Exploring the connections between mini-grid market regulation and energy access expansion: The case of Nigeria

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Abstract

About 140 million people across Africa are expected to gain access to electricity from mini grids by 2040. Nigeria, with the least dependable electricity supply on the continent, stands to benefit significantly from this boon. Accordingly, the government has put in place clear regulations to incentivise private investment and drive market growth. While the techno-economic dimensions of the growing mini-grid sector and the broader electricity industry have been extensively studied, less attention has been paid to analysing the impacts of the regulatory framework on the achievement of rural electrification and universal energy access goals. Drawing on qualitative data obtained from key regulatory and market actors in the Nigerian mini-grid sector, this paper interrogates the premise of pursuing widespread rural electrification through a regulatory framework that is primarily geared toward increasing market efficiency. The study

finds that, while the current framework has enabled growth in the sector, complementary mechanisms are required to achieve equitable distribution of access, especially among the mainly rural populations dwelling on the fringes of mainstream electricity markets. The findings are instructive for practitioners and policy makers seeking evidence-informed approaches to achieving the goal of universal energy access in Africa.

Keywords: Africa, Electricity governance, Energy access, Mini grids, Nigeria, Rural electrification

1. Introduction

Significant progress has been realised in recent years toward fulfilling SDG 7 ("affordable and clean energy") and the UN Sustainable Energy for All mandate to achieve universal energy access by 2030. According to the International Energy Agency (IEA), there are 770 million people who do not have access to electricity - a statistic that, despite having fallen consistently since 2013, still sees nearly half of the population in sub-Saharan Africa (around 580 million people) being in that category (IEA, 2019). Moreover, the COVID-19 pandemic has hampered progress toward universal access in recent years, further reducing the likelihood of meeting the goal under business-as-usual scenarios (Cozzi et al., 2020).

It is widely agreed that closing the energy access gap in sub-Saharan Africa requires a socio-technical transition in which decentralised and off-grid renewable electricity generation, including mini grids, will play a critical role (Odarno et al., 2017; Peters et al., 2019). The IEA projects that by 2040, an estimated 140 million rural Africans might be supplied by 100,000–200,000 mini grids and an additional 80 million people could be reached by off-grid solutions (IEA, 2019). It is envisaged that these new technologies will replace, or at least compete with, the centralised power generation, transmission, and distribution infrastructure, which is mostly dependent on traditional thermal and large hydroelectric sources (Ockwell & Byrne, 2016).

Nigeria, with a population of around 206 million people, is expected to become the world's third-most populated country by 2050 (UNDESA, 2017). According to Power Africa (2022), around 60 percent of the country's population has access to electricity, with 86 percent of these living in urban areas and 34 percent living in rural areas. The country has the least dependable electricity supply on the continent, according to BloombergNEF (2019), with only a quarter of its installed capacity of 16,000 MW being utilised for generation, mostly from thermal and large hydropower sources (Edomah et al., 2021; Power Africa, 2022). Consequently, a large portion of the nation's electricity consumers—whether residential, commercial, or industrial—rely on pricey self-generation from small and medium-scale diesel generators (Saifuddin, et al., 2016). On the other hand, periodic increases in electricity tariffs are frequently met with public and labour union opposition, reflecting partly the majority's poor purchasing power but also public opinions of the power sector as being corrupt and overly bureaucratic (Edomah et al., 2021; Pallavi, 2020; Roche et al., 2020).[1]

In response to these challenges, the Nigerian government has announced plans to raise power production to 30,000 MW by 2030 and increase the share of renewables in the energy mix to 30 percent by that same year (Federal Ministry of Power, n.d.). Concrete developments on the ground seem to indicate some progress towards those targets. The country's off-grid solar sector is expanding, especially for solar home systems (ACE-TAF, 2022), and it has been named a "frontier" country in the sector due to the thoroughness of its mini-grid regulations, which cover matters like licensing, retail tariff setting, and preparations for the grid's arrival (ESMAP, 2019).

[1] In a recent development, the nongovernmental organisation Socio-economic Rights and Accountability Project sued the federal government over what it described as latter's failure to "reverse the illegal, unfair, and arbitrary increase in electricity rate and to investigate the spending of public funds as 'investments and bailouts' to DisCos (Distribution Companies) and GenCos (Generation Companies) since 2005" (Vanguard Newspapers Editorial, 2023).

According to Roche et al. (2020), solar-diesel hybrid mini grids and solar home systems will likely replace a substantial portion of the country's diesel generators, potentially providing electricity to as many as 42.9 million people, or about a fifth of the country's population (ESMAP, 2022). Taken together, these developments suggest that mini grids have the potential to revolutionise the field of affordable, pro-poor, low-carbon, universal electrification in Nigeria (Sesan, 2020). Pedersen (2016, p. 1) describes mini grids as "a third alternative to rural electrification, coming between the option of large-scale grid extension and pico-scale stand-alone solutions like solar home systems or solar lanterns". From an electricity planning perspective, these systems have particular appeal for historically hard-to-reach populations like those in informal settlements, dispersed locations, and/or remote locations where the cost of connection to the centralised national grid can be prohibitive. Mini grids can, in principle, help bridge the energy access gap by enabling locally generated and distributed renewable electricity tailored to the needs of local populations.

Notwithstanding these optimistic narratives, however, the deployment of mini grids poses significant governance, regulatory, and socioeconomic challenges. Indeed, mini-grid development has frequently occurred in the absence of regulation rather than as a result of it, and countries with low levels of electricity access and/or significant levels of inequality - many of them in sub-Saharan Africa - either lack defined rules for such integration or are still developing and revising them (Baker et al 2022; Antonanzas-Torres et al., 2021). This can create a situation in which the benefits of mini grids are unevenly distributed among different social groups, with those in the lower socio-economic classes unable to access the electricity generated due to poverty or lack of resources.

Against this background, our paper sets out to unpack the governance and regulatory context within which the mini-grid sector in Nigeria is developing. Through this study, we respond to calls from development and energy geographers for a more "refined categorisation and

contextualisation" of the decentralisation of electricity (Rothfuß & Boamah, 2020, p. 165), and a deeper understanding of the evolving conflict and co-existence between the extension of the national electricity grid and decentralised and off-grid systems (Jaglin, 2019; Jaglin & Guillou, 2020). These calls are, in turn, a response to existing scholarship on rural electrification and energy access in low and middle-income countries, which has been dominated by perspectives from engineering and economics and tended to privilege technological and financial enablers and barriers. Such perspectives have often focused on narrow definitions of "business models" (Muchunku et al., 2018; cf. Pedersen, 2016) rather than considering the political, economic and socio-cultural complexities of regulation and governance. As a result, and as Ahlborg (2017, 2018) argues, energy access interventions are too often framed as neutral welfare schemes when, in fact, they are inherently political. This is because in many cases, these interventions introduce large-scale changes to existing energy production and consumption patterns, which can often lead to power imbalances between social groups or classes.

In engaging with these debates, the paper asks the following questions: what governance and regulatory frameworks exist for the development of mini grids in Nigeria, and how do they combine with pre-existing frameworks for grid electricity to reconfigure patterns of access and distribution? In particular, to what extent have mini grids in the context enabled rural electrification, and what key governance challenges need to be addressed for more equitable access?

The paper is structured as follows. Section 2 situates mini grids within the broader context of the electricity sector, highlighting the changing orthodoxies within sub-Saharan Africa over time with regard to ownership and governance structures. Section 3 describes the approach taken to empirical research into the governance of mini grids in Nigeria, while section 4 presents the findings from the fieldwork conducted. Section 5 discusses the implications of the study's findings for the achievement of rural electrification goals in the country and universal access

goals more broadly. Section 6 concludes with recommendations for enhancing the inclusiveness of regulatory and governance structures so they can better serve the most vulnerable populations across the country.

2. Mini grids in the context of electricity sector governance

As a large-scale networked infrastructure and a complex, interconnected, and interactive system of artifacts and technologies (Hughes, 1983; Rip & Kemp, 1998; Smith et al., 2005), electricity is not easily governed. Electricity is subject to vested interests and uncertainty in the adoption of new technologies, and it is influenced by factors such as the nature of domestic, industrial, agricultural, and residential electricity demand, national varieties of capitalism, and national and sub-national governance systems (Baker et al., 2021).

