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Renewable Energy in Nigeria: Prospects and Challenges

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ABSTRACT

Energy is the main driving force for the socio-economic growth and development of any nation. This paper investigated the concept of prospects of renewable energy in Nigeria and the challenges associated with its implementation. Nigeria as a nation is blessed with several renewable energy sources. Renewable energy sources such as wind, solar, hydroelectric and biomass were identified as being prevalent in Nigeria. The spread and distribution of these resources were also studied in this paper, with solar and biomass found to be the most nationally available of these renewable energy resources. The scope of implementation of these resources was also discussed in the paper with examples cited on the installed current electricity production capabilities of these sources. Several challenges were identified as being limiting factors to the implementation of renewable energy in Nigeria. The identified factors included; a lack of financial investment, infrastructural limitations, regulation and policy hurdles and ineffective grid integration. This study thus suggested that Nigeria must look into developing policies, frameworks, infrastructure and the technology required to effectively harness and utilize its abundant renewable resources, through a combined participation of the public-private partnership.

Keywords: Renewable Energy, Wind, Biomass, Solar, Hydropower

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1. INTRODUCTION

Any nation's socioeconomic development and growth are based on its energy supply. As a traded commodity that may be used to create cash to support the government's developmental projects and programmes, energy plays a crucial role in a country's international diplomacy (Akuru et al., 2016). Energy is a necessary weapon for politics, security, and diplomacy as well as an input that powers the creation of products and services in a country's transportation, agriculture, industrial, health care, and educational sectors globally (Sambo, 2009). Every nation that wants to experience quick and sustained socioeconomic growth must have access to high-quality infrastructure services, particularly electricity (Amadi, 2015). Over 200 power outages have resulted from the deterioration of Nigeria's national energy infrastructure in the last nine years (Ekeng et al., 2024).

Nigeria is blessed with an abundance of energy resources to meet its current and future needs for growth. Nigeria is endowed with an abundance of energy resources, including coal, natural gas, tar sands, crude oil, and generally high-quality sources. Crude oil accounts for over 90% of the nation's economic activity (Igbinovia & Krupka, 2018). With a resource estimated to be at 36 million barrels or roughly 4.9 billion tonnes of oil equivalent (toe), Nigeria was classified as the tenth largest producer of crude oil in the world in 2006 (Chris et al., 2021). Natural gas reserves in the nation are estimated to be 5210 billion m3 (187 trillion SCF) as of 2006, making them more abundant than oil. This comprises both linked and unlinked reserves, positioning Nigeria as one of the top ten nations in the world with the biggest gas reserves (Uyigue & Archibong, 2010). In addition, Nigeria has 1.52 billion tonnes of coal and lignite, as well as 4.1 billion tonnes of tar sands (Shaaban & Petinrin, 2014).

Petroleum in particular continues to be the most significant source of foreign exchange earnings and government revenue in the energy subsector. Between 2002 and 2006, the GDP benefited on average by 25.24% from the petroleum industry. Nevertheless, other economic sectors are contracting despite the oil industry's success. For instance, although overall or total electricity consumption showed a marginal increase of 1.8% from 5.63GWh in

2002 to 7.47GWh in 2006, actual electricity usage decreased by 13.4% between 2002 and 2006. In Nigeria, just 40% of homes are wired into the national grid.

