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Who triggers change? Social network mapping, stakeholder analysis and energy systems interventions in Nigeria's electricity sector

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ABSTRACT

Following decades of energy systems interventions, there has been growing concerns about the impact of historical interventions on-the-ground and how they shape changes in energy systems. Who are the key actors and how have they shaped historical energy systems interventions? In this study, an analysis of stakeholders in Nigeria's electricity sector through a social network mapping lens was conducted. First, a stakeholder mapping based on an interest-influence matrix that shows the degree of various stakeholder interest and influence in shaping decisions and interventions in both centralized and decentralized electricity systems was developed. Secondly, a stakeholder network grid that shows the relations between the various stakeholders (who knows whom) was developed. The study reveals that there are stronger network relations among stakeholders involved in issues and decisions on centralized electricity grid infrastructure which is influenced by the presence of stronger regulations/regulatory instruments. However, these stakeholder relations are weaker in decentralized electricity systems due to less stringent regulations in the decentralized electricity space. The study concludes by highlighting the impact of the stakeholder relations and the interest-influence tussle on the future of electricity systems development in Nigeria

Keywords

Developing countries;
Energy governance;
Energy in Africa;
Energy stakeholders;
Future Energy;

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1. Introduction

Energy stakeholders are an essential group of actors that shape decisions in the energy market. These actors, often working as policy workers, help in addressing specific societal challenges through proffering solutions on issues related to policy formulation and implementation. Indeed, energy plays a vital role in the global economy [1,2]. It is the prime mover of global economic activities [3,4]. All sectors such as transport, housing, agriculture and industry (at municipal, sub-national, national, regional and global levels) depend on it [5,6]. The need to provide energy that facilitates sustainable development, impact health and improve human wellbeing has been a major driver of energy demand and energy systems interventions [7,8]. Addressing issues around increased energy demand also provides an opportunity to address the energy transition challenge.

Energy transitions broadly refer to processes that entail changes from one form, style, state, place or scale of energy system to another [9–13]. This change often occurs at different scales within different contextual norms. Rojey argues that transiting to sustainable low-carbon energy system helps in addressing three important threats [14]: first, to guarantee long-term availability of energy resources required for development; second, to address issues of security of supply; and lastly, to ensure the availability of the means to avert catastrophic climate effects.

Addressing the challenge of energy transition requires acting from a perspective of sustainable development [15],

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which points to the need for global regulation and governance to mitigate climate risks [16]. The future of energy is of great concern to policy makers, industry players, end-users and other stakeholders. It is generally believed that future energy systems will be driven more by policy instruments and regulations in order to accelerate the speed of change to transition to cleaner and more sustainable energy sources [17,18]. This paper explores the Nigerian case by addressing the following question:

- Who are the energy stakeholders and how does interaction among them shape energy systems interventions in Nigeria's electricity sector?

In structuring this paper, we introduce intervention theory and energy systems interventions in Section 2 while Section 3 outlines the materials and methods used in this research. In Sections 4, we present the regulatory contexts shaping stakeholder interactions and interventions while Section 5 highlights the historical institutional and regulatory interventions in Nigeria's electricity sector. In Sections 6 and 7, we present the stakeholder network grid (who knows whom) and the stakeholder mapping of key actors (with respect to interest versus influence in shaping energy decisions). The discussions and concluding thoughts are presented in Sections 8 and 9 respectively

2. ntervention theory and energy systems interventions

Intervention theory entails the analysis of various decision making problems that involves effectively intervening in addressing specific issues in order to achieve a desired outcome [19]. This theory helps to probe the effectiveness of different forms of interventions and to question at what point it is desirable and appropriate to intervene in addressing a particular issue [20,21]. Historically, policy makers and government institutions have addressed many systemic problems in different sectors through interventions [22]. This is also true with the energy sector. However, what dimensions have historical energy systems interventions taken over time?

The energy sector, which is one of the sectors dominated by "hard infrastructure", account for far more development investment than other sectors [23,24]. Energy investments have become very complex, incorporating environmental, behavioural and social goals over time [25,26]. These also underpin the various forms of innovations and interventions provided. Since energy is a major area for global development assistance expenditure, many development institutions see the need for various forms of interventions through: policy development [27,28]; infrastructure investments; energy access interventions for rural electrification [29]; improvement of cleaner fuels [30]; inclusive energy systems that addresses the needs of women [31,32]; and issues addressing sustainability [33].

Indeed, energy systems interventions occur at different scales within different contextual norms. In highlighting successful energy policy interventions in Africa, Karekezi *et al.* argued that following the experiences of some projects already implemented, there is a need for adequate policy frameworks and financing schemes to improve the current energy situation [34]. They further argued that policy interventions in the areas of electricity generation (particularly geothermal energy in Kenya and cogeneration in Mauritius) and distribution (in South Africa and Ghana), Liquefied Petroleum Gas (LPG – in Senegal) and biomass for improved cook stoves across different parts of Africa have yielded some results. Karekezi et al. further argued that some factors are necessary in ensuring the success of policy initiatives within the electricity sector [34,35]. These include:

- Long term commitment of public and private sector actors.
- Focusing on initiatives that provide opportunities for increased income generation.
- Preferences given to specialized initiatives with a specific focus.
- Building energy initiatives around existing networks that minimizes setup cost for new networks and accelerate scale-up.
- Focus on local skill development in the case of new technologies.