In the first half of the twentieth century the electricity sector, in countries where it was established, was generally a state-owned, vertically integrated monopoly. This gave the government complete control over the production and distribution of electricity, including price regulation, aimed at preventing exploitation and promoting the role of governments as guardians of the welfare state (Sandmo, 1998). However, by the 1980s and 1990s, the “standard model” of power sector reform was established as a global blueprint, in keeping with the neo-liberal economic orthodoxy of the time. In developing countries, this model was promoted by the World Bank and related consultants and endorsed by other multi-lateral lending institutions as part of loan and debt relief conditionalities under structural adjustment programmes (Baker et al., 2022). The model was informed by the experiences of a small group of countries including the USA, UK, Norway and Chile and followed the assumption that state ownership was unable to meet the high levels of investment required by the electricity sector (Gratwick & Eberhard, 2008). According to such an assumption, state-owned utilities should therefore be unbundled into private generation, distribution and transmission companies, with a significant role for

wholesale markets and ultimately, retail competition (A. Sen, 2014). The creation of a strong independent regulator to “regulate the monopoly prone parts” of the industry was also prescribed (Victor & Heller, 2007, p. 7).

Despite the apparent simplicity of the standard model, its implementation was more complex in practice, resulting in various forms of failure, partial implementation, and stranded assets from surplus generation capacity. Given the role of the centralised electricity sector as a strategic source of “revenue, political power, and influence,” these donor-driven power sector reforms have often faced resistance from various government departments (Godinho & Eberhard, 2019, p. 10). The model has also been criticised for making broad assumptions about the state's ability to implement it and attract investment, regardless of country context (A. Sen, 2014). In addition, national regulators have rarely been as empowered per the model’s prescriptions, have faced significant political challenges, and have struggled to negotiate the complex contractual and regulatory terms of power sector liberalization (Baker et al., 2021). This implies that the centralised standard model of electricity sector reform is not a one-size-fits-all solution but requires a nuanced approach, acknowledging the geographical, political, and social contexts in which the reform will take place (Foster & Rana, 2020).

While many principles of electricity liberalisation remain influential, other socio-technical dynamics have come into play in recent years, not least the deployment of renewable electricity at multiple scales, including that of mini grids.[2] This deployment has been accompanied by the emergence of new players and the reconfiguration of old ones; changes in national electricity policy, planning, and regulation; and shifting trends in global investment and technological

[2] Despite a diversity of definitions, the term mini grid refers to a low-voltage or medium-voltage generation and electricity distribution network which can operate in isolation from the main grid, but also connect to it should the network expand (Tenenbaum et al 2014). The nature of a mini grid is such that power can be generated much closer to the point of consumption, thereby reducing the probability of service failure and energy losses often experienced on the distribution or transmission network.

innovation, all of which are fundamentally reshaping the electricity sector (Baker et al 2022). Developments in decentralised and off-grid renewable systems in particular mean that electricity can now be generated and accessed without the centralised mediation of the transmission or distribution grid (Brisbois, 2020). Debates over the governance of electricity have therefore gone beyond the simplified dichotomy of state versus market to include competition and co-existence between different scales and configurations of centralised and decentralised electricity (Baker & Phillips, 2019).

In many sub-Saharan African countries, there are growing tensions between, on the one hand, incumbent utilities (state-owned and otherwise) largely dependent on conventional technologies, and on the other hand, new institutions and actors in the renewable energy space which are often private-sector led. The latter largely embody a shift to solar-powered or “third-generation” mini grids (ESMAP, 2019, p. 26), as distinct from the large hydro and diesel-powered mini-grid schemes from earlier generations led by utilities in countries like Kenya and Tanzania. This shift toward decentralised renewable mini grids, which began in Kenya in 2011, is now evolving elsewhere on the continent (Pedersen & Nygaard, 2018).

Mini grids have been conceptualised as a “disruptive innovation” (Verbong & Geels, 2010) given their potential to radically change the way in which electricity is produced, consumed, purchased, regulated, financed, paid for and owned. Because they are technologically flexible and modular, mini grids can cater to needs at multiple scales, from basic services such as lighting, mobile phone charging and small appliances, e.g., fans and radios; to productive uses such as grain milling, water purification and fish drying; and institutional electricity needs, for example, schools, clinics and businesses.

Indeed, the potential of third-generation mini grids is often discursively pitted by the mini-grid industry against that of the ageing, indebted, corrupt, capital-intensive, inefficient, vertically

integrated, state-owned utility, supplying an increasingly expensive and unreliable source of electricity, from coal, gas-fired or large hydroelectricity, to a low-consuming user base (AMDA, 2020; Trimble et al., 2016). Such a discourse is accompanied by the assumption that the dynamism of the private sector (New Climate Economy, 2018) and the creative financing that dismantles market constraints (Wohlgemuth & Painuly, 1999) can push forward the roll-out of renewable electricity generation and distribution at scale.

Some of these dynamics are at work in Nigeria, where extensive electricity sector reforms resulted in the unbundling of the erstwhile state-owned grid utility into generation companies (GenCos), distribution companies (DisCos) and a national transmission company by the 2005 Electric Power Sector Reform Act (EPSRA) (Edomah, 2018). Much of the literature on the governance of the sector focuses on the structure of this large-scale networked system, with little reference to what obtains outside the grid (Babatunde et al., 2023; Chukwujindu et al., 2021; Edomah et al., 2016, 2021; Nwozor et al., 2021; Pavanelli et al., 2023). The studies that do explore mini-grid development in areas unserved by the national grid largely focus on issues related to the optimisation of power generation, auction systems, and market development (Arowolo et al., 2019; Azimoh & Mbohwa, 2019; Lane et al., 2018; Yakubu et al., 2018), with little reference to the governance context that defines the remit of actors in the sector.

The dearth of literature on the governance of mini grids in Nigeria is incongruent with the reality of the country's status as a leading market for mini grids in Africa, having developed frameworks to support private-sector investment and prescribe grid-compatible technical standards (ESMAP, 2019). These frameworks are encapsulated in the much-lauded Regulation for Mini-grids 2016, which sets clear guidelines for deploying mini grids of varying sizes (up to 1 megawatt) and configurations (i.e., isolated or interconnected with the national grid) (Regulation

for Mini-Grids 2016, 2017).[3,4] The perceived market-friendliness of the regulatory climate has spurred a flurry of activity on the ground: according to (ESMAP, 2022), 2,700 third-generation mini grids were planned for the country as of that year.

The underrepresentation of mini grids in the discourse on electricity regulation is consequential in universal access terms, not least because it has largely obscured the primary role of the Rural Electricity Agency (REA) - an implementation arm created by the same power sector liberalisation process that established the commercially oriented GenCos and DisCos - in expanding access to unserved and underserved areas. In light of the complexity of institutional arrangements in the sector, it is essential to scrutinise the roles and interests of key actors, with a view to understanding how they converge or diverge to shape the realities of mini-grid expansion and access for local populations.

Drawing on data from qualitative research conducted in Nigeria, our paper interrogates aspects of the governance and regulatory landscape as they have enabled the development of the mini-grid sector in some ways and constrained it in others. Importantly, the disparity between the capabilities of DisCos, the substantive “last-mile” operators per the provisions of the 2005

[3] Notwithstanding the date indicated in the title of the regulation (i.e., 2016), it was ratified by the Nigerian Electricity Regulatory Commission in 2017.

[4] Under the regulation, mini grids of 1 MW or below may either be isolated, to be deployed in an area within a DisCo’s network where there is no existing distribution system or interconnected to a DisCo’s network in an underserved area. In the case of the latter, operators must enter a tripartite contract with the community and the DisCo and gain the approval of the Nigerian Electricity Regulatory Commission (NERC). There are different requirements for different sizes of mini grid, as follows: i) projects below 100 kW are only required to obtain a simple registration with NERC but may still choose to obtain a permit voluntarily because this will qualify the project for exit compensation should the distribution grid arrive; ii) projects between 100 kW and 1 MW must obtain a permit and adhere to minimum network technical and safety standards. Should the main distribution grid arrive and displace the mini grid’s operations, the permit holder will then be entitled to compensation equivalent to the depreciated value of the mini grid’s network investment, plus one year’s worth of revenue; and iii) generation projects larger than 1 MW are governed by the provisions of the 2005 EPSRA.

EPSRA, and the constraints highlighted by relevant provisions of the 2016 Regulation for Mini-grids will be discussed, as will the implications of the status quo for rural electrification in Nigeria. First, though, we describe the approach we took to framing our inquiry and conducting fieldwork in-country.

