



## Addressing Nigeria's Electricity Challenges: Past, Present, And Future Strategies

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### Abstract

*This paper provides a comprehensive analysis of Nigeria's on-going electricity challenges, examining the historical, current, and future aspects of the nation's power sector. It begins by reviewing the structural and policy decisions that have shaped Nigeria's electricity infrastructure, highlighting key issues such as limited investment, inadequate grid capacity, regulatory problems, and an over-reliance on traditional energy sources. These factors have led to a fragile power supply system characterized by frequent grid collapses, high transmission losses, power outages, and an evolving tariff structure that fails to fund necessary infrastructure improvements. The paper delves into the out-dated power infrastructure, inconsistent regulatory frameworks, and inadequate financing that hinder progress in the power sector. To address these challenges, it proposes several strategies and policy reforms. These include significant investments in modernizing infrastructure, regulatory changes to attract private investment, expanding renewable energy sources, and focusing on decentralized, regionally managed grids. Additionally, the paper emphasizes the importance of stakeholder engagement, arguing that active participation from all parties is essential for the success of these strategies. It underscores the need for coordinated efforts from the government, private sector, and international partners to achieve a sustainable and reliable electricity supply. By implementing these targeted strategies, Nigeria can develop a robust, equitable, and forward-looking electricity sector that promotes economic growth and development, ensuring that all stakeholders feel valued and integral to the solution.*

**Keywords** Nigeria's Electricity Challenges; Future Strategies; Inadequate Grid Capacity; Traditional Energy Sources

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## Introduction

The electricity supply in Nigeria has yet to meet the demand, as the country is flooded with poor electricity supply and blackouts. The urgency of this situation cannot be overstated. The inability of the power sector to meet the growing electricity demand has made it difficult for the citizens to realise their pledges for tangible development and improvement of the standard of living, stifling economic growth and hindering access to essential services such as healthcare, education, and clean water (Tambari et al., 2020). This incapacity could be better addressed through comprehensive infrastructure upgrades, enhanced maintenance schedules, diversification of energy sources, and robust policy reforms to attract private sector investment and ensure sustainable development. With about 180 million people, Nigeria is the most populous country in Africa. Unfortunately, most of the population works in the informal economy (agriculture), and most economic activities occur in cities and urban centres. This has dramatically pressured the country's power infrastructure (Babatunde et al., 2020). The present government assured the citizens of stable electricity, but a reliable and stable power supply remains a mirage (Bamisile et al., 2020). Electricity is the most visible and closely watched infrastructure (Chaban et al., April 21, 2021). This is because electricity not only energises the production, distribution, and consumption of goods and services, but it is vital to daily activities that determine the citizens' standard of living (Agbo et al., 2021). The primary role of electricity is to create conditions necessary for economic growth, a prelude to a better standard of living. The electricity supply in developing countries has declined over the years. The inability of these countries to improve their electricity supply is primarily due to several critical development challenges, including the availability of cheap and efficient energy sources, inadequate energy policies and regulatory frameworks, managerial incompetence, and insufficient research and development (2024), (2023). Additional factors include poor maintenance and infrastructure, financial constraints, inadequate investment, insufficient project planning and supervision, limited development capacity and commitment, corruption, and external conditions. Immediate action is needed to address these challenges and ensure a sustainable and reliable electricity supply for Nigeria.

## Historical Background

Unfortunately, Nigeria's electricity supply history has been bedevilled by a near-total collapse. First, it was the Nigerian Electricity Supply Company Limited (NESCO); then, the Electricity Corporation of Nigeria (ECN); and later, the National Electric Power Authority (NEPA). And now, the Power Holding Company of Nigeria (PHCN). The name may change, but the fact remains that each organisation's attempts at delivering uninterrupted power supply to Nigerians have been sinuous and unfulfilling (Chukwuma, 2020). Electricity constitutes an integral part of the nation's development drives. No meaningful development can be realised in an environment characterised by a total blackout. As the nation grows economically, it increasingly depends upon a regular and adequate electricity supply. Electricity usage over time exemplifies this interplay as households, firms, organisations, and government institutions all need electrical power for lighting and heating, not forgetting the demands for diverse electrical appliances (Nwani et al., 2020). Electric power supply fuels economic growth in solid mineral mining, manufacturing, and modern service industries, such as water, information and communication technology, and electric power utilities. This became more manifest as manufacturing production methodology includes an increasing share of process line operations that cannot be interrupted by power shortage (Musa, 2022; Oshodi et al., 2017).

## Current Electricity Situation

Reflecting on Nigeria's past achievements and challenges in the power sector is pivotal for addressing its current and future energy needs. Over fifty-five years ago, a significant milestone was achieved when electrical energy was transmitted between different geographical areas. This was accomplished in just 25 months in the early 1970s by a population of about 30 million people. In contrast, it took thirty-two years for a modern Nigeria, now with a population of approximately 150 million, to complete similar projects, showcasing the need for revisiting and refining the principles that drove earlier successes. As of July 2012, Nigeria's power supply capacity had reached 5,750MW, with a peak of 4,517MW and a maximum daily energy output of 89,000MWh. This performance represents a substantial improvement compared to the period between 1980 and 1985, when the maximum demand did not exceed 1,500MWh, with peak power at 1,052MW and an energy output of less than 60,000MWh every three days. Despite these advances, Nigeria faces significant challenges, including frequent power outages, ageing infrastructure, and demand far exceeds the available supply. These issues are exacerbated by a growing population

and increased industrial activity. The blend of current challenges and proactive future policies illustrates Nigeria's complex energy landscape. By addressing infrastructure needs, embracing renewable energy, and fostering a regulatory environment conducive to investment, Nigeria aims to build a more reliable, efficient, and sustainable energy sector. The success of these plans will significantly depend on practical implementation, governance, and the capacity to adapt to technological advances and evolving market dynamics.

