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Historical Drivers of Energy Infrastructure Change in Nigeria (1800–2015)

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Additional information is available at the end of the chapter

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Abstract

This chapter, building on a previously published paper, presents the key historical drivers of energy infrastructure change in Nigeria. The study revealed five main drivers that impacted on the Nigerian energy transitions which are: (a) Policy and institutional interventions on energy; (b) Technological interventions and energy technology pathways; (c) Social (societal) practices and public values for energy; (d) Available energy resource options; and (e) Economic considerations. Based on these drivers, four important influences that impacted on energy systems choices and the kind of energy infrastructure Nigeria ended up with were also discussed. These influences are: (a) Politics and energy governance structures; (b) Technological changes; (c) Energy resources (and the quantity of available reserves); (d) The geographies of energy. It concludes by highlighting some of the implications of these influences on the future of energy in Nigeria.

Keywords: energy transitions, energy future, energy sector, energy governance, electricity regulation

1. Introduction

Energy transitions entail a shift, or movement, in decreasing the use of fossil fuel in our energy supply systems [1]. Across the world, fossil fuels, such as coal, crude oil and natural gas, accounts for a large percentage of our energy supplies. There has been growing interest in energy transitions because beyond the fact that most fossil fuel resources are reserve based, which means that are limited, the major driver of energy transitions is the threat posed by burning the available large quantities of fossil fuels and their corresponding impact on the environment [2]. To generate this transition, the role of policy cannot be overemphasized. The

clean energy transition is somewhat unique because it has to be driven by policy. Markets cannot provide the platform to reduce greenhouse gas emissions, since markets naturally tend towards more consumption of fossil fuels. As such, it is important to understand the role of policy, policy levers and policy decisions, in effecting energy transitions [3].

In developing economies, energy supply shortages, poor or non-existent infrastructure and subsidized end-user prices are some key direct challenges which tend to slow-down the implementation of structural changes in energy systems. In industrialized countries, the main challenges are: rapid speed of change and imbalance in the development path of energy systems [4]. Understanding how policy decisions are taken, how current policies are interpreted and how energy infrastructure is shaped, is dependent on the understanding of the actors and stakeholders, their socio-psychological biases, the internal workings of the institutions within which they act, and their organization's wider interests. On this basis, the broader drivers, influences and consequences of the policy decision process and energy governance need to be considered.

According to the International Energy Agency (IEA), to facilitate energy transition, there is need for concerted, early and consistent policy action [5]. The IEA argues that well designed policies that aid decarbonisation through cutting down on household energy expenses related to fossil fuel and improving air quality can aid the transition to a low carbon economy. The International Renewable Energy Agency (IRENA) further argues that transiting to a low carbon economy will require a drastic deployment of renewable energy solutions and energy efficiency measures [5–7].

This paper serves as an extension of a previously published work titled “*Energy transitions in Nigeria: The evolution of energy infrastructure provisions (1800–2015)*”. In that work, the Nigerian energy transition was presented with emphasis on the key practices, interventions and events that led to changes in energy infrastructure supply and use within each energy era [8]. The Nigerian energy transitions, covering a period of 1800–2015 were divided into five major energy eras which are:

- *Pre-industrial (agricultural) era*—up to mid-1800s.
- *Early industrial (advanced metallurgy) era*—late 1800s.
- *Industrial (steam engines) era*—early to mid-1900s.
- *Late industrial (dynamo, internal combustion engines) era*—mid to late 1900s.
- *Information (microprocessor) era*—early 2000s onwards.

The previous work emphasized the connection between event, practices and changes in energy supply infrastructure without much attention to the drivers and how they influenced the transition in energy use. This paper looks at the key drivers within each energy era and how they influenced the Nigerian energy transitions.

In this chapter, some methodological considerations used in this research are presented in Section 2. In Section 3, the drivers and influences of Nigeria's energy supply infrastructure changes are presented. Section 4 discusses these influences further and what they mean for the future of energy in Nigeria. The concluding thoughts are presented in Section 5.

2. Materials and methods

Data from documentary archives and other published sources that links to the Nigerian historical energy infrastructure provisions were used for analysis in order to have a better understanding of the Nigerian energy (infrastructure) history. Diaries, letters, memos and policy documents from the archives of the Nigerian Railway Corporation were used and analyses.

The detailed account of the history of the Nigerian Railways by Francis Jackel (1997) covered in three volumes was also useful sources of data.

It is noteworthy that in many existing transition studies, one can easily notice the extensive use of quantitative (and qualitative) data from published literatures, and particularly archives of some agencies, used in collecting data and making meaningful analyses which serves as pointers, suggesting various constitutive elements of the energy history under study.

2.1. Why choose these documents?

These set of documents were selected for analyses for the following reasons:

1. The Nigerian Railway Corporation is the oldest institution in Nigeria which has existed since colonial times (in late 1800s). They hold some of Nigeria's oldest archives.
2. The archives of the Nigerian Railway Corporation (NRC) contain records of associated events that led to decisions on the provision of several rail infrastructure. Some of these documents contained the reasoning (and contexts) behind those decisions and the future benefits the government aimed at achieving. An example is the case of providing rail infrastructure linking Kano to Lagos to aid the easy movement of agricultural produce from the hinterland (in the north of Nigeria) to the ports (in the south of Nigeria) for export [9]. Some, trade and policy contexts on infrastructure decisions taken.

2.2. How were the documentary/archival records analysed?

Documentary and archival records were analysed and used to prepare a historical narrative on the various factors that influenced the evolution of energy infrastructure provisions in Nigeria [8]. The following steps were followed in analysing archival documents/records [10, 11].

1. *Meeting the documents*: this process involves checking to ascertain if there are any special markings or figures on the documents which could tell us something in connection with the subject under study.
2. *Observing the parts*: this entails finding out who wrote the documents and for what purpose. When was the record produced? Are those dates useful in analysing times of energy transition and how society develops over time?
3. *Trying to make sense of the documents*: this stage entails trying to obtain the main ideas of the documents. Why was the document written? Are there useful aspects that support my research and can be used as evidence?

