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Green Energy Utilization as a Panacea for Curbing Nigeria's Electricity Deficit

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Abstract

This paper explores the potential of green energy utilization as a solution to Nigeria's enduring electricity deficit. It begins by analyzing the current electricity landscape, highlighting the widespread power shortages that hinder economic growth and development. The economic implications of Nigeria's electricity deficit are discussed, emphasizing its negative impact on industries, employment, and overall economic productivity. Various green energy options, such as solar, wind, hydro, and biomass, are then presented as viable alternatives to fossil fuel-based power generation. The paper outlines specific strategies for leveraging these renewable resources to improve Nigeria's energy supply, while also examining the key challenges hindering their adoption, including high initial costs, regulatory inefficiencies, and inadequate infrastructure. Finally, the paper offers policy recommendations aimed at promoting green energy utilization, such as improving regulatory frameworks, enhancing access to financing, and investing in infrastructure development. The study concludes that green energy is a crucial pathway to addressing Nigeria's electricity deficit, fostering economic growth, and ensuring long-term energy sustainability.

Keywords: Green energy, Electricity, Renewable Energy, Power Deficit,

Introduction

Nigeria, the most populous nation in Africa, with a population exceeding 200 million, is currently facing a significant energy crisis characterized by recurrent power outages and unreliable electricity supply. This situation is particularly paradoxical given the country's abundant energy resources. Consequently, Nigeria ranks among the lowest globally in terms of access to electrical power, with over half of its population living in rural areas that have limited access to electricity [1]. Electrical power is the third most important production factor in economic models, making it an essential component of any economy and its prosperity. Inadequate generation availability, insufficient and delayed maintenance of infrastructure, obsolete facilities, and inadequacy in communication equipment are some of the difficulties facing the Nigerian power sector, resulting in a massive energy imbalance in the country [2].

When the effective demand for electricity exceeds the supply, there is an electric power deficit. It happens when there are transmission losses including power theft between supply sources and distribution hubs and when there are distribution losses to end users [3]. The pervasive electricity deficit has significantly impeded the nation's economic growth and development. Additionally, the dependence on fossil fuels has resulted in environmental degradation and elevated energy expenses, which are contingent upon foreign currency [4]. Green energy presents a viable solution to address these issues while simultaneously fostering economic development. The country has significant potential for renewable energy, and its effective harnessing can help bridge the energy disparities between rural and urban regions. This renewable energy potential encompasses biomass, wind, hydropower, and solar energy, all of which provide numerous benefits, including a reduction in greenhouse gas emissions and their associated impacts on climate change. [5].

The national energy projection for 2020 to meet the electricity depend of Nigerian's growing population, which was not realized due to the coronavirus pandemic, calls for the country's generation capacity to exceed 40GW, with an energy mix of 21% renewable, 69% thermal power and 10% coal. Nigeria's energy mix from its 23 generating plants connected to the national grid now comprises 83% natural gas, 17% hydropower, and less than 1% solar, wind, biomass. This projection can only be achieved via timely intervention using the country's existing untapped renewable energy potentials [1]. The rapid population expansion and increase in industrial activity have resulted in an additional energy shortage, with just roughly 40% of the population connected to the national grid. Compared to the global average of 3127KWh per capita energy consumption, Nigeria has a measly 144KWh, placing it at the bottom of the global table [6].. This article, therefore, looks at how increasing the use of green energy sources might help Nigeria manage its energy deficit and contribute to economic development.

Nigeria's Current Electricity Landscape and Electricity Deficit

Electricity, the world's most commonly used energy resource has remained volatile, particularly in Nigeria, where despite substantial conventional and renewable energy resources, the supply-demand mismatch remains massive. Frequent power outages and high

electricity costs can be ascribed to an over-reliance on fossil fuels, with its effect negatively harming industrial production and limiting access to electricity for millions of Nigerians [6]. The Nigerian electricity industry is divided into three subsectors namely, generation, transmission and distribution [7]. The generation sub-sector has 23 energy generation plants consisting of three hydro and nine thermal stations, their outputs are shown in Table 1.

