A Snapshot of Nigeria's Federal Rural Electrification Policy Landscape and the Definition and Fulfillment of Electricity Access

By

Panteleimon Stathopulos
University of Colorado Boulder

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Thesis committee

Dr. David Ciplet, Environmental Studies Program, Primary Advisor
Dr. Peter Newton, Environmental Studies Program, Honors Council representative
Dr. Lakshman Guruswamy, Colorado Law School, Outside Reader

Glossary

distribution companies	DisCos
Electric Power Sector Reform Act	EPSRA
Electricity Regulatory Index	ERI
Energizing Economies Initiative	EEI
Energizing Education Programme	EEP
Energy Commission of Nigeria	ECN
Energy Sector Management Assistance Program	ESMAP
Federal Republic of Nigeria	FRN
GDP	Gross Domestic Product
Global Tracking Framework	GTF
International EnergyAgency	IEA
International Governmental Organization	IGO
kilowatt-hour	kWh
Megawatts	MW
Ministry of Power	MOP
Ministry of Science and Technology	MST
Multi-Tier Framework	MTF
National Power Training Institute of Nigeria	NAPTIN
Nigerian Bulk Electricity Trading	NBET
Nigerian Electricity Liability Management Company	NELMCO
Nigerian Electricity Management Service Agency	NEMSA
Nigerian Electricity Regulatory Commission	NERC
Nigerian Electricity Supply Industry	NESI
Nigerian Electrification Project	NEP
Non-Governmental Organization	NGO
North West	NW
Not Applicable	N/A
Regulatory Governance Index	RGI
Regulatory Indicators for Sustainable Energy	RISE
Regulatory Outcome Index	ROI
Regulatory Substance Index	RSI
Renewable Energy	RE
Research Question	RQ
Rural Electricity Users Cooperative Society	REUCS
Rural Electrification Agency	REA
Rural Electrification Fund	REF
Rural Electrification Strategy and Implementation Plan	RESIP
Solar Home System	SHS
Solar Power Ninja	SPN
Stand-Alone System	SAS
Sustainable Development Goals	SDG
Sustainable Energy For All	SE4All
System Average Interruption Duration Index	SAIDI
System Average Interruption Frequency Index	SAFIRI
Transmission Company of Nigeria	TCN
United Nations	UN
watt-hours	Wh
Watts	W
World Bank	WB

Abstract

This thesis challenges how electricity access is defined and monitored, with a focus on national rural electrification policies in Nigeria. This thesis finds that Nigeria lacks an explicit definition for electricity access. Based on this, an implied framework is identified, showing a fair capture of the state of electrification. This fair capture claim is supported by scholarly literature, international publications, and Nigeria's electrification trends. Nigeria's planned and existing electrification metrics fulfill the power capacity threshold associated with the Multi-Tier Framework Tier 3 level of electricity access. This thesis theoretically expands upon the methodology used to determine fulfillment, providing a nuanced way to assess and track the true state of electrification. This thesis recommends that electricity access be defined and monitored by incorporating many perspectives, dimensions, and attributes.

Keywords: Nigeria, Electricity Access, Energy Poverty, Measurement Frameworks

1. Introduction

1.1: Justification

Energy poverty broadly refers to the lack of access to technologies that increase human productivity through energy efficiency gains. Most people experiencing energy poverty lack access to the most basic energy assets like cooking stoves, mechanical water pumps, solar lights, and sanitation technologies (Guruswarmy, 2011). Beyond these essential human services, those who are experiencing energy poverty also have inadequate access to electricity. Electricity is the most desirable energy source, as it serves needs at every scale, from household to industrial (Bryce, 2020). Electricity is integral to growth, as it powers industries that give capital to people who can then utilize electricity to better their livelihood and future generations' livelihood (Munyoro, Makurumure, and Dzapasi, 2016). Access to electricity may boost the most vulnerable populations out of poverty. Measuring access to electricity can provide insights into the development trajectory of a population.

International governmental organizations (IGOs) have traditionally played an essential role in the realm of international energy. The United Nations (UN) and associated institutions have taken on the role of financier and goal setter (Osborn, Cutter, and Ullah, 2015). To fulfill these duties, the UN collects, processes, and publishes vast amounts of information. Often the UN draws its data from non-governmental organizations (NGOs), specifically major energy corporations. These corporations are close to energy industry supply chains and thus closely track energy statistics. Alternative NGOs such as think tanks, advocacy groups, and research institutes are becoming increasingly active in the international energy industry . Groups like these are presenting innovative solutions to large corporations and IGOs while also challenging their methods (Auth et al., 2021). Additionally, many academic scholars publish research about international energy, working alongside and independently from large organizations.

Emerging energy technologies and finance schemes disrupt traditional provisioning pathways and expedite people's empowerment out of poverty (Enongene, Abanda, Otene, Obi, and Okafor 2020) . New cooperators have informational needs that are not being satisfied. This paper will propose two informational categories that will serve a progressing international energy industry.

Concise informational summaries are needed to help newcomers understand the environment they wish to enter. These summaries help outline essential facts and relationships. Furthermore, the mapping of informational sources can expedite future work. This information category is beneficial to newcomers who wish to participate financially and technologically.

Information that challenges preconceived assumptions is vital to cultivating a robust multilateral community whose mission is to help people. Research that exposes commonplace faulty methodologies will lend itself to the creation of more effective and equitable methods. This paper will attempt to challenge the way that we define electrification deprivation. A careful and thorough scrutiny of electricity access definitions will identify new potentials for defining the problem of deprivation. New approaches will be cultivated through problem posing (Freire, 1972), looking at different attributes of electricity access from different perspectives. This information category is beneficial to community newcomers who wish to participate in regulatory and operational processes.

A country-specific scope refined the information categories that are to be detailed and contextualized. Nigeria is the selected case study country for four main reasons. (1) Electricity deprivation among rural populations is extensive. (2) The official language of Nigeria is English, easing the study of legislative documents. (3) Nigeria's state-owned energy industry was unbundled in 2005, leading to the recent enactment of seminal legislation. (4) Personal connections to people living in Nigeria provided a context.

1.2: Background

In 2015, as part of "The 2030 Agenda for Sustainable Development", UN member states identified 17 sustainable development goals (SDGs) to "ensure peace and prosperity for people and the planet" (UN). The seventh sustainable development goal, SDG 7, sets out to "Ensure access to affordable, reliable, sustainable and modern energy for all" (Osborn, Cutter, and Ullah, 2015). Progress towards SDG 7 reinforces and has consequences for many of the other development goals. SDG 7 comprises five sub-targets with six indicators that together track progress towards the development goal. SDG 7.1.1 is the first sub-target, tracking the "proportion of the population with access to electricity" (Anon, 2020). The formal SDG 7 methodology states that access to electricity is fundamentally achieved when a household's "primary source of lighting is the local electricity provider, solar systems, mini-grid or stand-alone system (SAS)" (Indicator 7.1.1, 2020). While this formal criterion focuses on lighting, SDG 7.1.1 tracked the use of other electricity access definitions as well. Currently, electrification data informing SDG 7 comes from the World Bank (WB) global electrification database, which incorporates survey data from various sources.

Upon navigating to the WB database, the SDG 7.1.1 indicator cites its data sources to be the WB, Sustainable Energy for All (SE4ALL), the International Energy Agency (IEA), and the Energy Sector Management Assistance Program (ESMAP). SE4ALL and ESMAP cite the WB and IEA for their SDG 7.1.1 indicator data, failing to provide a formal definition for their definitional methodology and subsequent tracking system. The only explicit IGO definitions come from the SDG 7 methodology and the IEA methodology (Metadata, 2020; IEA, 2020).

The IEA is central to the international energy industry. Its work provides data, statistics, training, and cooperation throughout the globe. The IEA has been publishing electricity access statistics since 2002 (World Energy Outlook, 2002), and thus its defining framework is influential. The IEA "defining energy access methodology" is transparent, acknowledging the limitations and unsettled nature of "defining electricity access." The IEA methodology references common attributes such as sustainability, adequacy, reliability, convenience, and safety. The methodology also mentions benefits of electricity usage outside of the household, like economic centers and public services. While the IEA references multifaceted components, no benchmarks or standard metrics are in place to monitor, assess, or define these electricity access components (IEA, 2020). The IEA methodology does provide a normative consumption threshold that captures a "service-level" definition of electricity access. The IEA's normative annual electricity consumption threshold is 1,250 kilowatt-hours (kWh) per household with standard appliances and 420 kWh with efficient appliances, assuming five people per household. Other proposed thresholds that satisfy "access" include 250 kWh per year for a rural household and 500 kWh per year per urban household. The IEA access methodology also states the need for electricity consumption to increase over time to mirror a regional average. Although the IEA lists multiple attributes, spaces, and thresholds important to electricity access, these components do not influence electrification statistics published by the IEA, such as the percentage of the population with access to electricity. Rather, the IEA methodology explicitly states that their electricity database on access derives from the binary metric of whether a household has a connection to an electricity grid, SAS, or mini-grid (IEA, 2020). This binary approach to defining electricity access "serves as a benchmark to measure progress towards the SDG 7.1" (IEA methodology). Using a binary method to track SDG 7.1 limits the understanding of the true state of electricity deprivation (Ayaburi, Bazalian, Kincer, and Moss, 2020).

Currently, the most prominent non-binary electricity access definition is the multi-tier framework (MTF). The MTF captures the state of electricity deprivation by measuring access to electricity services instead of indicating solely access to electricity supply (Bhatia, and Angelou, 2015). The MTF suggests that access to electricity services should be defined based on the performance of six attributes. Each of the given attributes has specific tracking metrics and normative thresholds that determine the degree, or tier, of access. This approach to defining electricity access enables the monitoring of progress towards electrification and SDG 7 (Metadata, 2020). The identification of poor-performing attributes informs where action can be most effective. This positions the MTF to be a significant tool to improve people's livelihood through access to electricity services. MTF analysis of electricity deprivation is conducted by gathering survey information for a case study country, providing a diagnostic report.

Nigeria is a multicultural nation situated on the Gulf of Guinea. Home to 36 different states and the federal capital territory of Abuja, Nigeria has the largest population and GDP in all of Africa. Despite a large GDP, the national (binary) electrification rate for Nigeria is 57%, implying 85 million people have no access to electricity whatsoever (Metadata, 2020). Of the 85 million people with no electricity, 67 million live in rural communities. Unlike other countries, Nigeria's largest electricity-consuming sector is the residential sector (Rapid Assessment and Gap Analysis, n.d.). Crude oil and natural gas are the primary drivers of the Nigerian economy, and thus volatility in oil prices creates instability in the economy. Although Nigeria has large oil reserves, its refining capabilities are relatively small, making oil expensive (eia, 2020). Hydrocarbons provide 83% of Nigeria's generating capacity; hydroelectricity provides a 17% share. Generating capacity in Nigeria is around 12,552 megawatts (MW), but transmission capacity is only 7,500 MW (Transmission, n.d.). In 2020, monthly aggregate technical and commercial collection Losses averaged across all distribution companies (DisCos) was around 54% (NEMSA, 2020). These factors combine with others for an overall nonoptimal reliability in the energy sector. As a result, extraordinarily large amounts of expensive diesel generators supplement grid electricity, muddying the air and the meaning behind electricity access statistics (World Bank, 2014).

Globally, large gains in electricity access have been made since the start of the millennium. However, sub-Saharan Africa has benefited less than other developing regions (World Energy Outlook, 2020). Electricity access is especially critical considering COVID-19. In developing countries, 1 in 4 health facilities are unelectrified (Anon, 2020), and the economic stressors resulting from the pandemic are pushing families to the brink of poverty (World Energy Outlook, 2020).

2: Literature Review

Within Electricity Access literature, four main spheres will be reviewed that inform this research; (1) problem definition, (2) electricity reliability, (3) the multi-tier framework, and (4) critiques of the multi-tier framework. Each sphere's review will include key takeaways from influential scholars and executed case studies.

Energy poverty is often defined as the lack of sufficient access to energy services (Shyu, 2014). Similarly, electricity poverty is often defined as insufficient access to electricity services. The importance of energy access was studied by numerous scholars, showing a correlation between energy access and human development indicators (Fluitman, 1983). From their perspective, electricity access is vital to development. Access to electricity limits the time and effort required to do many tasks. This effort can then be redirected towards education or vocation. Electricity services also provide meaningful health services like space cooling or heating and refrigeration (Osborn, Cutter, and Ullah, 2015).

The following section does not attempt to review the entirety of energy access literature, as this scholarship occupies an enormous domain. Spheres of research not extensively reviewed by this paper are summarized in Table 1.

Table 1: Energy Access Literature outside of this paper's scope

Energy Poverty	Energy Justice	Access to sustainable energy technologies	Historical Energy sector transitions	Energy policy framework optimality	Energy policy effectiveness	Energy System planning	Energy system financing	Reviews of energy access literature
(Monyei, Adewumi, Obolo, and Sajou, 2018)	(Sovacool, Hefferon, McCauley, and Goldthau, 2016) (Jenkins, McCauley, Hefferon, Stephan, and Rehner, 2015)	(Guruswamy, 2011) (Nygaard, 2015)	(Gore, Brass, Baldwin, and MacLean, 2014) (Adhekpukoli, 2018)	(Punda, Capuder, Pandžić, and Delimar, 2017) (Thombs, 2019)	(Laleman, and Albrecht, 2014)	(Enongene, Abanda, Otene, Obi, and Okafor 2020) (Aliyu and Tekbiyik-Ersoy 2019) (Mir et al., 2020)	(Gallagher, 2018) (Ekouevi, and Elizondo-Azuela, 2013)	(Sovacool, 2014)

2.1: Problem Definition

The origin of coordinated international interest in energy access began with UN-organized sustainable development conferences (Osborn, Cutter, and Ullah, 2015). This interest solidified into a commitment in 2015 through the advent of sustainable development goals. As the planning for these goals took off, scholars quickly demanded clarification around utilized tracking methods.

