



A Critical Review on Electric Power Sector for Sustainable Energy Development in Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JENRR/2021/v9i130221

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Complete Peer review History: <https://www.sdiarticle4.com/review-history/72015>

Review Article

Received 17 July 2021
Accepted 27 September 2021
Published 19 October 2021

ABSTRACT

Electricity is one of the most important invention of Man. It powers the economy and everything in a Nation. This work seeks to carryout a critical review of Nigeria's energy crisis. A PricewaterhouseCoopers, PwC reports asserts that Nigeria still ranks 2nd worst in the global electricity access charts; a significant portion of electricity is generated from private generators at a higher cost of NGN 120/kWh while grid-based cost NGN 4-5/kWh; more than 50% Nigerians do not have access to electricity, however amongst the other 50% who have access, experience intermittent power supply; 5 - 6 times increase in electricity consumption required to match peer countries with similar GDP per capital; 25 % of potential energy reaches the end-user: Structural

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inefficiencies across the power value chain prevent electricity from reaching end-users. This work sets out to chronicle Nigeria's energy crisis: its challenges and prospects. Results from various reviews show that the major issue plaguing the nation's electricity sector isn't so much about resources, which the Nation has in abundance, albeit, some in potential state. From the reviews so far, the following are the major problems: 1. The National question 2. Lack of technical know-how 3. Sabotage of government's efforts and destruction of power sector physical assets. 4. Inconsistency in Policy formulation and implementation. The work therefore, proposes that for the long run, the nation tries to solve her national question; however, for the short run, the Federal Government should adopt the NLNG business model that has produced fantastic results for all its shareholders and stakeholders. The researchers therefore strongly advice the Federal Government to adopt the business model of the Nigeria Liquefied Natural Gas, NLNG Company.

Keywords: Electricity; power; energy resources; consumption; sustainable development.

1. INTRODUCTION

It has been reported that Nigeria's land mass is 923,768 km² with a total population of 177 million in the year 2014 according to the World Bank. Nigeria has abundance of conventional and non-conventional energy sources which includes, but not limited to, solar, wind, biomass, crude oil, coal, natural gas and bitumen [1]. Nigeria also has tidal and geothermal energy sources. Yet, the Nigeria's electricity sector is plagued with huge challenges that has defied years of countless input by successive governments. Irrespective of the efforts of successive governments to arrest the energy crises bedeviling Nigeria, little or no success has been achieved. In an attempt to resolve the energy crises, Nigeria's government broke its monopoly of the electricity sector by deregulating two of the three segments of its power sector - generation and distribution. However, the government's effort was to no avail as the challenges and power supply remains largely inadequate, unaffordable and unreliable in the country [2]. The Nigeria electricity sector generates, transmits, and distributes megawatts of electric power [3]. The generation companies (gencos) are presented in Table 1. The distribution companies (Discos) are presented in Table 2. While the transmission company of Nigeria is state owned.

2. REVIEW OF RELEVANT LITERATURES

Plagued by numerous problems, many researchers have studied the challenges and prospects bedeviling the nation's electricity sector. Olugbenga et al. [4] presented a review of the present challenges current and prospects of Nigeria's electricity sector privatization.

Ogagavwodia et al. [5] investigated Nigeria's power supply and national electricity development from 1980 – 2012. The focus of this work was to find out if the enormous expenditure that is made annually in the electricity sector has been translated into greater electricity generation. The study, which had three objectives, examines what impact the annual public spending in the electricity sector has on the supply of electricity. The econometric methodology is basically a model of co-integration and correction of parsimonious mistakes. The short-term results reveal that, although recurring spending has a positive impact on electricity generation, the opposite occurs between the latter and capital spending in the electricity sector. Megawatts of electricity generation, which is the variable of interest, were also found to exert a positive influence on real GDP and a negative impact on the industrial production index, all of which are statistically insignificant.

[6] suggested that the federal government alone cannot provide this level of funding. In fact, state governments, the private sector and foreign investors must participate. In addition, it is necessary to deploy all the country's energy resources to ensure that supply and demand coincide continuously. Ogbonna et al. [7] carried out a claims analysis on power generation capacity and economic growth in Nigeria. This study examined the impact of power generating capacity on economic growth in Nigeria from 1980 to 2015. In the specified model, Real Gross Domestic Product is a function of power generating capacity in kilowatts, the gross formation of capital and unemployment. With the help of the econometric techniques used (cointegration test, vector error correction mechanism and greater causality).

Ajenikoko et al. [8] carried out analysis of power sector performance, using Nigeria as a case study. This study analyzes the performance of Nigerian power sector so as to suggest possible means of ensuring improvements of the sector. Specification and estimation techniques were used for a period of eleven years. The result confirmed that deregulation of power sector has no effect on the efficiency of Nigerian power sector when the results were compared with the international best practice standards which are 30% and above for overall efficiency and 45% and above for thermal efficiency. (Barros et. al. [9] presented an analysis of the Nigerian energy sector. This study analyzes the change in productivity in the Nigerian energy sector between 2004 and 2008, applying the Malmquist index with the technological bias of the inputs. The results show that, on average, Nigeria's energy sector becomes more efficient and experiences technological improvements. Ogunleye, [10] provides a comprehensive evaluation of the reform, isolating the main challenges it faces and focusing on the developments of the political economy around regulatory, institutional, legislative and fiscal aspects, being the integration of clean renewable energies the main theme throughout the analysis.

Roche et al. [11] conducted an assessment of transition pathways to achieve sustainable development goals in Nigeria's energy sector. The aim of this study was to identify and critically examine the pathways available for Nigeria to meet its targets for access to electricity, renewable energy and decarbonization by 2030 in the energy sector. Using published data and stakeholder interviews, the authors constructed three potential scenarios for electrification and growth in demand, generation and transmission capacity. [12] carried out a detailed assessment of the legal framework of the energy sector reform and privatization program in Nigeria.

Olasunkanmi [13] studied, chronologically, the impacts of effective energy planning on sustainable development. On the basis of a proper review of data from government archives, magazines, conference or seminar documents, the research work analyzes the need for energy planning to implement sustainable development goals in Nigeria. This research paper initiated some policy endorsements that may be critical to aligning energy planning with government sustainable development strategies.

Rapu et al. [14] highlighted stylized facts about Nigeria's energy sector, including natural endowments in oil and gas reserves, with high potential for further economic growth, income generation and employment.