Table 1: Nigeria's power generation plants and their capacity utilization

Generation Plant	Fuel Type	No. of Units	No. of Units Available	Yrs	Installed Cap. (MW)	Available Cap. (MW)	Contr. to the Nat. Grid % (Approx.)
Kanji	Hydro	12	6	43	760	444	11.6
Jebba	Hydro	6	4	26	578	431	11.1
Shiroro	Hydro	6	4	22	600	508	13.1
Egbin	Thermal	6	5	25	1320	914	13.1
Geregu	Thermal	3	3	4	414	328	23.6
Omotosho	Thermal	8	2	4	335	306	8.5
Olorunsogo	Thermal	8	2	3	335	260	7.9
Delta	Thermal	20	12	45	912	466	6.7
Sapele	Thermal	10	1	33	1020	219	11.9
Affam	Thermal	20	3	48	294	234	5.7

Source: [8]

The total installed capacity of the nation's national grid is 12,522MW with only 4723.30MW as the available capacity as of July 2024 [9]. To cover the power needs of over 202 million Nigerians, the national grid must supply 202, 000MW of electricity. Based on the preceding, it is clear that the country has a power shortfall of 190,000 MW following thumb rule, which stipulates that for every 1,000,000 people a minimum of 1000 MW is required [10]. Lack of maintenance and deterioration of facilities are some of the main causes of the low performance of the national grid. Investigations have found that over 60 million Nigerians have been forced to find alternative off-grid solutions to make up for the lack of reliable electricity supplied by the national grid through the use of personal power-generating set [11]. The country's energy mix indicates its overreliance on thermal-powered plants with an installed capacity of 8,457.6MW out of a total of 12,522MW. A pivotal role is also played by the hydropower stations with a total installed capacity of 1,938.4MW [12].

The transmission network has a maximum wheeling capacity of only 6056MW. This is significantly lower than the national electricity demand. Due to poor infrastructure and a brittle, radial architecture, the network is vulnerable to voltage instability and collapse. Weak and strained systems produce voltage breakdown, leading to partial or whole system malfunctions and blackouts [11] . In the last nine years, the national electricity grid has collapsed more than 200 times resulting in regular blackouts [13] . The World Bank ranked Nigeria as the lowest performer in the power industry among 20 developing countries in its 2015 report. The report stated that the country has the largest percentage rate of system losses, the lowest generation capacity factor, average collected revenue, and the lowest return on investment [14].

The distribution network is the part of Nigeria's power infrastructure that directly interacts with the public. It is crucial in guaranteeing extensive network coverage, delivering a stable power supply, and offering effective marketing and customer service. However, Nigeria's distribution network has two major challenges: low voltage and large losses. These difficulties vary according to the network's loading patterns. In many regions, the distribution network is inadequate, resulting in low voltage profiles and erroneous billing. These issues are caused by a variety of circumstances, including inadequate network coverage, overloaded transformers, defective feeder pillars, inferior distribution lines, antiquated communication equipment, and low employee morale as a result of insufficient training and growth opportunities [15].

Successive governments implemented a variety of changes to alleviate the electric power shortfall. In 2001, it initiated reforms in the power sector that culminated in the unbundling and privatization of electricity generation and distribution, aimed at addressing the issues of power generation, transmission, and distribution due to government monopoly [16]. These reforms, however, only succeeded in changing the dimension of the challenges and the power supply remains largely inadequate and unreliable in the country [3].

Economic Implications of Nigeria’s Electricity Deficit

Economists, engineers, government organizations, and enterprises all acknowledge the importance of energy to a nation's economic progress. Electricity is an essential component of

energy consumption, as well as a crucial capital generation and manufacturing driver. [17] . Energy is a necessary driving element for all economic operations; global economies rely on it, and Nigeria is no exception. Energy efficiency is related to a country's ability to efficiently manage and completely utilize its available resources to achieve economic progress [14]. Lack of access to affordable energy is recognized as a major problem for the development of Nigeria, not the presence of energy, as the country is endowed with an abundance of energy resources. The electricity deficit in Nigeria is such that all manufacturing firms depend on self-generated electricity to power their operations and maintain backup power in the event of a power failure [18].