4. *Use the documents as historical evidence*: this stage helps in asking questions that can help provide answers to validate the use of those documents as evidence. For example, where can I find more information about a particular event referenced in the document? Where can I find more information about the person who wrote the document? Are there empirical evidences that are aftermaths of the things observed in the documents?

3. Energy supply infrastructure changes in Nigeria: drivers and influences

A panoramic view of the energy eras and the different features that characterized the Nigerian energy transitions within each energy era is presented in **Figure 1**. The study and analysis of these eras were centred on four important characteristic features that served as points of departure for understanding the influences that have impacted on changes in energy infrastructure supply and use in Nigeria. These central features are:

1. *Energy (re)sources* used in satisfying demand for energy.
2. *Technological interventions* that served as enablers in production and consumption of energy.
3. *Commercial and end-use practices* that shaped and influenced demand for energy
4. *Institutions responsible* for energy (and electricity) infrastructure governance and provision

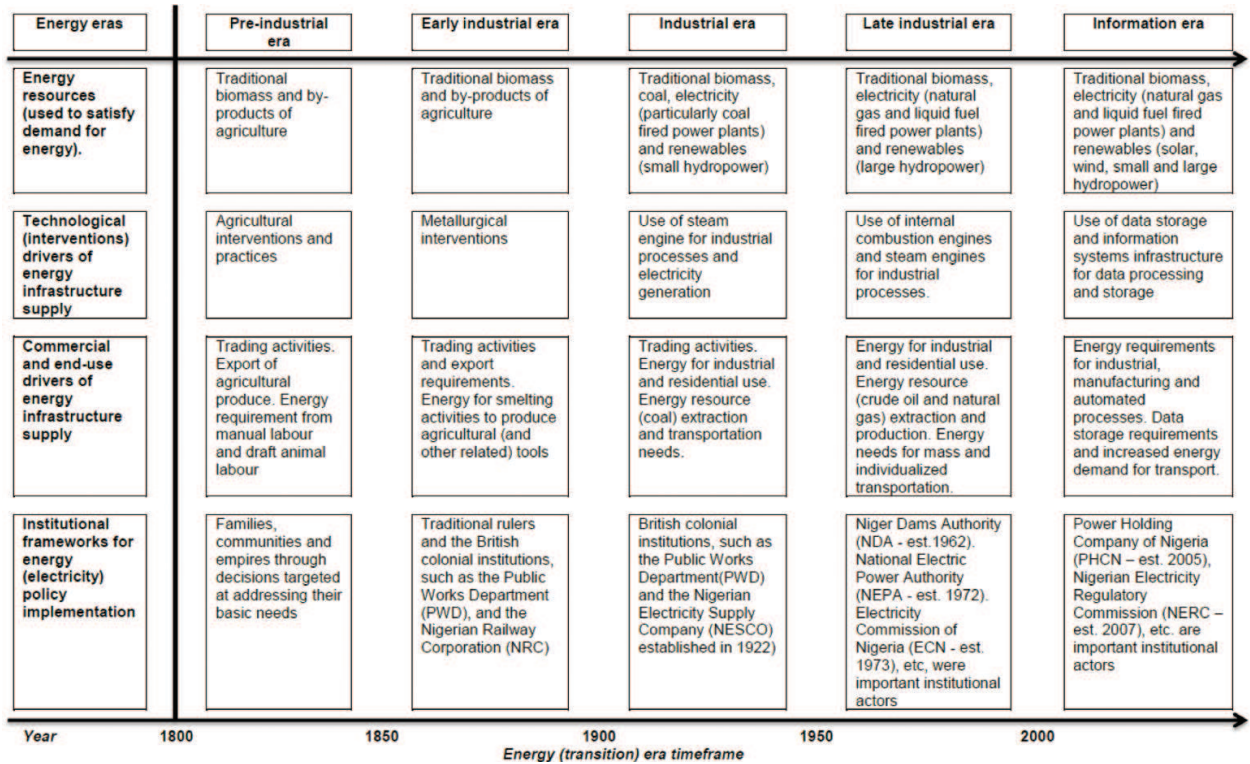


Figure 1. A panoramic view of the energy eras and the key features of the Nigerian energy transitions (1800–2015).

This research revealed that changes in Nigeria's energy supply infrastructure have been driven and influenced within the following contexts:

1. Policy and institutional interventions on energy
2. Technological interventions and energy technology pathways
3. Social (societal) practices and public values for energy
4. Available energy resource options
5. Economic considerations

Policy and institutional interventions have been one of the greatest contributors to changes and transformation in energy supply infrastructure systems. These policy interventions have come about as a result of the increasing need to address issues, such as energy access, energy security, decarbonizing future energy, and combating the effects of anthropogenic climate change and its consequences.

Technological interventions and different technological pathways have also contributed to changes in energy infrastructure systems in Nigeria over time. This started with the use of steam engines (up to early 1900s), coal fired power plants (up to mid-1900s) and thermal power plants (since the 1980s). The development of renewables (hydroelectric power) started in the mid-1900s. This development is deemed to continue due to national and international pressures to cause a shift to the use of renewables (including the use of solar photovoltaic cells, wind power and nuclear energies where applicable).

Public values for energy was driven more by the perceived (and actual) merit that provision of energy infrastructure conferred. Indeed, there were changes in societal and social practices brought about by the provision of electricity supply infrastructure. Some of these practices, such as commuting, trading and entertainment became more energy intensive. The provision of electricity infrastructure did not only help guaranty the continuation of these practices, but also aided its sophistication.

The availability of natural resources, particularly primary energy resources such as coal, crude oil and natural gas aided the increased use and consumption of those resources. Resource availability served as a primary driver of energy consumption. Rising demand for energy served as a secondary reason. Indeed, the effect of rising demand and resource availability led to transitions in energy use as shown in **Figure 1**. This same transition was also supported by, and influenced the creation of, several decision-making institutions within each era, as well as the policy direction of the government (see **Figure 1**).