Mapping interventions also requires a targeted approach. Kok *et al.* argues that to ensure energy-related behavioural change, there are six important steps that must be followed in intervention mapping [36]:

- Needs assessment – which entails an analysis of the problem and its consequences.
- Programme objectives – which entail answering the *Who, Why* and *What* questions for individual and organizational agents.
- Methods and application – which entail defining methods and applications to meet the programme objectives.

- Programme development – which entails actual development of the interventions.
- Planning for programme implementation – which entails a plan for the implementation of the interventions.
- Planning for programme evaluation – which entails the effective measurement of the intervention impact using some measureable indicators.

3. Materials and methods

The Nigerian electricity sector was chosen for this study because of the inherent challenges in the sector [37,38]. Nigeria's electricity sector somewhat mirrors the worst sort of challenges one can experience within a global south context such as unreliable fuel supply for electricity generation, high grid (technical and non-technical) losses, among others [39,40]. Indeed, with a population of over 200 million people, Nigeria only generates an average of 4,500MW of grid electricity and still has about 45 percent of the population (amounting to over 90 million people) without access to electricity [41–44]. Understanding historical interventions in Nigeria's electricity sector and the dynamics around such interventions can help shape current and future decisions around energy infrastructure provisions that address the need of people in society in a more sustainable way.

The associated data used for the preparation of this article were primarily from secondary data sources. The research aimed at mapping the various stakeholders in Nigeria's electricity sector to ascertain how the various stakeholder interactions shape energy and electricity systems interventions. The following steps were used in establishing the stakeholder of focus and how data was collected. We have referenced some important data sources within each step.

1. To determine the various decision making and non-decision making stakeholders in Nigeria's electricity sector in both centralized grid and decentralized electricity sectors, we focused on obtaining secondary data from government (national) and multi-lateral agencies such as the Rural Electrification Agency and the International Energy Agency [45,46].
2. To determine the role of each stakeholder in electricity systems interventions and how they shape electricity systems decisions, we obtained data through interview of some stakeholders and data from published literature on stakeholder activities [47]. These data helped us to ascertain the various influence-interest dynamics among the different stakeholders.
3. The purpose of the interviews conducted was to confirm the actual activities and interactions among stakeholders whose activities were not so obvious in the public domain. Some examples of such stakeholders include: some private generation companies; Original Equipment Manufacturers (OEMs); electricity systems installers, traders and retailers; among others.
4. We obtained data from secondary sources on stakeholders whose activities are readily available in the public domain. Examples are those stakeholders in centralized grid systems who are mandated (by regulation) to provide periodic data on their activities.

Indeed, materials and data (such as policy reports and archival documents) that aided the design of the stakeholder mapping were obtained from the following groups.

1. Selected Nigerian grid-connected generation companies
2. Selected Nigerian grid-connected distribution companies
3. Transmission Company pf Nigeria (TCN)
4. Nigerian Electricity Regulatory Commission (NERC)
5. Rural Electrification Agency of Nigeria
6. International Energy Agency (IEA)
7. Energy Information Administration (EIA)
8. World Bank
9. African Development Bank

In preparing the stakeholder mappings, the following procedure was followed [48,49]:

- *Identify the relevant stakeholders in Nigeria's electricity sector*: Some stakeholders are leaders in shaping decisions, while others are better contributors and some act as just bystanders.
- *Categorize/classify the relevant stakeholders based on their market presence and segment* (centralized or decentralized electricity market)
- *Analyze the relevant stakeholders and classify each stakeholder based on their influence (low, medium or high) and interests (low, medium or high) for both centralized and decentralized electricity space*.

- *Develop a power (influence)/interest matrix that situate each relevant stakeholder*. The development of this matrix is influenced by interest, impact, motives, contribution and benefit of each stakeholder in shaping electricity policy and infrastructure decisions. These factors influence the level of stakeholder interest and influence.

The archival record analysis was followed by semi-structured (telephone) interviews of some stakeholders in the Nigerian electricity sector to confirm the validity and reliability of some records obtained from the archives. The stakeholder groups represented in the interviews are as follows:

1. Electricity generation companies (including Independent Power Producers - IPP)
2. Transmission Company of Nigeria (TCN)
3. Electricity distribution companies
4. The Nigerian Electricity Regulatory Commission (NERC)
5. Electrical installation service companies
6. Energy users.

The semi structured interviews were conducted among selected stakeholders with relevant experience in Nigeria's electricity sector. The target participants were made up of people who work within organizations that are directly impacted by various forms of interventions. Table 1 shows a summary of the experiences of interviewees and the date of interview.

4. Regulatory context shaping stakeholder interactions and interventions in Nigeria's electricity sector

In this section, we provide two important backgrounds that helps to provide an understanding of the context that shape interactions among stakeholders in the Nigerian electricity sector. First, we provided a summary of some strategic policy documents prepared to help address some specific market challenges in the sector (in section 4.1). In section 4.2, we highlighted the important regulations shaping the on-grid and off-grid electricity space and the essential features of these regulations.

4.1 Strategic Policy documents and Regulatory Acts of Parliament on Electricity Provision in Nigeria

The Electric Power Sector Reforms Act (EPSRA) of 2005 is the only policy document (backed by an Act of Parliament) that governs the affairs of the Nigerian electricity sector. This document provided the foundation for the establishment of two important institutions:

1. The Nigerian Electricity Regulatory Commission (NERC) whose mandate is to govern and regulate the affairs of stakeholders in the Nigerian electricity industry
2. The Rural Electrification Agency (REA), and by extension the Rural Electrification Fund (REF) to aid the deployment and expansion of electricity infrastructure to communities without access to the grid, particularly in rural centres.