There is no arguing that electricity is critical to attracting investment and supporting growth in all sectors of Nigeria's economy. A reliable power supply often supports economic activities and provides critical services required to direct production operations in the agriculture and manufacturing sectors boosting economic growth and decreasing operational cost for businesses [3] . Inconsistent electricity supply poses a substantial burden for individuals and businesses, resulting in estimated yearly economic losses of $29.2 billion or 2% of GDP as estimated by the world bank. The residential sector consumes more electricity than the commercial and industrial sectors combined, despite the latter being more productive in the Nigerian economy. This inadequate power supply impedes economic production operations, resulting in a weakened industrialization, unemployment, withdrawal of foreign investment and her inability to compete in the global market [19].

The country's electricity shortage has directly resulted in the manufacturing industry's dependency on self-generated power, which dramatically raises operational and production expenses. This difficulty has contributed to the annual closure of around 95 manufacturing enterprises in Nigeria. According to a survey published by the Association of Small Business Owners of Nigeria, 25% of manufacturing enterprises will discontinue operations in 2023. This tendency is further indicated by the reduction in the nation's Gross Domestic Product (GDP), which dropped from 21% to 14% between 1994 and 2022 [20]. According to a survey by the Manufacturers Association of Nigeria (MAN), job creation in the manufacturing industry declined by 32% in 2022, with over 4,451 jobs lost annually. This reduction has worsened the country's unemployment situation, with more than 4% of the population

unemployed as of 2023, a poverty rate of 37% and 84 million people living below the poverty line [19].

In recent years, Nigeria has seen the departure of large multinational corporations such as GlaxoSmithKline, Consumer Nigeria Plc, Sanofi, and Unilever, owing to high operational expenses caused by electricity shortages. In 2022, manufacturers in the country invested approximately ₦144 billion in alternative electricity sources. This significant expenditure has made it increasingly difficult for Nigeria to recruit and maintain the foreign investors needed for sustainable economic growth [7].

Green Energy Options for curbing Nigeria's Electricity deficit

Nigeria, located on the equator, is inside a highly sunny region with a reasonably regular distribution of solar energy. The yearly daily average of total solar radiation varies from 3.5 kWh/m²/day in coastal regions to 7.0 kWh/m²/day in the northern locations. An estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy is received across the country's 923,768 km² land area. Nigeria gets an average of 5.3 kWh/m²/day of solar radiation annually, resulting in an estimated 1,770 TWh of solar energy [21]. Solar energy is the most promising renewable energy source in Nigeria, with the potential to meet the entire country's energy needs. When analyzed attentively, Nigeria's yearly solar energy availability is around 27 times more than the total fossil fuel reserves and more than 100,000 times the current electricity generation [22].

Table 2: Solar radiation zones (global horizontal irradiation

Zones	kWh/m2	h/d	kWh/m/yr	States
Zone I	5.7-6.5	6.0	2186	Borno, Yobe, Jigawa, Kano, Kaduna, Bauchi, Gombe, Adamawa, Plateau and Katsina
Zone II	50-5.7.	5.5	2006	Sokoto, Zamfara, Kebbi, Niger, Abuja, Nasarawa, Taraba, Kwara, Some parts of Plateau and Katsina
Zone II	<5.0	5.0	1822	Oyo, Osun, Ekiti, Kogi and Benue

Source: *[21]*

Despite its enormous potential, solar energy remains underutilized in Nigeria's energy mix, despite the country's suitability for a wide range of solar applications, from small stand-alone systems to large-scale grid-connected projects. Table 2 depicts Nigeria's solar radiation zones, which indicates three separate solar radiation zones (Zones I, II, and III), each with differing radiation levels suitable for different project requirements. As indicated in the table zone I contain all of the states in the North-East geopolitical zone. This zone has strong solar radiation on horizontal surfaces, making it ideal for large-scale solar photovoltaic (PV) projects, particularly in semi-arid regions. Zone II, which encompasses the North-West and North-Central regions, has abundant solar radiation, making it suited for major solar installations. Zone III, covers the southern section of the country, including the coastal regions, which receive less yearly global sun radiation. However, Zone III is still appropriate for stand-alone PV systems. Furthermore, some sites in the South-West and South-East regions are ideal for localized solar energy projects [23].