Economic considerations impacted on historical energy infrastructure investments. Future energy infrastructure supply will require further leadership and sustained investments by public and private entities in providing energy infrastructure that addresses the changing (current and future) needs of people in society. Governments, through public institutions, will have to provide economic incentives to increase energy infrastructure provision through promulgation of policies to aid private investment going into the future.

The following sub-sections now delve into the details of the various influences/drivers of energy systems change within each energy era.

3.1. Pre-industrial (agricultural) era—up to mid-1800s

This era, which was characterized more by agricultural practices and interventions, saw the extensive use of traditional biomass (mostly by-products of agriculture, such as wood) as the major source of energy. The following were key drivers of energy infrastructure supply in this era:

1. Institutional interventions
2. Economic considerations
3. Energy resource options
4. Social practices and public values

3.1.1. Institutional interventions

There were two pre-dominant decision-making institutions during this era:

1. Families
2. Traditional institutions (rulers)

Decisions at the level of families were made based on their available resources and needs. By-products from agriculture such as oils were used for addressing lighting needs using oil lamps [12]. A source of food for most families was through peasant farming. Decisions on domestic energy needs impacted on increased energy demand in the forms of food calories and other agricultural by-products required for various domestic needs such as wood for cooking. Indeed, the aggregate value of the combined energy needs of several families resulted in thinking about new innovative ways of addressing and satisfying the rising energy demand.

Rulers of traditional communities played a pivotal role with respect to trade activities. For most communities, traditional rulers, together with the traditional council (also known as ‘council of chiefs’ in some cultures in Nigeria) encouraged people within their communities to embark on activities that can potentially increase trade activities with other communities and foreign envoys [12]. There are several evidence of this in Badagry area of Lagos and the great Benin kingdom. Trade, which encouraged the exchange of practices and ideas led people in several communities to adopt practices that were energy intensive [13]. Increased trade activities during this era led to the cultivation of more crops for domestic consumption and export [14].

Families and rulers of traditional communities (together with traditional councils—the equivalent of congress at community levels) were the main institutional drivers of energy infrastructure changes and use during this era.

3.1.2. Economic considerations

During this era, increased agricultural output was considered synonymous to economic prosperity. Growth in agricultural productivity meant increased potential for more trade leading to increased income. Since agriculture was the mainstay of the economy during this era,

increased productivity helped in sustaining families, maintaining communities and supporting traditional festivals, such as: the harvest festivals.

3.1.3. Energy resource options

During this era, the available energy resource was from food calories. Decisions on energy resource use depended on families and local communities. The availability of food calories meant that most practices performed were based on manual labour and draft animal labour. This was very demanding as there was need other energy resource options that could help reduce the use of manual labour in achieving different practices.

3.1.4. Social practices and public values

During this era, energy from food calories was perceived as a common (societal) good. The availability of this energy source provided the basis for several practices to be implemented in different sort of ways, such as commuting and trade. Trade was a very important practice that led to more demand for energy. Trade activities improved and many Nigerian locals saw the need to increase their export produce that would be sold to their trade partners. It is the perceived value (a means of livelihood) and the trade practices that led to demand for new forms of energy to help increase production output of food produce, arts and crafts for export.

3.2. Early industrial (metallurgical) era—mid to late 1800s

This era saw the extensive use of metallurgical interventions in energy use. The key drivers of energy infrastructure supply during this era were:

1. Institutional interventions
2. Technological interventions
3. Economic considerations

3.2.1. Institutional interventions

The institutional decision-making platforms that were vital in shaping this stage of the Nigerian energy transition were:

- Colonial institutions
- Traditional institutions (traditional rulers)

The British colonial government was the key decision maker during this era. Since Nigeria was divided into regions, there were regional governors for the northern, western and eastern regions. Decision making on new infrastructural development was effected through some institutions established during this era. The two pivotal institutions set up during this era were:

1. The Public Works Department (PWD)
2. The Nigerian Railway Corporation (NRC)

The PWD was established to plan and develop several infrastructural facilities in Nigeria (roads, electricity, ports and harbours, etc.). The PWD intervened in the establishment of the first electrical power plant in Lagos, which served lighting purposes. This intervention led to increased demand for electricity since this provision led to increased perceived public value for electricity.

The NRC intervened in the planning, surveys and provision of rail transport infrastructure. The NRC was established to plan, implement and maintain rail infrastructure in order to open up the hinterlands of the country and aid the easy transportation of agricultural produce to coastal cities and ports for export. This led to the provision of the first rail line in Nigeria in 1896, linking Lagos and Ibadan, two cities in South-West Nigeria.

Traditional rulers still remained relevant in the scheme of things at the community level [15]. However, colonial rule and institutions were having greater impact in changing the infrastructure and governance landscape [14]. In order to gain acceptance at local community levels, the colonial institutions worked closely with community leaders to ensure decisions made were accepted and implemented at community level.

3.2.2. Technological interventions

Changes in energy systems during this era were also influenced by technological interventions. Two forms of technological interventions were evident during this era:

1. Metallurgical technology
2. Electrical technology

The extensive use of metallurgy during this era aided the planning and development of several infrastructure. Metallurgical interventions aided the production of farm tools to aid agricultural practices and increase crop production. The provision of the first railway line in Nigeria was also aided by the extensive deployment of metallurgical interventions during this era. These interventions aided the provision of mass transportation infrastructure (such as the railway line).

Electrical technology interventions aided the provision of the first electrical power plant in Nigeria which was used mainly for lighting applications. However, this initial provision paved the way for future electrical technology interventions to cater for future electrical energy needs due to increased demand for other applications, such as, electricity needs for the workshops of the Nigeria Railway Corporation.

3.2.3. Economic consideration

During this era, economic considerations were centred on increased trade volume, growth in income and productivity. Policies of the colonial administration at the time were centred on providing infrastructure aimed at economic development that supports trade. These were part of the considerations for the planning and eventual provision of the first railway line and electricity infrastructure in Nigeria.