Table 1: Summary of experiences of interviewees and the date of interviews

Interviewee	Sector experience within the electricity sector	Interview date
A	Over 15 years' experience working in the Nigerian electricity sector in different capacities. Initially worked with a multinational private OEM involved in providing energy services and later moved to a government utility-scale company.	November 2020
B	Over 15 years' experience working in the Nigerian electricity industry, spending a large part of that time working at a utility-scale electricity generation plant.	November 2020
C	Over 5 years' experience in the Nigerian electricity sector working with one of the largest electricity distribution companies in Nigeria	December 2020
D	An energy end-user who is very conversant with the developments in the Nigerian electricity supply industry	December 2020
E	Over 10 years' experience in the Nigerian electricity sector working with one of the largest electricity distribution companies in Nigeria	December 2020
F	Over 20 years' experience in the Nigerian electricity sector, working with a large utility-scale company.	December 2020
G	An independent consultant in Nigeria's electricity sector with over 7 years' experience working and consulting in the sector.	December 2020
H	Over 8 years' experience working with the electricity sector regulator in Nigeria.	December 2020

The EPSRA Act provided a basis for the mapping and development of several national strategic policy documents targeted at addressing specific challenges within the sector. Some of these documents include:

1. National Renewable Energy and Energy Efficiency Policy (NREEEP) (2015 – 2030) [50].
2. National Energy Efficiency Action Plan (2015 - 2030) [51]
3. Rural Electrification Strategy and Implementation Plan (RESIP) [7,52]

Indeed, the REA (as a strategy) have focused on using decentralized electricity sources to address the challenge of rural electrification, a large chunk of which include renewables (particularly solar energy solutions). Table 2 provides a summary of the various strategic policy documents, the year enacted/initiated, the purpose of each document and the implementation status thus far.

Table 2: Some strategic policy documents in the Nigerian electricity sector

	Policies/ Regulations	**Year enacted**	**Purpose**	**Implementation status**
1	Electric Power Sector Reforms Act	2005	To provide licensing and regulation for the generation, transmission, distribution and supply of electricity while enforcing performance standards, consumer rights and obligations	This is the overarching document governing all regulatory and intervention activities in Nigeria's electricity sector. This act enabled the creation of the following: - The Nigerian Electricity Regulatory Commission (NERC), which is the main regulatory body for the Nigerian electrical power sector. - Rural Electrification Agency (REA) that focuses on rural electrification initiatives to increase electricity access.
2	National Renewable Energy and Energy Efficiency Policy (NREEEP) (2015 - 2030)	2016	This is the overarching policy document on renewable energy and energy efficiency in Nigeria. It defines regional policy targets and national targets for renewable energy and energy efficiency.	With the help of this document, Nigeria have been able to set some targets for inclusive access to modern and clean energy resources to address energy security and climate objectives.
3	National Energy Efficiency Action Plan (2015 - 2030)	2016	Sets out the implementation strategy for the National Renewable Energy and Energy Efficiency Policy (NREEEP) It provides an overview on concrete policy and regulations, laws, incentives and measures to be implemented to achieve Nigeria's energy efficiency targets	A major outcome of this initiative is the development of the **Nigerian National Building Efficiency Code** in 2017 by the Federal Ministry of Power. This code sets the minimum standards for energy efficiency requirements in buildings in Nigeria. However, there is still a huge gap in the implementation of this policy
4	Rural Electrification Strategy and Implementation Plan (RESIP)	2016	Provides an implementation and measurement framework for driving rural electrification across Nigeria using on-grid and off-grid energy solutions.	The goal is to achieve electricity access of **75% and 90% by 2020 and 2030** respectively with **renewable energy contributing at least 10% to the energy mix by 2025.** This goal is currently implemented through a Rural Electrification Fund (REF) using open competitive bids (for grid extension, stand-alone systems and minigrid projects) that is implemented by the Rural Electrification Agency. Some vital challenges to the implementation of this strategy include: - Central coordination (with a top-down government planning and coordination approach) at national level - Willingness and ability to pay for electricity by rural dwellers impacts on demand and supply dynamics. - High cost of financing rural electrification and a scarcity of skilled technical personnel for energy projects. The current electrification rate in Nigeria hovers around 55%.

Table 3: Summary of existing regulations for on-grid and off-grid electricity infrastructure deployment (Source:[53])