Solar energy is converted into electricity using three basic methods: solar photovoltaic (PV), solar thermal, and concentrated solar power (CSP). These devices allow the conversion of solar energy into useful electricity. Solar photovoltaic technology is the most widely used in Nigeria and globally for electricity generation [10] . Photovoltaic (PV) technology has shown the greatest cost reduction among all energy technologies. Along with lower costs and higher performance, global PV deployment has expanded dramatically. Expanding PV adoption has the potential to significantly reduce greenhouse gas emissions and other pollutants from electricity systems [24] . Improving the efficiency of solar PV systems is an important technique for reducing the levelized cost of energy (LCOE). Although silicon-based PV technology now dominates the market, its efficiency is fundamentally limited at 29.4%. However, silicon-based tandem solar cells represent an innovation, with realistic efficiencies of over 33%, beyond the limitations of standard silicon technology [25].

Although there are currently no grid-connected solar projects in Nigeria, the usage of solar energy technology is increasing, particularly in low-energy applications including street lighting, water pumping, rural electrification, refrigeration, and powering communication stations. Solar power in Nigeria's electricity industry is expected to provide 1.26%, 6.92%, and 15.27% of the country's power consumption by 2015, 2020, and 2030, respectively. In the

long run, solar energy is predicted to account for up to 76.36% of total electricity consumption in the country [26] . To meet these projections, Nigeria's most developed strategies for expanding solar electricity generation include investing in solar farms, integrating solar power into the existing grid, and promoting solar home systems, especially in off-grid areas. These efforts aim to significantly increase solar energy utilization across the country [27].

Wind energy potential and speed in Nigeria varies from about 2 m/s along the coast to 4 m/s in the far north. Wind power generation is still relatively new in Nigeria, thanks to rapid technological improvements. Wind turbines, generators, and dynamos are examples of systems that can turn the energy in flowing air into mechanical energy. The Ministry of Science and Technology performed a wind mapping project, which found that Nigeria's wind energy potential is restricted and localized. Overall, the country is in a mediocre to moderate wind regime [28]. With an air density of 1.1 kg/m^3, wind energy intensity perpendicular to the wind direction in Nigeria ranges from 4.4 W/m^2 in the coastal areas to 35.2 W/m^2 in the far northern regions. Additionally, at a height of 10 meters, the country has an annual average wind speed, that increases from 3 m/s in the coastal areas to 7 m/s in the far North, where there is less vegetation [29]. Figure 2 is a map of Nigeria showing the average wind speeds of various states.