[15] studied the combined household-reported data on appliance ownership and energy expenditure with records of online sales of appliances to estimate current and future residential electricity demand in Nigeria, as well as the generation capacity required to achieve the 100% access to electricity, in various scenarios. Average residential electricity consumption was estimated at 18-27 kWh per capita, but these estimates vary between geographic areas, with the northeast and southwest representing extremes. In a universal access scenario, the future electricity supply system would be expected to have sufficient installed generation capacity to satisfy the estimated residential demand of 85 TWh. To better understand the infrastructure investment required as a whole and the approaches that might be preferred in rural versus urban areas, disaggregated, area-by-area and urban / rural data can provide more information than a country-wide approach. The data obtained is useful for identifying specific transitions at the subnational level that can minimize the investment required and maximize household energy access.

Oyedepo et al. [16] carried out a comprehensive review of the accessibility of clean and modern energy in Nigeria. Furthermore, this paper examines the potential of renewable energy (RE) resources in Nigeria that can be harnessed for continuous energy supply and government efforts to ensure the sustainability of RE. Nigeria is endowed with abundant energy resources, but the existing electrical power infrastructures are unable to meet the energy demands of a large population. There is an imbalance in the supply and demand of energy in the country. During the period from 2000 to 2014, there was an average of about 2.35 billion kWh of energy gap between energy production and energy consumption. The highest per capita electricity consumption recorded so far was 156 kWh in 2012.

Okonkwo and Nwosu [17] carried out an evaluation of the electricity sector reform in Nigeria. The work assessed the Obasanjo Administration's energy sector reforms to date with a view to highlighting the problems and prospects, challenges and shortcomings

associated with the reforms. The work also seeks to explore better ways to ensure the success of reforms by identifying certain key issues that need to be addressed by the government. The work uses the method of documentary analysis to classify the relevant information. The document concludes that the government should target the existing situations in the energy and electricity sectors respectively, as well as the national socio-economic and political order in general, instead of breaking with the existing situations.

Ajayi and Ajanku [18] and Emeteri [19] presented challenges and the way forward for electrification in Nigeria. The study states that a comprehensive analysis of the sector is necessary to understand the mechanics of the market and the reasons for current inefficient results, in order to allow stakeholders to identify an area of intervention.

Ukoha and Agbaeze, [20] conducted a review of Nigerian energy sector deregulation on performance. This work reviewed the literature on the impact of Nigerian energy sector deregulation on performance. As seen in this study, the impact of deregulation of Nigeria's electricity sector has been chilly to say the least. However, the increase in the number and size of generation, distribution and transmission companies and their consequent ability to improve power generation are not currently felt. It was observed that deregulation has the potential to increase the energy supply in Nigeria. (Aladejare, 2014) examined the energy, growth and economic development of the Nigerian electricity sector.

Usman et al. [1] presented the transformation of Nigeria's energy sector for sustainable development. This paper examines the country's energy sources and the electricity sector reforms adopted by the government. The study seeks to outline the current state of the Nigerian energy sector and analyze what opportunities this offers to the subsectors of grid-connected renewable energy, energy efficiency and rural off-grid electrification.

Iwuamadi and Dike, [21] carried out an empirical research analysis of the productivity of the Nigerian energy sector. This paper analyzes the change in productivity in the Nigerian energy sector between 1970 and 2010. The Malmquist index with the Cobb-Douglas Stochastic Production Frontier function was applied to

analyze the Nigerian energy generation data within the period in question. The results obtained showed that the 2005 National Electricity Reform Law produced a slight technical improvement. It is hoped that this work can help legislators and energy regulators to find a better framework for the full realization of the noble objectives set forth in this law.

Oniemola [22] asserts that there should be an affirmative law to support renewable energy and provide a framework to ensure that other laws do not constitute barriers to the deployment of renewable energy in the electricity sector. Oseni [23] presented an analysis of the Performance of the electricity sector in Nigeria Building on the above, the study analyzes the overall performance of the Nigerian electricity (electricity) sector and presents some policy guidelines to achieve a global standard energy market and sustainable development. The study found that the sector Nigerian electricity underperformers and there is an urgent need for a proper policy to achieve a quality and continuously functioning electricity market in the country. Usman and Abbasoglu [24] presented an overview of energy sector laws, policies and reforms in Nigeria. This work focused on the challenges of Nigeria's energy sector and the reforms proposed by the Government to address the challenges.

Oyedepo [25] carried out Performance evaluation and economic analysis of a gas turbine power plant in Nigeria. In this study, performance evaluation and economic analysis (in terms of power outage cost due to system downtime) of a gas turbine power plant in Nigeria have been carried out for the period 2001–2010.

Olakunle and Kehinde, [26] presented an overview of the Nigerian Power Sector to determine if the value investment is an opportunity or value trap? In view of this, their objective was to evaluate the investment case for the Nigerian power sector in light of developments in the operation of the new regime and core issues that have unfolded since the private investors took over. Kolawole et al. [27] presented reliability and power loss analysis, using case study of a power plant in Nigeria. In this study, an assessment of the reliability of a power generating plant was carried out to provide an opportunity to checkmate frequent fault occurrence and prolonged outages. Historical data were obtained from a generating plant in Nigeria. The generation loss

analysis indicated that gas restriction, grid constraints.

Dioha and Emodi, [21] presented research on the impacts of energy access scenarios on the Nigerian household sector by 2030. In this study, the authors applied the model of long-range alternative energy planning systems to analyze the impacts of different energy access scenarios for 2030. It was discovered that for domestic energy consumption, carbon IV oxide emissions plus air pollutant that by adopting energy resources which are sustainable in their exploration and production, would lead to a greener earth. While, if the proposed energy source is adopted, there would be significant reduction in local air pollutants, however carbon dioxide would increase. Their analysis shows that the benefits of access to modern energy have been limited in Nigeria due to poor funding and low household income levels. Papaefstratiou [28] presented a critical assessment of PHCN's privatization of the Nigerian energy market experiment. This document provided a brief overview and analysis of the Nigerian electricity sector, exploring the problems and challenges faced by private investors and possible solutions for reform. This article aims to briefly explore some of the underlying reasons why the privatization process did not achieve its stated objectives and to consider some of the areas in which changes can be made to resolve the stagnation affecting the sector.

Oyedepo et al. [16] analyzed the role of the decentralized renewable energy system in achieving sustainable electricity supply in Nigeria. In this study, a comprehensive review of clean and modern energy accessibility in Nigeria was carried out. Furthermore, this paper examines the potential of renewable energy (RE) resources in Nigeria that can be harnessed for continuous energy supply and government efforts to ensure the sustainability of RE. In order to improve access to clean energy supply and achieve sustainable development, this job pin points out the importance of decentralized renewable energy systems and the need for the government to review renewable energy development policies in the country. Tinuoye, [29] presented " Nigeria Power Sector Report: Is there light at the end of the tunnel? The question that the author tried to answer is why the sector has seen little progress. Osueke and Ezeh, [30] carried out an Assessment of the Nigerian Power Sub-Sector and Electricity Generation Projections.