In this paper, the problem definition sphere specifically refers to scholarly writing that identifies problems with the definition of electricity access, mainly critiquing common definitional approaches like the binary IEA methodology. In this sphere, scholars explain the complexities of measuring electricity access and suggest that new electricity access definitions are needed (Culver, 2017; Pachauri et al., 2011). The fundamental question that these scholars seek to answer is, "What does it mean to have access to electricity?" They challenge norms by refuting the statement that "access to electricity is solely dependent on household connection to an electric grid." Their point is made by contrasting vast disparities between those who have access, probing differences in quality, utility, reliability, and electricity safety. Scholars have found that the way we define electricity access has implications for people and policy (Jain, and Shahidi, 2019). If our focus as decision-makers is to provide grid connections exclusively, we neglect people suffering from poor electric quality, quantity, safety, and reliability. These findings have been applied to case studies, where authors highlight definitional shortcomings by exposing large disparities between countries' electricity consumption (Pielke, and Bazilian 2013).

2.2: Electricity Reliability

Reliability assessment of power systems is important for system planning (Bhattacharyya, and Timilsina, 2010), modern grid maintenance (Vugrin, Castillo, and Silva-Monroy, 2017), and as a relevant variable in the definition of electricity access (Ayaburi, Bazalian, Kincer, and Moss, 2020). The following section will focus on the sub-sphere of electricity reliability that is related to electricity access definitions. The linkage between reliability and access is grounded in the verbiage for SDG 7.1. Although electricity reliability is a component of SDG 7, no metric is designated to track it.

Energy system reliability is measured in countless ways. One study reviewing reliability literature identifies 154 different metrics utilized across 58 different papers (Willis, and Loa, 2015). Metrics that directly relate to electricity access definitions typically track the performance and outcomes of an energy system. The two most common performance metrics used to measure the reliability of access are the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAFIRI). SAIDI measures the "sum of customer interruption durations/total number of customers," while SAFIRI measures the "total number of customer interruptions/total number of customers" (Pham, 2013, 28.2). In other words, how often is electricity unavailable, and for how long. The multi-tier framework (MTF) utilizes these two metrics in its methodology for assessing reliability (Bhatia, and Angelou, 2015). Another group of scholars utilizes the same metrics but applies stricter parameters to denote "reasonably reliable" access. Their parameters for reliability, although arbitrary, estimate that 3.5 billion people worldwide lack access to reasonably reliable electricity (Ayaburi, Bazalian, Kincer, and Moss, 2020).

SAIDI and SAFIRI are often utilized in access definitions because they are regularly tracked and reported throughout the energy industry. Due to industry self-reporting, skepticism is often associated with the publication of these statistics. Some scholars predict that utilities, on average, report only 15% of system outage duration (SAIDI) (Taneja, 2017). Due to this conflict, MTF case study reports seek metrics on system outage duration and frequency by surveying households. These surveys measure SAIDI and SAFIRI by asking households to recall outage duration and frequency (Luiz, Beria, Koo, Rysankova, and Portale, 2020). Although self-reported survey data faces its unique uncertainties, there is likely value in assessing reliability metrics from the industry and consumer perspective. All of the foregoing methods focus on measuring energy system reliability based upon performance.

Another approach to measuring reliability focuses on energy system metrics related to inputs, capacities, and capabilities. This approach differs from the performance-based approach, as it seeks to improve outcomes through planning and strategy. For defining access to reliable electricity, the performance-based approach is most common. However, emerging research points to the importance of the second approach (Willis, and Loa, 2015; Gholami et al., 2018). Metrics related to the second approach become coordinated into a resilience plan. A resilience plan tracks metrics and identifies critical thresholds. When a threshold becomes breached, a resilience plan dictates a set of actions to be taken. Actions are taken and preemptively planned in order to minimize energy system disturbances. The minimization of disturbances connects resilience to reliable electricity access.

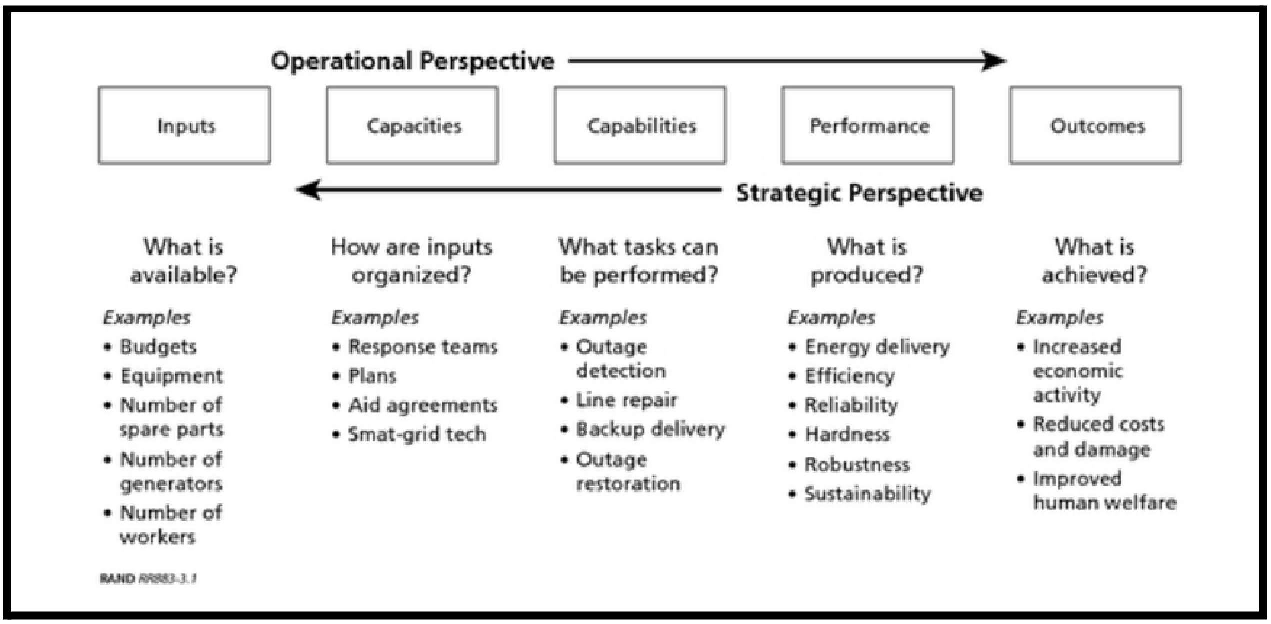


Figure 1. This table differentiates metrics from being strategic or operational. Each perspective is also accompanied by examples of what a metric can pertain to. Source: Willis, and Loa, 2015

One component of a thorough resilience plan mitigates high-impact rare events, including cascading technical failure, extreme natural events, cyber and physical attacks, and space weather attacks (Gholami et al., 2018). These high-impact-rare events occur at seemingly unknowable intervals and are the worst type of severe system disturbance. High-impact-rare events become mitigated by combining system protection schemes, remedial action schemes, defense plans, and recovery plans. These planning measures bolster a resilient and reliable power grid. Without these planning measures, people lose access to electricity, utilities lose money, reliability rankings plummet, and investment attractiveness decreases. Optimal electricity access is reliable (there when you need it) and resilient (elastic when threatened). Research suggests that resilience plans are an essential feature of reliable power systems, especially considering climate change risks (Willis, and Loa, 2015. From the MTF perspective, great gains in electricity access would be achieved in Nigeria if system disturbances were reduced (Luiz, Beria, Koo, Rysankova, and Portale, 2020), and resilience planning is essential to reduce disturbance impact.

Table 2: Differentiating four approaches to reliability

Approaches to Reliability	Characteristic	Metrics	Thresholds for access	Strengths	Weakness
MTF Survey Nigeria Approach (Luiz, Beria, Koo, Rysankova, and Portale, 2020)	-Surveys households on the frequency and duration of power system disturbances. -Maximum thresholds determine what tier of access is prescribed	-Asks survey question: "In a typical month, how many outages/blackouts does the enterprise experience each week?" -Asks survey question:"In a typical week, what was the total duration of all the outages/blackouts?" -Source of data is household surveys	Tier 3, SAIFI > 728 Tier 4, SAIFI between 156 - 728 Tier 5, SAIFI < 156 SAIDI < 6,240 min	-Addresses the reliability experienced by electricity consumers.	-Only measured for households connected to the national grid -Tier 0-2 have no reliability metric -No way to measure lower end reliability progress
MTF Multi-tier Matrix (Bhatia, and Angelou, 2015)	-Measures the frequency and duration of power system disturbances. -Maximum thresholds determine what tier of access is prescribed.	-SAIFI -SAIDI -Source of data is energy industry or governmental organization.	Tier 4, SAIFI < 730 Tier 5, SAIFI<156 SAIDI<6,240 minutes	-Addresses the reliability experienced by electricity consumers.	-Tier 0-3 have no reliability metric -Tier 4 only measures SAIFI -No way to measure lower end reliability progress -Tier thresholds are maximums, that are higher than reasonably reliable

Reasonably Reliable (Ayaburi, Bazalian, Kincer, and Moss, 2020)	-Measures the frequency and duration of power system disturbances. -Minimum SAIFI and SAIDI threshold determine if “reasonably reliable” access is achieved.	-SAIFI -SAIDI -Source of data is energy industry or governmental organization.	-Tier 1, SAIDI <12 SAIFI <12 -Tier 2 SAIDI <24 SAIFI <12	-Addresses the reliability experienced by electricity consumers. -Thresholds for access are “reasonably reliable”	-“Utility reported data underestimates outages”
Resilience Planning (Willis, and Loa, 2015)	-Tracks inputs, capabilities, and capacities. -Forms a plan around the status of these three areas in order to mitigate system disturbances.	-Large variety of possible metrics can be used for planning -Source of data is energy industry or governmental organization.	N/A	-Adresses system disturbances before they happen. -Theoretically improves reliability through planning.	-Does not monitor energy system performance and outcomes

2.3: The Multi-Tier Framework

One of the largest developments in electricity access definition scholarship goes “Beyond Connectedness” to suggest tiers of different access levels (Bhatia, and Angelou, 2015). This framework, referred to as the Multi-Tier Framework (MTF), accounts for the multifaceted nature of electricity access by incorporating thresholds for attributes such as capacity, availability, reliability, quality, affordability, legality, and safety. Allocation to one of the access tiers is based on the lowest-performing attribute. So, if six of the seven attributes designate tier-four access, but one attribute designates tier-three access, the overall electricity access of that population is tier 3. The six tiers of electricity access, as presented by the MTF, can be thought of as a progression of access, where Tier 0 represents poor access and Tier 5 represents optimal access. From the perspective of the MTF, progress towards SDG 7.1 is satisfied at any tier allocation greater than zero (Bhatia, and Angelou, 2015).

Attributes			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Capacity	Electricity	Power		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
		Daily supply capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		Typical source		Solar lanterns	Solar home systems	Generator or mini-grid	Generator or grid	Grid
2. Duration of daily supply				Min 2 hrs	Min 4 hrs	Min 50% of working hours	Most of working hours (Min 75%)	Almost all of working hours (Min 95%)
3. Reliability							Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
4. Quality							Voltage problems do not affect the use of desired appliances	
5. Legality							Energy bill is paid to the utility/pre-paid card seller/authorized representative/legal market operator	
6. Safety							Energy supply solutions have not caused any accidents over the last one year	

Figure 2: This table visualizes the multi-tier framework attributes and allocation process. Source: Bhatia, and Angelou, 2015

The MTF global survey is currently being used alongside the Global Tracking Framework (GTF) to provide a nuanced view of electricity deprivation. Combining these frameworks allows inter-governmental organizations to publish progress towards achieving SDG 7 (Anon, 2020). Metadata coordinated by the World Bank enables these publications. Metadata is available for 11 series, all of which provide a nuanced supply of information that tracks SDG 7 progress. This data tracking apparatus, referred to as the Global Tracking Framework, supports the MTF with information. Both frameworks come from previous scholarship, notably the Total Energy Access framework (Amatya, 2010) and the Multidimensional Energy Poverty Index (Nussbaumer, Nerini, Onyeji, and Howells 2012).

The Total Energy Access framework and Multidimensional Energy Poverty Index play an instrumental role in advocating multifaceted descriptive tracking of poverty. Their contributions influenced the metrics collected under the Global Tracking Framework, laying a foundation for the MTF. The Total Energy Access framework and Multidimensional Energy Poverty Index were innovative in their approach to aggregating the dimensions of poverty, although their work also came from scholarly inspiration (Nussbaumer, Nerini, Onyeji, and Howells 2012). The

Multidimensional Energy Poverty Index addresses poverty through a wide scope, while the Total Energy Access framework's scope is specific to energy poverty. The Total Energy Access framework identifies the importance of various energy services like clean cooking and space heating and electricity services. The Total Energy Access framework also identifies electricity needs at the community and enterprise-scale compared to the residential scale (Amatya, 2010). Original inceptions of the Total Energy Access framework and Multidimensional Energy Poverty Index lacked the tier-based allocations that would later come with the MTF. Practical Action, the organization managing the Total Energy Access framework, eventually became a fierce advocate for the MTF. Simultaneously, the Multidimensional Energy Poverty Index continues to provide multifaceted analyses on all aspects of poverty.

The MTF goes far beyond a single binary metric. One strength of the MTF is its ability to assess electricity access related to households, productive centers, and community centers. This feature is critical considering the positive benefits of electricity access outside of the household (Bryce, 2020). The MTF is a tool that can help track progress towards electricity access while also benefiting policymaker's ability to identify deficits in electricity access policies. The MTF has been utilized in at least 11 published case study reports (Publications, n.d.). These reports provide a comprehensive analysis of specific counties through the lens of the MTF.