3.3. Industrial (steam engine) era—early to mid-1900s

During the industrial era, there were five vital drivers of energy infrastructure supply. These were:

1. Technological interventions
2. Changes in social practices
3. Policy and institutional interventions
4. Economic considerations
5. Energy resource options

3.3.1. *Technological interventions*

During this era, the use of metallurgical and electrical technology interventions in infrastructural provisions became further widespread. New railway infrastructure opened up the hinterlands and connected more towns which aided mass transportation of people and goods. The use of steam engines for transport and manufacturing applications were also evident in this era.

New electricity supply infrastructure was provided to cater for increased electricity demand. The existing steam plants were expanded in response to increased demand. This era also saw the introduction of new technology pathways for electrical energy generation. The discovery of coal in 1909 paved the way for the introduction of coal fired electrical power plants in (Lagos and Enugu) Nigeria. There were also plans during this era which paved the way for future hydroelectric power plants.

3.3.2. *Changes in social practices*

The introduction of various technological interventions during this era led to changes in social practices of Nigerians which became dependent on more dense energy sources. Indeed, some of these practices became more energy intensive. The provision of more road and rail infrastructure led to a change in commuting patterns from walking to the use of mass transportation models, such as railway lines. This period also saw a gradual change from mass transportation (in the beginning of the era) to individualized transportation (towards the end of the era). The change in commuting patterns led to increased demand for more transport infrastructure which also had some effects on increased demand for energy infrastructure supply.

3.3.3. *Policy and institutional interventions*

This era saw the introduction of several policies, implemented within institutional frameworks, which aided the eventual provision of targeted infrastructure (including energy). This era was dominated by colonial institutions, established to achieve specific infrastructural and policy targets [16]. Two institutions were pivotal in the provision of electricity infrastructure during this era:

1. Nigerian Electricity Supply Company (NESCO)
2. Nigerian Government Electricity Undertaking (NGEU)

Established in 1922, the Nigerian Electricity Supply Company (NESCO) was tasked with the responsibility of developing electrical energy supply (generation) infrastructure. NESCO was involved in generation and bulk trading of electricity to different towns and cities such as Bukuru (1936) and Vom (1944), covering a total of 600 square-miles (including the mines). The peak load rose to 12 MW with an annual load factor of 60%. As of 1922, the Enugu building of NESCO was already in place, just off the railway workshops. Engines, dynamos, boilers and a riveted steel chimney were in position at an audited cost of over £103k, which is worth around £4.6m in current estimates. This power plant supplied electrical power to the mines from 1924.

The Nigerian Government Electricity Undertaking (NGEU) was established in 1946 to plan and implement the provision of electricity infrastructure by at least 200%. The aim was to ensure the provision of electricity to support industrialization. The implementation of this policy led to industrialization in the 1950s in Nigeria. Many manufacturing plants based their future growth projections on the electrical infrastructure expansion plans.

3.3.4. *Economic considerations*

Trade activities continued to grow during this era. This was evident by the complex movements of goods over time as highlighted in **Table 1**. The growth in trade was supported by increased agricultural productivity and the presence of small cottage industries. **Table 1** shows the goods tonnage and passenger journeys (1913–1976). Between 1925 and 1930, the movement of coal led to increased trade and commercial activities.

The introduction of the new energy policy for the provision of more energy supply infrastructure was based purely on economic considerations, to support industrialization. The Nigerian Government Electricity Undertaking (NGEU) had the responsibility of planning and implementing this policy. Indeed, economic considerations from individuals and government and impacted on more demand for energy which then influenced more electricity infrastructure supply.

3.3.5. *Energy resource options*

During this era, there was a deliberate attempt by the Nigerian government (still under colonial rule) to conduct surveys aimed at exploring and searching for possible mineral reserves. This led to the discovery of coal in 1909.

The discovery of coal changed the electricity and transportation landscape. There was a shift to the use of coal fired power plants for electricity generation due to the availability of coal. The use of coal in cottage industries also increased. The transportation landscape was also affected by the discovery of coal as more locomotives depended on coal as the fuel source.

Year	Paying tonnage ('000)	Non-paying tonnage ('000)	Total tonnage ('000)	Passenger journeys ('000)
1913	–	–	–	1160
1917	152	60	212	1094
1920	–	–	527	2211
1924/25	541	113	645	1023
1928/29	–	–	–	3162
1932/33	646	180	826	2378
1935/36	709	238	947	7941
1936/37	892	270	1162	8426
1941/42	1042	266	1308	4810
1943/44	1239	397	1636	5245
1944/45	1339	371	1710	5342
1952/53	1543	543	2086	5516
1953/54	1714	584	2298	5454
1954/55	1983	619	2602	5451
1955/56	2000	653	2653	6310
1958/59	2353	743	3096	7015
1960/61	2054	668	2722	9822
1961/62	2381	622	3003	11,061
1962/63	2209	551	2760	12,006
1963/64	2534	436	2960	11,288
1970/71	1493	111	1604	8942
1975/76	1521	126	1647	6755

Table 1. Goods tonnage and passenger journeys in Nigeria (Source: Archives of the Nigerian Railway Cooperation).

3.4. Late industrial (dynamo/internal combustion engine) era—mid to late 1900s

This era saw some drastic changes in energy infrastructure supply. These were influenced by the following:

1. Energy resource options
2. Technological interventions
3. Policy/institutional interventions
4. Societal practices and public values
5. Economic considerations

3.4.1. *Energy resource options*

The discovery of crude oil in commercial quantities in Nigeria in 1958 changed the entire energy landscape during this era. After the Nigerian independence and the civil war, there was a shift in the use of fuel from the use of coal to a greater dependence on natural gas and crude oil (and its by-products) for electricity generation and other industrial uses. Indeed, there were more options to choose from between coal, natural gas and crude oil. This era also saw the development of dams for hydroelectric power generation.

3.4.2. *Technological interventions*

During this era, dynamos and internal combustion engines played a key role as the major technology driver of changes in energy infrastructure supply. The extensive use of internal combustion engines for vehicles and road transportation impacted on fuel sources. This also led to extensive investment in road infrastructure and a gradual decline in the use of rail transport infrastructure.