s/n	Type	Features	Regulations
1	**Captive Generation**	*Generation of electricity exceeding 1 MW for the purpose of consumption by the generator, and which is consumed by the generator itself, and not sold to a third-party. A Permit holder must apply for, and receive prior written consent of the Commission before supplying surplus power not exceeding 1MW to an off-taker.* - Off-Grid - Power consumed by generating entity - >1MW - No distribution infrastructure required - Permit required from NERC	NERC Captive Power Generation Regulation
2	**Embedded Generation**	*Generation of electricity that is directly connected to (and evacuated through) a distribution system which is connected to a transmission network operated by a System Operations Licensee.* - Plant directly connected to distribution network. - > 1MW - Power sold directly to a distribution company through a bilateral contract. - License required from NERC - Good for cluster of customers e.g., Industrial estates	NERC Regulation on Embedded Generation
3	**Independent Power Plant – IPP (Off-grid)**	- Plant is not connected to the national grid. - Power is sold to an off-taker (commercial or residential) through a bilateral contract. - Good for cluster of customers e.g., housing estates, industrial customers, large installations of telecoms equipment - There may be a need to invest in distribution infrastructure - Requires license from NERC	NERC Generation Procurement Regulations.
4	**Independent Power Plant – IPP (On-grid)**	- Generation plant is connected to the grid - Power is evacuated to the national grid. - Suitable for large scale projects - Requires Power Purchase Agreement (PPA) with the Bulk Trader (Nigerian Bulk Electricity Trading - NBET) - Subject to capacity need and system constraints. - Requires license from NERC.	NERC Generation Procurement Regulations.
5	**Embedded Independent Electricity Distribution Network (IEDN)**	- For areas where there is presently no distribution network. - Will connect to existing distribution companies to be able to distribute power - Possibility of *ring fencing* a section of willing paying customers of a distribution company - Distribution Companies will be responsible for installation and management of electricity meters	Independent Electricity Distribution Regulation 2012
6	**Urban Off-Grid Independent Electricity Distribution Networks (IEDN)**	- IEDN in an urban area but not connected to any licensed transmission network - Separate tariffs to be approved by NERC - Installation and management of electricity meters will be the responsibility of investor - Requires license from NERC	Independent Electricity Distribution Regulation 2012
7	**Rural Off-Grid Independent Electricity Distribution Networks (IEDN)**	- Isolated IEDN in a rural area not connected to any licensed distribution or transmission network. - Rural area is defined as an area: (a) Situated over 10km from the boundaries of an urban area or city with less than 20,000 inhabitants. (b) At least 20km away from the nearest existing 11KV line. - Will be required to purchase power from a generating company through a bilateral contract. - Can seek financial support from the Rural Electrification Fund. - Requires license from NERC	Independent Electricity Distribution Regulation 2012

8	**Mini-Grids**	*Any electricity supply system with its own power generation capacity, supplying electricity to more than one customer and which can operate in isolation from or be connected to a distribution licensee's network.* - Integrated local generation and distribution system with installed capacity below 1MW, capable of serving numerous end-users independent of the national grid. - It may be 'isolated' with no link to any other network or 'interconnected' with the main grid such that energy exchange is possible between them. - May cater to power needs of either unserved or underserved areas. - A tripartite agreement between the mini-grid licensee, distribution company and the community may be required - May require license from NERC. However, for small projects (below 100kW) only a simple registration with NERC is required.	NERC Regulations for mini-grids 2016

4.2 Existing regulations supporting the deployment of off-grid decentralized electricity solutions in Nigeria – including renewables

The Nigerian Electricity Regulatory Commission (NERC) developed different regulatory tools to enable the effective deployment of different on-grid and off-grid electricity infrastructure (including renewables). The important regulations include:

1. NERC Captive Power Generation Regulation
2. NERC Regulation on Embedded Generation
3. NERC Generation Procurement Regulations.
4. Independent Electricity Distribution Regulation
5. NERC Regulations for mini-grids

These aforementioned regulations were enacted to address specific market failures. Table 3 presents a summary of these regulations highlighting their key features and the type of issues they aimed at addressing.

5. Historical institutional and regulatory interventions in Nigeria's electricity sector

Historically, energy systems change within the Nigerian electricity sector have been highly influenced by various forms of interventions in the forms of regulations or institutional establishments of agencies saddled with the responsibility of addressing specific energy related challenge(s) [4,47]. The archival analysis revealed that changes in energy systems within the Nigerian context were highly influenced by two important forms of interventions:

1. Institutional interventions (from 1896 to 2007)
2. Regulatory interventions (from 2005 to 2020)

These aforementioned forms of interventions were characterized by various government instruments and regulatory frameworks (in the forms of policy levers) targeted at achieving a set objective. The following sub-sections now delve into the dynamics of institutional and regulatory interventions and how they have impacted on energy systems change.

5.1 Institutional interventions and energy systems change

Various interventions in energy systems change in Nigeria (from 1896 to 2007) occurred through establishment of new institutions entrusted with the responsibility of achieving some set objectives. This was the case for over a century of energy systems development in Nigeria [54]. The dynamic of institutional interventions impacted greatly on energy resource use, choice of technology and energy consumption patterns [21,23]. Indeed, within the Nigerian context, institutional intervention was a major determinant of energy infrastructure choices between 1896 and 2007.

The establishment of the Public Works Department (PWD) whose responsibility was the development of public infrastructure contributed to the provision of the first electrical power plant in Lagos in 1896. The discovery of coal in 1909 aided the establishment of the Nigerian Electricity Supply Company (NESCO) in 1922, whose focus was to develop various electrical supply infrastructure in Nigeria. This led to the provision of various coal-fired electrical power plants from 1923 to 1948.

The need to provide more electrical generation capacity to support industrialization led to the establishment of the Nigerian Government Electricity Undertaking (NGEU) in 1946. The NGEU was charged with the responsibility to improve electricity infrastructure provision by at least 200% to support industrialization efforts in Nigeria. In 1950, the NGEU morphed into the Electricity Corporation of Nigeria and was charged with the responsibility of developing and planning Nigeria's electrical energy potential in a manner that provides cheap and reliable electricity from various sources.