One recently published case study utilizes the MTF methodology to assess electricity deprivation in Nigeria. This analysis was scoped within the North-West (NW) geo-political zones, specifically studying the states of Kaduna, Kano, Katsina, Kebbi, Jigawa, Sokoto, and Zamfara. Northwest Nigeria was specifically studied, as the region is home to a significant portion of the unelectrified population (Luiz, Beria, Koo, Rysankova, and Portale, 2020). Northwest Nigeria's energy access diagnostic report was accomplished by surveying 3,668 households from 262 different, specifically identified areas. Comprehensive surveys were provided to households to estimate metrics that inform the MTF tier allocation. The survey strategy utilized was designed to be representative of the two relevant regional electricity distribution companies. The survey strategy also fielded responses from a mix of rural and urban, electrified and non-electrified households. This survey technique allowed for deprivation to be analyzed across the NW region, along the urban-rural divide, and electrified-non-electrified divide. This technique allowed for the identification of context-specific barriers. Identifying barriers that are easily removed can efficiently lift communities to higher tiers of access once a plan is enacted to remove the barrier (Bhatia, and Angelou, 2015). This technique subsequently identifies non-issues for grid-connected households, which can speak to policy instrument effectiveness. Overall tier allocations based on NW Nigeria's MTF report are summarized in Table 3. The report's limitations derive from observations that (1) certain attributes are measured indirectly, (2) grid-connected households are assumed to have access to a specific level of service, and (3) certain attribute tier allocations only pertain to connected households.

Table 3: Results and limitations of MTF case study report for NW Nigeria

Attributes	Capacity	Availability (daytime)	Reliability	Quality	Affordability	Formality	Health and Safety
Percentage of NW residing households allocated to a tier (rounded to the nearest whole number)	**58% → Tier 0** 2% → TIer 1-4 40% → Tier 5	4% → Tier 0 21% → Tier 2 58% → Tier 3 15% → Tier 4 3% → Tier 5	24% → Tier 3 69% → Tier 4 7% → Tier 5	17% → Tier 3 83% → Tier 5	3% → Tier 2 97% → Tier 5	2% → Tier 3 98% → Tier 5	1% → Tier 3 99% → Tier 5
Limitations	-Measured indirectly -Assumes that all grid connected households have tier 5 access		-Only pertains to grid-connected households	-Only pertains to mini-grid and national grid-connected households		-Only pertains to grid-connected households -Measured indirectly	-Only pertains to grid-connected households

MTF reports serve as a valuable tool for policy and planning purposes. One analysis creates stochastic, i.e. randomly determined load profiles based on the MTF tiers (Narayan et al., 2020). This analysis compared load profiles to observed measurements in Rwanda to demonstrate the applicability of the MTF. These load profiles estimate future demand in a bottom-up, energy-service conscious approach, which means that total demand derives from household energy services demand rather than a theoretical threshold. Similarly, other researchers use MTF and energy system optimality to analyze low-cost solutions to achieve electricity access (Narayan et al., 2019). Load profiles can inform energy system planning, and good system plans ensure that networks are optimally budgeted and correctly sized for utility. Furthermore, load profiles created in a stochastic way can provide plans for customized, low carbon electricity solutions. When load profiles derive from MTF tiers, the profiles encapsulate access to energy services, enabling models to correspond to livelihood gains.

The theoretical approach of the MTF has also been influential in India, where the government has created its own tiered framework. This framework is known as Access to Clean Cooking Energy and Electricity Survey of States, and it is calibrated to the Indian context (Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016). Large countries like India and Nigeria have specific operational barriers. Scholars have encouraged these countries to develop country-specific frameworks for assessing energy access in a nuanced way (Ayaburi, Bazalian, Kincer, and Moss, 2020). Country-specific frameworks benefit from describing the state of energy service deprivation in a way that reflects the values and priorities of the specific country. From a justice standpoint, this approach might be preferred, as it gives agency to countries instead of enforcing international norms (Sovacool, Burke, Baker, Kotikalapudi, and Wlokas, 2017).

An important feature of any multi-tiered framework methodology is that it seeks to capture access to electricity services instead of electricity access in general. This reinforces the end goal of electrification, which is to improve the lives of people. Tier-based conceptualization has led to the proliferation of nuanced electricity access research. As described in Table 4, recent research applies the MTF to specific contexts, improves the MTF through contextualization and calibration, and critiques the MTF

Table 4: Scholarship related to the MTF

Purpose of scholarship	Application of MTF to specific contexts	Improve MTF through contextualization and calibration	Critiques MTF
Scholars	(Luiz, Beria, Koo, Rysankova, and Portale, 2020) (Publications, n.d.)	(Ayaburi, Bazalian, Kincer, and Moss, 2020) (Groh, Pachauri, Rao, 2016) (Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016)	(Thomson, Bouzarovski, & Snell, 2017) (Pelz, Pachuri, and Groh, 2018) (Broto et al., 2017)

2.4: Critiques of the multi-tier framework

Since its adoption by the WB, the MTF exists as the standard model for a multifaceted definition of electricity access, although the IEA definition remains the primary method used to track SDG 7.1, largely due to its simplicity. As the MTF increases in notoriety, it invites critical review. Critics argue that the MTF is limited by complexity, statistical requirements, a limited inclusion of reliability, a flawed inclusion of affordability, and a lack of ability to reflect reality.

The MTF lacks the accurate capacity to aggregate demand across different regions, where people face different circumstances with different values. Furthermore, the task of aggregation is made more challenging considering the data requirements needed to determine what tier of access a population falls under (Broto et al., 2017). Although large statistical requirements are required to conduct a MTF report, the UN is attempting to combat this by including MTF related questions in future global census reports. The authors of the MTF have proposed three differing framework levels; comprehensive, simplified, and minimalistic (Bhatia, and Angelou, 2015). Variance in the framework level limits the statistical requirements needed to conduct a comprehensive analysis.

Scholars who advocate for a reliability approach to defining electricity access argue that a methodological flaw is present in the MTF because lower tiers of energy access have no reliability threshold (Ayaburi, Bazalian, Kincer, and Moss, 2020). This flaw is especially relevant as it undermines the goal of the MTF, which is to understand in detail the state of electricity access. Excluding reliability metrics in lower tiers leaves no way to monitor progress at lower-tier levels (Ayaburi, Bazalian, Kincer, and Moss, 2020). Furthermore, the MTF case study report in Nigeria fails to capture the reliability of off-grid electricity users (Luiz, Beria, Koo, Rysankova, and Portale, 2020).

The MTF measures affordability by comparing household energy service costs to income. This approach has garnered criticism due to its focus strictly on monetary aspects of energy service costs and neglects appliance acquisition costs (Thomson, Bouzarovski, & Snell, 2017). Another shortcoming of the MTF affordability attribute is that it neglects wiring costs, a barrier to access (Luiz, Beria, Koo, Rysankova, and Portale, 2020).

An unvalidated assumption of the MTF approach to defining electricity access is that every step up in tier corresponds to the same step-up in utility (Pelz, Pachuri, and Groh, 2018). Without research into the benefits associated with each tier, we have no verifiable means to guage the utility of each incremental step-up to a new tier. This observed situation has inspired many scholars to test various MTF assumptions through case study monitoring and surveying (Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016).

One case study of 230 Bangladesh households reports that the MTF tier-based assessment is highly sensitive to parameter value changes. Meaning that small changes in assumptions impact tier allocation, speaking to the tiers' arbitrary nature (Groh, Pachauri, Rao, 2016). Something as simple as variance in utilized appliances is an example of an assumption change. Another case study from India surveyed over 8,500 households and documented electricity access satisfaction. They found that reliability is valued almost equally to grid connections for non-connected households, suggesting the inclusion of reliability for lower-tier access levels (Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016). Surveys have also revealed that reliability is likely to be overestimated by metrics like SAIDI and SAFIRI (Reinders, 2018). Other scholars are conducting phone-based surveys, collecting data vital to understanding electricity access's multifaceted nature (Dillon, 2010). Although surveys face specific problems (Jain, and Shahidi, 2019), they are a beneficial tool that enables the calibration of the MTF (Pelz, Pachuri, and Groh, 2018).

Scholarly literature has identified numerous individual and societal benefits of electricity access (Fluitman, 1983). Electricity deprivation currently affects between 0.75 and 3.5 billion people (Metadata, 2020; Ayaburi, Bazalian, Kincer, and Moss, 2020). Analyzing electricity access information defines a problem, informs us on progress towards electrification for all (Anon, 2020), and points to areas where action can be most effective. In order to analyze electricity access, it must first be defined. Variance in the definition of "access to affordable, reliable, sustainable and modern energy (SDG 7)" creates large discrepancies in the scope of electrification deprivation. Many scholars have spoken to the deficiencies associated with a binary definition (Pielke, and Bazilian, 2013). Other scholars have advocated for a user-specific definition of reliable access to electricity (Jain, and Shahidi, 2019). Recently, the MTF has become a forerunner in defining six tiers of electricity access, utilizing a multifaceted attributes-based approach. Two spaces where the literature base could be improved upon include: (1) comparing different approaches to electricity access; and (2) identifying definitional components of a government's approach to defining electricity access. The subsequent sections of this paper will attempt to address these missing spaces by extrapolating key findings from electricity access literature, studying Nigeria's federal rural electrification policy landscape, and comparing the fulfillment of different electricity access definitions.

2.5: Research questions (RQs)

RQ1: How are Nigeria's national rural electrification policies coordinated and structured?

RQ2: How is electricity access defined and success measured in federal rural electrification policies, and by federal agencies?

RQ3: To what extent is this framework effective at capturing the true state of electricity access and deprivation in the country and how could this be improved?

3: Methodology

3.1: Data Collection

This section describes the data collection process, where information contributes to answering RQ1-3. Information has been pulled from three main areas; the Government of Nigeria, International Agencies, and scholarly literature.

Government websites were extensively studied to speak to the coordination and structure of the rural electrification policy landscape. Starting at the Federal Republic of Nigeria's (FRN) home website (https://statehouse.gov.ng/), information was collected that located energy agencies with the highest authority. The Federal Ministry of Power (MOP) (https://www.power.gov.ng/) is responsible for creating policies that regulate energy generation, transmission, and distribution. The Energy Commission of Nigeria (ECN) (https://www.energy.gov.ng/index.php) evaluates and coordinates enacted energy policy put forward by the MOP. The Nigerian Electricity Regulatory Commission (NERC) (https://nerc.gov.ng/) is a recently created entity with an electrification-specific scope. The Rural Electrification Agency (REA) (https://rea.gov.ng/) is the federal agency charged with implementing policy.

The FRN, MOP, ECN, NERC, and REA websites were studied, looking specifically for seminal documents, hierarchical design, and rural electrification-related programs. Information drawn from these websites facilitated a summarization of rural electricity policy. Information under "structure" and "objective" tabs proved to be very useful. Landmark policy documents such as the EPSRA and the RESIP informed agency design within Nigeria's power sector. Analysis of policy documents gave special attention to keywords including "energy access," "electricity access," "Electricity consumption," and "Wh, kWh, mWh."

IGO databases also informed RQ1. A notable tool for identifying energy policies is the IEA Policy database (https://www.iea.org/policies). Database results were refined using "Nigeria" as a search term. The IEA policy database clarifies relevant published policies and their status as active or inactive.

The final supplementing data source for RQ1 included a review of scholarly literature. Databases and keywords used to review scholarly literature are given in Table 5. Search results were refined to be peer-reviewed and highly cited.

Table 5: RQ1 Literature review research methods

Databases	Keywords
CU Boulder OneSearch Web Of Science Google Scholar Springer Publishing Research Gate Science Direct	Nigeria Electricity Access Electrification institution Rural Electrification Policy Electricity Reliability Measurement Frameworks

RQ1 sought to analyze electrification policies from the outside, studying the space they occupy within an environment of legislation. RQ2 is positioned to study the interior of enacted policy, digging into the policy's definitional components.

Information relevant to answering RQ2 was collected using sources and keywords featured in Table 6.

Table 6: RQ2 Nigerian Government information research methods

Sources	Keywords
FRN website MOP website ECN website NERC website REA website Legislative documents Press releases Program brochures	Energy Access Electricity Access Energy Access definitions/defines/defined Electricity Access definitions/defines/defined Methodology/Method/Methods/Measurement W, Wh, kW, kWh, MW, MWh Success, objective, goal, purpose Benchmark, markers, tracking, metrics

Any information that provided clarity on the methodological approach used to define energy or electricity access was highly coveted. When electrification connection statistics were given, consumption and population data points were collected to illuminate possible examples of successful electrification. Information that laid out goals, benchmarks, and tracking processes was crucial to determining how the FRN sought to measure success.

A crucial source of information on electricity access is the UN, WB, and associated agencies and organizations, notably the IEA, SEA4all, and RSMAP. The 2020 energy access IEA methodology is the most utilized definitional methodology. Most IGO publications, and governments like Nigeria, broadly track energy and electricity access using a methodology similar to the IEAs, making it a vital source for RQ2 (IEA, 2020). RSMAP houses official reports for Nigeria and a "Tracking SDG 7.1 .1 electrification dataset" (Tracking SDG 7.1.1, n.d.).

Answering RQ2 broadly relied on summarized institutional information. Institutional information was collected from government websites and landmark policies. Nigeria's institutional information was summarized by identifying the goals, policies, and operational procedures, for a given institution. The summary of this information allowed for an implicit governmental framework to be identified.