High energy loss results from an insufficient metering system, physical degradation of the transmission and distribution infrastructure, and an increase in power theft via unauthorized connections. The lack of manpower and inadequate support infrastructure, the high cost of producing electricity, the lack of basic industries to serve the power sector, subpar billing systems, poor customer bill settlement, and low available capacity—roughly 40% of the installed capacity of about 6,000MW—are some of the other issues facing the power industry. Targeted sector expansion was impeded by insufficient finance (Sambo, 2009). In rural parts of the nation, the majority of end users rely on firewood. More than 60% of Nigerians who live in rural regions burn firewood. Nigeria uses more than 50 million metric tonnes of firewood per year—a rate that is higher than the amount that is replenished by various afforestation initiatives. One of the main causes of erosion in the southern part of the country and desertification in the states in the arid zone is the sourcing of fuel wood for home and commercial purposes. Reforestation only accounts for roughly 10% of the rate of deforestation, which is roughly 350,000 hectares each year or 3.6% of the current area of forests and woodlands (Akuru & Okoro, 2008; Oladipo, 2012; Sambo, 2009). Based on current extraction practices, it is projected that Nigeria's fossil fuel reserves will run out and become unprofitable by 2050 (Shaaban & Petinrin, 2014). It is therefore past time for Nigeria to make the switch from the search and use of traditional energy-rich resources to renewable resources with the right technologies (Chris et al., 2021).

1.1. Importance of Renewable Energy

A more sustainable strategy for rural development, ecosystem health, energy independence, and mitigating climate change is provided by renewable energy. Renewable energy is defined by the International Energy Agency (IEA) as energy derived from natural processes that regenerate more quickly than they are consumed (Chris et al., 2021). Reducing environmental effects is typically the driving force behind the switch from non-renewable to renewable energy (Ibanga, 2018). Using and switching to renewable energy offers several socioeconomic and environmental advantages, including:

i. Creation of clean energy, which emits less greenhouse gas than fossil fuels—either none at all or very little.
ii. Energy supply diversification, which lessens reliance on imported and fossil fuels.
iii. Fostering employment growth and economic development in the manufacturing, installation, etc.
iv. Enhanced energy accessibility and availability leading to higher productivity, which raises GPD.

This study seeks to review the prospects of renewable energy in Nigeria, and its challenges and present a way forward in the advancement and adoption of renewable energy in Nigeria. The types and sources of renewable energy available in Nigeria, the locations in which they occur and their scope of implementation so far will also be discussed in this study

2. RENEWABLE ENERGY SOURCES IN NIGERIA

2.1 Overview of Available Renewable Energy Sources

Renewable energy is becoming more and more popular. Renewable energy is any type of energy that comes from sunshine, either directly or indirectly, by heating the earth's surface differently and creating air movement, such as wind power. An adult individual can refill these energy sources during their lifespan. Renewable energy is widely available in Nigeria (Akuru et al., 2016). In terms of energy, Nigeria's renewable energy potential is roughly 1.5 times greater than that of its fossil fuel resources. Nigeria's low level of access to power can be significantly improved and changed by hydro, solar, biomass, and wind energy (Shaaban & Petinrin, 2014).

2.2 Solar Energy Potential

This energy source is dependent on the sun's core's nuclear fusion power. There are various methods for gathering and converting this energy. These range from sophisticated devices that directly convert sunlight into electrical energy using mirrors, boilers, or photovoltaic cells, to solar water heating using solar collectors or attic cooling with solar attic fans for home use. The fact that this energy source is insufficient to sustainably power our contemporary society is one of its main concerns. PV or thermal systems are the sources of solar electricity (Akuru & Okoro, 2008).

In general, there are two types of radiation conversion technologies: photovoltaic (direct conversion to electricity) and solar-thermal (solar heating, cooling, drying, thermal power plant, etc.). Crop drying, home heating, heating process water for industry, hospitals, air conditioning, food and medication preservation, and power generation are among the applications of solar thermal technologies. When it comes to low- to medium-power applications in distant locations, photovoltaic (PV) power can be used for things like communication stations, rural television and radio, streetlights, water pumping, refrigeration, and powering security cameras. These applications call for power of the range of one to ten kW. In rural settlements that are not connected to the national grid, it may also be utilized to supply electricity.

PV power can also be produced and fed into the national grid. Utility-scale power plants with a capacity greater than 20 MW can employ concentrated solar power (CSP) projects (Akuru et al., 2016).