The need to develop Nigeria's hydropower potential led to the setting-up of the Niger Dams Authority in 1962, charged with the responsibility to develop hydropower in Nigeria. However, the establishment and morphing of various institutions within the electricity sector led to some complications. There were cases of overlapping responsibilities and a lack of clarity on who takes responsibility for what [4,54].

In an attempt to address some of the institutional complications, the National Electric Power Authority (NEPA) was established in 1972. It was the result of a merger of the Electricity Corporation of Nigeria and the Niger Dams Authority. NEPA had the responsibility for the provision, operations and maintenance of electricity infrastructure in Nigeria. In 1978, the Energy Commission of Nigeria was set-up to focus on coordination and strategic planning of national energy policies (including oil, gas, and electricity).

To pave the way for the liberalization of the Nigerian electricity market, the Power Holding Company of Nigeria (PHCN) was set-up in 2005 as a holding company that would eventually break-up into eleven distribution companies, one transmission company and several generation companies. However, the PHCN only catered for centralized grid electricity system.

To address the needs of those without access to the grid, the Rural Electrification Agency (REA) was formed in 2006 to coordinate and promote rural electrification programmes in Nigeria. The establishment of the Nigerian Electricity Regulatory Commission (NERC) in 2007 marked a major milestone in ending an era of major institutional interventions in Nigeria's electricity sector. The NERC has the responsibility of ensuring regulatory compliance, issuing permits and licenses to market participants and ensuring consumer protection within the electricity sector [13]. Table 4 dhows a summary of various historical institutional interventions In Nigeria since 1896.

Table 4: Historical institutional interventions in Nigeria's electricity sector

s/n	Institutional interventions	Year	Key objectives of the intervention
1	Public Works Department	1896	An agency of the colonial government that had responsibility for the provision and maintenance of public infrastructure including roads, rail, ports, electricity, etc.
2	Nigerian Electricity Supply Company (NESCO)	1922	Charged with the responsibility for developing electrical generation (supply) infrastructure
3	Nigerian Government Electricity Undertaking (NGEU)	1946	Established as a holding company to pave the way for the formation of a corporation. Its task was to address challenges limiting the accelerated provision of electricity infrastructure in Nigeria.
4	Electricity Corporation of Nigeria (ECN)	1950	Charged with the task of planning and development of Nigeria's electrical energy potential in a manner that guarantees continuity of supply at the cheapest price.
5	Niger Dams Authority	1962	Charged with the responsibility for developing Nigeria's hydropower potential
6	National Electric Power Authority (NEPA)	1972	T7his is a result of a merger between Niger Dams Authority and the Electricity Corporation of Nigeria. It had the responsibility for the provision, operation and maintenance of electrical infrastructure across Nigeria.
7	Energy Commission of Nigeria (ECN)	1978	Charged with the responsibility for strategic planning and coordination of national energy policies.
8	Power Holding Company of Nigeria (PHCN)	2005	Established as a holding company to pave the way for the liberalization and privatization of national electricity assets
9	Rural Electrification Agency (REA)	2006	Promote and coordinate rural electrification programmes in Nigeria
10	Nigerian Electricity Regulatory Commission (NERC)	2007	A regulatory agency for the electrical power industry that is charged with issuance of licenses, permits to market participants and regulatory compliance
11	Nigerian Electricity Management Services Agency (NEMSA)	2015	Enforcement of Technical Standards and Regulations; Testing and Certification of Electrical Installations, Meters and Instruments, to ensure safety and reliability of electrical power supply in the Nigerian electricity supply Industry.

5.2 Regulatory interventions and energy systems change

Analysis of archival record shows that most energy systems interventions that happened after the establishment of the Nigerian Electricity Regulatory Commission (NERC) took the form of regulatory interventions. The NERC has been the major umpire responsible for the preparation and enactment of various regulations in Nigeria's electricity sector. The Electrical Power Sector Reforms Act (EPSRA) enacted in 2005 empowers the NERC to intervene in addressing issues in Nigeria's electricity sector through various forms of regulations [40]. Indeed, since 2007, most energy systems change experienced were influenced by regulatory interventions through the NERC.

The first major regulatory intervention by the NERC was the provision of a framework for the issuance of permits to market participants interested in captive power generation. This regulation was enacted in 2008. Captive power plants are plants of over one-megawatt (1MW) capacity whose generated power is consumed by the producer. In 2012, two important regulations were introduced to address some salient issues, the embedded generation regulation and the independent electricity distribution network regulation. Embedded generation is simply electricity generation that is connected to the distribution network rather than the high voltage transmission grid.

The embedded generation regulation paved the way for private sector participation in small scale electricity generation plants (mostly less than 20MW) that addresses the needs of some large residential estates, industrial hubs and business clusters. However, considering the possible bureaucracy in actualizing the aims of this regulation under the existing infrastructure ownership framework, the NERC enacted the independent electricity distribution network regulation. This regulation consists of a framework that enables the issuance of permits to market participants interested in the development and operation of independent distribution networks. In reality, most players in the embedded generation market also applied for permits to construct and manage their distribution network in order to ensure continuity of supply to their customers.