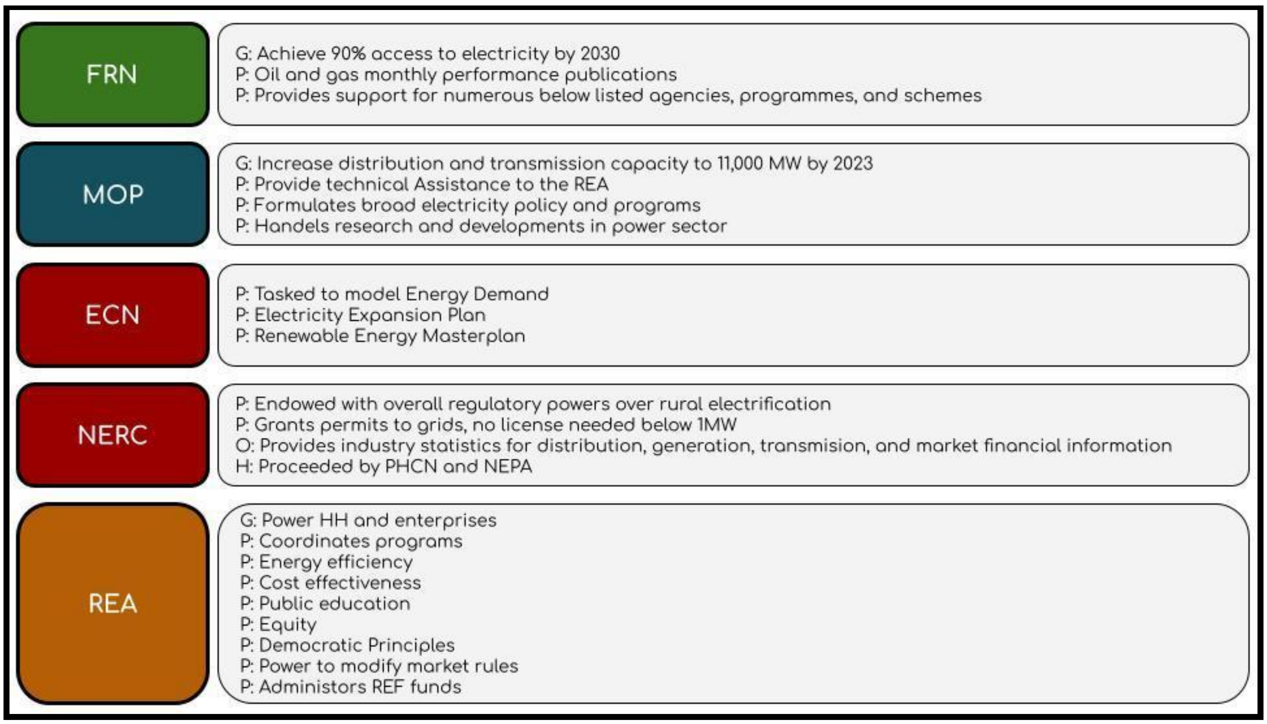


Figure 3: Goals(G), Policies(P), and Operational Procedures(O) for primary institutions related to National Rural Electrification in Nigeria

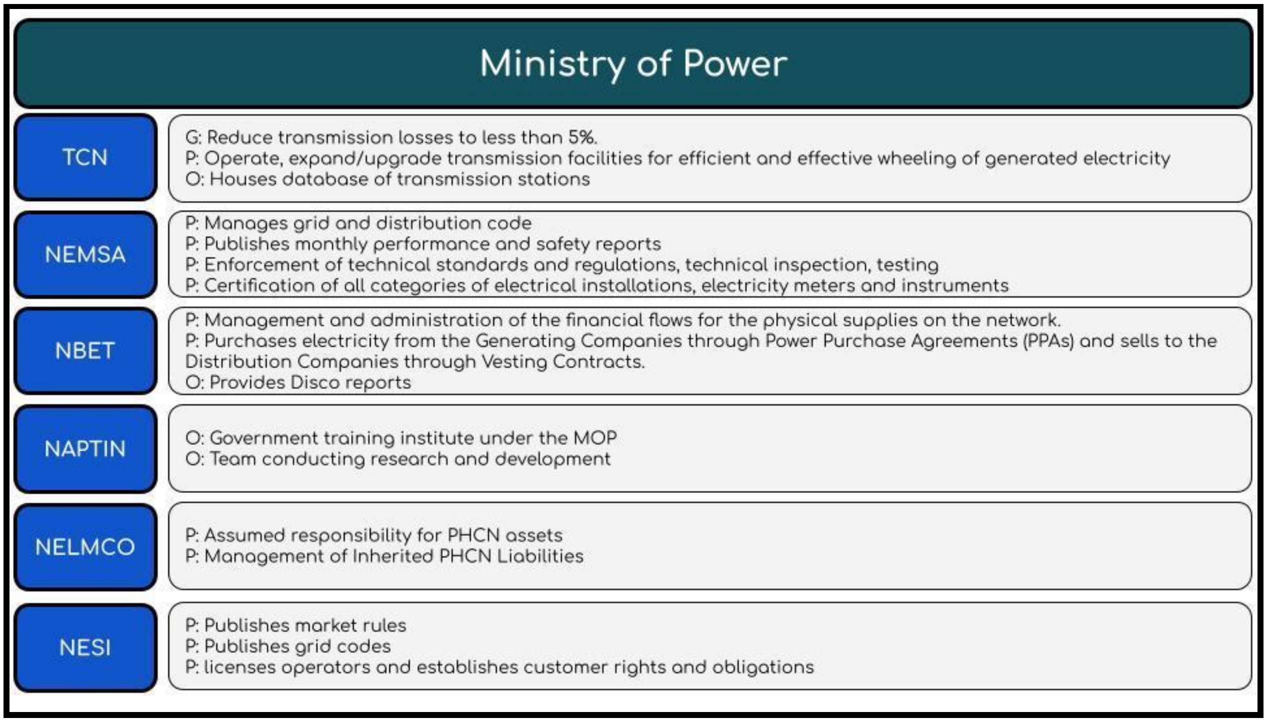


Figure 4: Goals(G), Policies(P), and Operational Procedures(O) for associated institutions related to National Rural Electrification in Nigeria

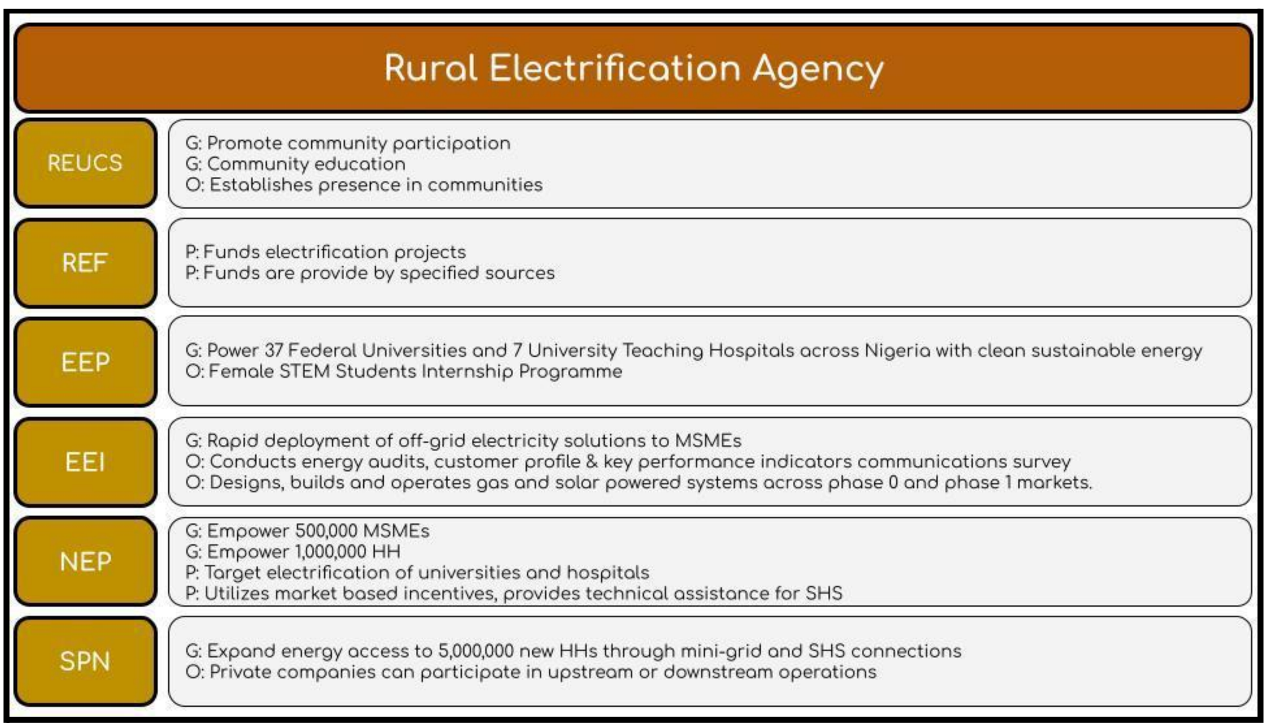


Figure 5: Goals(G), Policies(P), and Operational Procedures(O) for associated institutions related to National Rural Electrification in Nigeria

Outside the context of Nigeria's rural electrification policy, RQ2 has an entire literature base devoted to it. A review of this literature base was conducted using scholarship sources in Table 5. Due to the literature base's size, special attention was given to publications placing electricity in the foreground. Key-word searches were necessary to facilitate a review of the scholarship. Relevant search terms for RQ2 are congruent with the terms listed above. Articles with distinctive access definitions and methodologies played a valuable role in framing what it means to have access. Articles that presented critiques of definitional methodologies helped to understand the shortcomings of definitional components. The literature review also lent itself to the study of RQ3. RQ2 sought to understand the mode of rural electricity policy in Nigeria, while RQ3 is positioned to understand the political framework's effectiveness.

RQ3 was answered by collecting information from electricity-access scholarship, Nigerian Government resources, and IGO databases. MTF attributes were identified as fundamental since scholarly literature emphasizes these attributes (Tait, 2017). Where the Nigerian institutional environment addressed MTF attributes, documentation took place. This identification and documentation enabled a table to be created, showing places where Nigeria effectively captures electricity access attributes. IGO information provided electrification data over time. Nigeria's electrification data, from 2000 to 2018, was collected from the World Bank database (Metadata, 2020). This data was plotted over time to display Nigeria's electrification progression. Framework effectiveness was also gauged by referencing two legislative effectiveness indices, provided by the African Development Bank and Regulatory Indicators for Sustainable Energy (RISE, n.d.; ERI, 2020).

RQ3 has also been informed by the "fulfillment of access" methodology. This methodology gathers electrification information from the UN and FRN and compares it with access definitions put forward by the IEA and MTF. Statistics have been augmented to standardize units into annual and individual. The data collection process for the "fulfillment of access" methodology follows the process explained in Table 7.

Table 7: Data collection methodology for "Fulfillment of access"

Compound variables	Amount	Component variables and data source	Amount
Multiplied per capita consumption times population to derive total electricity	30,557,280,000 kWh	Collected population data; (Metadata, 2020)	195,880,000 People
		Collected electricity consumption data per capita from; (Metadata, 2020)	156 kWh per person per year
Multiplied access rate times total population to get the number of people with access	111,651,600 People	Collected electricity access rate; (Metadata, 2020)	57% of the population
		Population; (Metadata, 2020)	195,880,000 People

Divided total electricity by population with access to get electricity consumption per connected person	276 kWh per person per year	total electricity	30,557,280,000 kWh
		number of people with access	111,651,600 People
Divided installed capacity by number of people with access to get power capacity per connected person	112 W	Collected current installed capacity; (Trade.gov, 2020)	12,552 MW
		number of people with access	111,651,600 People
Multiplied number of HH connected by number of people per HH to get the new connected population	70,000,000 People	Identified connection goals in National legislation, Number of households connected; (RESIP, 2016)	10,000,000 households
		Identified connection goals in National legislation, Number of people per Nigerian household; (RESIP, 2016)	7 People per Household
Divided new capacity over new connected population to get RESIP capacity per new connected person	86 W	Identified connection goals in legislation, New capacity required to electrify new connected population; (RESIP, 2016)	6,000 MW
		new connected population	70,000,000 People
Derived per person benchmarks by taking consumptive household benchmark and dividing by number of people per household	Nominal: 250 kWh per person per year Urban: 100 kWh per person per year Rural: 50 kWh per person per year;	Identified Nominal IEA benchmark for electricity access; (IEA, 2020)	1,250 kWh per household per year
		Identified Urban IEA benchmark for electricity access; (IEA, 2020)	500 kWh per household per year
		Identified Rural IEA benchmark for electricity access; (IEA, 2020)	250 kWh per household per year
		Identified number of people per household, related to IEA benchmarks; Source IEA 2020 Methodology	5 people per household

Multiplied MTF daily supply capacity by 365 to get annual supply capacity	Tier 3: 365,000 Wh per household annual supply capacity Tier 5: 2,993,000 Wh per household annual supply capacity	Identified Tier 3 MTF benchmarks for electricity access, household daily supply capacity; (Bhatia, and Angelou, 2015)	1 kWh per household daily supply capacity
		Identified Tier 5 MTF benchmarks for electricity access, household daily supply capacity; (Bhatia, and Angelou, 2015)	8.2 kWh per household daily supply capacity
Divided annual household supply capacity by Number of People per Nigerian household, to get MTF annual individual supply capacity	Tier 3: 52 kWh annual individual supply capacity Tier 5: 425 kWh annual individual supply capacity	Tier 3 household annual supply capacity; (Bhatia, and Angelou, 2015)	365,000 Wh per household Wh annual supply capacity
		Tier 5 household annual supply capacity; (Bhatia, and Angelou, 2015)	2,993,000 Wh per household annual Supply capacity
		Number of people per Nigerian household; (RESIP, 2016)	7 People per Household
Divided HH power capacity byNumber of People per Nigerian household, get MTF individual power capacity	Tier 3: 29 W per person power capacity Tier 5: 286 W per person power capacity	Identified Tier 3 MTF benchmarks for power capacity; (Bhatia, and Angelou, 2015)	200 W per household power capacity
		Identified Tier 5 MTF benchmarks for power capacity; (Bhatia, and Angelou, 2015)	2 kW per household power capacity
		Number of people per Nigerian household; (RESIP, 2016)	7 People per Household

3.3: Data Analysis

This section comprises the processes used to analyze the collected data listed in section 3.2. Collected information has been analyzed to best answer the three research questions posed by this paper. The primary methods used to analyze collected information include; thorough review, categorization and summarization of sources, qualitative comparisons, and statistical comparisons.

Information collected for RQ1 was refined and presented to provide a "snapshot" or summary of Nigeria's federal policy environment, specifically as it relates to rural electrification policy. To refine the collected information, each Government agency was summarized into their duties, goals, and relationship with other agencies. Once agencies were organized, they were placed into a relationship flowchart that expresses Nigeria's national rural electrification agencies' hierarchical design. After an agency flow chart was created, landmark policies were added to the diagram to understand what space these policies occupy, given their context within the agency web.

Due to the lack of a Nigerian-specific electricity access definition, statistical comparisons became the main source of answering the definitional component of RQ2. Electrification statistics published by Nigeria were compared to statistics published by IGOs using the percent difference formula. Nigeria's self-reported "percentage of the population with access to electricity" differed from IGO publications by 5%.