During this era, new technological pathways were adopted for electrical energy generation. Extensive development of hydroelectric and thermal power plants was evidenced in this era. This era also saw a swift decline in the use of coal for electrical power generation and the retiring of several coal-fired power plants.

3.4.3. *Policy/institutional interventions*

This era saw the extensive use of policy and institutional frameworks as intervention tools in addressing issues of energy infrastructure supply. The rising energy demand after the Second World War led to increased electrical infrastructure supply constraints. As such, the government intervened by carving out a new unit off the Public Works Department called the Nigerian Government Electricity Undertaking (NGEU). The NGEU was established in 1946 as an entity that will metamorphose into a future corporation with the aim of preparing and implementing a plan that can aid the provision of more electricity infrastructure to aid industrialization. Indeed, the NGEU prepared a 10-year plan covering the period 1946–1956 with the aim of increasing electricity infrastructure provision by at least 200% to support industrialization.

Another important institution is the Electricity Corporation of Nigeria (ECN). The ECN was established on 6th July 1950 and was charged with the task of developing Nigeria's electricity potential in a manner as to provide cheap and affordable sources of energy in a consistent and sustainable way.

The beginning of this era saw the gradual handover of institutions under colonial control as the country prepared for independence (which took place on 1st October 1960) [17]. Series of military coups and counter coups experienced a few years after the independence led to instructional instability, highly militarized decision making structure, and less attention and adherence to laid down policy plans and processes [18, 19].

The Niger Dams Authority (NDA) was established in 1962 to develop Nigeria's hydropower potential. This paved the way for the development of hydroelectric power infrastructure in Nigeria with the building of several dams for irrigation, water supply and electricity generation.

The National Electric Power Authority (NEPA) was established in 1st April 1972 which is a product of the merger of the Niger Dams Authority (NDA) and the Electricity Corporation of Nigeria (ECN). The merger actually took effect from 6th January 1973. The NEPA was a public company, owned and managed by the Nigerian government. All through this era, NEPA had responsibility for the provision, operation and maintenance of electricity infrastructure in Nigeria.

The Nigerian National Petroleum Corporation (NNPC) established on 1st April 1977 to participate and regulate Nigeria's petroleum industry. The role of the NNPC in regulating activities of players in the oil and gas sector had direct impact on electricity infrastructure provision since fuels required to power the electrical power plants depended on the dynamics of the downstream oil and gas sector.

In 1979, an act of government (which was later amended in 1988 and 1989) established the Energy Commission of Nigeria (ECN). The ECN was charged with the responsibility of coordinating and strategically planning the national energy policies. The ECN have focused on developing actions plans that aids in addressing the Nigeria's energy challenges through establishing and implementing policies. Indeed, since its establishment, the ECN still has a huge gap to fill.

3.4.4. Societal practices and public values

In this era, there were swift changes with regards to social practices which impacted on energy demand and consumption. The public value for energy services was on the rise and energy was highly perceived as a public good. Education played a vital role in the changes in social practices and perceived public values for energy. There was an increase in the number of educational institutions at primary, secondary and tertiary levels. Educational institutions also needed energy for teaching and research.

With regards to commuting, there was a change in commuting patterns from mass transportation to individualized transportation. More people had their private vehicles for personal and business purposes. Aside the reasons of comfort and convenience, a major driver of change from mass transportation to individualized transportation were increased concern for security and safety. There were also changes in lifestyles and leisure that impacted on the energy consumption and use that leads to increased need demand for energy supply infrastructure.

Rapid population growth, migration and urbanization also impacted on changes in practices. Some towns and cities ended up becoming more cosmopolitan (such as Lagos). Multiplicity of diverse practices within cities, aided by migration and population growth, impacted on changes and provision of infrastructure for commuting (transport), leisure (recreation), learning (education), trading (commerce), etc. These practices impacted on energy use and increased demand for energy infrastructure supply.

3.4.5. *Economic considerations*

This period saw changes in trade and investment dynamics. The discovery of more natural resources paved the way for further trade activities and other economic considerations investments. Crude oil export started in the 1970s. Export of agricultural produce continued but at a reduced rate due to a shift in attention from agriculture to crude oil as the major income earner for the country. The produce that was now exported (crude oil) required a lot of energy for its exploration and production.

There was an increase in manufacturing activities during this era. Increased electricity requirements for industries posed a greater challenge with regards to electricity supply infrastructure. Inadequate supply during the latter part of this era impacted on many manufacturing and cottage industries. Industrial growth was pegged as a result of inadequate electricity supply infrastructure. Most industries opted for self-generation of electricity for their industrial needs. Indeed, this infrastructure deficit resulted in the need for planning and future provision of more electricity supply infrastructure.

3.5. Information (micro-processor) era—early 2000s

During this era, four major drivers of energy systems change were noticeable:

1. Technological interventions
2. Policy and institutional interventions
3. Societal practices and public values
4. Economic considerations

3.5.1. *Technological considerations*

During this era, the use of microprocessor technology was on the rise which impacted on automation of processes in different sectors. In manufacturing, microprocessor technology aided the automation of many industrial processes. The use of Programmable Logic Controllers (PLCs), industrial sensors and other related technologies in manufacturing depended on microprocessor technology. The automation of several industrial processes aided increased production of goods. Even though there was more attention on energy efficiency and energy conservation measures, the introduction of these new technologies in manufacturing also impacted on electricity demand as more industries opted for automation to improve productivity.

3.5.2. *Policy and institutional interventions*

This era is characterized by democratic and civil institutions involved in the decision-making and policy process [17]. At the start of this era, two institutions emerged:

- Power Holding Company of Nigeria (PHCN).
- Nigerian Electricity Regulatory Commission (NERC)

Owing to inefficiencies in the Nigerian electricity sector, the Nigerian government started a process of unbundling the National Electric Power Authority (NEPA) in order to reduce government bureaucratic process in electricity supply infrastructure provision, operation and maintenance. The PHCN was established on 5th May 2005 as a holding company, owning the various divisions responsible for generation, transmission and distribution of electrical energy. This paved the way for the future privatization of the PHCN, with transfer and controls of some national electrical power assets by private companies. The privatization process also brought about some changes in models of electricity financing, operation and maintenance.