In 2014, the NERC released two regulations that stipulate the local content requirements in Nigeria's electricity sector and a regulation that stipulates the requirements for the purchase of additional electrical generation capacity. This was shortly followed by four regulations in 2015 addressing some salient market issues. These are

1. Electrical network investment regulations, which stipulates the procedures and incentives for investments in electrical network capacity expansion
2. Electrical supply and installation regulatory standards, which defines the requirements and standards for electrical network equipment and installation procedures for Nigeria
3. Smart metering regulations, which outlines the requirements for metering systems in Nigeria's electrical supply industry
4. Feed-in tariff for renewable energy sources, which stipulates the procedure for purchase of renewable energy by wiling off-takers and how to connect it to the grid.

The minigrid regulation was released in 2016 with the aim of enabling the development of stand-alone (isolated infrastructure) or interconnected with existing electrical generation and distribution infrastructure. The permitted infrastructure capacity must be less than 1MW. In 2017, a regulation stipulating the conditions for eligibility of customers to qualify for a direct purchase of electricity from generation companies was enacted. With this regulation, large manufacturing plants could go into direct purchase agreements with electricity generation companies.

In 2018, the metering asset provider regulation was enacted. This regulation was aimed at addressing the metering infrastructure deficit for most energy consumers. It also targets to eliminate the case of estimated electricity billing. The involvement of private investments in metering services was aimed at accelerating the rollout of meters to end users.

As already outlined, regulatory interventions have been used more within the past decade to address evolving market issues in Nigeria's electricity supply industry. Table 5 shows a summary of the various forms of regulatory interventions/policy levers used, year of promulgation of the policy levers and the targeted objectives from 2007 to 2018. Indeed, institutional and regulatory interventions have been a dominant feature of the development trajectory of the Nigerian electricity supply industry.

6. Who knows whom? Stakeholder network grid in Nigeria's electricity sector

Stakeholder relations play a very vital role in forging relationships of mutually beneficial connections of

Table 5: Summary of historical regulatory interventions in Nigeria's electricity sector

s/n	Regulatory interventions	Year	Key objectives of regulatory interventions
1	Electric Power Sector Reforms Act (EPSRA)	2005	This is the primary legislation that governs the Nigerian electricity supply industry and its entire value chain (generation, transmission, distribution and utilization of electrical energy). It also establishes the Nigerian Electricity Regulatory Commission (NERC) to take charge of licensing and regulation of market participants in the industry
2	Permit for Captive Power Generation Regulation	2008	Provides a framework for issuance of permits to qualified operators of captive electrical power in Nigeria. Also ensures compliance to set standards.
3	Embedded Generation Regulation	2012	Provides a framework for issuance of licenses and permits to qualified operators of embedded electricity generation in Nigeria. Also ensures compliance to set standards.
4	Independent Electricity Distribution Networks Regulations	2012	Provides a framework for the issuance of licences to qualified operators to engage in electricity distribution, independent of the already existing successor distribution companies, and to ensure compliance with set standards
5	Regulations on National Content Development for the Power Sector	2014	Targets the promotion and utilization of Nigeria's human and material resources, goods, works and services in the industry as well as building capabilities in Nigeria to support increased investment in the industry
6	Regulation for the Pr8ocurement of Generation Capacity	2014	Provides and defines the process to be used by a buyer in procuring additional electricity generation capacity.
7	Regulations for the Investment in Electricity Networks	2015	Defines the procedures for investment in Nigeria's electricity networks. It aims to create incentives to encourage the transmission and distribution companies to make sustainable investments in electricity capacity expansion
8	Nigerian Electricity Supply and Installation Standards Regulations	2015	It contains a compendium of standards for the design, construction and commissioning of electrical infrastructure in Nigeria's electricity supply industry.
9	Nigerian Electricity Smart Metering Regulation	2015	This is a technical regulation that applies to all licensees deploying smart metering. It outlines the requirements for a smart metering system in Nigeria's electricity supply industry.
10	Feed-in Tariff for Renewable Energy Sourced Electricity in Nigeria	2015	This regulation estimates renewable energy tariffs. It allows for renewable electricity capacity to be bought by willing off-takers and connected to the grid
11	Mini Grid Regulation	2016	It allows for the development of integrated electricity generation and distribution supply systems less than 1MW. This can be achieved either as an isolated infrastructure or connected to existing distribution infrastructure
12	Eligible Customer Regulations	2017	This outlines the terms and conditions guiding direct purchase of electricity by end-users from generation companies
13	Metering Asset Provider (MAP) Regulations	2018	Targeted at closing the metering gap, eliminate estimated billings and promote private investments by providing for Meter Asset Providers (MAP) who offer metering services to assist in accelerated rollout of meters to end users.

Table 6: Stakeholder network grid in Nigeria's electricity sector

	Stakeholders	Relations													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Grid connected generation companies	V		V		V					V				
2	Private generation companies		V										V		
3	Transmission company	V			V	V									
4	Distribution companies	V		V	V	V					V		V		
5	Nigerian Electricity Regulatory Commission	V	V	v	v		V	V				V	V		
6	Rural Electrification Agency					V		V	V	V	V			V	
7	Development corporations (GIZ, DFID, USAID, JICA, etc.)					V	V						V	V	V
8	International financiers & donor agencies (World Bank, AfDB, etc)					V	V						V		
9	Electrical Network Installers						V						V		
10	Original Equipment Manufacturers of electricity assets				V		V			V		V			
11	Electricity appliance distributors and retailers									V			V		
12	Electricity end-users					V									
13	Electricity/energy and environmental advocacy groups					V		V		V		V		V	V
14	Non-governmental organizations							V						V	V

LEGEND

V	High/Strong
V	Medium/moderate
V	Low/weak

common interests among industry players in a given sector. Within the Nigerian electricity sector, stakeholder relations are forged among groups with common interests to influence decision outcomes that favours those involved. Table 6 shows a stakeholder network grid highlighting the stakeholder relations among stakeholders in the centralized and decentralized space of the Nigerian electricity sector. The degree of stakeholder relations (as shown in table 6) ranges from low (weak) to high (strong). The strength of the stakeholder relations is dependent on the (complexity of the) common objective to be achieved and the role of the individual stakeholder in shaping the desired outcome.