Masanet et al. [31] carried out a Life Cycle Assessment of Electric Power Systems. Ortiz et al. [32] developed and carried out exergetic and environmental analyzes of electricity generation in the Dutch mix to determine the performance. The study also performs a comparative evaluation of various technological pathways, including the consumption of fossil and renewable energy resources, in terms of exergy costs and specific CO₂ emissions; it also established the main causes of the energy crisis facing Nigeria, even with the enormous potential energy sources that the nation has.

3. THE NIGERIAN ELECTRIC POWER SECTOR IN REVIEW

The Federal Ministry of Energy formulates and implements Policies of the Federal Government of Nigeria (FGN) for the development and efficient operation of the Nigerian Electricity Supply Industry (NESI). The Ministry monitors and supervises: Generation; Electricity Transmission and Distribution. This responsibility is enshrined in Item 13 of the Concurrent Legislative List of the 1999 Constitution of the Federal Republic of Nigeria, as amended. The Ministry is also guided by the provisions of: (a) The National Electric Power Policy (NEPP) of 2001 (b) The Electricity Sector Reform Law (EPSR) of 2005 (c) The Roadmap for the Reform of the Electricity Sector of August 2010 (d) Strategic Plan for the Implementation of Rural Electrification 2016 and Investment Guidelines, among others. The Ministry executes its mandate through six (6) bodies, namely: NERC, TCN, NEMSA, REA; NELMCO, NAPTIN, NBET [33].

The energy sector comprises three main sections (phases) namely: the generation, transmission and distribution sections. The total installed capacity of the generating plants is currently 7,914.4 MW Obadote [34]; Sambo et al. [35]. The generating companies (GENCOS) are Egbin Electricity Generating Company (EEGC) and those of Sapele, Ughelli, Afam, Shiroro and Kainji. There are also some New Independent Power Producers (IPP) under the auspices of the Niger-Delta Power Holding Company (NDPHC) Obadote [34]; Sambo et al. [35]. As of the end of 2017, there are currently 77 grid-connected generation plants in operation in the Nigerian Electricity Supply Industry (NESI) with a total installed capacity of 12,800 MW and an available capacity of 7,139.6 MW. Most of the generation is thermal based, with an installed capacity of 9,044 MW and an available capacity of 6,079.6

MW. Hydropower from three main plants represents 1,938.4 MW of total installed capacity and an available capacity of 1,060 MW (Adebayo, 2016; Latham and Watkins Africa Practice. 2016) [36,7]. Nigeria's 28 bus 330 kV transmission system consists of ten generating stations, twenty-three charging stations, and thirty-two transmission lines. The system is divided into three main regions: north, southeast and southwest regions. Northern Nigeria is connected to Southern Nigeria by triple-circuit lines between Jebba and Osogbo, while the west is connected to the east through a transmission line from Osogbo to Benin and a double-circuit line from Ikeja to Benin [37-38]. Benin - Ikeja West - Ayede - Osogbo and Benin is the only major loop system. The country's weak and unreliable electrical system has been attributed to the absence of loops Onohaebi and Apeh, [39]. These three phases - the generation,

transmission and distribution sections - collectively contribute to the production of the 220 voltages of alternating current (AC220V) required by electricity consumers in Nigeria. The national electricity grid currently consists of fourteen generating plants (3 hydroelectric and 11 thermal) with a total installed capacity of approximately 8039 MW in 2008 Oyedepo and Fagbenle [40]. Nigeria's Transmission system comprises 5000km of 330 kV lines, 6000 km of 132 kV lines, 23 330/132 kV substations, with a combined capacity of 6,000 MVA or 4,600 MVA with a utilization factor of 80%. In turn, the 91 132/33 kV substations have a combined capacity of 7,800 MVA or 5,800 MVA with a 75% utilization factor. The Distribution sector is made up of 23,753 km of 33 kV lines, 19,226 km of 11 kV lines, 679 of 33/11 kV substations. There are also 1,790 distribution transformers and 680 injection substations Abanihi et al. [41].

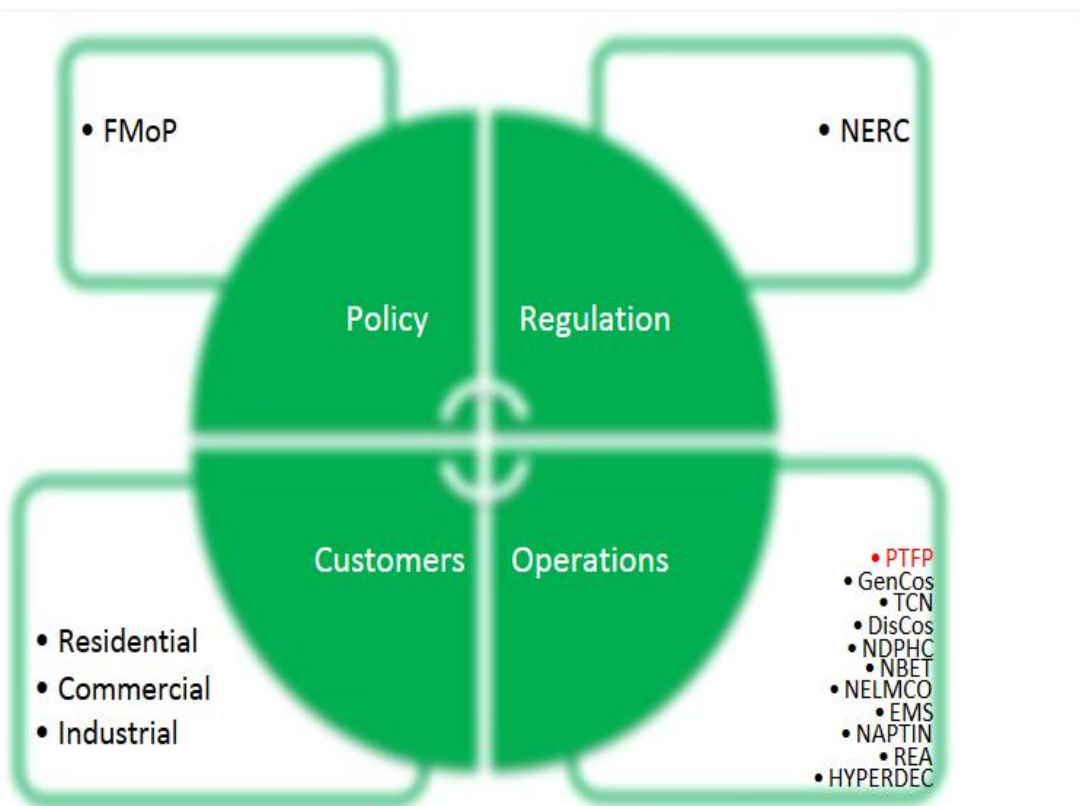


Fig. 1. Power sector structure [33]