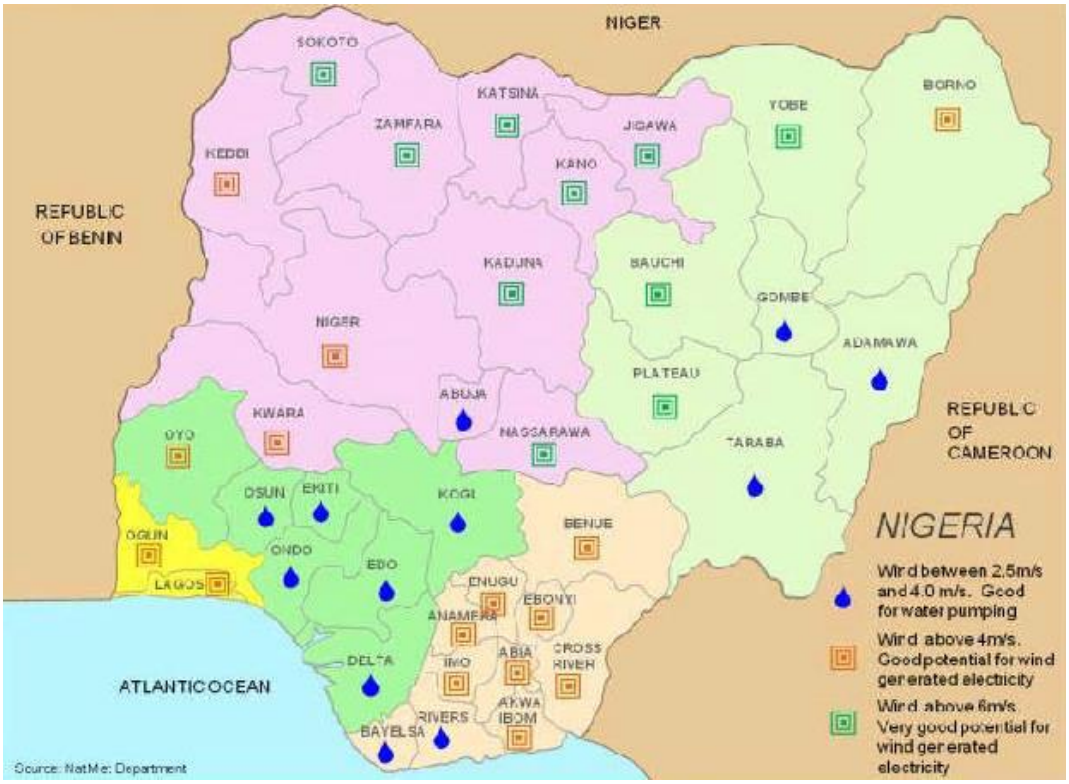

Figure 2: Average wind speed distribution map of Nigeria [30]

Out of Nigeria's total area of 125,728.6 km2, 2% is viewed as extremely suitable, 23% is very suitable, and 75% are suitable regions for the siting of wind farms, with Bauchi and Jigawa States taking the lead in potential [30].

Despite the potential for wind energy in Nigeria, wind power generation is still in its early phases, with no wind farms currently feeding into the national grid. Small-scale wind turbines are utilized for a variety of applications, including water pumping, battery charging, and small-business electrification. The sole large-scale onshore wind turbine in Nigeria is located in Rimi Local Government Area, Katsina State, and has a capacity of 10 MW [31]. Smaller systems include a 5 kW turbine in Sokoto (Sayyan Gidan Gada) and 1 kW turbines in Bauchi (Kedada) and Katsina (Goronyo) for pumping water. The country has yet to properly utilize its wind energy resources, which might greatly improve living conditions, particularly in rural areas. While Nigeria’s wind energy potential is less explored, regions with high wind speeds offer opportunities for wind power development. Major challenges include high initial costs and the need for infrastructure development [32]. To fully utilize the vast potentials and

generation capacities that may be harvested from wind energy, the government must make targeted investments, conduct feasibility studies, and collaborate with foreign partners to remove technological and financial constraints [33].

Hydroelectric power is Nigeria's earliest form of renewable energy technology. Key hydropower projects include the 760 MW Kainji Hydro Power Plant, commissioned in 1968, the 576.8 MW Jebba Hydro Power Plant, completed in 1985, and the 600 MW Shiroro Hydro Plant, launched in 1990, ongoing projects at Zungeru (700 MW) and Mambilla (3050 MW) [1] . The total technically exploitable large scale hydropower potential of the country is estimated at over 14,120 MW, capable of producing 50,832 GWh of electricity annually [22]. The small-scale hydropower potential is estimated at 734MW. Currently, hydropower generation is about 14% of the nation's hydropower potential and represents about 30% of the total installed grid-connected electricity [27] . Table 4 shows the Estimate of Current Exploitable Hydropower sites in Nigeria. A total of 277 sites with only the 32 shown in the table being utilized for large hydropower generation.

