fossil fuels, which are quickly running out, and its associated greenhouse gas emissions. The current study examined the historical background of power generation in Nigeria, including the government's past and present policies on ensuring an uninterrupted power supply to the nation's ever-increasing population, and it made recommendations for how to move forward in putting the government's goal of stabilizing electricity in Nigeria into practice. The paper identified various forms of renewable energy in each of the geo-political zones in Nigeria, this is to project the available renewable energy in each zone and their capability to be self-reliant on power generation. At least two renewable energy technologies are found in every zone in Nigeria, but still, the penetration of renewable energy technologies is very low compared to developed and some developing countries. The review of renewable energy technologies in neighboring African countries such as Ghana, South Africa, and Senegal revealed that governments have adopted various policies and laws to promote the development of renewable energy. In Senegal, for example, one of these policies stipulates that at least 15% of internal energy consumption should come from renewable sources. In Nigeria and some of the neighboring African countries studied, the potential of renewable energy for power generation is very high, but efforts are needed to harness this potential in the region. The government should encourage private partnerships and investment in renewable energy research and development (R&D) at all levels. Among the various renewable energy sources identified in the region, biofuel is a promising alternative. This is due to the abundant raw materials available for biogas production, such as municipal waste, animal waste, and agricultural waste. Factors affecting the full potential of biofuel in Nigeria include deforestation, land scarcity, and competition between energy and food security. Solar power products are growing worldwide and the Installed capacity in Nigeria can be increased if feed-in tariff policies are implemented. The inadequate maintenance culture in Nigeria needs to be revived if renewable energy expansion is expected to promote effective on-grid and off-grid power generation. Train and retrain workers and encourage local manufacturing of renewable energy equipment.

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