The NERC was established on 31st October 2007 as a regulatory body for the Nigerian power industry. The NERC has the responsibility for issuance of licenses and permits to market participants in the Nigerian electricity sector. They also ensure compliance to rules and regulatory guidelines in the Nigerian electricity sector.

3.5.3. Societal practices and public values

This era saw lots of private investments in the provision of infrastructure to satisfy the increased demand for convenience and comfort. This was evidenced in the emergence of shopping malls, cinemas, nature reserves and parks. The emergence of these infrastructure posed more pressure on demand for energy. This era continued to experience increased migration and urbanization which posed some infrastructure challenges (including energy). Indeed, in this era, the public value for energy services had increased and people had more dependence on energy to fulfill and accomplish several social practices.

3.5.4. Economic considerations

In this era, the need for increased productivity led to the embrace of automation in the industrial and manufacturing sector. Economic consideration during this era was characterized by the need to address both internal (local) and external (export) demand for certain products. Indeed, this led to more manufacturing activities. Most industrial players had to invest in electrical generation plants to satisfy their electricity needs. Self-generation of electricity also impacted on cost of finished goods as some companies could not measure up to the economies of scale for increased production output.

4. Important learnings from the Nigerian energy transitions

In Nigeria, a very important aspect of the governance of energy and electricity infrastructure provision is the individual interest of policy actors, the individualistic nature of which further emphasizes the need to incorporate economic and social psychological thinking. Some underlying questions they ask themselves before deciding on what type of energy infrastructure to provide include:

- How much does this infrastructure cost? Can our current budget accommodate it?

- How long will it take to deploy this infrastructure? Is it something that I can commission before leaving office?
- What social and political benefits will the provision of this infrastructure confer (on me and the populace)? Will the provision of this infrastructure offer me the possibility of acceptance and possible re-election by the populace?

Indeed, these aforementioned questions are crucial for individual actors within policy frameworks in taking decisions [20]. These also impacts on the governance of energy. This is in contrast with one of the arguments of Kuzemko et al. [21] who asserts that in governing sustainable energy systems change, innovation is important in sustainable energy transitions. In Nigeria, political actor interests are a major driver of energy transitions. The practice of policy making, intertwined with the interests of the political actors, is the principal driver of energy transitions. This is supported by the argument that linking governance with practices and outcomes, and defining energy and climate actor groups are very important in governing changes in energy supply infrastructure in a sustainable way [21, 22].

In Nigeria, institutional (government) interventions, changes in policy direction and new technology pathways constituted major drivers of changes in Nigeria's electricity systems. There are similar trajectories between the energy transitions dynamics of the Nigerian and the Dutch system. In considering the dynamics of the energy transitions in the Dutch electricity systems (1960–2004), Verbong argues that: changing perceptions and goals (1960–1973); direct government interventions (1973–1989); and major changes in rules, network and technology (1989–2004) characterized the Dutch electricity sector [23]. The Dutch system compares with that of Nigeria because electricity infrastructure provisions were influenced by: changing perceptions and goals prior to Nigeria's independence in 1960 (1890–1960) with evidence in changing technology and fuel sources for electricity generation during that period; direct government interventions (1940–1970), an example was the intervention by the then Nigerian Government Electricity Undertaking (NGEU) in 1946 to provide new electricity infrastructure by 200% in a space of 10-years [24]; and major changes in rules (2005–2015), characterized by the new electrical power sector reforms roadmap [25].

The following sub-sections discuss further four important influences of politics, technology, energy sources and geographies of energy on energy systems change in Nigeria.

4.1. Role of politics in energy systems change

Politics play a major role in effecting changes in energy supply infrastructure. For instance, the politics around crude oil and natural gas production and trade is vital for guaranteeing continuity of supply of electrical energy since most electrical power plants depends on the oil and gas sector for fuel to fire the power plants. This means fuel supply (in the forms of liquid fuel and natural gas) for most electrical power plants are highly dependent on the production, market, economics and political dynamics around crude oil and natural gas supply [26].

Arguably, the gas market is a lot more rigid than the oil market. This is because it requires large and expensive investments to ensure the easy transportation of gas around the world. Investing resources in a lot of long term infrastructure for this sort of business requires that

there is a good (long term) political relationship with the trade partners, wherever they may be. Indeed, it is easier to get entangled in the global prospect for natural gas, which can lead to a lot of energy security issues, both domestically and internationally.

Looking into the future, the major factor that could either make or break (clean) energy production is policy. This is the topmost variable because: policy plays a major role with respect to investment direction for most investors; it impacts on changes on the supply side of energy systems and infrastructure through definition of standards; and it imposes considerable changes in energy demand patterns and behaviours.

Within the Nigerian context, a major factor that led to the displacement of coal with liquid fuel and natural gas for electricity generation was simply the economics of natural gas over coal. Coal production and use for electricity generation in Nigeria is more expensive than the use of liquid fuels and natural gas. This transition started happening in the 1950s, but became more entrenched from the 1970s. All the coal fired power plants in Nigeria built from the 1920s to the 1950s have all been retired. Indeed, natural gas will gain a lot more grounds in Nigeria in the coming years due to its availability and the policy direction of the government encouraging the use of natural gas for electricity production.

4.2. The role of technology in energy systems change

In Nigeria, there have been lots of changes in energy technology and use over time. This will continue going into the future. Historically, Nigeria has transited from the use of steam engines, to coal-fired technology, thermal power plants and renewables. Going into the future, there will be more changes which will be shaped by the changing nature and politics of electricity infrastructure provision.