Table 4: Estimate of Current Exploitable Hydropower Sites in Nigeria

S/N	Location	River	Potential capacity (MW)
1	Donka	Niger	225
2	Zungeru II	Kaduna	450
3	Zunger II	Kaduna	500
4	Zurubu	Kaduna	20
5	Gwaram	Jamaare	30
6	Izom	Gurara	10
7	Gudi	Mada	40
8	Kafanchan	Kongum	5
9	Kufara I	Sanga	25
10	Kufara II	Sanga	15
11	Richa I	Mosari	35
12	Richa II	Datto	25
13	Mistakuku	Kurra	20
14	Korubu	Adamawa	35
15	Kiri	Adamawa	40
16	Yola	Adamawa	360
17	Karamti	Kam	115
18	Bali	Taraba	240
19	Garin Dali	Taraba	135
20	Sarkin Danko	Suntai	45
21	Gembu	Dongu	130
22	Kasimbila	Katsina Ala	30
23	Katsina Ala	Katsina Ala	260
24	Makurdi	Benue	1,060
25	Lokoja	Kogi	1,950
26	Onitsha	Onitsha	1,050
27	Ifon	Osse	30
28	Ikom	Cross River	730
29	Afokpo	Cross River	180
30	Atan	Cross River	180
31	Gurara	Gurara	300
32	Mambilla	Danga	3,960
Total			**12,220**

Source: [27]

Table 6 shows Small Hydro Potential in some States in Nigeria which have a total installed capacity of 56,610MW [34]. The huge small hydro potential in the country is yet to be utilized with only 1.7% been developed. From the table it can be seen that out of the eleven small hydropower sites exploited only four are completed and operational with the remainder still under construction [35].

Table 6: Existing Small Hydropower Stations in Nigeria

S/N	Location	State	Installed capacity (KW)	Current status
1	Kwall falls	Plateau	6,000	IIP (operational)
2	Kurra falls	Plateau	19,000	IIP (operational)
3	Bakalori	Sokoto	3,000	Dam construction completed. Electromechanical equipment not installed.
4	Tiga	Kano	6,000	Dam construction completed. Electromechanical equipment not installed.
5	Ikere gorge Iseyin	Oyo	6,000	Dam construction completed. Electromechanical equipment not installed.
6	Oyan	Ogun	9,000	Dam construction completed. Electromechanical equipment not installed.
7	Waya dam	Bauchi	150	Completed 2006 (technical assistance UNIDO)
8	Ezioha-mgbowo	Enugu	30	Completed 2006 (technical assistance UNIDO)
9	Challawa gorge	Kano	7,000	Dam construction completed. Electromechanical equipment not installed.
10	Gurara dam	Niger	30	IIP under construction
11	Tunga dam	Taraba	4,000	Under construction, electromechanical system on site(technical assistance from UNIDO)
Total			**56,610**	

Source: [35]

Despite its high initial cost, hydropower provides one of the most economical and cleanest sources of electricity. it can deliver to the developing countries around the world vital electricity especially Nigeria, along with additional services of water management and increased significant economic activities [35]. There is an urgent need to develop Hydropower Plants for the provision of electricity for the rural areas and remote settlements which will tackle the issue of power deficiency in the country.

Biomass energy or bio-energy refers to energy derived from the conversion of biomass into liquid or gaseous fuel. Biomass is the organic material produced by photosynthesis, a process that converts solar energy into stored chemical energy. Biomass sources generally

include wood, charcoal, animal dung, leaves, straw, agricultural residues, sawmill residues and dedicated crops [36] . Biomass fuels are overwhelmingly the most important energy source for rural households, agricultural production and rural industries. The biomass resources of the nation have been estimated to be about 8 to 102MJ [37]. When compared to wind and solar, biomass has just lately demonstrated a proven capability for renewable electricity. Given the rapid development of biomass collection technology, it has the potential to provide an increasing amount of biopower [7].

The conversion techniques to process biomass resources into useful biofuel for electricity generation, heat and transport fuel includes anaerobic digestion, Gasification conversion technology, Pyrolysis and Esterification process. Animal manure has a huge potential for bioenergy production in Nigeria. According to research, a single cow's daily waste can generate 1-2 kwh of power or 8-9 kwh of heat [36] . Table 5 shows the biomass energy potential in Nigeria. Biomass energy derived from agricultural and organic waste offers a sustainable alternative for rural areas. Biogas digesters and biomass gasifiers are two technologies that can help boost energy production. There are no biomass-fired power plants in Nigeria, except in Ebonyi State, where a five-megawatt biomass gas turbine facility is being developed in partnership with the United Nations Industrial Development Organization (UNIDO) at a cost of $15 million [26].