Figure 1 illustrates the geographical distribution of Electricity Distribution Companies (DisCos) in Nigeria. Each DisCo is responsible for distributing electricity within specific regions or states:

- 1) Kaduna Electric Disco (KAEDC) covers the states of Kaduna, Sokoto, Kebbi, and Zamfara in Northwestern Nigeria.
- 2) Kano DisCo (KEDC) covers Kano, Jigawa, and Katsina States in Northern Nigeria.
- 3) Jos DisCo (JEDC) covers Plateau, Bauchi, Benue, and Gombe States in Central Nigeria.
- 4) Yola DisCo (YEDC) covers the states of Yola, Adamawa, Borno, Taraba, and Yobe in Northeastern Nigeria.
- 5) Abuja DisCo (AEDC) covers FCT, Niger, Kogi, and Nassarawa States in Central Nigeria.
- 6) Ibadan DisCo (IBEDC) covers Oyo, Ogun, Osun, Kwara, and parts of Ekiti States in Southwestern Nigeria.
- 7) Ikeja DisCo (IKEDC) covers Ikeja, Agege, Ikorodu, Apapa, Lekki, and parts of Lagos State in Southwestern Nigeria.
- 8) Eko DisCo (EKEDC) covers the Lagos, Apapa, Festac, Ijora, Lekki, Ajah, Victoria Island, and Ikoyi areas of Lagos State in Southwestern Nigeria.
- 9) Port Harcourt DisCo (PHEDC) covers southern Nigeria's Rivers, Cross River, Bayelsa, and Akwa Ibom States.
- 10) Benin DisCo (BEDC) covers the states of Edo, Delta, Ondo, and Ekiti in southern Nigeria.
- 11) Enugu DisCo (EEDC) covers the states of Enugu, Abia, Imo, Anambra, and Ebonyi in Southeastern Nigeria.



Figure 1: The geographical distribution of Nigeria's different Electricity Distribution Companies (DisCos).

### Analysis and Implications

**Geographical Coverage:** The distribution of DisCos ensures comprehensive coverage across all regions of Nigeria, each responsible for its designated area.

**Regional Distribution:** DisCos are aligned with Nigeria's geopolitical zones, ensuring no region is neglected. Each is strategically placed to manage electricity distribution effectively.

**Service Delivery:** DisCos' effectiveness in delivering electricity services depends on infrastructure, management efficiency, and regional challenges.

Challenges: Common issues include infrastructure deficits, maintenance problems, financial constraints, and equipment theft or vandalism. Addressing these is crucial for improving reliability and efficiency.

Opportunities for Improvement: Significant potential exists through investments in infrastructure, modern technologies, and effective management practices. Public-private partnerships and regulatory reforms can enhance DisCo's performance.

Figure 1 visualises the distribution of electricity companies across Nigeria, highlighting their regional coverage and importance in Addressing Nigeria's Electricity Challenges: Past, Present, and Future Strategies for ensuring electricity delivery nationwide.

### **Causes of the Electricity Problem**

Non-compatible climatic conditions: Tropical climates comprise rainforests, savannahs, steppes, and semi-deserts due to increased temperature and weather changes. Unfavourable weather can disrupt the power supply in Nigeria and hence cause hardship for the citizens and economic resources. In this vein, it is pertinent to note that almost every source of power supply in Nigeria is adversely affected by weather (Kayaga et al., 2021). For instance, the need for a canal in thermal electricity is readily absorbable by the bodies (described below) during droughts, and it causes inefficiency. In hydropower, the dam is depleted of its dam and hence dilutes generation (Obada et al., 2024). During winter, the solar panel generates less electricity, and most of the time, people will have other uses for electricity from the solar panel; hence, at night, usage will solely depend on diesel and gasoline. This situation is due to bad planning and implementation of policy (Olówósejéjé, 2020). Until temperatures are reduced, dams will continue to dry quickly, and the sun will be more intense due to the survival of the fittest (Olujobi et al., 2023). Poor Technical Skills: The country's level of know-how in power maintenance and generation is inferior and inadequate for the country's existing electrical machinery and installation. There has been poor training, which makes the staff workforce unable to deliver quality and reliable performance on its equipment. This causes constant breakdown of the colossal equipment, which is not thoroughly repaired, given that the equipment cannot effectively carry out the duties they were meant to (ONIMISI). In this chapter, let us look at the causes of electricity problems in Nigeria. There are various interrelated reasons or causes for Nigeria's inability to generate enough electricity for its citizenry. Some reasons are more prominent than others, but with many causes, it shows that brainpower appears influential. However, to the same extent, it shows that a multifaceted problem requires multifaceted solutions.

### **Nigeria's Transmission Network**

Historically, Nigeria's electricity transmission network faced significant challenges, including underdeveloped infrastructure, reliance on a few power plants, and frequent blackouts. The early network was inefficient, with substantial transmission losses due to outdated technology and poor maintenance. The country depended heavily on a few hydropower and thermal plants, which often failed to meet demand, leading to power outages. Recent efforts have focused on improving the transmission network's capacity and reliability through ongoing projects. The current and planned infrastructure includes existing and ongoing 330KV transmission line projects, crucial for network strengthening, and numerous substations, particularly in Lagos, Delta, and Benin, which are key for local electricity distribution. The map also highlights various existing and planned thermal, hydro, and solar power plants, essential for a reliable and sustainable electricity supply. Proposed transmission lines and substations indicate future expansion plans to serve underserved regions and integrate more renewable energy sources.