In recent times, there has been a rise in the deployment of decentralized off-grid solar solutions in Nigeria. The rapid rise of renewables will continue and solar power will become a regular feature on the energy landscape. New technologies will support global deployment of wind farms and solar solutions. The rise in renewable solutions needed for a clean energy future will be driven more by the increase in energy demand for electricity. Incorporating these renewable technologies will also have impact on the traditional electricity grid as new hybrid grids (transmitting electricity over long distance) and micro grids (playing strategic role in electricity distribution and providing flexibility) will be the mainstream technologies in the future.

As is now being experienced in major urban centres in Nigeria, buildings are now producing electricity through roof top solar solutions. In the future, more buildings will produce energy rather than consume energy. Buildings will also function as energy hubs in the future, offering the entire energy system more flexibility and also ensuring stability of the electricity grid. The use of smart meters, greater energy storage capacity and low cost solar cells will be important technology catalysts of a cleaner electricity future.

4.3. The role of energy (re)sources in energy systems change

Energy sources play a vital role in energy systems change. In Nigeria, it all started with the use of steam engines for electricity generation. The discovery of coal as an energy source (in 1909)

changed the energy infrastructure landscape, leading to a switch from the use of steam engines to the adoption of coal-fired power plants. The need to diversify the electricity infrastructure mix led to the development of hydropower plants in Nigeria (with the formation of the Niger Dams Authority). The discovery of crude-oil in commercial quantities (in 1956) had a considerable impact on the electricity infrastructure landscape in Nigeria. The overriding economics of crude oil and natural gas over coal led to a shift to the use of (oil and gas-fired) thermal power plants. Increased demand and consumption of energy in Nigeria have been partly influenced by the availability of energy resources. **Figure 2** shows the Nigerian energy flow linking primary energy resources to end-use sectors.

Energy flow in society starts with the natural energy sources (such as coal and crude oil) which are then converted into different usable forms that society consumes. These usable forms of energy materializes through the services they render society (as evident in **Figure 2**). This is evident through the greater use of energy resources, driven by the need for comfort and more productivity. In Nigeria, the increased societal use of energy resources is impacted by three main sectors: building; manufacturing; and transportation sectors.

4.4. The role of ‘geographies of energy’ in energy systems change

Aside technological interventions, politics and energy resources, a major driver of energy systems change in Nigeria are the ‘geographies of energy’ which encapsulates the social, cultural and political dimensions of energy production and consumption. The geographies of

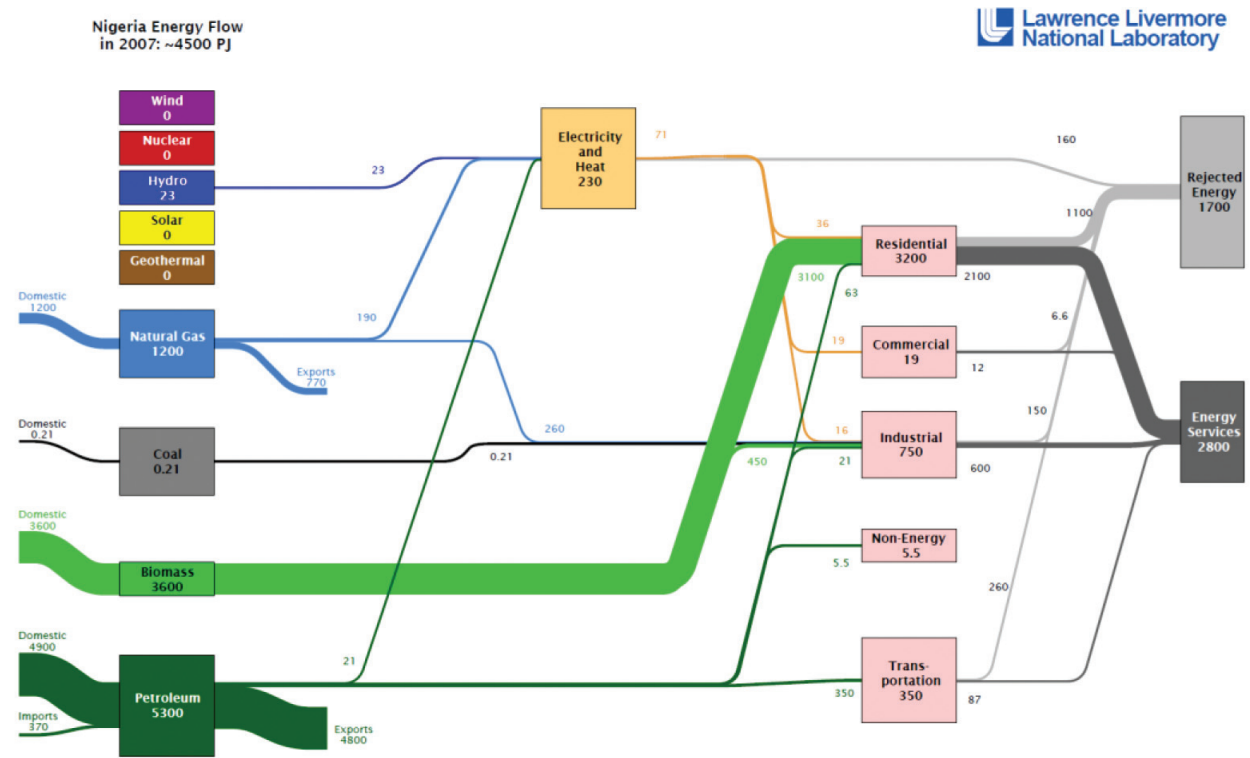


Figure 2. The Nigerian energy flow ([27], p. 90).

energy also considers how territorial, locational and spatial landscape impacts on (and co-constitutes) energy processes.

The geographies of energy played a very important role in Nigeria's energy transitions and infrastructure provision. Prior to Nigeria's independence in 1960, developmental infrastructure projects and provision were centred on regions. Starting with steam powered generation plants in the late 1800s, the discovery of coal in 1909 paved the way for many coal-fired electricity generation plants (mostly around the regions where coal reserves were available). Lagos was the only exception. This was largely because there was already rail infrastructure connecting some parts of eastern Nigeria (Enugu) to Lagos where coal could be easily transported via rail to the power plant in Lagos. **Figure 3** shows a map of the geopolitical zones in Nigeria.