3. Methods

This study relied on both secondary and primary sources of data. Secondary data were obtained through an in-depth review of the academic and grey literatures, including reports published by international institutions such as the World Bank, the United States Agency for International Development, the International Renewable Energy Agency and the International Energy Agency; national policy and other government documents; civil society reports; and national and international media sources.

Primary data were gathered mainly through key informant interviews. A total of 15 in-depth interviews were conducted between March and September 2022 with government officials, the independent electricity regulator, mini-grid developers, representatives of distribution companies and development finance experts. Interviewees were selected purposively, based on their role in their respective institutions and their positioning in the Nigerian Electricity Supply Industry more broadly. In line with the requirements of the ethical approval obtained for the study, all interviewees were provided with an information sheet detailing the aims of the study and their right to voluntary consent and participation.

Detailed interview guides were prepared for each interviewee category. With the exception of one case which allowed for a face-to-face interview, all the interviews were conducted virtually and audio-recorded. All the interviews were fully transcribed – a process which, Rohman and Rita (2013) assert, is crucial for gathering accurate data because it encourages greater conversation with the interviewee, improves data quality, better listening and concentration, and

the ability to resist the urge to omit or edit out some essential information. This is especially important if, as in our case, the interviewer is familiar with the situation and is therefore prone to assuming that certain details are “known” (Rutakumwa et al., 2020).

The data were coded and analysed using a structured and rigorous collaborative qualitative analysis approach (Richards & Hemphill, 2018). First, the interview transcripts were studied in detail to enable a fuller grasp of the data as a whole. Following this, a preliminary “global” codebook with themes, codes and corresponding definitions was produced from the literature review conducted in earlier phases of the study. This codebook was then iteratively refined to emerge with a grounded version that more adequately reflected the granularity of the primary data gathered. The codes that were generated for the governance and political economy theme through this process included: political context; institutional and regulatory context; macroeconomic conditions; global trade and supply chain issues; public/private/community ownership; tariff setting; technical standards; grid compatibility; and licensing regulations. It is worth noting that our analysis does not engage with individual provisions of the regulatory code, given that the focus of the paper is on the dynamic interplay between the regulatory regime and the market environment it has created, rather than on linking particular provisions to specific market outcomes. The latter would be a fruitful subject for further enquiry.

The findings reported below have been anonymised to protect interviewees’ confidentiality. Where direct quotes are used, the attribution is just sufficient to establish the context of each quote without revealing any identifying information about the interviewee involved.

4. The intersection of mini-grid regulation and market development in Nigeria

“The market mechanism is as good as the company it keeps.” - Sen (2015, p. 126)

This section discusses empirical findings from our inquiry into the regulation and governance of mini-grid development in Nigeria. The findings show how the local mini grid market has grown alongside, but not necessarily in tandem with, regulatory activity in the sector, with developments in both areas converging and diverging at different points along the way. In particular, Figure 1 shows the growth in electricity supply from third-generation mini grids, typically powered by renewable sources (solar, wind, hydro, biodiesel and biogas) – with backup provided by fossil fuels – from 2017 to 2022. This is distinct from an earlier spike between 2001 and 2005 that was fuelled by the installation of high-capacity gas-powered plants in a handful of states in the country.

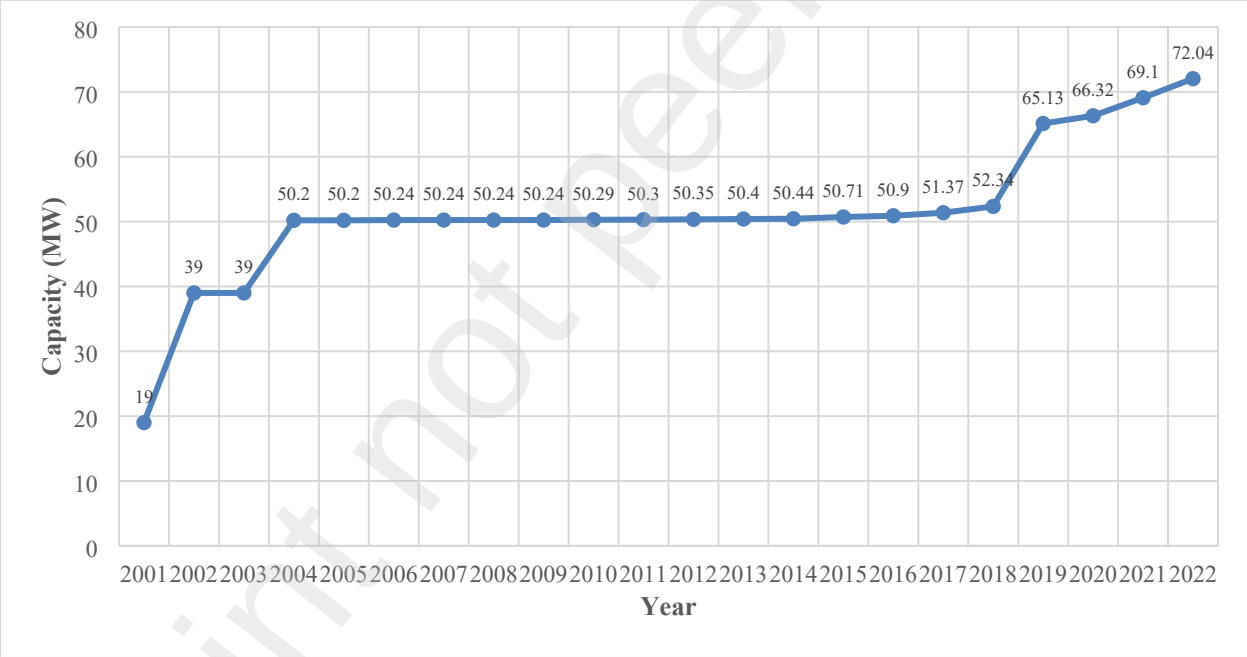

Figure 1. Growth in power output from operational mini-grids in Nigeria, 2001–2022. Source: Dataset compiled by authors (see Appendix A).

While the valorisation of private-sector investment and ownership models for the acceleration of third-generation mini grids has turned out to have some merit in the Nigerian case, this growth

has occurred under specific conditions, and challenges remain that indicate the need for a more holistic and integrated regulatory response. Three key points stand out for our analysis:

1. The growth of the mini-grid market in Nigeria predates regulation and associated development finance, but it has subsequently been shaped by these factors.
2. The advent of regulation and investment has helped to accelerate the activities of market actors, but winners and losers have emerged in the process.
3. The premise of electrifying last-mile communities through improved regulation and investment for mini-grid expansion is not aligned with institutional and financial realities.

4.1 The growth of the mini-grid market in Nigeria predates regulation and associated development finance, but it has subsequently been shaped by these factors

In recent times, the Nigerian mini-grid sector has experienced an increase in interest from various stakeholders, including development finance institutions, donors, investors, and local entrepreneurs. This increase has been driven by a combination of policy changes, technological advances, and greater national commitment to rural electrification.

The development of the local mini-grid market began in the mid-1990s when international companies such as German multinational Siemens began installing solar PV systems in Lagos, Nigeria's commercial capital. These companies brought in the funding and technology needed to create a mini-grid market, increasing the viability of solar energy options locally. Indigenous companies soon began to follow suit and quickly garnered substantial shares of the local market. These indigenous companies, mainly startups launched by a handful of enterprising individuals, were key to the early domestication and spread of the technology, at least for niche uses:

> "Then, it was only Siemens in Oshodi and a few others that were doing solar in Nigeria. Siemens and Solarmate at Yaba. Solarmate started in 1996. So, he was

like a father to us. We converged there to buy materials in 1997, 1998 and 2000. In 2004, we incorporated as a limited liability company because most of those Siemens businesses pulled out of Nigeria. So, they subcontracted most of us and what we did was to incorporate so they could give us a maintenance contract. In those days the places you see solar panels are either in NGO-run hospitals or [telephone-company] base stations. There are these [telephone-company] base stations that have solar panels and that is part of the projects we did then."

- Project Developer_Company 1_CEO

While the element of cooperation between international and local companies was conducive to early market penetration, it was the entrepreneurial drive of the latter that led to the expansion of the market and helped foreground the economic and social development opportunities presented by solar energy technologies.