2.3 Wind Energy Potential

The type of energy that depends on variations in surface temperature brought on by sunshine is this one. Although wind energy can be utilized to create power and pump water, it needs a large area of sky coverage to produce a meaningful amount of energy. There are additional constraints on this type of energy due to various factors that impact wind availability year-round. Grain milling and water pumping have been done for centuries using wind energy (Madhusudhan & Damodhar, 2019). Optimising the components of wind power generation and wind water pumping is a crucial prerequisite for meaningful wind energy exploitation (Musa, 2014).

In order to turn the blades of windmills or wind turbines, which could then turn electrical generators to produce electricity, wind energy is the energy contained in the flow of air in the form of wind. Large contemporary wind turbines function as "wind farms" to generate electricity for utilities, while smaller ones can handle specific, localized energy requirements. The ecological and societal costs of wind energy are minimal (Gupta, 2016).

Similar to South Africa, wind speeds in Nigeria vary from 4.0 to 5.12 m/s in the country's far north to 1.4–3.0 m/s in the south (Shaaban & Petinrin, 2014). For the most part, the latter has wind speeds between 4.0 and 5.0 m/s; but, in certain hilly areas, they can reach up to 8.0 m/s. This demonstrates that, except in coastal and offshore areas, wind speeds are typically low in the southern region. The entire usable wind energy reserve at 10 m height, according to research by the Energy Commission of Nigeria (ECN), may range from 8 MWh/yr in Yola to 51 MWh/yr in the hilly area of Jos, and it may even reach as high as 97 MWh/yr in Sokoto. Potential wind speed estimates for ten randomly chosen locations in Nigeria show a range of 3.6 to 5.4 m/s (Efurumibe et al., 2015).

2.4 Hydropower Prospect

The gravitational potential of the water that sunlight lifted from the oceans is what drives this type of energy. It's possible that hydroelectric energy isn't always renewable because reservoirs ultimately fill up and need to be excavated at great expense before they can be used again. In the developed world, the majority of the sites that are suitable for hydroelectric dams are already in use (Akuru et al., 2016). Global hydropower capacity was estimated at 2810 TWh in 2004 and is expected to reach 4903 TWh by 2030, growing at a pace of 1.8% annually; nonetheless, its share of the world's energy supply will stay around 2% (Gupta, 2016; Karekezi et al., 2003).

There are now several hydropower development projects underway throughout the world, with a combined capacity of roughly 100,000 MW. Asia makes up the largest contribution, at 84,000 MW. Other regions contribute 14,800 MW from South America, 1236 MW from North and Central America, 2211 MW from Europe, and 2403 MW from Africa (Singh et al., 2009).

With all of Nigeria's vast rivers, waterfalls, and dams, hydropower may be considered the country's main source of electricity generation and supply. The only widely used commercial RE technology in the nation's electricity supply mix is big hydropower technology. Under all CO2 emission limits, big hydropower technology dominates all commercial renewable energy resources used for electricity generation due to economies of scale (Efurumibe et al., 2015). Except the issue of water levels, hydropower is renewable and a continuous fuel source, unlike fossil fuels. Nigeria has a 14,750 MW hydropower potential in total. Nevertheless, only 1930 MW, or 14% of it, is now produced at Shiroro, Kanji, and Jebba, which accounts for almost 30% of Nigeria's total installed grid-connected electrical generation capacity (Chris et al., 2021).

This analysis focuses on massive hydropower, the kind that was utilized before the oil crisis of 1973. Nigeria still has a lot of untapped hydroelectric potential despite its large capacity. Because of this, small hydropower (SHP) has garnered significant attention in the world's developed and emerging countries. This is a result of the inherent