Table 7: Biomass Resources and the Estimated Quantities in Nigeria

Resources	Quantity (Million Tonnes)	Energy Value (000MJ)
Fuel	39.1	531.0
Agro-waste	11.244	147.7
Saw Dust	1.8	31.433
Municipal solid waste	4.075	-

Source: [38]

To promote the exploitation of biomass energy for power generation involves assistance for research and development, incentives for biomass projects, and integration into local energy networks. [39] . To meet its predicted electricity demand, renewable energy sources such as

bioenergy must account for 10% of total energy consumption in Nigeria by 2025. This involves a detailed evaluation of the system to discover and provide remedies [36].

Green Energy utilization as a strategy for addressing Nigeria's Electricity Deficit

The benefits of adopting green energy to boost Nigeria's electricity output cannot be emphasized. Green energy systems, particularly solar photovoltaic energy, hydropower systems, and wind energy systems, make a substantial contribution to overall electrical energy demand and are becoming popular. Utilization of these energy resources can help to address Nigeria's electricity deficit by decentralizing energy supply, notably through solar and small grid systems [40]. With over half of the country's population not linked to the national grid, decentralized solar PV systems and small-scale wind projects can power these off-grid areas. This is a more cost-effective, speedier, and sustainable alternative to grid expansion, which is usually delayed and costly due to infrastructural constraints in rural areas.

Green energy is a renewable, environmentally friendly, non-consumable energy source that does not harm the environment. The use of green energy technology in electricity generation can help to develop a sustainable system that is robust to climate change and resource depletion. Fossil fuel reserves are depleting at a rapid rate, and climate change affects hydropower generation plants, despite being renewable. Droughts as a result of climate change have caused climate-induced changes in water levels, compromising the performance of hydroelectric systems [41] .

Green Energy, Solar and wind energy, on the other hand, are less affected by climate variability. The relevance of solar energy in providing a consistent source of electricity during seasons when water levels drop, which frequently result in hydroelectric power outages is important. Green energy, therefore, provides a more resilient answer to the impacts of climate change on electricity generation [42].

A major challenge contributing to Nigeria's electricity deficit is the high level of transmission and distribution (T&D) losses, which stand at about 40%. This challenge can be addressed through green energy utilization for power generation by promoting distributed generation systems. Studies indicate that locally produced and consumed renewable energy reduces the distance electricity needs to travel from generation points to consumption points,

thereby minimizing T&D losses. A look at mini-grid and off-grid solar projects, electricity is generated close to the end-users, bypassing the inefficient transmission infrastructure and leading to more efficient and reliable energy delivery [6].

Because of the recent surge in fuel prices, green energy technologies that were previously considered inefficient have become quite cost-effective. Solar (PV) and wind energy technologies are becoming increasingly cost-effective. The economics of renewable energy in Nigeria reveals that the levelized cost of electricity (LCOE) from solar power is now competitive with, or lower than, the cost of electricity from gas-fired power plants. For example, the International Renewable Energy Agency (IRENA) notes that solar power projects have seen cost reductions globally, including in Nigeria, making it a viable option to generate affordable electricity. By integrating more renewables, Nigeria can produce electricity at lower costs, which could be passed on to consumers, thus making energy more accessible and affordable [43].

Green energy sources provide an alternative that can reduce the dependence on fossil fuels. Nigeria's electricity sector has relied on gas-fired power plants for electricity generation, which are vulnerable to disruptions from gas supply issues, vandalism, price fluctuations and outdated infrastructure. Nigeria due to its geographic location, can significantly reduce the country's reliance on gas for electricity generation. Renewable sources can stabilize electricity supply by diversifying the energy mix and reducing the risks associated with fossil fuel-based generation [44]. The integration of renewable energy into Nigeria's national grid can also help address the country's electricity deficit by increasing total generation capacity. The addition of large-scale solar farms, wind power plants, and small hydroelectric projects can boost overall capacity. For instance, the African Development Bank reports that the development of solar power projects in Nigeria, such as the Jigawa solar farm, has the potential to add hundreds of megawatts to the grid, thereby helping to close the gap between electricity supply and demand [43].