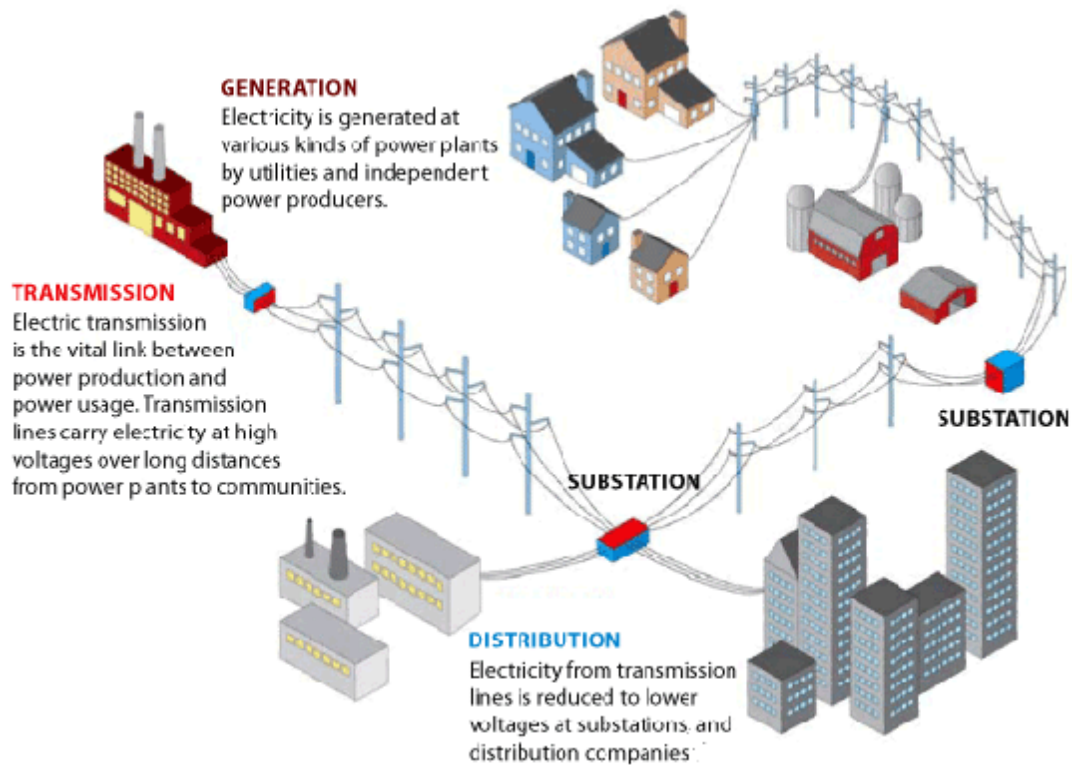


Fig. 2. Power supply chain [42]

In the electricity sector alone, Chief Obasanjo's administration spent \$ 16 billion approximately equivalent to # 3.52 billion, his successor Late Yar'Adua spent \$ 5.375 billion (# 1.183 billion), while the immediate former president, the administration of Goodluck Jonathan spent \$ 8.26 billion (# 1.817 billion). Simply put, the country, in the years under review, spent around \$ 29.635 billion amounting to # 6.52 trillion just in pursuit of a stable power supply. Leadership Newspaper [43]. The Buhari government has spent 1.7 billion naira in the energy sector [44].

Worthy of note is the Power sector restructuring in Nigeria started in March 2005 with enactment of the law of the Electric Power Sector Reform. The main effect of the reform is on the sector's organization: Corporatisation of the state-owned utility that changed from NEPA to Power Holding Company of Nigeria (PHCN): Unbundling PHCN with 18 descendant companies (10-Generation, 1- Transmission and 7 -Distribution) that are being privatized. The reform, however, has not proved to be attractive to private investors who still perceived the Nigerian electricity sector as significantly risky Abanihi and Ovabor [41] Since inception of NEPA, the authority has been expanding annually in order to meet the ever-increasing demand. Unfortunately, majority of

Nigerians have no access to electricity and the service to those provided with access is irregular and of poor quality Edomah et al. [45].

Technically, the operation of a thermal plant that generates electricity using combustion of fossil fuel is much more complicated as compared to a hydroelectric plant Valera-Medina et al. [46].

The regular and adequate supply of energy is the hallmark of a developed economy. the frequency and reliability of electricity supply has been tied to the growth an economy. Once again, it is an inevitable prerequisite for the development of any nation. Power Holding Company of Nigeria (PHCN) in 2005 was a successor of NEPA after deregulation of the electricity sector. Pursuant to the Power Sector Reform Act of 2005, the privatization of PHCN was finally established in 2013. After its privitisation, PHCN was split to a transmission company, TCN, 6 generation companies, Gen-Cos, and 11 distribution companies, DisCos. Currently, the transmission capacity of Nigeria's electricity transmission system consists of approximately 5,523.8 km of 330 KV lines and 6,801.49 km of 132. it is reported in national daily, that the government intends handling over the transmission company to a private company. The Nigerian Electricity

Supply Industry (NESI) has about 23 grid-connected generating plants in operation. Its total installed capacity is 10,396.0 MW and an available capacity of 6,056 MW. Most of the generation is thermal based, with an installed capacity of 8,457.6 MW (81% of the total) and an available capacity of 4,996 MW (83% of the total). Hydropower from three main plants represents 1,938.4 MW of total installed capacity (and an available capacity of 1,060 MW) Onochie et al. [47].

NERC's operations include service delivery, energy production, revenue accumulation, safety standards, and compliance with regulatory demands. Since independence, Nigeria has made several attempts to address lapses in the energy sector. Some of the recent attempts include the rehabilitation program started in 1999 to reform the existing electrical infrastructure. The National Integrated Power Project (NIPP) followed in 2004.