benefits of SHP, which include reduced environmental effects, limited civil works, inaccessible morphology, and the potential to generate power in addition to flood prevention, navigation, irrigation, and fishing. 277 locations can produce about 734 MW of SHP (Shaaban & Petinrin, 2014). Estimated at 3500 MW, the SHP potential accounts for roughly 23% of the nation's overall hydro potential. A total of 30 MW of installed SHP capacity is now in use in three of the surveyed states: Kano, Sokoto, and Plateau. The Nigerian Electricity Supply Company (NESCO) is also producing 21 MW from six additional Plateau State locations. Only about 5 percent of the SHP capacity that is available is being used at this time; the remaining capacity is being held over for future expansion. Only 32 MW of the 734.2 MW total capacity have been constructed, and the remaining 702.2 MW are still undeveloped (Sambo, 2009). These must be developed on schedule. To bring electricity to more rural and isolated sections of the nation, more mini- and micro-hydropower projects might be set up. Nigeria's hydropower potential should be fully utilized to help the nation and lighten its financial burden. In addition to having the ability to bridge the gap between generation shortage and load demand, hydro energy may offer isolated communities a reliable, environmentally friendly supply of electricity. The rural villages' available minor rivers could be developed into SHPs. By this development, rural areas can become urban hubs, a variety of socioeconomic activities can be enhanced, and the requirements of rural residents can be sustainably satisfied.

2.5. Biomass and Bioenergy Resources

This relates to plant-based energy. This type of energy is widely available everywhere. Among these energy sources, burning trees for warmth and cooking is the most prevalent. This method contributes significantly to air pollution in many places by releasing a large amount of carbon dioxide gases into the atmosphere. Modern biomass energy sources include the manufacture of alcohol and methane for use as fuel in cars and electric power plants. Various techniques can be employed to transform biomass into electrical energy. Direct combustion of biomass, such as woody or agricultural waste, is the most used method. Anaerobic digestion, pyrolysis, and gasification are more alternatives. Through the process of gasification, biomass is heated with less oxygen than required for complete combustion, producing a synthesis gas with a usable energy content. By quickly heating the biomass in the absence of oxygen, pyrolysis produces bio-oil. When organic matter is broken down by bacteria without oxygen, anaerobic digestion creates a renewable natural gas. Various techniques are effective with various kinds of biomass. To provide energy, woody biomass like sawdust, pellets, and chips are usually burned or gasified. The remaining corn Stover and wheat straw are either baled for burning or treated in anaerobic digestion to produce gas. Anaerobic digesters are used to transform very wet wastes, such as those from animals and humans, into a gas with a medium energy content. Furthermore, pyrolysis may be utilised to turn the majority of other biomass types into bio-oil, which can be utilised in furnaces and boilers (Akuru et al., 2016).

Nigeria has an abundance of biomass resources, including wood, aquatic biomass, wastes from forestry, agriculture, cities, and industries, and forage grasses and shrubs. The projected amount of biomass resources in the country is $8x10^2$ MJ. MJ. Small-scale businesses can use plant biomass as fuel. Anaerobic bacteria might also ferment it to create inexpensive, very flexible biogas. In addition to being utilized for firewood, wood is also utilized for sawn wood, plywood, paper goods, and electric poles. In Nigeria, however, 80 million m^3 of firewood are used each year for cooking and other household needs.

Small-scale businesses can use plant biomass as fuel. Anaerobic bacteria might also ferment it to create inexpensive, very flexible biogas. In addition to being utilized for firewood, wood is also utilized for sawn wood, plywood, paper goods, and electric poles. In Nigeria, however, 80 million m3 of firewood is used each year for cooking and other household needs. The firewood/fuelwood that is being used has an energy level of $6.0x10^9$ MJ. Of which only 5% to 12% can be profitably used for home purposes like cooking. Between 1989 and 2000, fuelwood and charcoal made up between 32 and 40 percent of all primary energy usage. In 2000, it was predicted that the country needed 39 million tonnes of fuelwood. Households used almost 95% of the fuelwood consumed for cooking and small-scale industrial processes including processing oil seeds and cassava. Biomass availability was estimated to be $9.1x10^{12}$ MJ in 1973; however, current biomass availability appears to be lower. In addition to its usage as an energy source, the demand for wood in the furniture and construction industries is the cause of the shortfall (Shaaban & Petinrin, 2014).