In particular, local entrepreneurs, by dint of experience and foresight, were quick to see the value proposition of deploying solar energy technologies in off-grid rural areas. The combination of technical expertise and knowledge of the context put them in a position to adapt existing technologies to the realities of local conditions. Early community-scale projects implemented with the support of development partners such as GIZ revealed the need to build delivery models that encouraged cost recovery and therefore had a higher chance of achieving financial sustainability:

"We pioneered mini-grids with meters in 2010 in Onitsha with UNDP where we did the first mini-grid that was metered. They found out that the market was large but the bottleneck was energy to automate production. So, there is a lot of [animal] hide coming from Kaduna, there are willing hands to work, there is demand, but they can't produce at pace and that is where the idea came up to do a mini-grid. Then a

sustainable plan beyond UNDP came up. How do we run it in a sustainable way? It means someone had to pay for it so that the money could be used to run the system. That is how we started talking about how to meter the system. So early in those days, there were no mini grids and that is how we started mini grids."

- Project Developer_Company 1_CEO

The market ambled along with very little support until the ratification of the Regulation for Mini-grids by the independent Nigerian Electricity Regulatory Commission in 2017, at which point the economic incentive to invest in mini grids increased significantly. The regulation provides a legal framework for local developers and investors to accelerate the provision of mini-grid electricity to rural areas not served by the national grid. Importantly, it clearly outlines terms and requirements for the participation of all the actors involved. For example, it stipulates varying degrees of accreditation and compliance for different levels of investment in a bid to lower barriers to entry for smaller electricity generators. This approach enables developers to set cost-reflective tariffs and ensures that they do not take advantage of their customers by charging higher tariffs than is necessary.

Provisions like this encouraged local developers, including some of the early comers to the market, to scale up their investment in mini grids in the aftermath of the regulation. On the whole, developers agree that the regulation has provided clarity on the roles and responsibilities of stakeholders, set the rules for the operation and management of mini grids, and helped create an enabling environment for private sector investment, even if areas of uncertainty remain:

"...we are coming full circle where we have given this permit and we are testing the waters with coming to see the quality of the regulatory environment because investors come in and do their due diligence; that is where you put those documents

to test. So, we are having a lot of tweaking, here and there, trying to adjust the documents to suit investors' appetite so that it can be a broadly accepted document, not just locally but within. But with some untested provisions... There are still some grey areas that need to be worked out to align with what investors would be comfortable with."

- Project Developer_Company 1_CEO

Concurrently with the introduction of the Regulation for Mini-grids, the Nigerian government secured major development financing for the sector in the form of a joint USD 550 million loan from the World Bank and the African Development Bank. Termed the Nigeria Electrification Project (NEP) and launched in 2018, the intervention extended technical advice and credit to the country's Rural Electrification Agency (REA) which, in turn, awarded performance-based grants to private companies for the development of off-grid electrification projects in rural areas.[5] A key goal of the project was to prime the pump investment-wise and consequently catalyse the growth of the mini-grid market in the country. The NEP funding was closely tied to the development of the Regulation for Mini-grids, in which the World Bank played a major role:

"You recall the regulator, five or six years ago, approved the Mini-grid Regulation, so that was actually the work that we did behind the scenes to support that process… we came in and advised on how to expand access more efficiently, which is by categorising these customers to unserved and the underserved, and then try to see those customers that are not within the coverage of the distribution companies, and then work possibly on what the regulation can actually do to create this framework that would allow mini-grid developers to extend access to them. Those were the contributions we made..."

[5] The World Bank has published detailed information on the Nigeria Electrification Project here: https://projects.worldbank.org/en/projects-operations/project-detail/P161885

- DFI_World Bank_Energy Specialist

According to ESMAP (2022), the NEP constitutes the largest mini-grid programme in Africa with a target of 850 projects and an approximate capacity of 3,000 MW across 250 sites by 2025. Market orthodoxy has featured strongly in the design and implementation of the NEP - an unsurprising outcome given the neoliberal underpinnings of the development finance institutions supporting the scheme. So far, the project's hopes of encouraging market growth through initial seed investments appear to have materialised to a degree, at least according to some developers:

> "Then, for the NEP, we have well over 20 projects. We have signed a grant agreement for 14. We have completed 6 and 8 are under construction at the moment. So that is where we are. Out of the 6 projects, 4 are here in Abuja and 2 are in Niger State. This is for the completed projects. We are building 8 more and out of 8, 2 are currently at an advanced stage so we are at different levels of construction and operation under the NEP projects."
>
> - Project Developer_Company 1_CEO

> "I think to date we have four projects operational and by the end of this month we will be commissioning an additional 26, making the total mini-grids we have in the country to about 30, serving about 200,000 people across those 30 communities… Last year, we closed about $4.6million to build the additional 26 projects which we are about completing."
>
> - Project Developer_Company 3_CEO

The upshot of the above is that the regulatory environment has helped to grow the mini-grid market, with small- and medium-scale developers moving from simple Engineering,

Procurement and Contracting models in the early days to relatively sophisticated micro-utility models that are more conducive to financial and technical sustainability. As the paper goes on to show, however, this market growth has not occurred evenly, with implications for the country's ability to meet the goal of expanding electricity access to rural areas.

4.2 The advent of regulation and investment has helped to accelerate the activities of market actors, but winners and losers have emerged in the process

The previous section showed how the Nigerian mini-grid market grew from the efforts of a handful of bootstrapping entrepreneurs to become a burgeoning sector supported by a robust regulatory framework and development financing over the course of two decades. This section elaborates on how the gains resulting from this process have not been distributed as evenly as may be required to achieve the kind of broad market participation envisaged by regulatory and finance actors in the context.

Mini-grid investments in the Nigerian context are generally perceived as risky and challenging due to a host of unfavourable macroeconomic factors. These factors include a weakening local currency, fluctuating exchange rates of the Naira against other currencies, rising inflation and lack of clarity over tax regulation. These issues are particularly consequential for the mini-grid sector because it is heavily reliant on imported components, from the photovoltaic panels used for solar energy generation, to the batteries used for storage and the smart meters that enable transparent billing. In the absence of affordable local credit, many developers take on debt in foreign currency - usually US dollars - and find their loan amounts doubling or tripling in real terms over the space of a few years due to a steep decline in the value of the Nigerian naira, which is the currency in which their transactions are denominated (Oladipo & Ndigwe, 2022). In this kind of macroeconomic environment, only the most resilient developers survive - and these include several local companies (such as the ones referenced above) that struck out early and

were well positioned to seize the opportunity presented by the regulatory and financial incentives introduced to catalyse growth in the mini-grid market.

The drawback to this development is that it has essentially created a rather narrow pool of legacy “winners” who may be more concerned about protecting their advantage in the market than they are about expanding opportunities for others in the sector:

> “So, I came up with, okay, let's develop a site selection criteria framework, whereby any new entrant that comes into the business will not make the same mistake the pioneer developers made… So we did that and we spoke to everybody. But what we saw was the big guys would say no, that they already knew these things. I said, yes, fine you guys are the big guys, but there are new people coming into the sector, they have not experienced what you've experienced. They will need a guide or a tool or something that will help them know. So yes, there will always be people that will think that a generic [framework] is not the best idea, because when I spoke with some developers, they did not want to share theirs. They felt it was their intellectual property...”
>
> - Business Developer_Company 1_Consultant

On the other hand, there is the broader question of why the DisCos, with their assumed power of incumbency and wide geographical coverage (see Figure 2), have not played a more prominent role in the current mini-grid era.