Looking ahead, Nigeria's strategy emphasizes sustainability, efficiency, and meeting increasing demand. Implementing smart grid technologies, such as advanced metering infrastructure, grid automation, and fault detection, will enhance efficiency and reliability. Integrating renewable energy sources like solar and hydro will reduce dependency on fossil fuels and promote sustainability. Planned projects aim to expand the grid to remote areas, ensuring reliable electricity access.

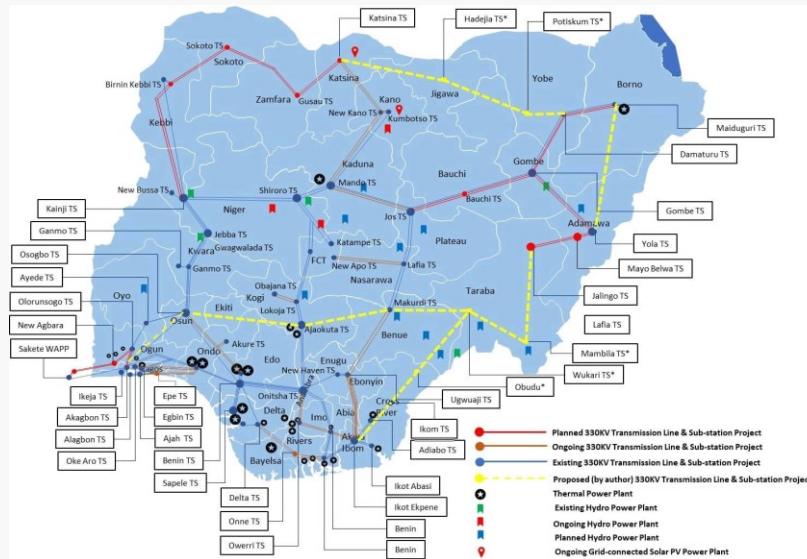


Figure 2: Current and Planned Infrastructure for Electricity Transmission in Nigeria

Upgrading existing infrastructure to handle higher capacities and reduce transmission losses is critical. Strengthening regulatory frameworks and attracting private investment are essential for growth and development. Public-Private Partnerships (PPPs) can provide the capital and expertise needed for large-scale projects. Investing in workforce training will ensure skilled personnel for maintaining and operating the infrastructure. Regular maintenance and proactive management will prevent outages and extend the infrastructure's lifespan. Addressing Nigeria's electricity challenges requires expanding transmission networks, integrating renewable energy, modernising the grid, and fostering a supportive policy environment. By implementing these strategies, Nigeria can achieve a reliable, efficient, and sustainable electricity supply, supporting economic growth and improving citizens' quality of life.

### Electricity Collapse in Nigeria Since 2020

The causes of electricity collapses in Nigeria are multifaceted, including infrastructure deficiencies, maintenance issues, fuel supply problems, technical challenges, and vandalism. The ageing national grid infrastructure is a significant factor, with many outdated components unable to handle current demand, leading to frequent breakdowns. Inadequate maintenance of power plants and transmission lines results in technical faults, causing grid collapses. Irregular gas supply to power plants disrupts generation, contributing to instability. Frequency imbalances and load rejection can lead to sudden outages, while vandalism and theft exacerbate the problem. The impacts are profound, including economic losses, disruption of business operations, and significant financial setbacks for industries. Residents' quality of life is severely affected, with power outages causing discomfort and inconveniences, particularly in urban areas. Healthcare facilities and educational institutions also face disruptions, affecting service delivery and learning. Businesses and households rely on alternative power sources like generators, increasing operational costs. To mitigate these issues, necessary measures include investing in modernising the national grid, implementing routine maintenance, promoting alternative energy sources like solar and wind, strengthening policies to encourage private sector investment, and raising public awareness about protecting power infrastructure. Comprehensive measures, including infrastructure upgrades, effective maintenance, diversification of energy sources, and robust policy reforms, are required to improve the stability and reliability of Nigeria's power supply, fostering economic growth and enhancing citizens' well-being.

Figure 3 illustrates Nigeria's electricity collapse from 2014 to 2024. The data shows significant variability in the frequency of collapses over this period.

- i. **2014-2015:** The collapses were relatively moderate, with 13 incidents yearly.
- ii. **2016-2017:** There was a sharp increase, peaking at 28 collapses in 2016 and slightly decreasing to 24 in 2017. This indicates a period of severe instability in the electricity grid.
- iii. **2018-2019:** The number of collapses decreased to 13 in 2018 and 10 in 2019, showing some improvement.

- iv. **2020-2024:** From 2020 onwards, the frequency of collapses significantly declined, stabilising at lower numbers. The numbers were 4 in 2020, 4 in 2021, 5 in 2022, 3 in 2023, and 5 in 2024.

Overall, the figure highlights a notable improvement in the stability of Nigeria's electricity grid from 2020 onwards compared to the high incidence of collapses observed in the mid-2010s.

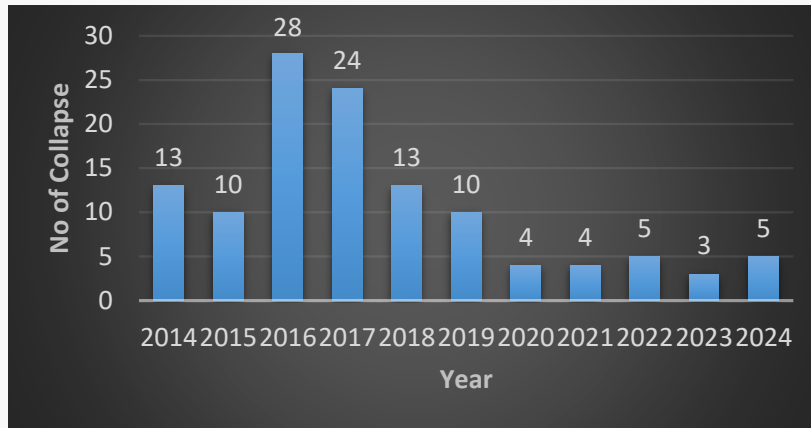


Figure 3: Electricity collapses in Nigeria since 2020

**A. Inadequate Metering**

A significant portion of electricity consumers were historically unmetered, leading to widespread estimated billing practices. These often resulted in inaccurate and unfair charges, causing frustration among consumers. The lack of precise metering hindered effective energy management and planning, contributing to overall inefficiency in the sector.