Challenges Militating the Utilization of Green Energy in Curbing Nigeria's Energy Deficit

Although Nigeria has enormous resources and tremendous potential for generating electricity to alleviate its power shortfall, the implementation of green energy confronts a number of hurdles. Some of the hurdles to utilizing this resource in Nigeria are:

High initial investment cost of establishing green energy infrastructure is a significant barrier to its utilization in Nigeria. The development of renewable energy systems such as solar farms, wind turbines, and hydropower plants requires substantial investment in technology and infrastructure. Although the long-term operational costs of green energy are relatively low, the initial capital outlay discourages widespread adoption for developing countries like Nigeria [43].

The absence of a solid and clear regulatory framework in Nigeria has slowed the advancement of green energy initiatives. Government policies have failed to encourage viable investment in renewable energy resources among potential investors. Even when such policies exist, they are poorly enforced, with insufficient incentives for independent power providers (IPPs) to engage in renewable energy, resulting in delayed private sector participation. Furthermore, the process of obtaining licenses and permits for renewable energy projects is usually hampered by bureaucratic delays [21].

The aging and inefficient electricity grid is not prepared to handle the integration of renewable energy sources. The current grid infrastructure is vulnerable to technical losses, with transmission and distribution (T&D) losses exceeding 40%, making it difficult to link large-scale renewable energy installations. [11]. This obstacle has prevented the country from reaping the benefits of renewable energy in electricity power generation. Projects to tap the country's green energy potential are expensive due to a shortage of competent people to develop, implement, and maintain them. As a result, Nigeria frequently relies on foreign professionals to construct and operate green energy projects, which causes delays in timelines [21].

Limited access to finance, lack of political will and governance, low level of public awareness about the benefits of renewable energy and environmental and climatic variability

are also some challenges facing the development of green energy in the country. These issues have contributed in slowing down the growth of the sector.

Conclusion

This paper explored the utilization of green energy as a solution to Nigeria's electricity deficit. It examined the country's current electricity landscape, emphasizing the severe power shortages that hinder national development. The implications of this electricity deficit on the economy were highlighted, including rising unemployment, significant financial losses for industries, and increased operational costs. The paper also discussed green energy options available to Nigeria, such as solar, wind, hydropower, and biomass, along with strategies for implementing these resources to offer sustainable and decentralized power solutions.

However, several challenges were identified that impede the full adoption of green energy in Nigeria, including high initial costs, inadequate infrastructure, and an inconsistent regulatory framework. To overcome these barriers, the paper recommended strengthening regulatory frameworks, improving access to financing, investing in infrastructure, and raising public awareness about the advantages of renewable energy. Ultimately, transitioning to green energy offers Nigeria a critical opportunity to reduce its electricity deficit, drive economic growth, and build a sustainable energy future. By addressing these challenges, the country can unlock the full potential of its renewable resources, paving the way for a more reliable and resilient energy sector.

Policy Recommendations

1. Research has shown that electricity supply channels have a positive relationship with economic growth in the short run and have a significant impact on economic growth in the long run. As a result, the government should implement sound energy policies to boost electricity production through the use of green energy systems, given the country's abundant energy resources.
2. Greater private and public investment should be promoted through solid policy to enhance output and supply in order to stimulate productivity and economic growth in the long run.
3. To attract investment government policies should provide financial incentives, tax breaks, and subsidies for green energy projects to reduce initial costs.
4. A thorough maintenance policy is required to realize the nation's goal of producing enough electricity to meet demand. This policy should incorporate a well-organized maintenance approach for the power infrastructure, which includes fostering the right

attitude toward maintenance, ensuring sufficient budget allocations, implementing a risk analysis system for plant equipment and components, adopting an appropriate maintenance strategy, establishing a spare parts inventory program, and utilizing tools like computerized maintenance management systems (CMMS) for data collection and analysis

5. Other policy initiatives to improve the efficiency and adoption of green energy technologies in the power sector include investment in infrastructure development and research, as well as public awareness and education about the benefits of this vast energy reserve in terms of national economic growth

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