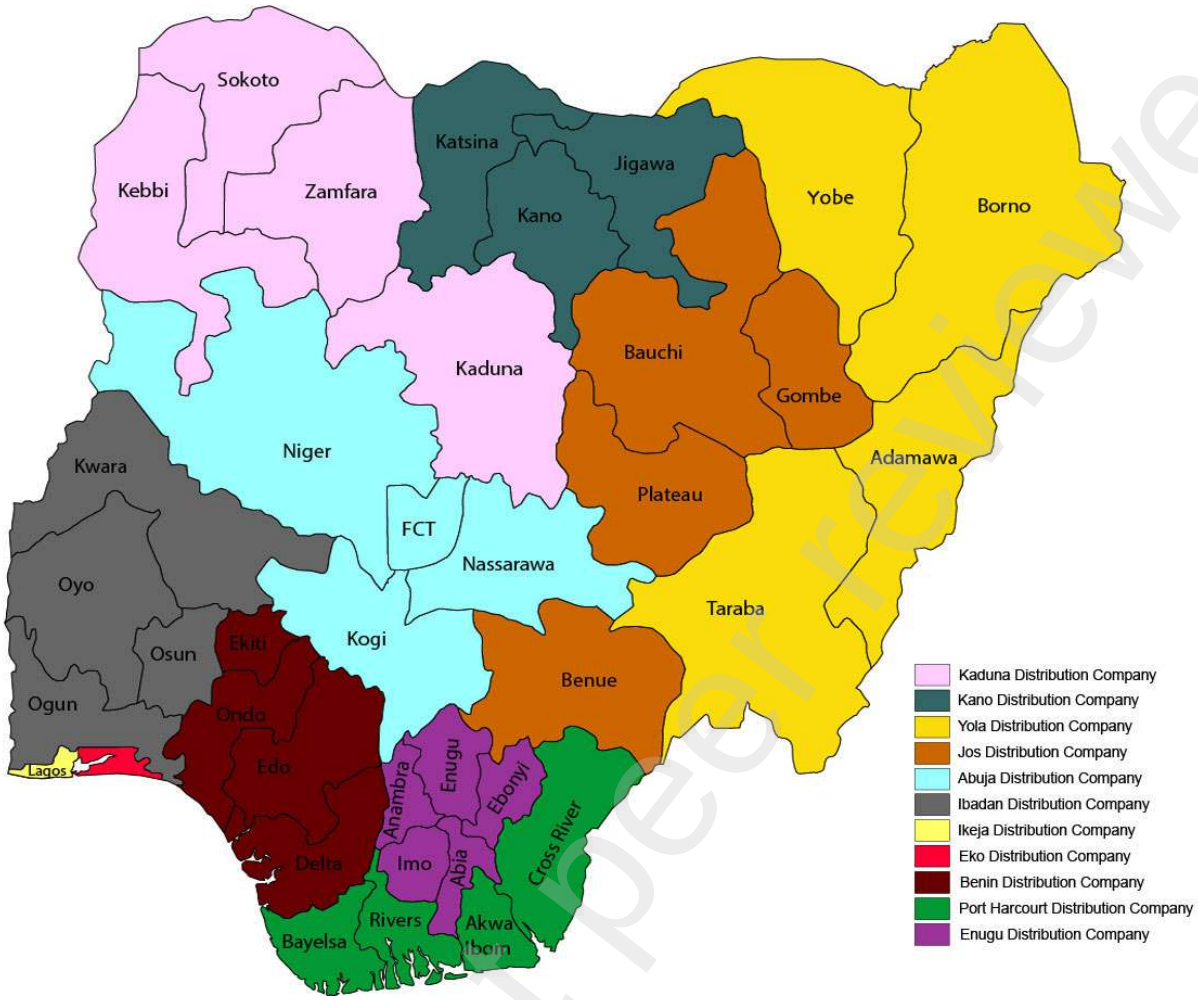

Figure 2. Coverage area of electricity distribution companies in Nigeria.
Source: https://nerc.gov.ng/index.php/contact/discos

There are several factors that might warrant an expectation of the opposite: the World Bank's Energy Sector Management Assistance Programme (ESMAP), for example, argues that mini grids, whether they are interconnected or isolated, generally achieve higher levels of reliability for their customers than DisCos in Nigeria do through the national grid. ESMAP further asserts that mini grids that interconnect with the distribution grid will create positive economic outcomes for DisCos, mini-grid operators, and customers alike (ESMAP, 2022). In the same vein, Howard (2022) states that DisCos in the Nigerian context play "a key role in a value chain that relies on their ability to provide last-mile connections and generate revenue". Notwithstanding these

positive prognoses regarding the utility of DisCos for expanding electricity access in Nigeria, however, they have been largely missing from efforts to reach last-mile communities with mini-grid electricity.

A closer look at the broader regulatory environment beyond the 2016 Regulation for Mini-grids sheds some light on the reasons for the seeming discrepancy between DisCos' apparent relevance and their diminished role in the mini-grid sector. It would appear that the 2005 EPSRA which unbundled the state-owned utility into seven generation companies, 11 distribution companies and a national transmission company pre-determined what is possible and/or profitable for each of those entities to do in the mini-grid regime that followed a decade later.

As such, by design, there are limited incentives for DisCos to invest in mini-grid development. Crucially, the remit of DisCos, as spelled out in the 2005 EPSRA, is limited to electricity distribution and does not extend to generation, which is a defining attribute of mini-grid operation. DisCo officials acknowledged in interviews that it is possible, at least in theory, for the companies to incorporate subsidiary entities that can invest independently in mini-grid electricity generation. In practice, however, this is not an option that many DisCos are willing to contemplate given that their current operations are hobbled by low technical and financial capacity. The option to partner with smaller developers on interconnected mini-grid schemes is potentially more appealing;[6] again, however, this is a nascent sector that the generally risk-averse DisCos approach with caution.

[6]Interconnected mini grids in the context, in contrast to isolated mini grids, are meant to be deployed by private developers in partnership with DisCos connected to the main grid. In principle, this model can boost electricity supply to underserved areas - mostly urban and peri-urban areas that are already connected to the national grid but have unreliable power supply. In practice, however, only a handful of DisCos have welcomed collaboration with developers in this regard, with many preferring instead to consolidate their position within the grid ecosystem.

The DisCos' financial problems persist despite the recent infusion of development finance (to the tune of US$ 1.743 billion) into the sector under the World Bank-supported Nigeria Distribution Sector Recovery Programme (DISREP) launched in 2021.[7] A key objective of DISREP is to provide DisCos with funding for capital expenditure and infrastructure improvements, with a view to enhancing electricity distribution, reducing technical losses and consequently increasing revenue generation (Federal Ministry of Power, 2020) Given this background, many DisCos are not interested in taking on mini-grid development within their jurisdiction, as this seems guaranteed to increase their transaction costs without assuring them of profit. The current strategy for most DisCos is therefore to focus on consolidating their financial position with their existing grid customer base:

> "The DisCos are more concerned about reducing losses from the existing networks and not looking out to create islands where they have to worry."
>
> - Utility_Benin DisCo_Regulatory Affairs

The subtext in the above assertion is that the rural areas that the 2005 EPSRA and 2016 Regulation for Mini-grids conceive of as being the primary beneficiaries of isolated mini grids are not profitable for DisCos, a point that comes across more clearly in the following quotes:

> "Priority will be given to expanding the [DisCo] networks to where the returns vis-a-vis the endeavour will be substantial, and that is why network expansions are more likely to be in the areas where there are high cluster industrial areas than in communities that are just going to return pennies."
>
> - Utility_Benin DisCo_Regulatory Affairs

[7] The World Bank has published detailed information on the DISREP here: https://projects.worldbank.org/en/projects-operations/project-detail/P172891

> "The DisCos will never go to the rural areas because it is not economical for them. The value of going there is zero."
>
> - Business Developer_Company 1_Consultant

This raises the question of how sound the premise of electrifying rural areas through improved regulation and financing for mini-grid expansion is. On the one hand, the small- and medium-scale developers that have benefitted from the existing regulations do not have the economies of scale to expand access to rural areas at competitive costs. On the other hand, the DisCos that have the required institutional and geographical reach do not find the idea of extending their services to rural customers a worthwhile proposition. The following section discusses the implications of this tension for electricity access expansion in more detail.

4.3 The premise of electrifying last-mile communities through improved regulation and investment for mini-grid expansion is not aligned with institutional and financial realities

At the time of the privatisation of the Nigerian Electricity Supply Industry (NESI), about ninety million people nationwide were not connected to the main grid (Onaguruwa, 2011). A core objective of the 2005 EPSRA was to bridge this access gap by extending electricity to hitherto unserved populations around the country, the majority of them in rural areas. The institution mandated by the Act to achieve this objective of last-mile electrification was the Rural Electrification Agency (REA) and the associated Rural Electrification Fund (REF), both established in 2006 (Baker et al 2022). Underlying the creation of a dedicated institution to administer rural electrification initiatives was a recognition that the commercial model envisaged for the newly established DisCos and GenCos would necessarily differ from that for customers in poorer rural areas who exist on the periphery of mainstream electricity markets.