**B. Service Interruptions**

Frequent power outages and service interruptions were common, disrupting daily life and business operations. This unreliable power supply affected household activities and hampered industrial productivity and economic growth. Businesses had to invest in alternative power sources, such as generators, leading to increased operational costs.

**C. Billing Issues**

Billing inaccuracies and a lack of transparency further compounded consumer dissatisfaction. Many consumers received inflated bills due to estimated billing, while others struggled to understand the charges. This lack of clarity and consistency eroded trust between consumers and electricity providers.

Table 1: The Factsheet presents data on Metering and Customer Service performance for Distribution Companies in April 2024



Metering					Customer Complaints										
<b>13,410,795</b> Total registered customers					<b>23,724</b> ▼ 58.37% Customers metered in April					<b>97,959</b> ▲ 3.37% Complaints received					
<b>5,990,053</b> Total metered customers					<b>44.67%</b> ▼ 0.13% Metering rate					<b>53.40%</b> Metering		<b>10.44%</b> Service interruption		<b>9.47%</b> Billing	
State of metering in DisCos					Types of complaints received by DisCos										
DisCo	No. of registered customers ('000)	Customers metered in April 2024	Total no. of metered customers ('000)	Metering rate	DisCo	Metering	Interruption	Billing	Others	Total complaints received ('000)					
Aba Power	196.92	7,210	69.53	<b>35.31%</b>	Aba	931	36	126	237	<b>1.33</b> ▲ 2.62%					
Abuja	1,456.76	7,896	891.34	<b>61.19%</b>	Abuja	4,189	742	2	2,156	<b>7.09</b> ▼ 31.62%					
Benin	1,360.26	2,817	672.18	<b>49.42%</b>	Benin	63	260	393	1,711	<b>2.43</b> ▼ 27.01%					
Eko	767.96	665	437.23	<b>56.93%</b>	Eko	7,597	3,058	1,178	7,013	<b>18.85</b> ▲ 81.67%					
Enugu	1,396.44	1,325	631.93	<b>45.25%</b>	Enugu	5,132	906	900	921	<b>7.86</b> ▼ 33.71%					
Ibadan	2,479.01	807	1,067.91	<b>43.08%</b>	Ibadan	12,431	443	2,125	1,172	<b>16.17</b> ▼ 5.83%					
Ikeja	1,260.07	1,013	921.46	<b>73.13%</b>	Ikeja	3,502	675	767	1,399	<b>6.34</b> ▼ 20.36%					
Jos	744.16	599	248.71	<b>33.42%</b>	Jos	3,432	578	2,064	962	<b>7.04</b> ▲ 7.39%					
Kaduna	871.65	441	209.53	<b>24.04%</b>	Kaduna	680	1,011	107	223	<b>2.02</b> ▼ 8.18%					
Kano	880.82	274	211.81	<b>24.05%</b>	Kano	5,392	223	161	51	<b>5.83</b> ▲ 55.51%					
Port Harcourt	1,179.19	660	501.48	<b>42.53%</b>	Port Harcourt	8,528	2,115	1,448	10,197	<b>22.29</b> ▲ 17.48%					
Yola	817.55	17	126.94	<b>15.53%</b>	Yola	432	179	3	108	<b>0.72</b> ▼ 22.78%					
<b>Total</b>	<b>13,410.80</b>	<b>23,724</b>	<b>5,990.05</b>	<b>44.67%</b>	<b>Total</b>	<b>52,309</b>	<b>10,226</b>	<b>9,274</b>	<b>26,150</b>	<b>97.96</b> ▲ 3.37%					

#### D. Present State

The Nigerian Electricity Regulatory Commission (NERC) factsheet from April 2024 provides a snapshot of the electricity sector's current state, highlighting both progress and ongoing challenges from Table 1.

#### E. Metering

- i. Total Registered Customers: 13,410,795
- ii. Total Metered Customers: 5,990,053 (44.67% metering rate)
- iii. Customers Metered in April 2024: 23,724, a significant reduction of 58.37% from previous months, indicating a slowdown in new meter installations.

Despite efforts to improve metering, less than half of the registered customers are metered. DisCos like Abuja and Ikeja show relatively higher metering rates at 61.19% and 73.13%, respectively, while others like Yola and Kaduna lag significantly at 15.53% and 24.04%.

#### F. Customer Complaints

Total Complaints Received: 97,959, an increase of 3.37% from the previous month.

Types of Complaints:

- i. Metering: 52,309
- ii. Service Interruption: 10,226
- iii. Billing: 9,274
- iv. Others: 26,150

Metering issues constitute the majority of complaints, followed by service interruptions and billing issues. DisCos such as Eko and Port Harcourt reported the highest complaints, highlighting significant consumer dissatisfaction in these regions.

### **F.1. Metering Complaints**

The NERC factsheet underscores the critical issue of inadequate metering. Although there has been some progress, the metering rate remains insufficient at 44.67%. This deficiency perpetuates the reliance on estimated billing, exacerbating billing disputes and consumer dissatisfaction. With higher metering rates, DisCos like Abuja and Ikeja demonstrate that targeted efforts can yield positive results. However, the stark contrast in metering rates among different DisCos, such as Yola and Kaduna, highlights the need for a more comprehensive and uniform approach to metering nationwide.