Our study reveals that the stakeholder relations among industry players in the centralized grid electricity space in Nigeria's electricity sector are much stronger than the decentralized electricity space. A major factor responsible for this is that the centralized electricity space is more regulated, with well-defined regulatory tools and instruments governing the affairs of various stakeholders and mode of infrastructure interventions. Indeed, to effectively complete a project in the centralized electricity space, there necessarily must be some sort of interface between at least two stakeholders which oftentimes results as an unintended consequence of the regulatory tools and policy levers in place.

In the decentralized electricity space, stakeholder relations are weaker. This is partly due to the weak regulatory regime in place. There are less policy levers and regulatory tools governing the affairs of the various activities in the decentralized electricity space. Indeed, the Nigerian Electricity Regulatory Commission (NERC) only provided guidelines defining the minimum requirements that must be met in order to proceed with certain decentralized electricity projects. A good example is the solar minigrid regulation, which defines the minimum requirements to deploy a solar minigrid of various capacities. In this way, projects may be executed by a single stakeholder as long as the minimum requirements are met.

7. Interest vs influence: Stakeholder mapping of key players in Nigeria's electricity sector

In this section (following our analysis) we show and categorize the various stakeholders based on their degree of interest and influence in shaping decisions in Nigeria's electricity sector. This is done by creating an interest-influence stakeholder map of industry players in Nigeria's centralized (see figure 1) and decentralized (see figure 2) electricity sector. The mapping shows the dynamics and interplay between and amongst industry

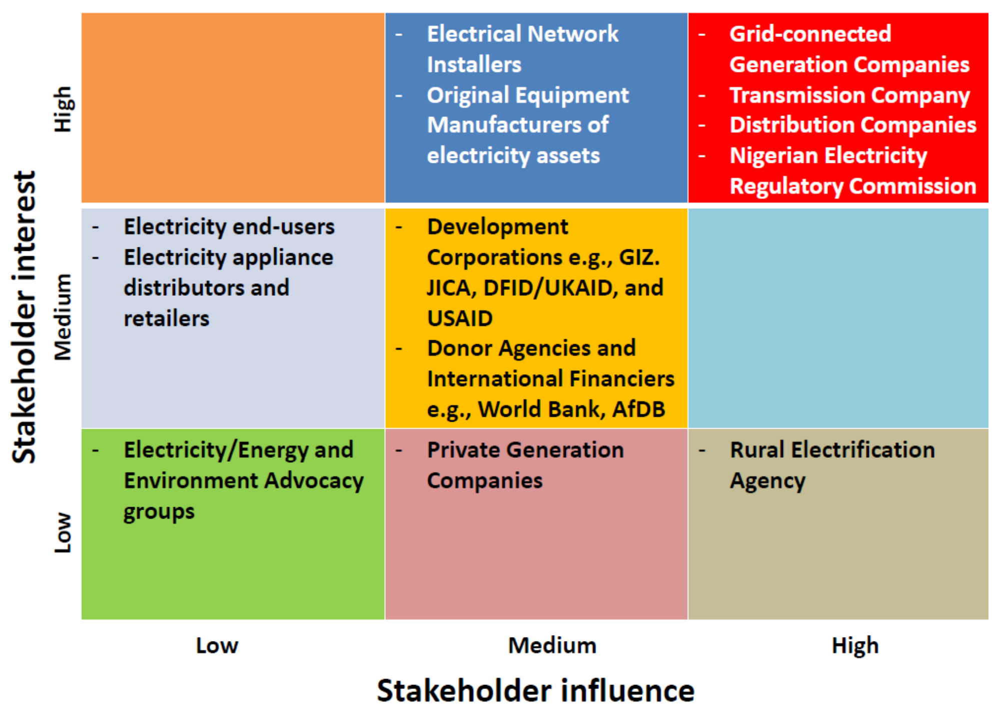

Figure 1: Stakeholder mapping of Nigeria's centralized electricity sector.