Importantly, the provisions made for rural electrification in the EPSRA encompass a broad range of delivery mechanisms, including the expansion of both grid and off-grid systems, and involving contributions from both public and private sector actors. In other words, the mandate of rural electrification in the country predated the current focus on off-grid solutions and was agnostic with regard to the means for achieving the goal of universal access. Since the arrival of mini grids on the national scene, however, the REA has de-emphasised alternative solutions, leaving private sector-led - albeit publicly subsidised - mini-grid deployment (and, to a lesser extent, standalone solar systems) as the dominant model for rural electrification.[8] The widespread appeal of this model notwithstanding, the uneven dynamics of market participation observed in the wake of the 2016 Regulation for Mini-grids suggest that its valorisation of a commercial approach to mini-grid development needs to be weighed against its ability to serve the rural poor in way that helps achieve, in the words of the EPSRA, "more equitable regional access to electricity" (Electric Power Sector Reform Act, 2005, p. A.120).

The Regulation for Mini-grids has, in many ways, enabled the REA to approach its mandate with greater transparency and legitimacy. In particular, stringent donor requirements guiding the allocation and disbursement of NEP funds have helped the agency sidestep pressure from other arms of government to implement politically motivated projects that almost invariably lack technical or economic merit[9]. The penchant for undue political influence has been a bane of rural electrification projects in the past[10] (see also (Osunmuyiwa et al., 2018), with change only coming from recent reforms championed by the REA:

[8] All seven ongoing electrification initiatives featured on the REA's website are aimed at boosting the commercial viability of off-grid schemes implemented by private developers (rea.gov.ng).
[9] An example of the transparency enabled by the NEP is seen in the way the World Bank publishes details of the project's finances online.
[10] In 2009, Musa Yar'adua, then preseident of Nigeria, wrote to the Senate, requesting it to repeal the Rural Electrification in light of a 5.2-billion-naira scam reportedly initiated by several members of the National Assembly and top government officials (https://www.vanguardngr.com/2009/06/n52bn-fraud-yaradua-to-scrap-rea).

> "...part of the budget emanates from us and the rest comes from the National Assembly, and they have the power to even change what we present to them… They have, as we say in Nigerian parlance, they have the yam and the knife. But we try to employ stakeholder management before the budget is passed… we're there to advise them technically, professionally as to, for instance, what it would cost to provide a transformer, as opposed to doing it arbitrarily, and how much it would cost to extend a grid from a certain community to the other, and what technology should even be considered - should it be solar, SHS, or whatever. This has been yielding some fruit."
>
> - Government Department_REA_Official 1

However, while the recent successes recorded by the REA under the auspices of the 2016 Regulation for Mini-grids and the NEP have enabled a significant boost in technical, institutional and financial capacity, there remain real limitations to the agency's ability to deliver on its mandate of ensuring equitable distribution of electricity access under the current regulatory regime. This is because, even with capital subsidies that are available to private mini-grid developers under the NEP, the electricity arrives in rural areas at a cost that is typically unaffordable for the average household or business. The costs are even higher for mini-grid projects that do not have access to these publicly funded subsidies, resulting in tariffs that are several times higher than those for grid-connected populations and exacerbating the inequities in electricity access between rural and urban areas:

> "According to the mini grid regulatory framework, that framework allows mini-grid developers to charge what we call a cost-reflective tariff. Now, typically, across most mini grids… tariff ranges from about 130 per kilowatt hour to about 180 per kilowatt hour. Now, you may want to argue that it is relatively high compared to what those

of us in the urban area pay, you know, 50 to 60 naira, but the truth is that as of today Nigerians don't pay the true cost of electricity…"

- Project Developer_Company 3_CEO

It is important to recognise that the country is still in the early stages of its third-generation mini-grid boom, and therefore, any inferences about the uneven growth of the market can be deemed tentative. Nonetheless, our findings indicate that a more holistic assessment of the role of mini grids in Nigeria's rural electrification outlook is required, one that prioritises the goal of equitable access alongside that of regulatory efficiency. The paper concludes with recommendations for how to achieve this.

5. Conclusions and Policy Implications

This paper has analysed the regulatory framework governing mini-grid development in Nigeria within the context of broader developments in the Nigerian Electricity Supply Industry (NESI). Our analysis goes further than the majority of existing studies on the NESI which, to the extent that they explore the dynamics of mini-grid development in the country, tend to do so from a largely techno-economic perspective. Our findings highlight the wins that the country has recorded in mini-grid regulation and investment especially in the last half-decade, but also the challenges of access evinced by these strides and their implications for the achievement of the national and global goals of rural electrification and universal energy access respectively. Crucially, we argue that contradictions in the overall regulatory landscape restrict the ability of various actors to leverage the opportunities presented not just by mini grids, but also by other potential solutions (including conventional grid options), and these need to be resolved if electricity is to be accessible for the majority of rural dwellers.

The paper has shown how the "standard model" of electric sector governance has led to underwhelming outcomes in Nigeria, creating a cohort of generation and distribution companies

that mostly lack the institutional capacity to supply reliable power to customers on the national grid. The status quo represents a case of stalled liberalisation in many respects: the state has had to keep subsidising the private investors that took over the grid utility in the wake of the EPSRA (Akintayo, 2022), and, according to recent media reports, the state maintains 40 percent ownership of all DisCos to ward off potential liquidation of the companies (The Nation Editorial, 2022). Furthermore, many of the companies are heavily indebted to Nigerian commercial banks, partly because they continue to struggle with revenue collection and infrastructure maintenance - which, in turn, are occasioned by operational difficulties such as persistent metering gaps and electricity theft.

It is against this background that smaller and more dynamic developers have emerged on the national mini-grid scene. For isolated mini grids in rural areas of the country at least, the tensions observed by (Baker & Phillips, 2019) between legacy utilities and newer decentralised actors in other country contexts is not apparent, as the latter have seemingly stepped into a lacuna resulting from the interplay of technical, financial and regulatory factors in the broader electricity industry. Indeed, the activities of these smaller developers - as well as the regulation governing them - are viewed as a relatively quick fix for lingering problems in the electricity sector that can be traced back to earlier regulatory regimes. Our analysis has shown that the current regulatory era, while it has boosted the efficiency of decentralised electricity markets, has had limited effectiveness in terms of its ability to substantially reconfigure unequal patterns of electricity distribution, with the most disadvantaged populations remaining poor rural dwellers at the last mile. The following recommendations emerge from our analysis as being potentially relevant for enhancing regulation and financing that are more responsive to the needs of those populations.

Harmonise the regulatory environment. Much attention has been paid to the 2016 Regulation for Mini-grids by public and private actors alike given its apparent relevance for the growth of the

sector. Attempts to improve on the regulation tend to be forward-looking: a review process was recently launched, for instance, and the National Assembly has proposed a new piece of legislation targeting renewable energy more broadly. Our findings however indicate that progress can also be facilitated by looking back to the 2005 EPSRA and revising provisions that developers say are out of step with current realities, such as restrictions on the size of mini grids and protections that make DisCos impermeable to competition even when they fail to deliver power to their customers.[11]

Situate mini-grid development within the broader framework of rural electrification policy. More than 30,000 Nigerian households and businesses have gained access to electricity from mini grids to date,[12] signalling that the technology has an important role to play in the country's electrification strategy. However, this still represents a fraction of the population - and, considering the challenges of affordability faced by rural dwellers, progress on this front will likely be slow. Consequently, mini grids are perhaps better viewed as one of several possible means of achieving the overall policy goal of rural electrification. Broadening the perspective in this way will allow for the consideration of a range of regulatory and financing mechanisms, including the commitment of significant public funding that has historically enabled the electrification of poor rural populations (Karekezi & Majoro, 2002).

Institutionalise mechanisms for transparent governance of the sector. The mini grids implemented under the NEP have exhibited a high degree of transparency, largely due to the

[11] A newly approved (as of 2023) Electricity Act aims to spur market competition by allowing the decentralised generation and distribution of electricity by public and private actors within state borders (Anyaogu 2023). It is not yet clear what impact the Act will have on rural electrification, however, as it does not specify mechanisms for addressing potential disparities in the distribution of access within and across states.