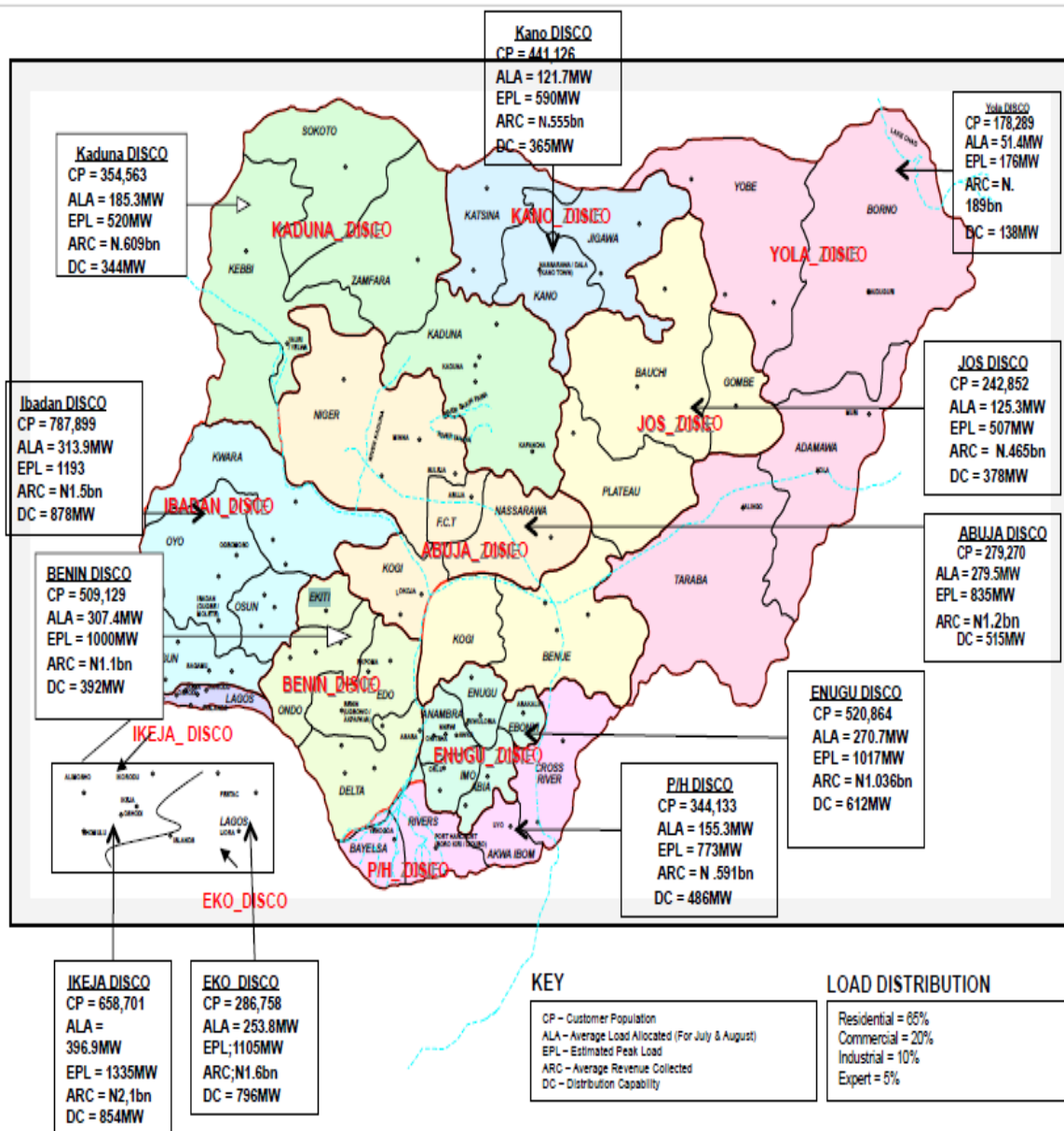


Fig. 3. Opportunities in distribution companies market statistics [48]



Source: Global Energy Network Institute

Fig. 4. National electricity transmission grid of Nigeria [49]

After the establishment of the NIPP, then the National Electric Power Policy (NEPP) of 2001, the NEPP would lead to the Electric Power Sector Reform Act (EPSRA) of 2005 and the Nigerian Electricity Regulatory Commission (NERC) World Bank Report [50].

3.1 The Transmission Company of Nigeria

The transmission company of Nigeria (TCN) manages the electricity transmission network in the country. It is one of the 18 companies that was unbundled from the defunct power holding of Nigeria (PHCN) in April 2004 and is a product of a merger of the transmission and system operations parts of PHCN. The TCN's licensed activities include: electricity transmission, system operation and electricity trading. It is responsible

for evacuating electricity generated by the electricity generating companies (GenCos) and wheeling it to distribution companies (DisCos). It provides the vital transmission infrastructure between the GenCos and the DisCos' Feeder sub-stations. The TCN consists of three operational departments: Transmission service provider (TSP), System operations (SO) and Market operations (MO) NERC [51].

3.2 Generation Companies

The federal government has fully divested its interest in the six generating companies while 60% of its shares in the 11 distribution companies has been sold to the private operators NERC [51] The generating companies are presented in Table 1.

Table 1. Generation companies

Generating company	Type of Fuel	Capacity	Source
Kainji Jebba Power Plc	Hydro powered	1330 MW	(NERC, 2019) [51]
Ughelli Power Plc	Gas powered	942 MW	(KPMG, 2016) [36]
Sapele Power Plc	Gas powered	1020 MW	(KPMG, 2016) [36]
Shiroro Power Plc	Hydro powered	600 MW	(KPMG, 2016) [36]
Afam power plc	Gas powered	987.2 MW	(KPMG, 2016) [36]
Niger Delta Power Holding	Gas powered	5455 MW	(KPMG, 2016) [36]
IPP	Gas powered	1392 MW	(KPMG, 2016) [36]
Egbin Power plc	Primary fuel: Gas powered; secondary fuel: oil	1320 MW	Egbin-power.com [51]

3.3 Distribution Companies

Table 2. Distribution companies

There are eleven distribution companies NERC, 2021 [51]

Distribution company	Districts covered
Kaduna electricity	Kaduna, Makera, Doka, Birmin kebbi, Gusau, Sokoto and Zaria
Yola distribution	Yola, Maiduguri, Taraba and Damaturu
Enugu electricity	Aba, Abakaliki, Abakpa, Ogui, Onitsha, Owerri, Nnewi, and Umuahia
Abuja electricity	FCT, Kogi, Nasarawa, Minna, Suleja, Lokoja, Lafia
Ibadan electricity	Abeokuta, Dugbe, Molete, Ijebu-Ode, Osogbo, Illorin, Sango-Ota and Oyo
Jos electricity	Jos, Makurdi, Bauchi and Gombe
Eko electricity	Festac, Ijora, Lagos Island, Ajah, and Badagry
Ikeja electricity	Ikeja, Shomolu, Akowonjo, Ikorodu, Oshodi and Abule-Egba
Port Harcourt electricity	Calabar, Diobu, Ikom/Ogoja, Borokiri, Uyo and Yenegoa
Benin electricity	Ado-ekiti, Afenonesan, Akure, Asaba, Akpakpava, Ugbowo and Warri
Kano electricity	Nasarawa, Dala, Katsina, Dutse, Kumbotso, Funtua and Dakata

4. METHODS

This work presents a comprehensive review of Nigeria's power sector. The sector's performance from 1886, when the then colonial administration installed two generating sets in the then colony of Lagos was analyzed based on [1]:

- i. Energy sources for electricity generation in Nigeria includes; both conventional and non-conventional energy sources.
- ii. Nigeria's electricity challenges, prospects and the nexus with Nigeria's economic growth.
- iii. Present and past government have made efforts as to electricity sector reforms to address the challenges bedeviling the sector
- iv. A critical review of government's policy formulation and implementation and its reforms.