Table 8: Data collection methodology for determining percent difference between intergovernmental and Nigerian electrification statistics

Source	Data Retrieved From	National electrification rate (as a percent of the total population)
Nigeria NEP 2018	https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/PESR_NG_NIGERIA_ELECTRIFICATION_PROJECT_CORR_EN-final.pdf	55%
WB 2018	https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NG	57%
IEA 2018	https://www.iea.org/data-and-statistics?country=NIGERIA&fuel=Electricity%20and%20heat&indicator=SDG71	61%
ESMAP 2018	https://trackingsdg7.esmap.org/country/nigeria	57%
seforall 2018	https://www.seforall.org/system/files/2020-10/Analysis-SDG7-Progress-2020.pdf	57%

An average national electrification rate was derived from the four IGO sources by averaging the four electrification rates. This average rate was compared to the Nigerian published rate using the percent difference formula, [(IGO Average rate - Nigeria rate) / Nigeria rate], which produced a difference of 5%.

Additionally, Nigeria's rural electrification plans were studied, looking for information that could provide insight into the question of "What does it mean to have electricity access from the perspective of the FRN." Information found in the RESIP explained a goal to connect x amount of users to y amount of capacity. If these connections were to occur, the electricity access rate would jump up to z percent, and success would be proclaimed in progress towards electricity access for all Nigerians. The new user capacity rate under RESAIP, explained by y/x, was the closest capacity metric used to answer RQ2 explicitly.

Table 9: Methodology for determining RESIP capacity per new connected user

X	Y	Y/X
70,000,000 People	6,000 MW	86 W (RESIP capacity per new connected person)

Undertaking a broad approach to understanding RQ2 was reliant on the summarization of Nigeria's institutions. Nigeria's institutional information was summarized by identifying goals, policies, and operational procedures. The summary of this information identified 10 components comprising Nigeria's implicit framework for addressing electricity deprivation. The 10 components were selected if they fulfilled one of the following requirements:

Requirement 1: Component is referenced as a valuable aspect in the literature
Requirement 2: Component portrays a nuanced understanding of electricity deprivation.
Requirement 3: Component is addressed by numerous institutions.

Statistical analysis enabled Nigeria's electrification trends to be displayed over time, which provided insights for RQ3. Methods used to display electricity statistics are presented in Table 10.

Table 10: Methodology for producing graphs 1-3

Graph Number	Steps used	Functions executed
Graph 1	Step 1: Collect per capita electricity consumption, and access to electricity data from 2000-2018 for Nigeria. (Metadata, 2020)	N/A
	Step 2: Plotted data	Excel: Insert → 2-D Line Chart
Graph 2	Step 1: Collect per capita electricity consumption,	N/A

	access to electricity, and population data from 2000-2018 for Nigeria. (Metadata, 2020)	
	Step 2: Derived percent change from the year 2000, for each of the following years, for all three variables.	[(Data from Year 2000 - Data from Year x) / Data from Year 2000]
	Step 3: Plotted percent change data	Excel: Insert → 2-D Line Chart
	Step 4: Added a timeline to the x-axis displaying the year landmark policies were enacted.	N/A
Grap 3	Step 1: Collect per capita electricity consumption, access to electricity, and population data from 2000-2018 for Nigeria. (Metadata, 2020)	N/A
	Step 2: Derived annual percent change year to year, for all three variables.	[(Data from Year n - Data from Year n+1) / Data from Year n]
	Step 3: Plotted annual percent change data	Excel: Insert → 2-D Line Chart

Electrification data for Nigeria was also fit into a model that shows "the degree to which real consumption and capacity (as well as planned capacity) fulfills "access" definitions." This model is referred to as the "fulfillment of access" methodology. The purpose of this methodology is to compare capacity to an access threshold to determine fulfillment of said access definition. This approach enables comparisons between existing and planned capacity and comparisons across different access definitions. The annotative steps taken to analyze data from the "fulfillment of access" methodology are provided in Table 11.

Table 11: Data analysis methodology for "Fulfillment of access"

Step 1	Access benchmarks (Nominal, Urban, Rural, Tier 3 supply capacity, Tier 5 supply capacity, Tier 3 power capacity, Tier 5 power capacity) were annotated as "Demand", as they represent the energy or power demanded to proclaim "access".
Step 2	Consumption and capacity measurements (electricity consumption per connected person, power capacity per connected person, RESIP capacity per new connected person) were annotated as "Supply", as these figures represent the real (observed) or planned (RESIP, 2016) consumption or capacity that an individual does, or would have access too.
Step 3	Demand was divided over supply to assess "The degree to which real consumption and capacity (as well as planned capacity) fulfill "access" definitions".

Expressions used in Figures 8 and 9 are explained in Table 12 and 13.

Table 12: Expressions used for "Fulfillment of access" figure 8

Expressions for figure 8	Result
Demand (IEA nominal) / Supply (electricity consumption per connected person)	0.906
Demand (IEA urban) / Supply (electricity consumption per connected person)	0.362
Demand (IEA rural) / Supply (electricity consumption per connected person)	0.181
Demand (MTF Tier 3 supply capacity) / Supply (electricity consumption per connected person)	0.188
Demand (MTF Tier 5 supply capacity) / Supply (electricity consumption per connected person,)	1.547

Table 13: Expressions used for "Fulfillment of access" figure 9

Expressions for figure 9	Result
Demand (MTF Tier 3 power capacity) / Supply (power capacity per connected person)	0.259
Demand (MTF Tier 5 power capacity) / Supply (power capacity per connected person)	2.554
Demand (MTF Tier 3 power capacity) / Supply (RESIP capacity per new connected person)	0.337
Demand (MTF Tier 5 power capacity) / Supply (RESIP capacity per new connected person)	3.326

Results are interpreted according to the following relationships:

Table 14: Analysis of results from "fulfillment of access" expressions

If Demand/Supply ratio is = to 1, the access definition is perfectly fulfilled.
If Demand/Supply ratio is > 1, The access definition is not fulfilled.
If Demand/Supply ratio is < 1, The access definition is fulfilled.

Recommendations have been identified by observing deficits in the FRN framework. Deficit identification and recommendations are based on findings from scholarly literature.

4: Results

4.1: How are Nigeria's national rural electrification policies coordinated and structured?

The Federal Republic of Nigeria operates under the framework provided by the 1999 constitution, where executive, legislative, and judicial branches have been established. The Federal Government of Nigeria, led by President Muhammadu Buhari and his appointed cabinet ministers, sets national goals and coordinates policies to meet those goals. The most important electrification goal provided by the FRN is a mission to achieve 90% access to electricity by 2030 (RESIP, 2016). The Federal Legislature crafts legislation in the National Assembly, comprising a 109- member Senate and a 360-member House of Representatives. The Federal Ministry of Power (MOP) is the preparer of electricity planning documents (EPSRA, 2005). The Federal Ministry of Science and Technology (MST) is associated with large-scale energy planning (EPSRA, 2005). Work in big picture energy projects is performed by the Energy Commission of Nigeria (ECN), working closely with the MST. The ENC was established under Act No. 62 of the 1979 Energy Commission of Nigeria Act. The ECN executes important duties such as modeling total energy demand, drafting electricity expansion plans, and renewable energy master plans. A recent document put forward by the MST and ECN has a chapter dedicated to electricity policy. However, the policies, objectives, and strategies described are brief and high-level, reinforcing a framework crafted in previous policy documents (National Energy Policy 2003, 2018).

MOP responsibilities include the formulation of broad electricity policy and programs (EPSRA, 2005). Under the MOP's jurisdiction resides eight agencies; the Transmission Company of Nigeria (TCN), Nigerian Bulk Electricity Trading (NBET), Nigerian Electricity Liability Management Company (NELMCO), Nigerian Electricity Management Service Agency (NEMSA), National Power Training Institute of Nigeria (NAPTIN), Nigerian Electricity Supply Industry (NESI), National Electric Regulatory Commission (NERC), and the Rural Electrification Agency (REA). Each of these agencies plays an important role in the rural electrification policy landscape for Nigeria. TCN is responsible for the operation of transmission facilities. This task is very important, as transmission losses in Nigeria are substantial and contribute to an overall reliability deficit. NEMSA, established under the NEMSA Act of 2015, plays a pivotal role as the manager of grid codes and enforcer of technical standards and regulations. NEMSA publishes performance and safety reports that assess electricity access along the attributes of reliability and safety. NBET purchases electricity from generating companies through power purchase agreements and sells electricity to distribution companies through vesting contracts. This management of financial flows ensures that generated electricity meets end consumers. NAPTIN provides an important service as a training institute for the MOP. NAPTIN trains future employees to ensure the lineage of a functioning power sector. NAPTIN research and development also contribute to innovations in the sector. NELMCO has played an important role as manager for the assets and liabilities of the Power Holding Company of Nigeria , formerly the National Electric Power Authority . This managerial role facilitated the transition from a state-owned to liberalized power sector. The NESI serves a function vital to the integrity of the power industry as an institution. Its responsibility as the publisher of market rules and grid codes ensures an operating industry ready for private sector involvement. Additionally, its duties as a license operator and establisher of customer rights and obligations ensure that the legality of electricity provisioning is ensured. Ensuring legality addresses one of the attributes of the MTF. Two of the dominant agencies related to rural electrification policy are NERC and the REA. NERC possesses overall regulatory authority over rural electrification and exists as an independent regulatory body.

Rural electrification legislation prepared by the MOP is implemented by the Rural Electrification Agency (REA), whose work establishes democratic and equitable principles and provides electricity education to the public. Evidence of these characteristics is provided by five of the REA policy themes (REA.gov, n.d.). Theme one regulated the tariffs that can be applied to customers, demanding 60% of customers agree to an outside tariff and ensuring that all tariffs are cost-reflective. Theme two looks to increase renewable energy (RE) projects' attractiveness. Attractiveness is enabled from demand stimulation. This is achieved by raising community awareness of RE alternatives and providing grants covering RE projects' initial start-up costs. Policy theme three educates end-users on RE and energy-efficiency, lowering the energy intensity of energy services. Policy theme 4 encourages local participation in energy projects through community ownership of RE project stock. This effort is backed by promoting equitable distribution of RE projects, targeting poor infrastructure communities. Policy theme 5 works with communities to preserve electricity assets and seeks to engage all relevant stakeholders (REA.gov, n.d.).

The REA's role as a program coordinator positions itself to house six operational institutions; the Rural Electricity Users Cooperative Society (REUCS), Rural Electrification Fund (REF), Energizing Education Programme (EEP), Energizing Economies Initiative (EEI), Nigerian Electrification Project (NEP), and Solar Power Ninja (SPN). The REUCS promotes community participation and education by establishing chapters in local communities (REA.gov, n.d.). REUCS exists to ensure that electricity users are engaged, providing a space for customers to collectively bargain. The REF provides an invaluable service of project financer, collecting and allocating funds based on the policy crafted by higher authority institutions (EPSRA, 2005). The EEP is a program that targets the electrification of 37 Universities and 7 University teaching Hospitals across Nigeria. The EEP also houses a program that facilitates women's professional growth in the power sector (REA.gov, n.d.). Where the EEP seeks to electrify Universities, the EEI seeks to electrify micro, small, and medium enterprises (MSMEs). EEI functions by designing, building, and operating natural gas and solar-powered electricity systems for MSMEs (REA.gov, n.d.). The EEP and EEIs work is advantageous, as it addresses the limitations of exclusive focus on household electricity access. The NEP mission is to increase electricity access, targeting MSMEs, Universities, and households. The NEPs four-component domains include solar hybrid mini-grids, stand-alone solar systems for households and MSMEs, energizing education, and technical assistance (REA.gov, n.d.). The NEP also provides project implementation manuals, appraisal frameworks, resettlement processes, and social management strategies (REA.gov, n.d.).

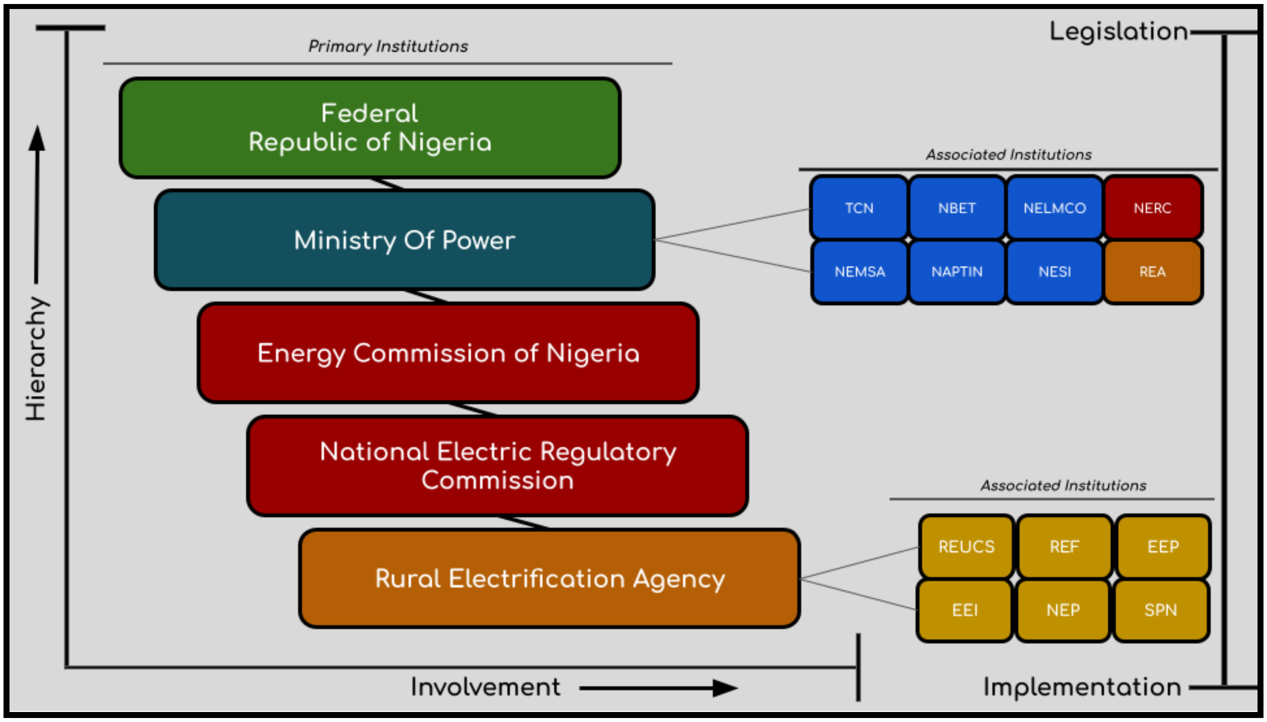


Figure 6: Institutional structure of Nigeria's National Rural Electrification Institutions

The Electric Power Sector Reform Act of 2005 (EPSRA) is a landmark piece of legislation that effectively sought to democratize Nigeria's power sector. The democratization process began with the unbundling of a state-owned monopoly, NEPA. NEPA was unbundled into 18 successor companies that are now privatized. This unbundling led to the establishment of competitive electricity markets (Adhekpukoli, 2018). The move towards liberalization enabled a power sector that could better meet the needs of electricity users. Liberalized power sectors, in theory, provide better services at cheaper prices (Adhekpukoli, 2018). In practice, the EPSRA established institutions that work towards improving electricity access for all Nigerians. The EPSRA was enacted by the National Assembly of the Federal Republic of Nigeria. The act provides a legal foundation for NERC, REF, and the REA. Part three of the EPSRA establishes the functions and powers of the NERC. This electricity commission is tasked with preserving an efficient industry and market structure. NERC essentially assumes accountability for the liberalization of the power sector through its regulatory powers. As described by the EPSRA, NERC regulates the unbundled successor companies partnered under the NESI.