### **F.2. Customer Complaints**

The increase in customer complaints, particularly regarding metering, service interruptions, and billing, reflects ongoing challenges in the sector. The high number of complaints about metering indicates persistent issues with inaccurate billing and the slow pace of meter installations. Service interruptions remain a significant concern, disrupting both residential and industrial activities. Billing issues, including inaccuracies and lack of transparency, continue to erode consumer trust and satisfaction. The regional disparities in the number of complaints, with Eko and Port Harcourt facing the highest levels, point to the need for targeted interventions to address specific regional challenges.

### **Government Initiatives**

The government's audit and privatisation of the power system and the delayed disengagement of NEPA staff led to a decline in system generation to as low as 177,200 GWh. By 2009, available gas could generate 6,026 GWh. Several policy decisions, particularly under former military President Ibrahim Badamosi Babangida, had been effective until the privatisation issues of 2015-2016. Since then, gas, coal, hydro, nuclear, solar, wind, and geothermal energy initiatives have diminished. The new government in 2015 attempted to re-privatize the already privatised sector. The generation performance under private management is significantly lower than that of previous government-managed initiatives, such as Obasanjo's power quintuplet plan. Historically, the National Electric Power Authority (NEPA) generated 5,971 GWh when load generation equilibrium was maintained with available gas, thanks to a sustainable fuel supply without highly compensated gas invoices. Sustained fuel supply contributed to high generation, optimising power supply to meet customer demands, with an estimated 75% market satisfaction. However, this high generation caused congestion in the 33kv/11kv transformers and significant loads on the 11kv feeders, resulting in overvoltage issues, as noted by NEPA in a 1995 publication. This led to maintaining stations close to their Mvar generation capacity, as non-banked 132kv/33kv transformers couldn't handle the generated voltage. NEPA managed the system to mitigate some of these overvoltage problems.

### **Challenges Faced**

In conclusion, Nigeria requires a significant transformation to improve its current energy situation. This includes making suitable investments, better-coordinating policies, eliminating political interference, and demonstrating total political will (Onumonu, 2022). Effective monitoring and surveillance schemes should be activated, with redoubled efforts to meet set objectives (Maisule et al., 2023). Implementing efficient, cleaner technology is crucial, especially for rural Nigeria, representing the future concern (Heaton, 2024). With abundant renewable energy sources such as solar, wind, and biomass, Nigeria can join the developing world in achieving full development using these resources (Onyeche, 2021). Historically, pre-colonial Nigeria relied on renewable energy sources such as traditional biomass and human or animal labour for heating, cooking, lighting, and small-scale industries. A 1962 United States Information Services (USIS) study highlighted that pre-colonial Nigeria had an adequate and economical energy supply for modern power utilisation. This historical perspective underscores the potential for reintegrating renewable energy into Nigeria's modern energy framework, guided by lessons from its energy-utilization heritage (Oyosoro).

***The power sector faces several challenges, including:***



a. Severe power shortages leading to frequent blackouts and operational constraints. b. Inadequate and unstable generation capacity resulting in inconsistent power availability. c. Power supply inadequacies characterised by insufficiency, intermittent interruptions, unreliability, and irregular delivery. d. High electricity tariffs burden consumers and hinder economic growth. e. A substantial shortfall in megawatt generation compared to the ever-increasing demand. f. Inefficient utilisation of the workforce, resulting in underperformance and productivity limitations. g. The scarcity of funds and lack of long-term capital investment opportunities impede the sector's growth and modernisation initiatives.

### **Impact on Economy**

How come the Federal Government of Nigeria in 2001 could neither supply nor distribute enough electric energy for domestic consumption use nor industrial productive use? Electricity supply and distribution in Nigeria is so enigmatic that Nigeria most times sells part of its current generated to some West African countries like Niger, Togo, and Benin Republic (Adeyemi-Kayode et al., 2021). On several occasions, the current generated is allowed to waste away in the process of producing hydroelectric power plants at Kainji, Jebba, and Shiroro when the organisation producing electric current generator feedback stored current inside the natural dams from where water used for generating the electric power initially is allowed to flow back into River Niger (Kirk-Greene, 2022). Receiving electric currents at home and in industries has become part of Nigeria's history. Nigeria gets a percentage of electric current produced daily at the Kainji, Jebba, Yellow Cap, and Shiroro hydroelectric power generation. Electric power is also generated at other gas turbine stations (Ibrahim et al., 2021). Furthermore, Nigeria is an oil-producing nation with seven major and minor oil companies. It has the easiness and availability of refined oil products to function as Nigeria generates electric power energy. Despite the abundance of resources, the inefficiency in the sector continues, exacerbated by inadequate infrastructure and policy misalignment (Ozoegwu & Akpan, 2021).

### **Environmental Concerns**

Privatisation of power-generating activities, on the other hand, is expected to control emissions and alleviate problems in the power sector's gas supply. One can see, however, some concrete clues in the leading-edge technology options chosen for the bulk purchase of impressive renewable energy supply solutions by high-profile companies and countries, like Sat-5 for the Internet to connect indigenous broadband technology clusters, World Neighbor for rural health, Sombo LG Solar 6MW wind farm; Katsina State for hot rock geothermal solution, Zungeru for 700MW controversial supercritical coal plant (Ndaaru, 2021). One of the significant dangers and a severe threat to public health comes from the improper disposal and burning of mercury lamps (Selim et al., 2021). Nigeria lags in energy conservation and the use of efficient low mercury discharge lighting systems that are now common in countries like Brazil and Mexico, even though all the reforms and government-endorsed UNDP projects on energy conservation for Nigeria identified the lighting subsector as the most promising for significant energy conservation, is due to the peculiar architecture of the Nigerian energy economy where the overriding public policy concern presently is the reform of the electricity industry from a disastrous non-polycentric government monopoly to a polycentric liberalised market structure (Viana et al., 2022). However, the proposed reform program of the Federal Government actualises managing scarcity by increasing investment with lower marginal cost (Keane et al., 2023).