While biomass is undoubtedly a significant renewable energy source, it is important to comprehend how sustainably it is produced. Nigeria should use its oil palm products, woods, municipal waste, rice, and sugar cane

husk for biogas energy production because it has an abundance of biomass resources, just like South Africa and Malaysia, which share Nigeria's climate, vegetation, and equatorial disposition (Shaaban & Petinrin, 2014).

3. PROSPECTS OF RENEWABLE ENERGY IN NIGERIA

3.1 Energy Demand and Population Growth

Nigeria's electricity consumption was estimated to be more than 32 terawatt hours in 2022. This is in line with an increased trend seen in Nigeria's energy industry. This is explained by the nation's rapidly expanding population (Sasu, 2023). Nigeria is expected to have 223,804,632 citizens as of mid-2023, placing it sixth among all countries in the world in terms of population. By 2050, the population is projected to reach approximately 400,000,000, growing at a rate of 2.4% per year. A little over half of Nigerians were reported to be without electricity as of 2020, with frequent occurrences of load shading, power outages, and system breakdowns.

According to Shaaban and Petinrin (2014), the estimated energy demand for Nigeria under a 10% economic growth rate scenario is 16,000 MW, 30,000 MW, and 192,000 MW in the short, medium, and long term, respectively. Because of the nation's rapid population increase, alternative sustainable electricity sources are consequently required.

3.2 Economic Benefit and Job Creation

The availability of energy has a major impact on the world economy. A world with little economic activity is one devoid of energy. We rely largely on energy, which is mostly derived from non-renewable resources like fossil fuels, even in our daily lives. These conventional energy sources are a significant source of carbon emissions since they are being used up far more quickly than they can be produced (Shaaban & Petinrin, 2014).

Because our homes and companies depend on energy to run, we must make a significant transition to sustainable and renewable energy sources. The switch to renewable energy sources could result in the creation of new jobs, a decrease in emissions, and the availability of sustainable electricity for millions of people globally.

There is proof that renewable energy creates jobs. For instance, compared to energy produced through conventional sources, energy produced through solar photovoltaic cells, landfill gas, or biomass facilities creates more jobs per unit of energy produced (Eluwa et al., 2015).

Increased net profit margins, longer and more varied supply chains, and higher labour intensity are the reasons behind renewable energy's beneficial impact on employment creation. Along the whole value chain, jobs in renewable energy can be generated both directly and indirectly in the production of chemicals, equipment, installation, operation, and maintenance, as well as in the manufacturing and distribution of inputs. Increased employment opportunities in the gathering of feedstock and other biomass can be advantageous for those employed in the agricultural industry, especially women and young people. Enhancing the energy supply with renewable energy sources can also help current economic activities in other industries grow. Additionally, employment generated by the production of renewable energy has the advantage of less hazardous working circumstances. When compared to traditional energy sectors, employment in renewable energy can open up new avenues for creative communication arrangements between companies and employees, improving the calibre of jobs. This translates into better and more respectable work in addition to more jobs (Klemmer, 2022).

3.3 Environmental Sustainability

According to Akuru and Okoro (2008), the main idea behind sustainability is to satisfy current needs without compromising the capacity of future generations to satisfy their own. Low-carbon energy sources include renewable energy sources, which are also favourable to the environment. Greenhouse gases are not produced by renewable energy sources like solar, wind, geothermal, and hydroelectric power. Renewably-produced energy sources refill more quickly than non-renewable energy sources, including fossil fuels. Because renewable energy sources like solar, hydroelectric, and geothermal energy are naturally occurring and an essential part of the planet and universe, they can never run out. Ayaz (2019) claimed that the amount of solar energy that is radiated on the earth's surface each day is approximately 10,000 TW. This illustrates the endless nature of these renewable energy sources. To put this into perspective, it has been calculated that 17.4 trillion watt-hours (TW) of energy were utilized worldwide in 2015. As a result, solar energy may efficiently provide the world's annual electricity needs in a matter of hours if it is adequately harnessed (Ayaz, 2019).