Part nine of the EPSRA establishes the purpose and scope of the REF and REA. REF funding sources are explicitly described in sections 53, 89, 90, and 91. These funding sources include surpluses, fines, donations, contributions, monies appointed by the National Assembly, and license fees. As stated in section 88, funding allocations designated to the REF are to be audited and managed by the REA, ensuring that transparent allocation criteria follow REF funding distribution. As stated in the EPSRA, the MOP is tasked with formulating a rural electrification strategy and plan, with considered submissions from the REA and NERC. The EPSRA was preceded by the National Electric Power Policy of 2001 (NEPP). NEPP created the Nigerian Electrification Programme, designed to expand electricity access. NEPP was replaced by recent policy, but its mission to expand electricity access is referenced here.

As the EPSRA formed a legal justification for electrification action, the Rural Electrification Strategy and Implementation Plan of 2016 (RESIP) actualized the justified framework. This strategy and implementation plan became the national sector-wide roadmap to identify least-cost electrification solutions for rural communities across Nigeria (RESIP, 2016). The FRN put forward the RESIP as a plan to accomplish the goals established in the EPSRA. The implementation plan maintains the MOP's responsibility to set policy guidelines. The MOP is also tasked to monitor and evaluate the performance of the plan and its agencies.. Under the RESIP, NERC is responsible for establishing and enforcing tariff models specifically designed for rural areas. The RESIP was implemented with capital from the REF, an agency under the REA, as defined by the EPSRA. The mission of the RESIP is to increase electricity access, especially in rural areas. The paradigm for this strategy embraces centralized and decentralized approaches, advocating for increases in RE, grid-extensions, off-grid solutions, and stand-alone systems. Instruments utilized to achieve this new approach include tariff policy, regulatory policy, participation from non-traditional operators, promotion of low-cost technologies, promoting the reduction of equipment cost, capital subsidies, promotion of RE, equitable allocation, community education, dealing with legacy projects, constituency projects, capital building, local participation, energy efficiency, and dealing with network expansion and ownership (RESIP, 2016). The RESIP concludes by calling on relevant parties to participate in the rural electrification agenda, working to achieve universal electricity access by 2040 (RESIP, 2016). The RESIP was preceded by policy documents such as Rural Electrification Policy 2005, and 2009. The RESIP replaced the Rural Electrification Policy documents of 2005 and 2009, but these document's commitments to rural electrification are referenced here.

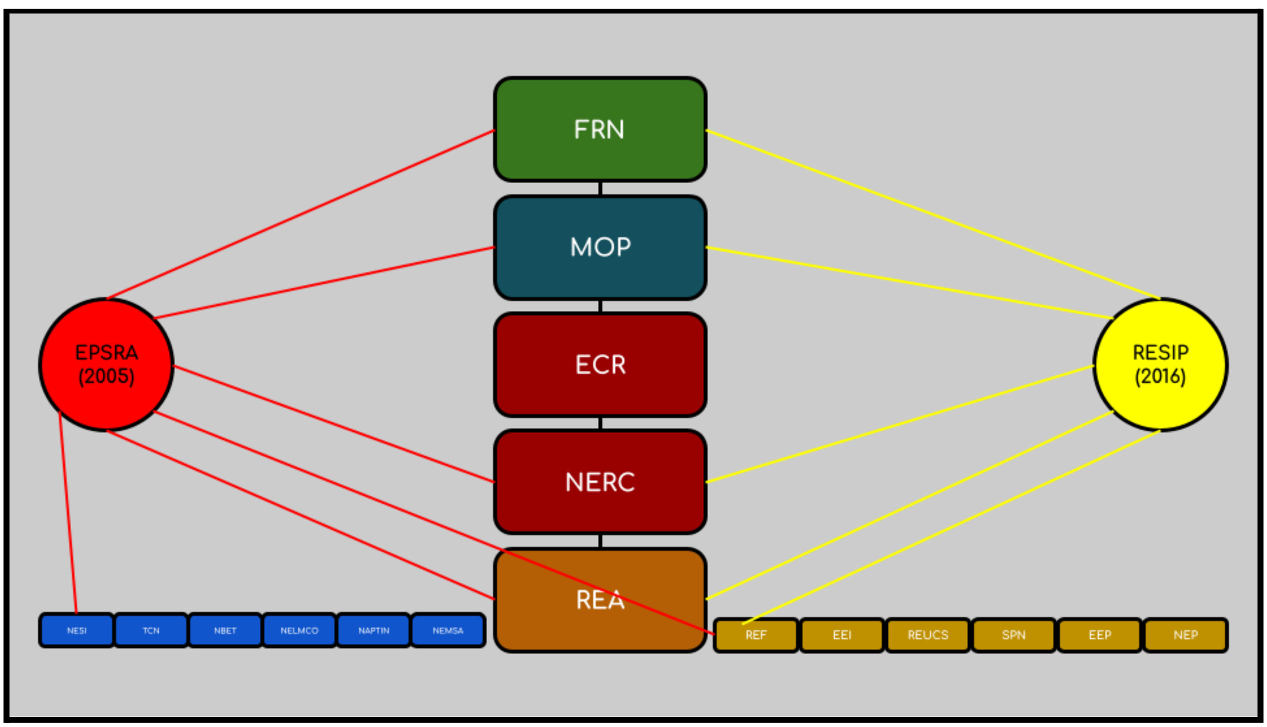


Figure 7: Institutional structure of Nigeria's National Rural Electrification Institutions, and interactions with seminal legislation

To summarize the results of RQ1, a hierarchy exists among “Primary institutions” disseminating from The Federal Republic of Nigeria (FRN), to the MOP, to the ECN, to the NERC, to the REA. Primary institutions at the bottom of the hierarchy are more involved with implementation, as opposed to legislation. The NERC and REA are two of eight “associated institutions” under the MOP. Other than NERC and REA, MOP-associated institutions are positioned to aid in the maintenance of the existing power sector. The NERC is a pivotal institution that regulates rural electrification. The REA coordinates six programs that increase electricity access. These six programs are referred to in this project as associated institutions, and together they help to bridge electricity deprivation in rural Nigeria.

The two most pivotal legislative documents related to rural electrification are the EPSRA and RESIP. Together, these documents provide the framework and justification for institutions to carry out their work. Central to the two documents are liberalization principles of equity, transparency, and market-efficiency.

4.2: How is electricity access defined and success measured in federal rural electrification policies, and by federal agencies?

Results for RQ2 vary based on the utilized approach. A narrow approach identifies explicit definitions of electricity access and their associated measurements that track success. A broad approach to answering RQ2 considers Nigeria’s multifaceted approach to combating electricity deprivation and integrates it into an implied electricity access definition. This implied definition targets several aspects of electricity access beyond connections, leading to more metrics that track success.

Narrow Approach:

A thorough review of government websites, seminal legislation, press releases, and program brochures finds no explicit electricity access definition. An electricity access definition is derived by identifying published electrification statistics. The 2018 Nigeria Electrification Project publishes a national electricity access rate of 55%. 2018 national electricity access rates published by four IGOs (WB, IEA, ESMAP, SEA4ALL) are averaged to equal 58%, for a 5% difference from the Nigerian source. All four IGO publications lead back to the IEA, which is the only institution that provides a transparent methodology for electricity access. If a 5% difference is insignificant, then it can be assumed that the Nigerian methodology for assessing electricity access is congruent with the IEA’s. The IEA definition does not provide capacity benchmarks that determine electricity access, nor does it account for other electricity access attributes like reliability. To find a power-capacity-specific benchmark for a Nigerian electricity access definition, we turn to the RESIP. A central goal of the RESIP was to achieve a national electrification rate of 75%. To achieve this goal, 10,000,000 HH would need to be connected, with a required new generating capacity of 6,000 MW. This goal implies a new connection capacity of 600 W per household, or 86 W per person, assuming seven people per household (RESIP, 2016). Thus, successful Nigerian electricity access connects new users to a capacity of 86 W.

Measuring new grid (on and off) connections is the primary way to measure electricity access success (IEA, 2020; RESIP, 2016). Moreover, from the Nigerian RESIP standpoint, having a power capacity of 86 W is required to achieve electricity access (RESIP, 2016). Methods to track this benchmark include tracking installed capacity, the number of households connected, and household size. If the new user capacity allocation was converted into a consumption value, then the generation source's capacity factor would need to be measured, or households would need to be metered.

Broad Approach:

Although the FRN fails to define electricity access explicitly, they address electricity deprivation formally, fighting it in many ways. One consistent way that the FRN refers to electricity access is as a means to improve quality of life (EPSRA, 2005; RESIP, 2016). Electrification is achieved through a framework that is newly liberalized. Coordination of electrification efforts is transparent, with vested interest at every hierarchical level. While the FRN fails to deliver an explicit access threshold or a tier-based access allocation system, they do not fail to address electricity deprivation. Components and tracking metrics that the FRN uses to address electricity access are provided in Table 15.

Table 15: 10 components of Nigeria's implied framework to address electrification deprivation

	Component	Agency	Ways to measure
1	Cost-effective project identification	REA	Cost-Benefit Analysis, monitoring benefits of installed projects.
2	Advocating for high quality, availability, and reliability	NESI	Measuring voltage fluctuations, SAIDI and SAFIRI, hours available during the day and night, other reliability indices, and resilience plans.
3	Cost-reflective electricity tariffs	NERC	Cost-benefit analysis, transparency. Price per kWh. HH electricity expenditure.
4	Energy sector planning	ECN	Demand forecasting. Energy efficiency.
5	Safety and technical standards	NEMSA	Creating and enforcing safety and performance standards.
6	Increasing RE	SPN	Share of RE in the energy mix
7	Implementing electrification projects	REA REF NEP	Tracking how many projects are viable, tracking how many projects are executed, how much transmission line is laid, how much new capacity is installed, how many new HH connections, HH

			electricity consumption, tracking the total cost to electrify a HH.
8	Community participation	REUCS	Amount of communities engaged in the REUCS program, percentage of community stock held in a project
9	Health center and University electrification	EEP	The number of healthcare facilities and Universities electrified. Details on the quality of electricity services utilized.
10	MSME electrification	EEI	The number of new MSMEs electrified. Details on the quality of electricity services utilized.

Fundamentally, this approach is far more than binary. The effectiveness of these institutions at accomplishing their goals, or satisfying the expectations associated with these components, is a RQ for another project. All that is said here is that, on paper, the FRN identifies all these components as necessary in combating electrification deprivation, and each component has relevant, unique metrics that track success.

4.3: To what extent is this framework effective at capturing the true state of electricity access and deprivation in the country (and how could this be improved)?

A narrowly scoped answer to RQ2 provides a limited assessment of electricity access. Evidence from the literature suggests that a binary approach to defining electricity access does not reflect the true state of electricity deprivation (Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016). Furthermore, the seminal rural electricity access planning document discludes availability, along with other attributes, from its planned electrification goal (RESIP, 2016). Negligence of attributes like availability would assume that, from a legislative perspective, these attributes are non-issues for newly electrified populations. A false assumption made clear by the observation that 97.3% of households in the NW region have limited availability (Luiz, Beria, Koo, Rysankova, and Portale, 2020). Failure to explicitly address the multifaceted nature of electricity access results in an ineffective capture of the true state of deprivation in rural Nigeria.

From a broad approach, Nigeria does seem to capture electricity deprivation's true state, although improvements are still needed. The ten components assumed as comprising the FRN electricity access definition provide an expansive understanding of Nigeria's electricity access. Nigeria does address the attributes of the MTF through legislation and institutions (RESIP, 2016). Current and planned electrification does fulfill the capacity thresholds at the MTF Tier 3 level. Regulatory indices score Nigeria's legislative comprehension with positive results (ERI, 2020; RISE, n.d.). Binary electrification rates and electricity consumption have been increasing in Nigeria, a possible sign of progress.

The implied Nigerian framework for addressing electricity deprivation, based on ten components, does well to address the many aspects of deprivation. Legislative focus is provided to serious areas such as equity, democracy, sustainability, future planning, and electrification in communities. One way to qualify the assumed Nigerian framework's succinctness is to compare its components against those advised in the literature. Based on the literature, each of the ten components can be validated.