### **Future Plans and Policies for the Power Sector**

In Nigeria, where the national energy strategy relies on the slow and steady deployment of baseload (usually, single-digit growth of electricity demand is the norm in Nigeria at present), Mega-grids are the norm and are considered to be a saviour for Small and Medium Scale Enterprises (SME) and the model for Future Rural Electrification policy, especially in the face of parlous funding from Nigeria Rural Electrification Fund (REF) or National Rural Electrification Strategy (NRES) (Nel, 2023). Supergrids, which are tenable to run across borders, are mainly considered for countries supplied with excess energy, typically from massive hydro projects and recent nuclear and solar projects over 10 to 15 Gigawatt capacity (Petrović, 2021). Only countries like Ghana, Gambia, and its developing neighbour, Nigeria, which have similar electricity pricing mechanisms, are considered appropriate for the Super-grid scheme (Reader, 2021). The Nigerian Electricity Regulatory Commission (NERC), as one of the agencies created by the Act, has been working carefully towards sustainable plans for future electricity development in Nigeria. According to the chairman of NERC, Dr Sam Amadi, several sound Electricity Market and Regulatory Governance frameworks, including the creation of a Future Electricity Options Plan (FEOP), Setting Distribution Control Interface, and Development of Super-grids have been proposed to solve emerging electricity challenges, (Anifowose et al., 2021). In addition, the

institute has come up with the innovative idea of setting up a Community Energy Scheme and bolstering Mega-grid Transformational Roles to encourage Independent Power Producers, as related to Figure 4, which are needed to complement the roles of existing gas power plants and the national grid (Tarekegne, 2021).

In response to these enduring challenges and in pursuit of enhanced service delivery and sustainability, Nigeria has outlined several strategic plans and policies:

- 1) **Expansion and Modernization of Infrastructure:** There is a significant focus on expanding and modernising the existing transmission and distribution infrastructure to accommodate higher capacities and reduce losses.
- 2) **Investment in Renewable Energy:** The government actively encourages investments in renewable energy sources, such as solar, wind, and hydroelectric power, to diversify the energy mix and decrease reliance on fossil fuels.
- 3) **Decentralization of the Grid:** Efforts are underway to decentralise the power grid, facilitating regional management and potentially improving efficiency through regional grids that can better meet local energy demands.
- 4) **Regulatory Reforms:** Reforms are being considered to attract more private sector investment and participation. These reforms aim to create a more favourable environment for investments and ensure that the regulatory framework supports innovation and efficiency.
- 5) **Public-Private Partnerships (PPPs):** The government plans to expand the energy sector to leverage private sector efficiencies and capital, which is expected to accelerate infrastructure development and bring technical expertise.
- 6) **Capacity Building:** The sector's focus on capacity building aims to enhance personnel's skills and capabilities to manage complex grid operations and integrate new technologies.
- 7) **Energy Efficiency Measures:** The strategic plan's key components include adopting energy efficiency measures and promoting consumer energy conservation. These measures are expected to alleviate some pressure on the grid by reducing overall energy consumption.

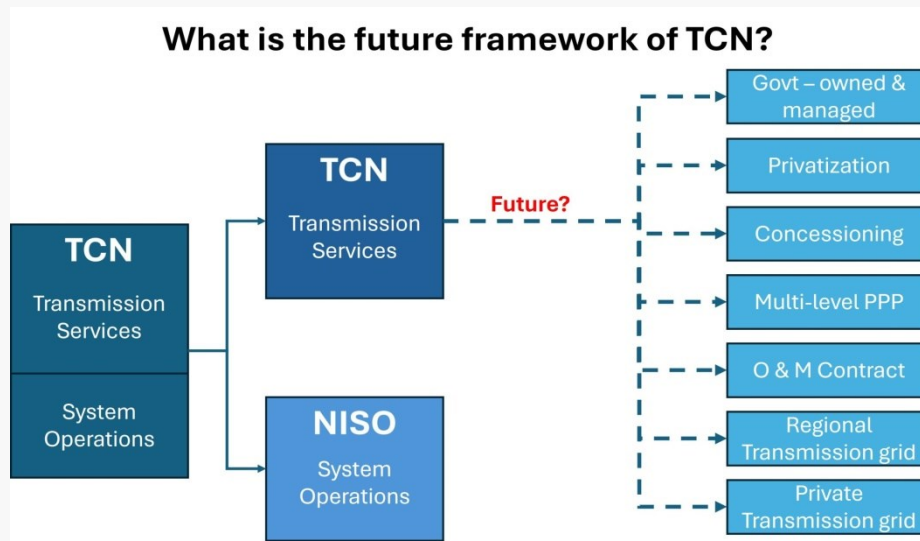


Figure 4: The strategic framework for the future.