Most crude oil and natural gas resources are concentrated around the South-South and South-East zones of Nigeria. These zones also have a higher concentration of: electricity power plants; natural gas refineries and export terminals; and crude oil refineries and export terminals. Indeed, these zones have the highest concentration of energy production and electricity generation infrastructure in Nigeria. However, for political reasons, government infrastructure decisions have also favoured setting up crude oil refineries outside the zones where the resources are. An example is the crude oil refinery located in Kaduna, North-Central Nigeria. The natural crude had to be transported to the refineries via pipelines. Indeed, political decisions of this sort has created historical tensions among socio-political groups in the geographies where the natural resources are domicile (and beyond), leading to cases of pipeline vandalism, political actions and other forms of externalities which impacts on the energy infrastructure landscape and energy security.

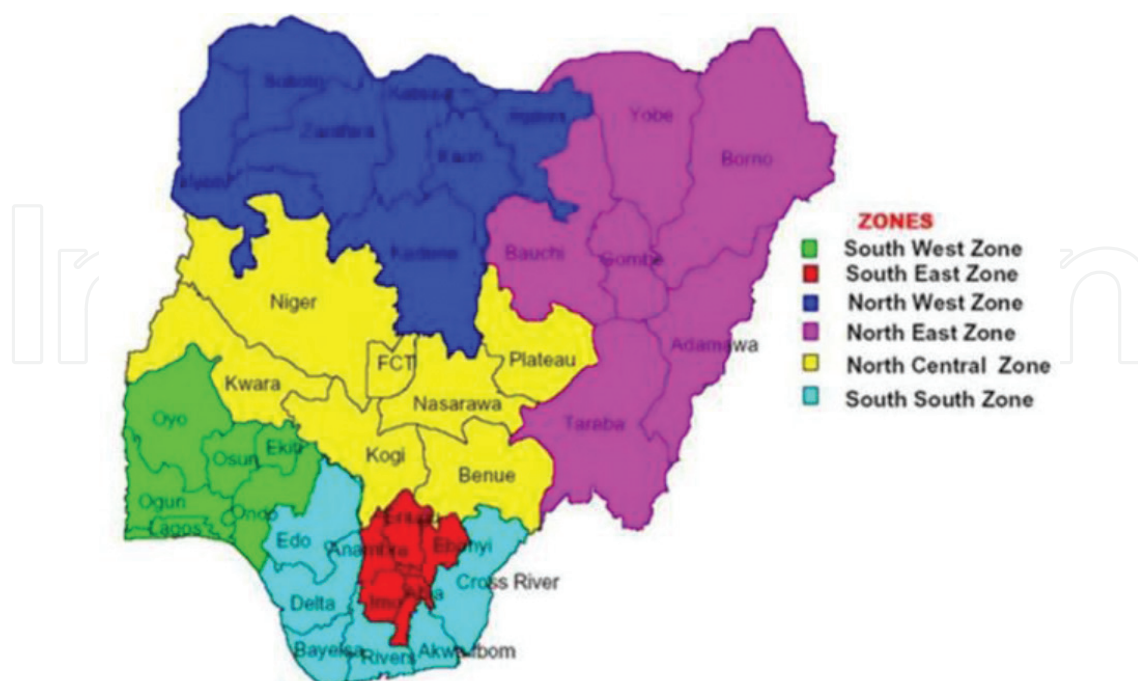


Figure 3. Map of the geo-political zones in Nigeria (Source: <http://www.nigerianmuse.com>).

5. Conclusion

The Nigerian historical energy transition with respect to the evolution of energy infrastructure provisions was investigated. The dominant drivers of electricity infrastructure supply within each energy era in Nigeria were also investigated. These drivers, which comprises technological interventions and pathways, institutional interventions, social practices and public values, energy resources and other economic considerations, played an important role in the governance and provision of historical electricity supply infrastructure in Nigeria.

A complex connection between resources, trade, institutions and political structures existed. These complexities were further aggravated by the creation of several decision making institutions within each energy era, as well as the policy direction of the government. Decisions by these (public) institutions led to serial changes, and eventual transition, in the use of different primary energy resources (coal, crude oil, natural gas) to satisfy the growing demand for energy. It also reveals that the increased use of primary energy resources were primarily influenced by the availability of those resources, while the growing demand served as a secondary reason.

This chapter presents the need for a greater understanding of the motives and objectives of energy systems supply. What exactly motivates the changes in the energy sector in a given country as against the background of the overall energy demand and supply situation? Possible motives, such as competitiveness, public acceptance, energy security and environmental concerns—within institutional contexts and policy frameworks—needs to be investigated at country levels, for a better understanding of the key drivers of energy transitions within countries.

There is a need to understand the drivers and governance of changes in the respective energy sectors. How are changes promoted in the energy sector? Some possible drivers, such as: technological innovation, government policies, etc., needs to be investigated at country level to ascertain their impact on the institutional structures and frameworks of energy policy governance.

The study of Nigeria's energy transitions presents some policy implications. Since energy infrastructure choices contribute to environmental problems, and changing these energy infrastructure choices requires adequate knowledge of their effects and consequences, there is need for a wide range of changes in energy policies and energy systems to help address these problems. Energy users, including policy makers, generally prefer energy policies that is perceived to have more benefits and less cost. However, since energy infrastructure provision is primarily a political choice, the acceptance of different energy policies (and changes in energy supply systems) is influenced by institutional actors within institutions through institutional values, workings and frameworks responsible for energy infrastructure decisions and choices.

Energy production, distribution and supply are very complex matters. This complexity is evident when viewed with respect to the role of technology, energy resources and geographies of energy in effecting changes in energy supply systems. This implies reliance on parties, such as: energy companies, scientists, non-governmental organizations and policy makers. How

much people trust these parties will influence the acceptability of energy policies. Knowledge and understanding of Nigeria's energy past can surely shape current and future decisions. Short term energy decisions have to be put in perspective with the longer term visions in order to limit the effects of unintended consequences.

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