This work began by conducting both conceptual and theoretical framework review of electric power sector for sustainable energy development in Nigeria; the study was drawn from peer reviewed journals and non-academic literature. Peer reviewed journals were used, as well as online publications from relevant government agencies with the objective of fashioning out the way forward; also, consulted were national dailies. Peer reviewed journals and national dailies were carried out using search engines.

After subsequent rigorous review, the authors, motivated by the NLNG business model and its success story in Nigeria's complex yet complicated business environment, it became clear that work deserved to be broadened to include the dynamism between Nigeria's energy crises and political [52]. Searches were conducted through academic libraries, Web of Science, Scopus, and popular search engines to

select academic peer-reviewed literature in English and published books related to these objectives [52].

The source review was carried out in four iterative steps. First, the set of sources was coded to identify definitions, findings and conclusions, and calls for research. Additional sources were added based on cited references within the initial collection, especially historically significant works [53], resulting in about 20 sources reviewed in total. Processing then involved repeated thematic classification of coded materials, identification of patterns and relationships, writing analytical memoranda, and observation of reflections (Miles et. al., 2014). Topics that emerged iteratively for the conceptual review on Nigeria's energy crises policy formulation and implementation, political interference and energy sustainability. Topics for theoretical development broadly included energy, renewable energy and political power, and tensions, gaps, and ambiguities. The breadth of the reviewed work and the thematic categories that emerged inspired the decision to approach the coded material through two distinct lines of inquiry to engage more deeply with emerging issues, namely the emerging concept of energy sustainability and its applications, and the relationships between energy systems and political power dynamics [52].

The third step consisted of organizing the classified materials within a conceptual scheme used to guide the initial writing of the review sections. Finally, once drafted, the analytical memoranda and reflections noted throughout this process were reviewed, categorized, and used to synthesize and critically evaluate reviews, confirm or modify themes and organization, and extract key implications and gaps for support theoretical development.

Finally, after a prognosis of the nation's power sector, recommendations were made. These recommendations are based partly on the review of the works researchers and partly on the successful policy formulation and implementation of such reforms by other nations Burke and Stephens, [52]

5. RESULTS AND DISCUSSION

5.1 Power Sector Challenges

- I. To say that Nigeria is facing an unprecedented crisis in its energy sector

is to state the obvious. In 2013, Nigeria initiated a comprehensive reform of the sector, in a privatization movement that was hailed as one of the boldest energy reform initiatives in the world, with earnings from divested assets estimated at US \$ 3 billion. The overall objectives of the reform were twofold: to address chronic efficiency gaps in old utilities, and to attract the private capital needed to boost the sector to meet Nigeria's growing demand for electricity. This is just one of many efforts by governments and their successors and predecessors to resolve Nigeria's energy crisis. A PwC report claims that Nigeria still ranks second in worst place on global electricity access charts; a significant part of the electricity is generated from private generators at a higher cost of NGN 120 / kWh, while the grid-based cost is NGN 4-5 / kWh; more than 50% of Nigerians do not have access to electricity, and those who do experience intermittent electricity supply; A 5- to 6-fold increase in electricity consumption is required to match peer countries with similar GDP per capita; 25% of potential energy reaches the end user: structural inefficiencies along the energy value chain prevent electricity from reaching end users.

- I. The electricity crisis in Nigeria is due to poor financing and low household income levels Dioha and Emodi, [21].
- II. The fee structure, Multi-Year Fee Order (MYTO II), which is not commercially sustainable as it currently is [54].
- III. Delay in the declaration of the Transitory Electricity Market (TEM) and due to the unexpected establishment, in December 2013, of an Interim Period of Rules for an indefinite time [55]
- IV. Inadequate generation of electricity [56].
- V. Breach of contractual terms [56].
- VI. Inability of non-compliant parties to be sanctioned by regulatory agencies when legal agreements are broken [56].
- VII. Nigeria's electricity sector has defiled all efforts of present and past government: outdated equipment, inadequate generation and transmission capacities, and high aggregate technical and commercial losses [1,16,57,58,59].

- VIII. Infrastructure restrictions throughout the value chain, from fuel to the energy distribution chain, including undiversified energy sources for electricity (80% thermal and 20% hydroelectric), insufficient gas pipelines, obsolete inadequate and poorly maintained generation plants and equipment, as well as transmission and distribution networks. All compounded by vandalism [2].
- IX. Insufficient end-user tariffs / prices: due to increased supply cost (associated with inflation, currency devaluation, unexpected infrastructure restrictions) that have not been accompanied by timely tariff adjustments [2].
- X. Inability to Reduce Aggregate Technical, Commercial and Collection Losses (ATC & C): The design of the electricity sector reform makes the viability of distribution companies (DisCos) critical for the long-term sustainability of the sector. Nevertheless, DisCos are unable to recover cash shortfall on account of the lack of investment in network rehabilitation and metering (partly due to low tariffs and inability to obtain loans from Nigerian banks due to unpaid debts) [2].
- XI. **Debts, Electricity Theft, and Non-payment Culture of the Public:** Especially government ministries, department and agencies who owe the industry an estimated \$72 million as at the end of 2016; contributing to the sector's cash shortfall [2].
- XII. These challenges stem from decades of neglect, mismanagement and inadequate funding [1,57,60] (PwC, 2021);
- XIII. The problems worsened as a result of massive increase in demand of electricity due to economic and population growth [1]. Access to clean modern energy services is an enormous challenge facing the African continent because energy is fundamental for socioeconomic development and poverty eradication. Yet, 60% to 70% of the Nigerian population does not have access to electricity; Babanyara et al. [61,58] yet,

still, a panel cointegration test shows a long-run equilibrium relationship and a bi-directional Granger causality between electricity and economic growth found that an increase in 1% in electricity consumption boosts the real GDP by 1.72% [62,63]. This relationship could as high as 3%, asserts some economic scholars.