### Renewable Energy Sources

Nigeria has enormous potential for renewable energy but low-capacity utilisation, as Tambari et al. (2020) outlined. Solar radiation, one of Nigeria's critical renewable sources, has significant potential yet remains underdeveloped. Solar energy can be harnessed through photovoltaics (PV), solar thermal systems, or wind energy converters. In

2009, solar energy contributed only about 0.6% of Nigeria's total renewable energy consumption, equating to 15.5 Mtoe (Amole et al., 2023). To increase the penetration of renewable energy, Bamisile et al. (2020) discussed the need to bridge the gap between technical prospects and economic reality, concluding that more policy frameworks and regulations are required for significant progress. The Nigerian energy sector is weighed down by depleting conventional sources, resulting in dwindling reserves and environmental pollution. Conversely, if further developed, renewable energy sources could meet significant portions of Nigeria's energy needs. This chapter identified various renewable energy types, including hydro, ocean, solar, wind, geothermal, bioenergy, and regional sources such as gravity and magnet. Somoye et al. (2022) emphasised the potential for Nigeria to diversify its energy generation mix and highlighted the need to bridge the gap between technical prospects and economic reality.

Figure 5 illustrates Nigeria's renewable energy potential and clean technology conversion process. It highlights sources such as tidal energy from coastal movements, hydro energy from rivers and dams, biomass from organic materials, solar energy from abundant irradiance, wind energy from favourable northern winds, and geothermal energy from specific locations. Clean conversion technology involves integrating natural gas and biomass for power generation, reducing greenhouse gas emissions compared to conventional fuels.

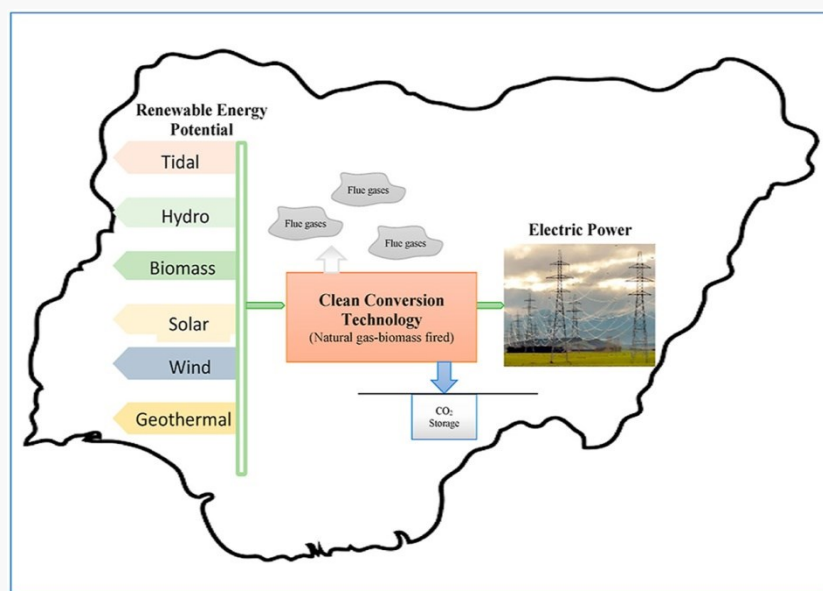


Figure 5: Nigeria's renewable energy potential

Renewable sources feed into this system and are converted into electricity through natural gas and biomass combustion, producing flue gases that must be managed. The output is electric power distributed through the national grid, with carbon dioxide (CO<sub>2</sub>) captured and stored to mitigate climate impact. These renewable sources can diversify Nigeria's energy mix, enhance security, reduce emissions, and promote economic development. Developing renewable infrastructure can create jobs, stimulate growth, and improve rural energy access. The figure conveys Nigeria's renewable energy potential and the role of clean conversion technology in transforming these resources into electric power, supporting a more reliable, efficient, and environmentally friendly energy sector.

### Foreign Investments

By the local content policy, China had to open and establish local manufacturing plants staffed by senior Chinese experts and their indigenous understudies, mainly for transformers such as under the brand of ABB (Asea et al.), but in reality, duplicated and foreign Chinese proprietaries (Abegunrin & Manyeruke, 2020). The weak and inadequate generation, transmission, and distribution of electricity, because, among other causes, of the economic bankruptcy of local generating, transmission, and distribution stations, leading to a lack of maintenance of necessary and vital components, including the Nigerian electricity water and gas pipelines for hydropower turbines and gas-fed generators, the electricity power sector continues to be recapitalised and rejuvenated using a massive import-dependent policy of electricity power plants, spares, and even technical administration and labour workforces and schemes (Akubo & Maduagwu, 2021). Considering the insufficiency and limitations of local generation and

transmission of electricity, resulting, among others, from inadequate financial capital base, lack of local manufacturing of equipment components, and absence of personnel training due to prolonged military rule, several countries, including China, have bought significant assets and interests in local electricity power generation, transmission, and distribution erection or renovations. Notable is the contract given to the Chinese contractors for the erection of the 10 National Integrated Power Project (NIPP) sites, some of which are idle 12 years after commissioning due to missing gas supply pipelines to feed the power turbines (Yuguda et al., 2023). The situation underscores a complex interplay of local challenges and international influences that define the electricity sector's current state in Nigeria (Afolabi & Oji, 2021).

### **Technological Advancements**

The main aim of this work is for one to use the circumstances experienced by Nigeria in her power sector to undertake necessary research projects that would lead to technological innovations and advancements, giving judges the required bold judgments (Nyanyoh & Wanie, 2024). It might not necessarily apply to the Nigerian judiciary; it is a sure refresher to make Plan C and also double-check some necessities to ensure the capabilities of the Nigerian judiciary ruling on Nigerian intellectual properties and related matters are substantially boosted and will eventually be sustainable (Yu et al., 2023). Everything is always flawed, and everything, including several advanced processes and product outcomes, does have a beginning and is never beyond periodic improvements. As such, we know with fair certainty that the next advancement in the electric power sector of Nigeria starts now (Rathod & Subramanian, 2022). There has been a need to upgrade the technological structure of Nigeria's electricity sector. However, the upgrades needed may be categorised again into three distinct sub-divisions – generational capacity development, transmission advancements, and distribution network enhancement. The emergence of privately owned power generating plants (PPGs) is a suitable catalyst which we hope using the Paris-type climate protection exhorts, and this shall fetch the increase in a substantial number of streams of fuel imports, e.g., kerosene for power generation so that the necessary amount of the available (maximum) power output is fully utilised for the benefit of Nigeria (Albuquerque & Guedes, 2021). A proper non-food type biofuel economic management plan and a project that could produce 25% of the extra bulk fuel products consumable by Nigeria by 2030 is recommended for establishment.