Table 16: 10 components of Nigeria's implied framework and scholarly advocacy

Component	Scholars advocating for component
Cost-effective project identification	Oyedepo, 2012 Nygaard, 2015 Aliyu, and Tekbiyik-Ersoy, 2019
Advocating for high quality, availability, and reliability	Aklin, Cheng, Urpelainen, Ganesan, and Jain, 2016 Jain, and Shahidi, 2019 Mbaka, Obiero, and Kisaka 2017 Reinders, 2018 Ayaburi, Bazalian, Kincer, and Moss, 2020
Cost-reflective electricity tariffs	Beck, and Martinot, 2004 Sovacool, Hefferon, McCauley, and Goldthau, 2016
Energy sector planning	Bhattacharyya, and Timilsina, 2010 Narayan et al., 2020
Safety and technical standards	Tait, 2017 Bhatia, and Angelou, 2015
Increasing RE	Karim et al., 2019 Amin, and Rahman, 2019
Implementing electrification projects	Bernard, 2012 Munyoro, Makurumure, and Dzapasi, 2016 Ogwumike, and Ozughalu, 2016
Community participation	Karim et al., 2019 Nygaard, 2015
Health center and University electrification	Oyekale, 2017 Monyei, Adewumi, Obolo, and Sajou, 2018
MSME electrification	Nygaard, 2015 Fluitman, 1983

Another way to qualify the effectiveness of the FRN broadly assumed framework includes identifying places where MTF attributes are addressed in Nigeria's political environment. The MTF has established credibility as a leading framework in defining electricity access (Pelz, Pachuri, and Groh, 2018). Seeing as the MTF attributes are addressed in the Nigerian political landscape, some degree of justification is given to the labeling of Nigeria as relatively effective in capturing the true state of electricity access.

Table 17: Where MTF attributes are addressed in Nigeria's national rural electrification political landscape

Attribute	Capacity	Availability	Reliability	Quality	Affordability	Legality/ Formality	Health and Safety	Addressing access outside of household
Legislation where attribute is addressed	-EPSRA -RESIP	-RESIP	-RESIP	-RESIP	-RESIP -2014 Market Rules	-2018 Grid Code -2014 Market Rules	-Nigerian Electricity Health and Safety Standards Manual (2008) -Nigerian Electricity Health and Safety Code (2014)	-RESIP
Federal institutions that address attribute	-REA -NEP	-REA -TCN -NESI	-TCN -NEMSA -NESI -REA	-TCN -NEMSA -NESI	-NESI -NERC -REA -REF	-NBET -NERC -NESI	-NEMSA -NERC	-EEI -EEP -NEP -REA

Results from the "Fulfillment of access" methodology suggest that Nigeria's current and planned capacities fulfill a medium demand for electricity services. For the "Fulfillment of access" methodology, five electricity access definitions were selected.

The IEA definitions selected differ from the traditional binary methodology and are not currently used to track electricity access. Rather, these definitions are put forward to speak to certain minimum thresholds that should satisfy an access definition. The three IEA definitional thresholds are based on the electricity consumption required to provide a minimum bundle of electricity services. The nominal IEA access definition includes "electricity to power four lightbulbs operating at five hours per day, one refrigerator, a fan operating 6 hours per day, a mobile phone charger and a television operating 4 hours per day" (IEA, 2020). The Urban and Rural electrification thresholds entail a smaller bundle of electricity services, and thus have lower consumptive thresholds.

Two definitions were also selected from the MTF, Tier 3 and Tier 5. Minimum thresholds for Tier 3 and 5 can be determined by consumption (Wh) or power capacity (W). Like the IEA definitions, the MTF definitions also correspond to energy or power required to provide a bundle of electricity services. The Tier 3 definition provides a bundle of electricity services that include lighting, entertainment services, and medium-power appliances like water pumps, refrigerators, rice cookers, and air coolers. The Tier 3 access level was selected based on the electricity services that it provides and its position as the middle tier in the MTF approach. The Tier 5 definition includes electricity services provided in Tier 3 and high and very high-powered appliances like wash machines, electric cookers, and water heaters (Bhatia, and Angelou, 2015).

In Figure 5, the energy demand required to fulfill the five definitions is compared to existing energy available to the electricity-connected portion of Nigeria's population. In Figure 6, the power demand required to fulfill the two access definitions is compared to the existing power available to the electricity-connected portion of Nigeria's population. The two access definitions are also compared to the planned power available if the electrification goals put forward in the RESIP were achieved (RESIP, 2016). Figures 5 and 6 show the degree to which existing and planned statistics fulfill the five access definitions and their associated bundle of electricity services.

Demand (Nominal) / Supply (Consumption)	**0.906**
Demand (Urban) / Supply (Consumption)	**0.362**
Demand (Rural) / Supply (Consumption)	**0.181**
Demand (Tier 3) / Supply (Consumption)	**0.188**
Demand (Tier 5) / Supply (Consumption)	**1.547**

Figure 8: Fulfillment of access results for existing electricity consumption

Results and interpretations of Figure 5 conclude that four out of the five access definitions are fulfilled by the current per capita electricity consumption (the electricity-connected population). The fulfillment of the Nominal IEA definition suggests that, on average, electricity-connected Nigerians have access to a bundle of electricity services corresponding to the Nominal IEA benchmark. This result reinforces the claim that Nigeria does a fair job capturing the true state of electricity deprivation, as its policies have provided Nigerians with a bundle of electricity services far more valuable than a grid connection alone. Results from Figure 5 also suggest that on average, the MTF Tier 5 access definition is not fulfilled by existing consumption of the electrically-connected population. This observation highlights the need for increased consumption to achieve a more optimal bundle of electricity services.

Demand (Tier 3) / Supply (Existing Capacity)	0.259
Demand (Tier 5) / Supply (Existing Capacity)	2.554
Demand (Tier 3) / Supply (New RESIP Capacity)	0.337
Demand (Tier 5) / Supply (New RESIP Capacity)	3.326

Figure 9: Fulfillment of access results for existing and planned power capacity

Results and interpretations of Figure 6 shows that Tier 3 access definition is fulfilled by both existing power capacity (of the electricity-connected population) and planned power capacity (put forward by the RESIP). These results suggest that Nigeria's electrification plans, if achieved, will be able to provide consumers with the bundle of electricity services associated with Tier 3. This result is promising and speaks to how Nigeria's planning addresses more than an electrical connection by providing a bundle of electricity services. Other findings from Figure 6 suggest that existing power capacity fulfills access definitions to a greater degree than planned power capacity. Additionally, existing and planned power capacity would need to increase substantially to achieve Tier 5 access. This finding suggests that Nigeria could better address electricity deprivation by increasing power capacity and planned power capacity, which would provide a greater bundle of electricity services.

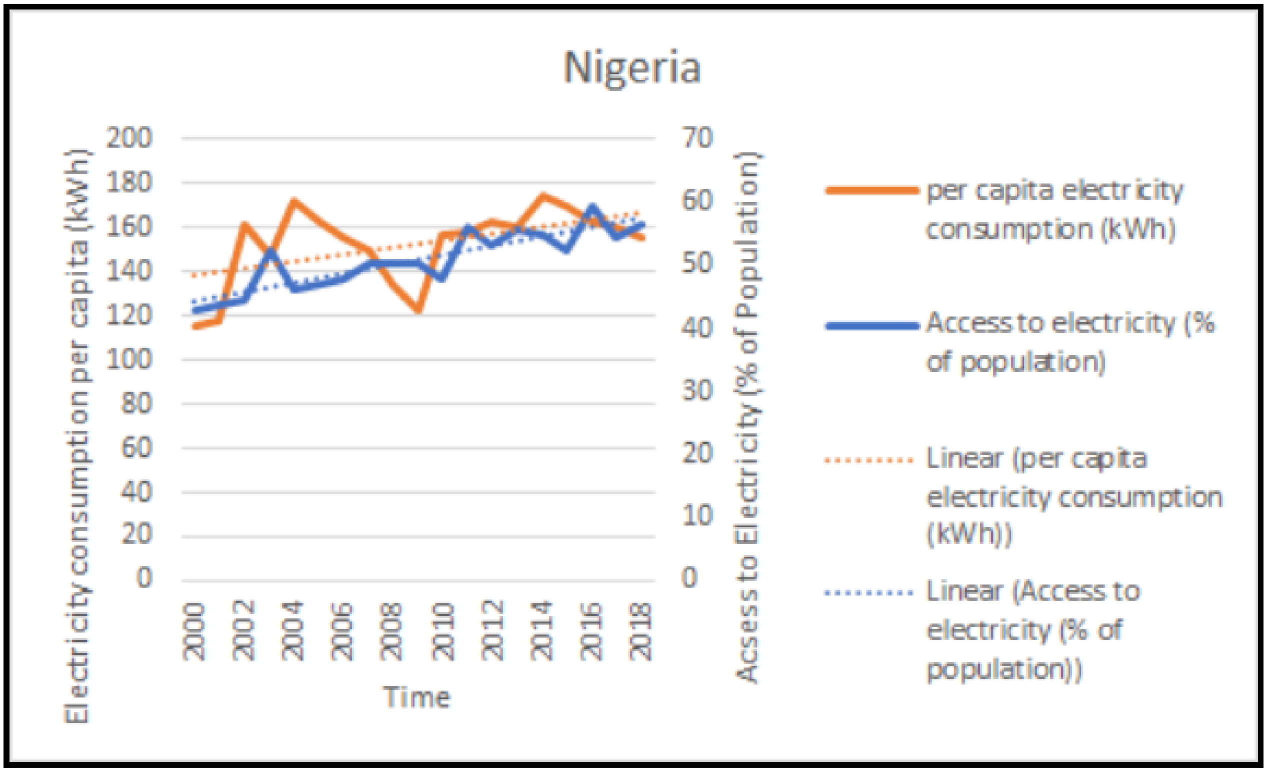
Another method used to qualify RQ3 comes from IGO publications. The Electricity Regulatory Index for Africa in 2020 aggregates components of successful policy and assesses the state of a regulatory and institutional framework relative to the energy sector. One assessment is provided by the Regulatory Governance Index (RGI), which publishes a country score from 0-100 (bad to good). The FRN has received an RGI score of 90, implying that Nigeria's electricity regulatory framework exists at a high (good) level (ERI, 2020). Another relevant assessment index comes from the Regulatory Indicators for Sustainable Energy (RISE), orchestrated by the WB and ESMAP. RISE examines the regulatory indicators and sub-indicators for four of the energy topics related to the SDGs. (Electricity access, clean cooking, renewable energy, and energy efficiency). For the topic of electricity access, eight indicators are provided. Each of these indicators is composed of sub-indicators. Sub-indicators receive binary scores based on the country's regulatory capacity, and each sub-indicator is weighted and aggregated to provide the overall indicator a score out of 100. Each of these indicators is then averaged to achieve an overall electricity access score from the regulatory perspective. The overall electricity access score for Nigeria, given by RISE, is 72, a fair to good score (RISE, n.d.). A disaggregation of indicator scores shows the two poorest performing indicators to be "Framework for grid electrification" and "Utility Creditworthiness" (RISE, n.d.). These two areas provide insight into where the FRN framework falls short.

Importantly, RQ3 addresses the degree to which policy captures the problem of electricity deprivation. Consequently, RQ3 does not ask the question to what degree the Nigerian framework puts comprehension into action and therefore results. This question is a logical next step and arguably more important. Solid evidence would point to lackluster performance of actualized policy (ERI, 2020). This paper will not seek to comprehend the full effectiveness of Nigerian rural electrification policy, but it will provide some evidence to justify research into this domain.

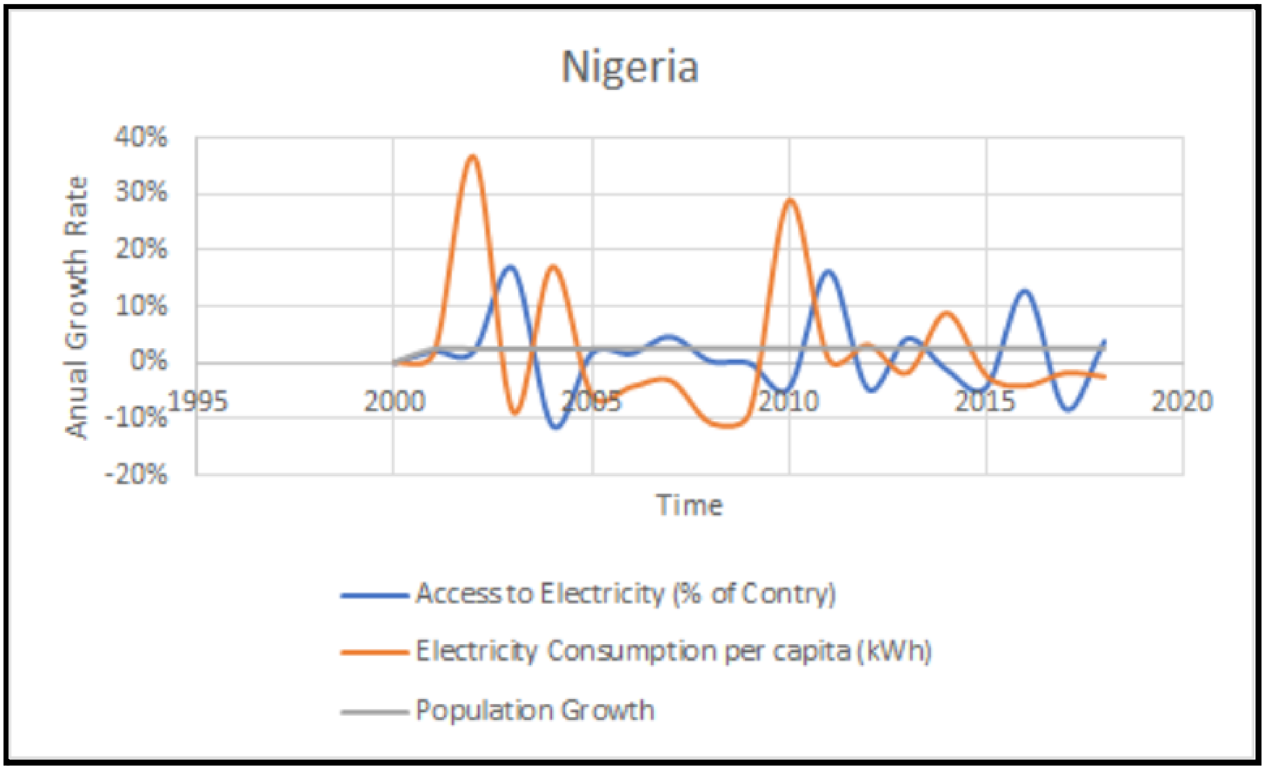
Other indices published by the African Development Bank are relevant to understanding the effectiveness of Nigeria's policies at alleviating electricity deprivation. The Regulatory Substance Index (RSI) assesses the degree to which regulation is actualized, and the Regulatory Outcome Index (ROI) assesses outcomes as they relate to regulation. Both performance scores are unsatisfactory in general, especially when compared to the RGI counterpart. RSI for Nigeria is scored at 0.79, while ROI is scored at 0.417 (ERI, 2020). The World Energy Council provides another relevant assessment called the World Energy Trilemma Index. Nigeria's 2020 report card for this index shows an energy equity ranking of 106/190 and an environmental sustainability ranking of 100/190 (World Energy Trilemma Index, 2020). These index scores justify future research into the effectiveness of Nigeria's rural electrification policy.