[12] According to data from the Rural Electrification Agency, 30,665 electricity connections have been enabled through the World Bank-financed Nigeria Electrification Programme (https://nep.rea.gov.ng/) In addition to these, several other mini-grid projects have been financed through varying combinations of grants from other sources, private debt and equity. This is a fraction of the millions of people that, according to World Bank data (https://data.worldbank.org/indicator/SP.POP.GROW), are added to the Nigerian population every year.

provisions of the Regulation for Mini-grids and stringent donor requirements for administering programme funds. While this is a win, it falls short of what is required to institutionalise mechanisms for allocating and disbursing funds for rural electrification at the national level. In particular, attention needs to be paid to strengthening the autonomy of the REA to make technical decisions with minimal influence from political actors.

Review regulatory provisions to unlock latent subsidies for rural electrification. The Rural Electrification Fund set up by the 2005 EPSRA makes provision for the cross-subsidisation of tariffs between urban and rural dwellers, a mechanism that enables the latter to pay relatively low rates for electricity (Azimoh, 2016). However, the overall subsidy amount available is undermined by low rates of electrification in urban areas - a situation that can be improved by increasing electricity supply to those wealthier areas, including through opening up existing DisCos to competition from isolated mini grids. Future reviews of the EPSRA and the Regulation for Mini-grids should integrate provisions that allow for greater complementarity between different segments of the electricity market so that the needs of all can be met.

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References

ACE-TAF. (2022). *State Off-Grid Solar – Nigeria*. Africa Clean Energy Technical Assistance Facility. https://www.ace-taf.org/wp-content/uploads/2022/07/State-Off-Grid-Solar-Policy-Brief-NIGERIA-2.pdf

Ahlborg, H. (2017). Towards a conceptualization of power in energy transitions. *Environmental Innovation and Societal Transitions*, *25*, 122–141. https://doi.org/10.1016/j.eist.2017.01.004

Ahlborg, H. (2018). Changing energy geographies: The political effects of a small-scale electrification project. *Geoforum*, *97*, 268–280. https://doi.org/10.1016/j.geoforum.2018.09.016

Akintayo, O. (2022). Should Nigeria reverse nine-year power privatisation? *Punch Newspapers*. https://punchng.com/should-nigeria-reverse-nine-year-power-privatisation/

AMDA. (2020). *Benchmarking Africa's Mini Grids*. Africa Minigrid Developers Association. https://www.ruralelec.org/sites/default/files/CEMG%20Development%20Guide%20EN.pdf]

Antonanzas-Torres, F., Antonanzas, J., & Blanco-Fernandez, J. (2021). State-of-the-Art of Mini Grids for Rural Electrification in West Africa. *Energies*, *14*(4), 990. https://doi.org/10.3390/en14040990

Anyaogu, I. (2023). Tinubu assents landmark electricity bill. *BusinessDay Newspapers.*

Arowolo, W., Philipp Blechinger, Catherina Cader, & Yannick Perez. (2019). Seeking workable solutions to the electrification challenge in Nigeria: Minigrid, reverse auctions and institutional adaptation. *Energy Strategy Reviews*, *23*, 114–141. https://doi.org/10.1016/j.esr.2018.12.007

Azimoh, C. L. (2016). *Sustainability and development impacts of off-grid electrification in developing countries: An assessment of South Africa's rural electrification program*. Mälardalen University Press.

Azimoh, C. L., & Mbohwa, C. (2019). Optimized Solution for Increasing Electricity Access with Mini-Grid Technology in Nigeria. *Journal of Sustainable Development*, *12*(1), 156. https://doi.org/10.5539/jsd.v12n1p156

Babatunde, O., Buraimoh, E., Tinuoye, O., Ayegbusi, C., Davidson, I., & Ighravwe, D. E. (2023). Electricity sector assessment in Nigeria: The post-liberation era. *Cogent Engineering*, *10*(1), 2157536. https://doi.org/10.1080/23311916.2022.2157536

Baker, L., Sesan, T., Bhattacharyyra, S., Pueyo, A., Bukari, D., Meena, S., Onsongo, E., Oyinlola, M. T., Sawe, E., Otu-Eleri, E., Uduka. U., Handem, Y., Onjala, B., Katyega, M (2022). 'Of monopolies and mini grids: case studies from Kenya, Tanzania, Nigeria and Senegal', SIGMA working paper 1, [available at: https://static.s123-cdn-static-d.com/uploads/3093860/normal_62f3d6304c7b0.pdf]

Baker, L., Hook, A., & Sovacool, B. K. (2021). Power struggles: Governing renewable electricity in a time of technological disruption. *Geoforum*, *118*, 93–105. https://doi.org/10.1016/j.geoforum.2020.12.006

Baker, L., & Phillips, J. (2019). Tensions in the transition: The politics of electricity distribution in South Africa. *Environment and Planning C: Politics and Space*, *37*(1), 177–196. https://doi.org/10.1177/2399654418778590

Bloomberg NEF. (2019). *Solar for Businesses in Sub-Saharan Africa*. https://data.bloomberglp.com/professional/sites/24/BNEF_responsAbility-report-Solar-for-Businesses-in-Sub-Saharan-Africa.pdf

Brisbois, M. C. (2020). Shifting political power in an era of electricity decentralization: Rescaling, reorganization and battles for influence. *Environmental Innovation and Societal Transitions*, *36*, 49–69. https://doi.org/10.1016/j.eist.2020.04.007

Chukwujindu, O., Ukeje, I., Ekwunife, R., & Nwangbo, S. (2021). Management Innovation and Power Sector Governance in Nigeria. In *Global Encyclopedia of Public Administration, Public Policy, and Governance* (pp. 1–13). Springer.

Cozzi, L., Contejean, A., Samantha, J., Dasgupta, A., Rouget, A., & Arboleya, L. (2020). *The Covid crisis is reversing progress on energy access in Africa*. International Energy Agency.

Edomah, N. (2018). Historical Drivers of Energy Infrastructure Change in Nigeria (1800–2015). In S. Gokten & G. Kucukkocaoglu (Eds.), *Energy Management for Sustainable Development*. InTech. https://doi.org/10.5772/intechopen.74002

Edomah, N., Foulds, C., & Jones, A. (2016). Energy Transitions in Nigeria: The Evolution of Energy Infrastructure Provision (1800–2015). *Energies*, *9*(7), 484. https://doi.org/10.3390/en9070484

Edomah, N., Ndulue, G., & Lemaire, X. (2021). A review of stakeholders and interventions in Nigeria's electricity sector. *Heliyon*, *7*(9), e07956. https://doi.org/10.1016/j.heliyon.2021.e07956

ESMAP. (2019). *Mini grids for half a billion people: Market outlook and handbook for decision makers (2019)* (Technical Report No. 014/19). Energy Sector Management Assistance Program.

ESMAP. (2022). *Mini grids for half a billion people: Market outlook and handbook for decision makers (2022)*. Energy Sector Management Assistance Program. https://documents1.worldbank.org/curated/en/099635009232259510/pdf/P1751510dd4ab407e083a6098d1905fa94f.pdf

Federal Ministry of Power. (n.d.). *Nigeria SE4All: Mini-grids*. https://nigeriase4all.gov.ng/mini-grids

Federal Ministry of Power. (2020). *Nigeria Distribution Sector. Recovery Program (DISREP) Environmental and Social Management Framework*.

Electric Power Sector Reform Act, Pub. L. No. 6, A77 (2005). https://rea.gov.ng/wp-content/uploads/2017/09/Electric-Power-Sector-Reform-Act-2005.pdf

Foster, V., & Rana, A. (2020). *Rethinking Power Sector Reform in the Developing World*. International Bank for Reconstruction and Development / The World Bank.

Godinho, C., & Eberhard, A. A. (2019). *Learning from Power Sector Reform Experiences The Case of Kenya'*. http://documents.worldbank.org/curated/en/451561555435655366/Learning-from-Power-Sector-Reform-The-Case-of-Kenya

Gratwick, K. N., & Eberhard, A. (2008). Demise of the standard model for power sector reform and the emergence of hybrid power markets. *Energy Policy*, *36*(10), 3948–3960. https://doi.org/10.1016/j.enpol.2008.07.021

Howard, M. (2022). Between Aso Rock and a hard place: Nigerian disco privatisation's very public problems. *Africa Energy*. https://www.africa-energy.com/news-centre/article/between-aso-rock-and-hard-place-nigerian-disco-privatisations-very-public

Hughes, T. P. (1983). *Networks of Power: Electrification in Western Society, 1880-1930*. Johns Hopkins University Press.