### **Role of the Private Sector**

Sustenance has always been an issue in power management in Nigeria. Power is mandated by law to be available to all, a feat that is yet respected or submitted to by all: consumers or the private sector, which are the expected entrants for operation. The private sector should see every citizen as a customer and tailor their investment to cater for their needs. However, they do not. If they do, they will not pretend to hold the power sources too close, produce without upgrading the transmission/distribution systems, and value the consumers, or drip poorer designs down to the final point of consumption, which usually affects the usage at the elongation points (Olajuyin & Eniola, 2022). Consumer participation should probably be planned to function via energy cooperatives; small consummative groups get overexcited about new openings and force collaborations. They asked that the private sector be involved. Initially, nobody came forward. Some fellas came but fell back after grilling the figures. As the power companies were handed over to the investors, more problems cropped up. Maintenance began to die a little. Maybe some investors never knew the extent of rot in the sector; services to substations and power plants were decimated, and some were dying (Olajuyin & Olubakinde, 2022). Just before, during the handover, the most significant mega power stations threw up issues that affected power transmission from source to faraway users. The knocked-off 330kv lines began to rattle the system (Adoghe et al., 2023). The government should have looked into those issues to enable a smooth operation of the systems. When the private sector sensed the situation's challenges, fresh investors receded. The Federal Ministry of Power then stepped in to push power transmission. The ERA IaTED, fighting a high overhead, already had to carry out more grid region-by-region exercises to address and realign these operational problems so that service to the users was sustained (DIMKPA et al., 2021; Komolafe & Udofia, 2020).

### **Public Awareness and Education**

We consider the importance of public awareness of the electricity problem in Nigeria, its importance in the sustainability of any solution to the problem, and suggest some measures that could be taken by researchers, policymakers, and institutions, especially by our universities and polytechnics to improve the level of public awareness and education in this area. The boundaries of the electricity problem in Nigeria are known, and we have identified a few actions that could be taken by individuals, policymakers, and institutions such as universities and polytechnics to bring success closer to society. Some of these measures require more research, some are purely in policy, and others are based on how our tertiary institutions could utilise their existing structures to improve public awareness and education (Lei et al., 2023). Research shows that success in achieving any goal through policy implementation in any society is significantly related to such a society's public awareness and education. For instance, research has shown that homes with economically literate parents have better-educated children or children who do well academically (Bonikowska & Frenette, 2020). With a sound knowledge base of economic fundamentals, especially starting from the formative years, people know better what actions to take towards future success (Purohit & Patel).

### **International Cooperation**

Nigeria is in her trying day in the area of electricity problems. From the look of things, the days of long waiting are gone. This would be appreciated by going into the identified plant with purpose. Such a plant is needed, and the time the plant can be produced is if planned processions and a predetermined amount are adhered strictly to without cheating (Agbo et al., 2021). If a plan is made for a specific output, that would be the output. If we do not want the day to end like those advertised on television long ago, we should remember the revolutionary slogan. If help had not been conducted in the past, we would have conducted the most advanced research, and the result was always an invention (Ugwoke et al., 2020). Similarly, if the plan cannot be written, we conclude there is no reason for the Nigerian power problem. The new Nigerian renovating technologies are finally in tropical countries. The Nigerian electricity problem is not a national problem alone but also a world problem because the world moves in every respect with energy. In this connection, one would have expected that international collaboration should have brought the needed uplift to electricity advancement in Nigeria. Only lately has some light begun to be appreciated from an international angle, but this is still at the government level where, before getting his share, a man must know somebody before the ordinary light switches on in the parlance of innovations (Komolafe & Udofia, 2020). International companies have contributed to the welfare of most African countries with the aid of kind and, in some cases, in cash payments for the rendered service. Any social organisation established should contribute to the workforce needs or any other area to the best of its capability, not minding the fear that our best hand should be to take over.

### **Conclusion**

The paper highlights on the current electricity challenges in Nigeria and propose future strategies to address these issues comprehensively. These challenges, which began in the past, persist today and will continue into the future until they are effectively resolved. It is crucial for those in charge, including policymakers, energy sector stakeholders, and government officials, to recognize and address this problem urgently. Nigeria's electricity industry plays a pivotal role in the nation's development, influencing economic growth, industrialization, and the overall quality of life. Therefore, a comprehensive national electricity and energy development blueprint should be considered and formulated. This blueprint will serve as a strategic framework for better planning, execution, and management of the power industry. It should outline clear goals, policies, and initiatives to enhance electricity generation, transmission, and distribution. Fraud and corrupt practices have significantly hindered the progress of the electricity sector. To ensure that budgeted projects are successfully completed, it is imperative to discourage such practices through stringent regulations and accountability measures. Transparent and ethical practices must be promoted to build trust and attract investments in the sector. Encouraging individuals to form cooperatives or join the Electricity Supply Association (ENSA) can provide additional capital for the industry. Cooperatives and associations can pool resources, facilitating larger investments in electricity infrastructure and projects.

This approach not only strengthens the financial capacity of the sector but also fosters community involvement and ownership. Furthermore, it can create employment opportunities, thereby reducing youth unemployment and contributing to social stability.



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