5.2 Government's Efforts So Far

The Government employed various strategies including encouraging private sector participation, diversifying sources of power generation, and promoting energy efficiency for sustainable development. The Government has spent billions of dollars since 2003 on the construction of new power generation facilities, transmission lines and distribution centers to boost electricity supply, while at the same time beginning the process of selling existing facilities to private investors. . In addition, the Nigerian Energy Commission embarked on programs and strategies aimed at boosting power generation from renewable sources. On the other hand, the commission focuses on the need for energy efficiency both in demand and supply to reduce greenhouse gas emissions and the viability of energy systems. The renewable energy sector was boosted by the implementation of several renewable energy generation projects such as the Lekki biogas plant, the Katsina wind farm and the establishment of renewable energy research and development centers throughout the country [1].

5.3 Developments in Nigeria's Power Sector

Contrary to [21], the problem in Nigeria's energy sector is not a shortage of funds. ESI Africa reports that the Nigerian federal government will spend \$ 3 billion on the power sector in the next 24 months and will end current electricity subsidies by December 2021.

The goal is to increase the energy carried by the Nigerian transmission company (TCN) from the current 4,900 MW to at least 7,000 MW.

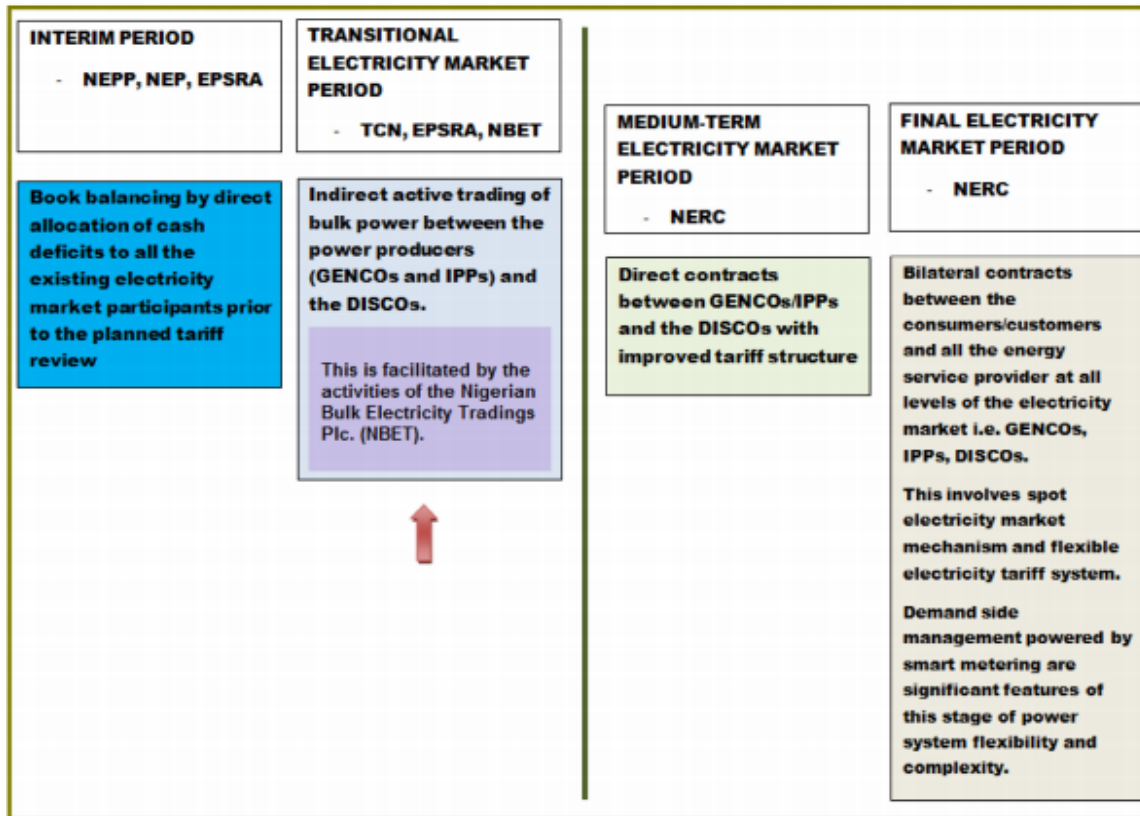


Fig. 5. Stages of Nigerian power sector reforms and the involved policies and sectors [60]

Table 3. Developments in Nigeria’s power sector

Year	Development	Source
1886	• Installation of two generating sets in the then colony of Lagos	(NERC, 2021) [51]
1951	• Act of Parliament established the Electric Corporation of Nigeria (ECN).	(NERC, 2021) [51]
1962	• The Niger Dam Authority (NDA) was established for the development of hydropower.	(NERC, 2021) [51]
1972	• A merger of NDA and ECN was carried out to give birth to national electric power authority (NEPA)	(NERC, 2021) [51]
2005	• The Electric Power Sector Reform Law was introduced • Regulator (NERC) established • Formation of Power Holding Company of Nigeria	(PwC, 2020) [61]
2006	• Breakdown of assets (transmission, distribution and generation) • ten National Integrated Power Projects (NIPP) were implemented • Nigerian Transmission Company Market Operations Department established • Rural Electrification Agency (REA) established	(PwC, 2020) [61]
2008	• Appointment of a body to supervise the progress of the unbundled generation and distribution companies • Multi-year tariff order was approved	(PwC, 2020) [61]
2010	• Introduction of National Energy Roadmap: Established Nigeria Bulk Electricity Trader (NBET)	(PwC, 2020) [61]
2012	Transmission Company of Nigeria enters into a management contract with a utility and asset management company • Signing of memorandums of understanding (MoU) on nuclear energy	(PwC, 2020) [61]