IEA. (2019). *Access to electricty*. International Energy Agency. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity]

Jaglin, S. (2019). *Off-grid Electricity in sub-Saharan Africa: From rural experiments to urban hybridisations*. https://shs.hal.science/halshs-02078148

Jaglin, S., & Guillou, E. (2020). Decentralized electricity solutions: Innovation in essential services is no substitute for policy. *Field Action Science Reports*, 58–63.

Karekezi, S., & Majoro, L. (2002). Improving modern energy services for Africa's urban poor. *Energy Policy*, *30*(11–12), 1015–1028. https://doi.org/10.1016/S0301-4215(02)00055-1

Lane, J., Hudson, W., Walley, L., & Hamden, Y. L. (2018). *Mini-Grid Market Opportunity Assessment: Nigeria.* SE4ALL Africa Hub & African Development Bank. https://greenminigrid.afdb.org/sites/default/files/minigrid_market_opportunity_assessment_nigeria_june_2018.pdf

Muchunku, C., Ulsrud, K., Palit, D., & Jonker-Klunne, W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *WIREs Energy and Environment*, *7*(3). https://doi.org/10.1002/wene.282

New Climate Economy. (2018). *Unlocking the Inclusive Growth Story of the 21st Century: Accelerating Climate Action in Urgent Times*. https://newclimateeconomy.report/2018/

Regulation for Mini-grids 2016, (2017). https://rea.gov.ng/wp-content/uploads/2018/07/NERC-Mini-Grid-Regulation.pdf

Nwozor, A., Oshewolo, S., Owoeye, G., & Okidu, O. (2021). Nigeria's quest for alternative clean energy development: A cobweb of opportunities, pitfalls and multiple dilemmas. *Energy Policy*, *149*, 112070. https://doi.org/10.1016/j.enpol.2020.112070

Ockwell, D., & Byrne, R. (2016). *Sustainable Energy for All: Innovation, technology and pro-poor green transformations* (1st ed.). Routledge. https://doi.org/10.4324/9781315621623

Odarno, L., Sawe, E., Swai, M., Katyega, M. J. J., & Lee, A. (2017). *Accelerating Mini-grid Deployment in Sub-Saharan Africa: Lessons from Tanzania*. World Resources Institute. https://files.wri.org/d8/s3fs-public/accelerating-mini-grid-deployment-sub-saharan-africa_1.pdf

Oladipo, O., & Ndigwe, C. (2022). Solar eludes electricity-starved Nigerians on FX crisis. *BusinessDay Newspapers*.

Onaguruwa, B. (2011). *A Presentation to the West African Power Industry Convention.* https://www.esi-africa.com/conference-papers/west-african-power-industry-convention-wapic-conference-program-2011/

Osunmuyiwa, O., Biermann, F., & Kalfagianni, A. (2018). Applying the multi-level perspective on socio-technical transitions to rentier states: The case of renewable energy transitions in Nigeria. *Journal of Environmental Policy & Planning*, *20*(2), 143–156. https://doi.org/10.1080/1523908X.2017.1343134

Pallavi, R. (2020). *The potential of small and medium enterprises: Off-grid solutions to corruption in Nigeria's electricity sector*. Anti-Corruption Evidence Research Consortium. https://ace.soas.ac.uk/wp-content/uploads/2020/06/ACE-BriefingPaper010-200629.pdf

Pavanelli, J. M. M., Sang, E. V., de Oliveira, C. E., dos Reis Campos, F., Lazaro, L. L. B., Edomah, N., & Igari, A. T. (2023). An institutional framework for energy transitions: Lessons from the Nigerian electricity industry history. *Energy Research & Social Science*, *97*, 102994. https://doi.org/10.1016/j.erss.2023.102994

Pedersen, M. B. (2016). Deconstructing the concept of renewable energy-based mini-grids for rural electrification in East Africa. *WIREs Energy and Environment*, *5*(5), 570–587. https://doi.org/10.1002/wene.205

Pedersen, M. B., & Nygaard, I. (2018). System building in the Kenyan electrification regime: The case of private solar mini-grid development. *Energy Research & Social Science*, *42*, 211–223. https://doi.org/10.1016/j.erss.2018.03.010

Peters, J., Sievert, M., & Toman, M. A. (2019). Rural electrification through mini-grids: Challenges ahead. *Energy Policy*, *132*, 27–31. https://doi.org/10.1016/j.enpol.2019.05.016

Power Africa. (2022). *Nigeria Power Africa Fact Sheet*. https://www.usaid.gov/powerafrica/nigeria

Richards, K. A., & Hemphill, M. A. (2018). A Practical Guide to Collaborative Qualitative Data Analysis. *Journal of Teaching in Physical Education*, *37*(2). https://doi.org/10.1123/jtpe.2017-0084

Rip, A., & Kemp, R. (1998). Technological change. In S. Rayner & E. L. Malone (Eds.), *Human choice and climate change: Vol. II, Resources and Technology* (pp. 327–399). Batelle Press.

Roche, M. Y., Verolme, H., Agbaegbu, C., Binnington, T., Fischedick, M., & Oladipo, E. O. (2020). Achieving Sustainable Development Goals in Nigeria's power sector: Assessment of transition pathways. *Climate Policy*, *20*(7), 846–865. https://doi.org/10.1080/14693062.2019.1661818

Rohman, K., & Rita, E. (2013). Capturing the Witness Statement. *AWI Journal*, *4*(3).

Rothfuß, E., & Boamah, F. (2020). Politics and (Self)-Organisation of Electricity System Transitions in a Global North–South Perspective. *Politics and Governance*, *8*(3), 162–172. https://doi.org/10.17645/pag.v8i3.3636

Rutakumwa, R., Mugisha, J. O., Bernays, S., Kabunga, E., Tumwekwase, G., Mbonye, M., & Seeley, J. (2020). Conducting in-depth interviews with and without voice recorders: A comparative analysis. *Qualitative Research*, *20*(5), 565–581. https://doi.org/10.1177/1468794119884806

Saifuddin, N., Bello, S., Fatihah, S., & Vigna, K. R. (2016). Improving electricity supply in Nigeria: Potential for renewable energy from biomass. *International Journal of Applied Engineering Research*, *11*, 8322–8339.

Sandmo, A. (1998). The welfare state: A theoretical framework for justification and criticism. *Swedish Economic Policy Review.*, *5*(11–33).

Sen, A. (2014). *Divergent Paths to a Common Goal?: An overview of challenges to electricity sector reform in developing versus developed countries*. Oxford Institute for Energy Studies2014. https://www.oxfordenergy.org/publications/divergent-paths-to-a-common-goal-an-overview-of-challenges-to-electricity-sector-reform-in-developing-versus-developed-countries/

Sen, A. K. (2015). Sharing the world: Interdependence and global justice. In *The Country of First Boys and Other Essays* (pp. 115–126). Oxford University Press.

Sesan, T. (2020). Clean energy: Game-changer for Nigeria? *International Trade Forum*, *2020*(4), 26–27. https://doi.org/10.18356/15645304-2020-4-12

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, *34*(10), 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005

The Nation Editorial. (2022). *Fed Govt holds 40% equity stake in all DisCos*. https://thenationonlineng.net/fed-govt-holds-40-equity-stake-in-all-discos/

Trimble, C., Kojima, M., Arroyo, I. P., & Mohammadzadeh, F. (2016). *Financial viability of electricity sectors in Sub-Saharan Africa: Quasi-fiscal deficits and hidden costs* (Policy Research Working Paper Series). The World Bank Group.

UNDESA. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables.* (Working Paper No. ESA/P/WP/248). United Nations, Department of Economic and Social Affairs, Population Division.

Verbong, G. P. J., & Geels, F. W. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Technological Forecasting and Social Change*, *77*(8), 1214–1221. https://doi.org/10.1016/j.techfore.2010.04.008

Victor, D. G., & Heller, T. C. (Eds.). (2007). *The Political Economy of Power Sector Reform: The Experiences of Five Major Developing Countries* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511493287

Wohlgemuth, N., & Painuly, J. (1999). Promoting private sector financing of commercial investments in renewable energy technologies. *Finance for Sustainable Development: Testing New Policy Approaches*.

Yakubu, A., Ayandele, E., Sherwood, J., Olu, A. O., & Graber, S. (2018). *Mini grid Investment Report: Scaling the Nigerian Market*. The Nigerian Economic Summit Group.