3.4 Energy Access in Rural Areas

Nigeria, being a developing nation, is unable to claim complete energy penetration or energy availability throughout its rural and urban areas. According to Sasu's (2023) report, as of 2022, 59.5% of the population has access to electricity. Nigerians living in rural areas were projected to number 101,575,770 as of 2021. According to the World Bank, just 24.6% of Nigerians living in rural areas have access to electricity (Pelz et al., 2023).

4. CHALLENGES OF RENEWABLE ENERGY ADOPTION IN NIGERIA

4.1 Financial and Investment

Financial considerations severely limit Nigeria's ability to accept and use renewable energy. Given that Nigeria is the world's centre of poverty and has a weak manufacturing sector, the majority of the facilities, parts, and equipment needed to adopt renewable energy are not readily available in the country. Before they can be implemented, they must first be imported. Nigeria's high cost of installing and purchasing renewable energy capacity is the outcome of this.

Even though Nigeria has made significant investments in renewable infrastructure, particularly in the field of solar energy, the total amount of funding obtained to far has not been able to meet the needs of the nation in terms of renewable infrastructure.

4.2 Infrastructural and Technological Limitation

The absence of infrastructure and technology to facilitate the development of these energy sources is a major obstacle to the implementation and utilization of the abundant renewable energy resources found in Nigeria. For instance, Nigeria is endowed with year-round sunshine and minerals including silicate, lithium, lead, tin, zinc, and cobalt that are used to make solar panels and batteries. But other than cables, Nigeria doesn't produce solar panels, batteries, or any other part used in solar installations. Few people have the financial means to buy and install solar power as a standalone supply or backup supply because of the high cost of solar energy installation caused by the absence of infrastructure and technology for the production of these parts.

Also, Nigeria currently lacks infrastructure for the exploitation of wind and tidal energy. Nigeria is not using various sources of energy to generate power as a result of the lack of this infrastructure. Therefore, regulations and investments are needed to solve the physical and technological gaps that are now preventing Nigeria from fully using these renewable energy sources.

4.3 Grid Integration Issues

Against the existing production capacity of over 12,000MW, the Nigerian national system can currently transmit barely over 6000MW of power. This led to other power plants implementing redundancy. The difficulty of incorporating renewable energy sources, such as solar microgrids, into the national grid is another effect of this.

4.4 Regulation and Policy Hurdles

Nigeria's attempt to encourage the diversification of its energy mix resulted in the creation of the Renewable Energy Master Plan (REMP), which was revised in 2011 after being approved by the government in November 2005. The United Nations Development Programme (UNDP) and the Energy Commission of Nigeria (ECN) collaborated on this plan to create a broad vision, objectives, and action plan for resolving the nation's major energy-related problems through the rapid development and utilization of renewable energy sources. With the help of an inclusive framework for the development of renewable energy policies, law, technology, human resources, infrastructure, and the market, REMP establishes clear and verifiable national targets for the short, medium, and long term. There were three sets of targets: medium-term for 2015, long-term for 2025, and short-term for 2007.

Nigeria's efforts to advance the country's sustainable development goals, as outlined in the National Development Policy papers known as Nigeria Vision 2020 and the NASPA-CCN, National Adaptation Strategy, and Climate Change Action Plan for Nigeria, must be taken into consideration when implementing the REMP. The proposal is expected to boost the demand for renewable energy sources and ease the shift from crude oil to a less carbon-intensive economy. The start of the REMP was more than ten years ago. Except for the hydroelectric power plants that are now in operation, no particular advancements in this field have been observed to date (Chris et al., 2021). No increased grid generation of electricity from renewable sources has been noted.