Year	Development	Source
2013	<ul style="list-style-type: none"> • Improvement of hydroelectric plants. US \$ 1.72bn disbursed for the construction of three stations) • MoUs signed for coal power associations 	(PwC, 2020) [61] NERC, 2021)
2014	<ul style="list-style-type: none"> • Strengthening of renewable energy programmes • Seven out of ten NIPP generation asset sales have been completed 	(PwC, 2020) [61]
2015	<ul style="list-style-type: none"> • Transitional power market was established 	(PwC, 2020) [61]
2016	In 2016, the NERC directed Discos to complete metering of all peak electricity customers on its network in November 2016 or earlier.	(PwC, 2020) [61]
2017	<ul style="list-style-type: none"> • The NERC issued the Eligible Clients Regulations in November 2017 • The Federal Government introduced the Power Sector Recovery Program (PSRP) in March 	(PwC, 2020) [61]
2018	<ul style="list-style-type: none"> • The Mini-Grid Regulations was adopted by the NERC • The Meter Asset Providers Regulation was approved by NERC • The World bank approved an estimated \$486 million to improve and upgrade electricity transmission's network of infrastructure and rehabilitate substations and lines in Nigeria. 	(PwC, 2020; Daily times, 2021) [61]
2019	<ul style="list-style-type: none"> • The World Bank has approved additional funding of US \$ 22.5 million for the Regional Off-Grid Electricity Access Project (ROGEAP or "the Project") in West and Central Africa. The additional fund, which comes in the form of grants from the International Development Association (IDA) and the Clean Technology Fund (CTF), will complement the US \$ 150 million and US \$ 67.2 million previously provided by IDA and the CTF, respectively, for the project in April 2019. 	(ESI-Africa, 2021). [64]
2020	<ul style="list-style-type: none"> • The Nigerian government spent N1.5 billion on the electricity sector in two years • The Federal Government of Nigeria (FGN) and Siemens AG signed a contract for the pre-engineering phase of the Presidential Power Initiative (PPI). The FGN approved the payment in May 2020 and established a special purpose vehicle, FGN Power Company, to work with Siemens to implement the initiative. This pre-engineering phase will include engineering design, finalization of project specifications, and commissioning work for transmission and distribution systems, network development studies, power simulation, and local capacity training. • The French Development Agency (AFD) has allocated 300 million euros to finance the Abuja Electric Backup Project, in collaboration with TCN. • In addition, an additional € 200 million has been earmarked to support North West Electricity to strengthen the electricity transmission network. The projects will improve electricity supply to the country's capital and surrounding regions. 	(KPMG, 2020) [36]
2021	<ul style="list-style-type: none"> • The Ashama 200 megawatts/ HR solar photovoltaic (PV) farm – the largest solar PV farm project in West Africa¹. The project, which is a public-private partnership arrangement will be led by a consortium of a Nigerian investment company, Sunnifred Global, and a Singaporean renewable energy company, B&S Power Holding PTE. It has an expected fifteen months completion timeline and will occupy 304 hectares of land in Ashama village, Delta State. The Ashama project is expected to provide access to electricity to approximately 36% of the state's rural population, while reducing the impact of carbon emissions in the immediate environment. 	(KPMG, 2021; NERC, 2021) [36,61]
	<ul style="list-style-type: none"> • Other noteworthy investments include the new 100 kilowatt Adebayo2 and Havenhill3 solar hybrid grid in Adebayo, Edo State and Budo, Oyo 	

Year	Development	Source
	State, respectively, under the Nigerian Electrification Project (NEP). • Structured replacement of faulty / obsolete meters from end-use customers	
2021	• The Nigerian federal government will spend \$ 3 billion on the electricity sector in the next 24 months and will end current electricity subsidies by December 2021. The goal is to increase the power being wheeled by the transmission company of Nigeria (TCN) from the current 4,900 MW to at least 7,000 MW.	(ESI-Africa, 2021) [64]
2021	• \$500 million loans secured by the federal government from world bank to boost the power sector • The federal government is also expecting another loan facility from the African Development Bank (AfDB). • The central bank of Nigeria announced the disbursement of N120.2 Bn to different electricity distribution companies (DisCos), power generating companies, in order to address the liquidity and funding challenges facing the sector. • The World bank has announced it is in talks with the Nigerian government for a \$2.5 billion loan to solve the problems of the country's power sector	(Premium Times, 2021) [65]

6. RECOMMENDATIONS AND CONCLUSION

The economic, social and solidarity implications of energy poverty are becoming massive, especially in regions where the income level is low and the average cost of modern energy technology is relatively high, such as sub-Saharan Africa [66].

Nigeria is endowed with abundant energy resources, but the existing electrical power infrastructures are unable to meet the energy demands of a large population. During the period from 2000 to 2014, there was an average of about 2.35 billion kWh of energy gap between energy production and energy consumption. The highest per capita electricity consumption recorded so far was 156 kWh in 2012. This makes Nigeria one of the countries with the lowest per capita electricity consumption in the world [16].

This subsection seeks to provide recommendations for solving the Nigerian energy sector crisis, even with the enormous resources provided by successive governments. This paper estimates that the Nigerian government has spent around a whopping \$ 7 trillion. These recommendations are based on expert opinions, research results from your trade journals, and industry experts.

6.1 Solutions

- I. In order to improve access to clean energy supply and achieve sustainable

development, this work pin points the significance of decentralized renewable energy systems and needs for the government review the renewable energy development policies in the country [58]

- II. For a 100% modern energy access in Nigeria by 2030, there is a need to explore local and foreign funding sources, and a serious need to couple energy access programs in the country with income-generating activities [21]
- III. Laws and policies aimed at addressing the various energy generation, transmission and distribution challenges bedeviling the energy sector are supposed to be formulated and implanted.
- IV. embracing embedded generation as a potential option to improving power supply in Nigeria Oladipo et. al., [55].
- V. adopt integrated generation as a potential option to improve energy supply in Nigeria Oladipo et al. [67]
- VI. Adoption of smart grid Amuta et. al., [68]. Granting of power stations to already granted license by NERC becomes fully operational, power generation and distribution in Nigeria will improve NERC, 2021 [51].
- VII. The significance of decentralized renewable energy systems and needs for the government to review the policies on renewable energy development in the country Oyedepo et al. [16].

- VIII. Structure reforms aimed at putting in place so as to enable the power sector fund itself sustainably
- IX. While the authors agree to all these recommendations from peer reviewed literatures as well as from the present study carried out, the best options for the solution to the electricity problem which has resulted to an energy crises, is the institutionalizing of the NLNG business model in the power sector. The researchers are of the believe that the major problem plaguing Nigeria's power sector isn't so much different from what plagues Ukoha the Nation. It is the suggestion that the nation strife to solve its internal contradiction or adopt the Nigeria Liquified natural gas company model – a partnership between Federal Government and international oil companies and others, where the federal government owns 49 % of the equity and the former owns the remaining equity. This model remains one of the most successful in Nigeria.
- X. Proper implementation of Bulky Power Purchase as highlighted in Electric Power Sector Reforms Act no 6 section 68 of 2005 NERC, 2021 [69]
- XI. Honesty in tackling corruption [4,1]
- XII. Government investment at any level in the electricity market should not be based on politics or quota system but strictly on integrity, competence and professionalism [4].
- XIII. Encourage foreign participation based on experience, financial capacity and performance [4,16].
- XIV. Reduce the number of thermal generating plants locations and increase their generating capacity to avoid the complexity of gas pipeline network.
- XV. Reduce risk of vandal and achieve cost savings.
- XVI. Efficient natural gas reclamation (Otene et al. [70]).
- XVII. Again, this work proposes that for the long run, the nation tries to solve her national question; however, for the short run, the Federal Government should adopt the NLNG business model that has produced fantastic results for all its shareholders and stakeholders. The researchers therefore strongly advice the Federal Government to adopt the business model of the Nigeria Liquified Natural Gas, NLNG Company.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
<https://www.sdiarticle4.com/review-history/72015>