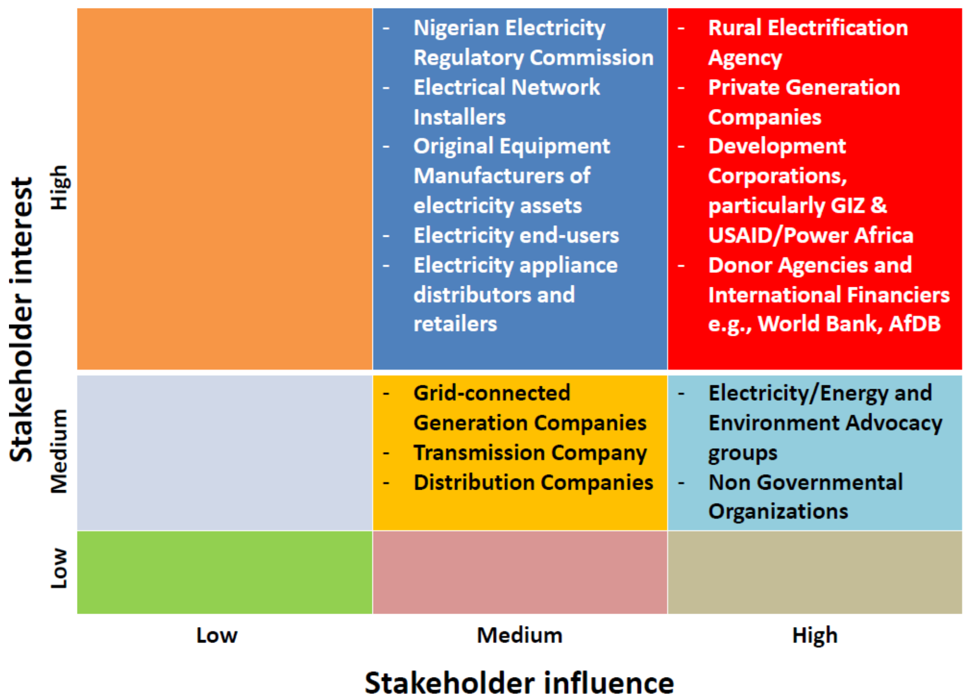

Figure 2: Stakeholder mapping of Nigeria's decentralized electricity sector.

players based on the degree of stakeholder interest and influence.

Within the centralized electricity space, stakeholder interest and influence is highly dispersed, varying from low to high. This interest-influence variation among different stakeholders is shaped by the regulatory regime governing their activities and the necessary procedures that must be adhered to in addressing grid-connected electricity infrastructure challenges. Indeed, following our analysis and findings, there must necessarily be some sort of connection, interface or handshake between (at least two) stakeholders before any grid-connected infrastructure project/challenge can be addressed or completed based on the current regulatory regime for grid connected electricity infrastructure.

Our study and analysis reveals that the stakeholder interest-influence dynamics is quite different within the decentralized electricity space. It is more concentrated, with various stakeholders operating between medium to high on the interest-influence scale as shown in figure 2. The study also reveals that a major factor that increases the interest-influence appetite of stakeholders in the decentralized electricity space is that projects can begin and get completed by a single stakeholder without necessarily interfacing with another stakeholder. For example, a single stakeholder can design, install, market and sell solar home systems or complete a solar minigrid project without necessarily interfacing with other stakeholders in the process (as long as the minimum technical standards and guidelines are met). This is possible because there are no stringent regulatory tools in the decentralized electricity space as much as is currently available in the centralized grid system.

8. Discussion

From this study, it is evident that there is a need to ensure that approaches to addressing supply-side energy issues follows that path of participatory governance with key stakeholders and policy actors at various levels to achieve desired outcomes [55,56]. Indeed, Bell and Gill argued that it is necessary to address technical, policy and regulatory challenges associated with delivering a highly distributed electricity system [57]. They further argued that: respect for the technical limits of systems to ensure their operability; developing well designed support mechanisms for innovation; and the proper assignment of risks to the different stakeholders and market actors are crucial challenges that must be surmounted [57]. The governance of power networks is being challenged by the ongoing energy transition which points to a need to amend regulatory interventions to tackle innovation and transition [58].

Within the Nigerian context, government interventions have played a major role through institutional and regulatory interventions [22,34,59]. This also continues even after the partial liberalization of the electricity market [41]. The need to improve customer protection, facilitate sustainable development and address market failures, among others, are some reasons necessitating supply-side policy interventions in the electricity sector [60–62]. .

Indeed, some supply-side policies focus on product markets, designed in a manner to make them either more competitive or contestable which is geared towards stimulating a faster pace of invention and innovation [63]. This is important if we are to address some implementation challenges. For example, how do we reduce unintended consequences? Can policies around electricity infrastructure be more decentralized and polycentric? How do we address the dangers of policy somersault for future electricity planning as is common in many developing country contexts?

Another factor to consider is the need to redefine the pattern and scale of interventions and the stakeholders required to achieve it [12,64]. This begins with the reconfiguration of scale and patterns of interventions which leads to a need to answer some important questions [12,65]. Should policy and/or regulatory interventions be done at municipal, sub-national or national levels? Indeed, there is a need to evaluate the role of policy interventions at different scales because implementation dynamics and stakeholders differ at different levels. Culture and social ethos also affect the nature of interventions provided because some cultural practices pose some implementation challenges to energy infrastructure provision [66].

9. Conclusion and policy implications

This study brings to the fore some important issues for consideration. First, many historical energy systems issues in Nigeria's electricity sector have been addressed through (institutional and regulatory) interventions shaped by different multi-level actors. Secondly, since the needs of communities may vary, there is a need to consider the scale of interventions that addresses the energy needs at sub-national levels by exploring the policy, regulatory and stakeholder dynamics within different energy geographies to help address implementation challenges. Thirdly, there is a need for a framework for deliberate stakeholder engagements to ensure that various interventions achieve its intended goals that yields multiple benefits in a sustainable way. Fourthly, there is a need to reconsider energy systems intervention approaches that consider the role of technologies, fuels, scale and pattern of activities of energy users. Lastly, the need to explore more options that addresses energy interventions issues on the demand-side is paramount for effective planning and provision of electricity supply infrastructure.

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