The growth of Nigeria's renewable energy industry has been hampered by a number of issues that, for the most part, also threaten the implementation of the REMP. The principal identifications are as follows:

i. Political and policy barriers: even with the best of intentions, government-developed policies may not ultimately be enacted or, if they are, may not be fully executed.
ii. Market distortions: The nation's present energy market is characterized by price distortions, a lax regulatory framework, and inadequate infrastructure.
iii. International development barriers: A concept like the REMP is often under pressure from globalization in the flow of capital, technology, goods, and ideas.
iv. Barriers to standards, quality, and control: Inadequate standards and quality control of both locally produced and imported technology are a key impediment to the growth of Nigeria's renewable energy market.
v. Research and development obstacles: To reduce inefficiencies and lower the cost of construction and procurement, the long-term goals of the REMP call for quality improvement in research and development in renewable energy systems.
vi. Environmental hurdles: Even though renewable energy sources offer a more environmentally friendly substitute for hydrocarbons, some environmental barriers, such as the disruption of plant and animal habitats, human relocation, and resettlement, may still exist.

4.5 Potentials for Renewable Energy Growth

4.5.1 Solar Energy

With its extensive sunshine belt, solar energy has enormous promise in this country. The yearly average of total solar radiation varies from approximately 3.5 kWhm-2day^{-1} in coastal latitudes to 7 kWhm-2day^{-}1 in semi-arid regions in the far north. On the other hand, Nigeria receives 19.8 MJm–2 day^{-1} of solar radiation. It is believed that the country receives six hours of sunshine on average every day, with a fairly even distribution of solar energy. The minimum average rate in Calabar is 3.4 kWhm–2day$^{-1;}$ in August, the minimum average rate in Katsina St at e is 3.55 kWhm–2day^{-1} in January; and in Nguru, the maximum rate is 8.0 kWhm–2day^{-1} in May. In Nigeria, solar electricity generation is possible at 11850x10^{3} GWh per year, more than 100 times the country's current electricity consumption rate, if solar radiation is used to cover 1% of the country's land mass area of 923,773km^{2} and at an average rate of about 5.5 kWh m–2day-1 (Oladipo, 2012).

4.5.2 Wind Energy

The result of the sun's heating of the earth's surface is wind. The yearly rates of 4.0 m/s in the country's far north and 2.0 m/s in its coastal regions are constantly accessible for the resultant force inequalities (Oladipo, 2012)
In the country's core northern region, wind energy intensity ranges between 35.2 W/m^{2} and 4.4 W/m^{2}, assuming an air density of 1.1 kg/m^{3}, perpendicular to the wind direction.
In the northern part of the nation, wind energy has been tested to pump water from wells at several secondary schools in the states of Kano and Sokoto as well as the states of Katsina, Bauchi, and Plateau. A 5kW wind power conversation has been generated for the hamlet electrification of Sayyan Gidan Gada in Sokoto State (Sambo, 2009).

4.5.3 Biogas

Nigeria offers a variety of biomass resources, such as crop residue and agricultural waste, fuel wood, sawdust and shavings, animal dung, poultry droppings, municipal solid waste, industrial effluents, and sawdust and shavings (Singh et al., 2009).
While the rainforest in the southern portion of the country generates the best grade of woody biomass, the guinea savannah vegetation in the country's north-central region produces more agricultural leftovers than savannah zones in the Sahel and Sudan. In the most densely populated sections of cities, you can produce a large amount and excellent grade of municipal waste (Oladipo, 2012).

4.6 Recommendations for Addressing the Challenges facing Renewable Energy Adoption in Nigeria

Having explored the vast untapped resources of renewable energy Nigeria is endowed with, it is important to propose measures or a framework to effectively harness renewable energy sources to meet the energy demands in Nigeria.

i. Solar Energy being the most abundant and feasible of all other renewable energy sources identified in Nigeria can be effectively harnessed to bridge the energy gap in Nigerian society. A clear framework must be established for the proliferation, adoption and integration of solar energy resources into the National grid system and also as stand-alone microgrid systems. Firstly, Nigeria is not a producer of Solar panels, Batteries and other components of solar energy installation. This has to be addressed. The Nigerian government should establish public-private partnerships to address this challenge as the natural resources required for solar panels, batteries and other components of a solar grid are readily available in the country. Investments in solar panel and battery production will greatly reduce the cost of implementation of solar energy thus allowing for a wider implementation.

ii. Wind energy in Nigeria remains largely untapped. The excuse has always been that Nigeria, being in the equatorial zone has a lower wind pressure when compared with other countries in temperate zones. This justification is however not valid as several parts of the country have sufficient wind pressures that can sustain the harnessing of wind energy. Therefore, efforts should be centred on harnessing wind energy in those areas with relatively higher wind pressure. The electricity harnessed for these areas which are mostly remote can be used in addressing the electricity challenges in such areas and not necessarily fed into the national grid. Also, Nigeria is blessed with a long coastline, stretching from Lagos in the South-west to Calabar in the South-east. This can be harnessed in the area of offshore solar wind farms as is being done in Germany, the Netherlands, China, etc.

iii. Biogas being a cheap, easy to implement and readily available source of renewable energy is another area which requires massive investments. This investment does not necessarily mean investment of capital but of knowledge and skill in biogas processing. Owing to biogas being a cheap alternative to implement, the Nigerian government can fashion out educative programs to train rural and urban dwellers on biogas production. Thus, providing an alternative source of cooking fuel, manure and electricity.

4.7 The Role of Renewable Energy in Nigeria's Energy Future

In Nigeria, renewable energy solutions are thought to be practical for resolving the nation's energy problems, both in the country's rural and urban areas. Nigeria's renewable energy resources have a lot of promise. This could be a viable way to lessen the nation's energy crisis. Nigeria produces roughly 5000 megawatts of power, which is less than what is needed given the size of the nation's population. One of the most developed nations on the African continent, it has less than 48 hours of electricity per week in rural areas and less than 84 hours in metropolitan areas. Renewable energy, especially solar energy, is being quickly embraced as an off-grid power source due to current issues with the nation's electricity supply. Investments in renewable energy sources are being considered by the government and various private sector entities.

5. CONCLUSION

Energy resources classified as renewables replenish more quickly than they are used. As a result, they are limitless resources. Nigeria is endowed with a wealth of renewable energy resources of many kinds. Nigeria is blessed with year-round sunshine, rivers and streams that can be used to generate hydroelectric power, an abundance of biomass for the production of biogas, a large cost line, and an arid Sahel region with enough wind pressure to harness tidal and wind energy. Nigeria is located in the equatorial and Sahel regions. Nonetheless, fossil fuels remain Nigeria's main source of energy for cooking and electrification today. However, because they release greenhouse gases into the atmosphere, these fossil fuel sources are bad for the climate.

Moreover, Nigerian society today lacks the infrastructure and technologies needed to fully utilize these renewable energy sources. As a result, the majority of the parts needed to install these energy sources must be imported into the nation. Only a small number of people and organizations have been able to access these sources of electricity due to the country's weak currency, high import costs, and generally poor income. Due to all of these factors, half of Nigeria's population suffers from a lack of electricity, while the other half is constantly experiencing power outages and irregular power supplies.

Nigeria must so focus heavily on creating the structures, laws, infrastructure, and technologies necessary to efficiently harness and use its wealth of renewable resources. It is impossible to overstate the importance of public-private partnerships in doing this.

Nigeria has to solve its severe energy shortages, which have hampered its growth and development, in addition to working to maximize its renewable energy resources to create a more environmentally friendly future. Nigeria has an enormous amount of renewable energy resources, which when used well can reduce the country's reliance on fossil fuels for energy, helping Nigeria become a carbon-neutral society.

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