Finally, we can inspect the effectiveness of capturing electricity deprivation by analyzing trends over time for two of the most fundamental outcome electrification statistics; access to electricity (binary) and per capita electricity consumption. Results from Graph 1 highlight that both access to electricity and per capita electricity consumption has been increasing over the last 20 years. This finding would suggest that something has to be working in the Nigerian framework for addressing electrification. Graph 2, on the other hand, shows that the annual growth rates for access to electricity and per capita electricity consumption are volatile. This result may speak to the complexities of increasing fundamental electricity access while also increasing per capita consumption. Lastly, Graph 3 shows that although variability is present, the percent change in access to electricity and per capita electricity consumption from the year 2000 shows an increasing trend. Once again, this finding suggests that some component of Nigeria’s framework must effectively address electricity deprivation at a fundamental level.

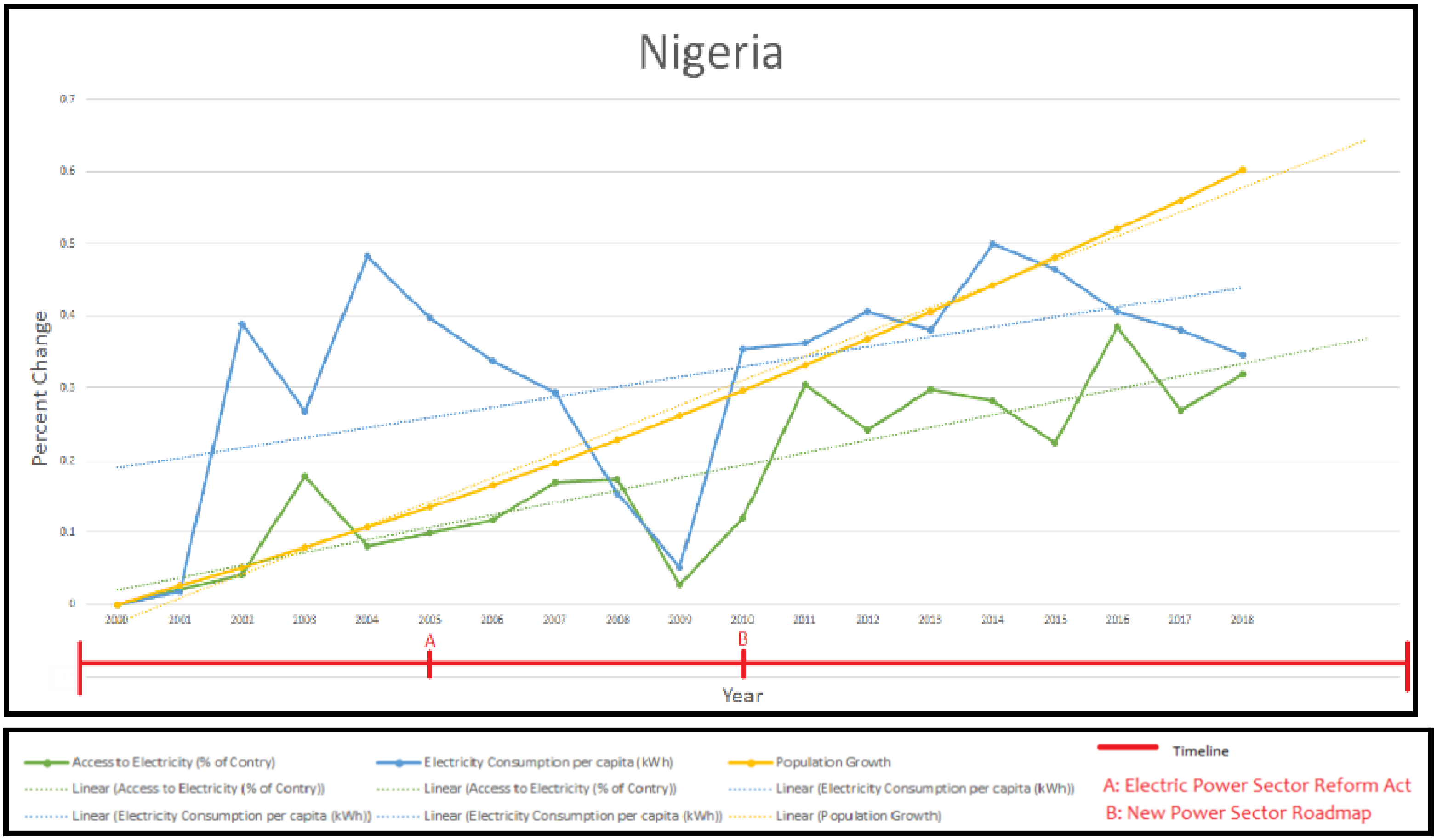
Graph 1: Per capita electricity consumption and access to electricity over time



Graph 2: Annual growth rate of Per capita electricity consumption and access to electricity over time



Graph 3: Percent change in Per capita electricity consumption and access to electricity from the year 2000



To summarize the results from RQ3, a broad understanding of Nigeria's framework for addressing electrification deprivation would suggest that Nigeria does a fair job assessing the true state of electrification deprivation. This claim is based on the presence of scholarly recommended components in the implied Nigerian framework, the existence of institutions to address MTF attributes, the fulfillment of medium access definitions by existing and planned energy and power capacity, positive scores on regulatory indices, and observed gains in binary electricity access and electricity consumption over the last two decades. Qualities that limit an outstanding capture of the true state of electricity deprivation include; limited transparency of Nigeria's explicit electricity access definitions, planned electrification projects not fulfilling the power capacity requirement for Tier 5 access, non-outstanding scores on regulatory indices, and volatility in electrification access growth rates.

5: Discussion

5.1: Key takeaways

One insight coming from this project suggests that Nigeria has an underlying multifaceted framework that addresses electricity deprivation. While the Nigerian framework does well to address deprivation holistically, improvements could be made related to transparency and tracking. The Government of Nigeria could benefit from explicitly communicating the components of its framework. This transparency could guide accountability and planning in a centralized way. Tracking the components of the Nigerian framework would also be beneficial. A monitoring assessment program would be enabled by clear metrics tracking components. For each component, multiple thresholds should be provided, mirroring the tier-based approaches put forward by the GTF and MTF (Tait, 2017; Bhatia, and Angelou, 2015). Thresholds could then be used to set and track goal progress beyond the binary level. Altogether, a transparent framework with relevant tiered thresholds could coalesce into a Nigerian-specific electricity access definition. This definition could reflect the country's context and values and provide an accountable way for electricity deprivation to be monitored. With strict monitoring comes the identification of good and bad performing areas. Good performing areas should be studied and replicated. In comparison, bad performing areas should be identified, along with their critical flaws, in order to improve performance.

An expansion of the fulfillment of access methodology might better assess the true state of electricity deprivation. This practice could be performed independently from the government of Nigeria and applied to all countries. The fulfillment methodology could be expanded to incorporate multiple attributes. Multiple tiers of electricity access could be defined for each attribute based on differing thresholds or metric sources. Definitional thresholds for access would then be compared to observed or planned electrification metrics to determine the degree of fulfillment. Any metric-based definitional threshold would need to be based on research. Research would be needed that provides evidence of the benefits associated with different attribute thresholds. Research that identifies informative and consistently available metrics would ease the model's statistical requirements. Examples of research questions that could inform threshold levels include; how much space cooling is required to maintain a safe body temperature in equatorial zones, how much electricity is needed to power different sized hospitals, and what is the minimum level of reliability and resilience needed to electrify industrial centers.

Individual fulfillment of definitional thresholds could be aggregated into an overall fulfillment index or an attribute-based fulfillment index. (1) An overall index or attributes-based index would comprise average performance across multiple electricity access definitions. This approach would mirror a methodological practice similar to consensus forecasting, where an index would be reflective of average "fulfillment" across a variety of definitional "models". Approach 1 would provide a universal index and could be used to compare the state of electrification across counties.

Another approach (2) could parameterize electricity access thresholds through survey or industry information. This approach would provide a contextualized fulfillment index, mirroring the methodological practices of ensemble forecasting. One way to parameterize access thresholds would be to ask a survey question similar to “What do you consider to be a satisfactory level of (x) attribute?”. This survey question could be given to firms to provide a firm-specific threshold. Alternatively, it could be given to a population at large to provide a contextual threshold level. Parameterization of access thresholds could also stem from industry information. Thresholds would be placed within limits based on what current infrastructure could reasonably provide within a given timeframe. Thresholds limited by available infrastructure could increase over time at a rate corresponding to a metric like GDP per capita. Another way to contextualize the overall index score would again rely on survey information. Survey questionnaires could be given to stakeholders asking them to rank their most preferred attributes. With this information, the overall fulfillment index would weigh attributes based on the values of stakeholders. Approach 2 could be used to compare the state of electrification in a country over time. One benefit of utilizing a contextualized approach is that contextualized electricity access thresholds would reflect stakeholder values and preferences. Meaning that the stakeholder community is likely to gain more utility per unit increase in electricity access for a contextualized approach than a universal approach.

Either approach could be used to assess the degree to which an electrification plan fulfills different electricity access definitions. The benefit of using an expansive fulfillment methodology provides a way to aggregate different electricity access definitions, valuing different thresholds based on different metrics. The expansive fulfillment methodology could have associated simplified methodologies, limiting the data requirements needed to determine the fulfillment of access. Hypothetically any amount of attributes and definitions (thresholds) could be used and combined. The more attributes and definitions utilized, the higher the degree of multifaceted comprehension. Appendix 3 provides an experimental template for the expansive fulfillment methodology comprising senseless thresholds not intended to represent real electricity access definitions. This methodological approach draws from scholar's advocacy for non-capacity attributes, which are referenced in the appendix. Notable inspiration comes from the MTF, where electricity access is defined in a nuanced way (Bhatia, and Angelou, 2015).

5.2. Limitations

Scholars debate the causal relationship at the heart of the electrification-development nexus. Some scholars believe that electricity access leads to development and improved livelihood (Fluitman, 1983). Others believe that development leads to electricity access, and both processes improve livelihood (Riva, Ahlborg, Hartvigsson, Pachauri, Colombo, 2018). There is a divide between the camp that believes electrification empowers development. One side leans on the idea that household electricity use leads to development (Oyedepo, 2012). The other side's logic believes that enterprise electrification enables household electricity demand, furthering development (Munyoro, Makurumure, and Dzapasi, 2016). Whether at the household or enterprise-level, any gains in electricity access are beneficial to the well-being of people oppressed by lack of access to electricity services. However, decision-makers should be aware of every process that bolsters development and improves people's livelihood.

The electricity-access scholarship base is immense, stemming from an active and involved transnational community. While the field has a legacy of extensive scholarship, recent developments continually bolster the community. When this project was in its early stages, a paper titled "Reasonably Reliable" was published. This paper found extensive underestimation of sufficient electricity access using a reliability-based approach (Ayaburi, Bazalian, Kincer, and Moss, 2020). In the later stages of this project, a MTF report of NW Nigeria was published. This case study report provides a valuable contribution to understanding electricity deprivation for rural communities in NW Nigeria (Luiz, Beria, Koo, Rysankova, and Portale, 2020). Due to the literature base's size and pace, important research projects may have been unintentionally omitted from the literature review.

Similarly, the information provided by international governmental and non-governmental organizations is expansive. Summary reports, industry trends, and datasets provide crucial information to understanding electricity access. Due to this information source's size, not every piece of information could be applied to this project.

On the same note, the Nigerian energy policy landscape encompasses many agencies and pieces of legislation. The scope of this paper focuses on federal rural electrification policy. This paper's legislative analysis focuses on the Electric Power Sector Reform Act of 2005 (EPSRA) and the Rural Electrification Strategy and Implementation Plan of 2016 (RESIP). Consequently, other important pieces of legislation were only briefly reviewed, largely due to time constraints. Important information related to RQ1-3 could be located within unstudied legislation. Appendices 1 and 2 provide a list of important policy documents and Nigerian policy databases to address this limitation. The neglect of policy documents produced by transmission, distribution, and generation companies provides a limited understanding of rural electrification policy at large.

Additionally, political information at the state level fell outside of the scope of this paper. This omission is significant to consider, as the state level's political structure possibly includes more actionable policy. Due to the limited scope of this project, if provided political diagrams are taken out of the context of rural electrification, the diagrams risk misleading readers.

The process of collecting information from Nigerian government websites was trying. Documents were often unavailable and frequent error-messages limited access to certain web-pages. Collecting information from the World Bank and associated organizations was challenging in its own regard. World Bank and associated IGO web-pages lack centralization and explicit coordination, making the information collection process challenging. Variation in methodological approaches across different IGOs makes for an uncoordinated assessment of electrification.

Large amounts of online information are available on the topic of Nigerian rural electrification policy. While this information exists, it may not be accessible to all stakeholders. Conducting this project's research required a large amount of electricity. Conducting this project likely consumed a greater amount of electricity than a rural Nigerian has access to. This observation suggests that information asymmetry could undermine the democratic components of Nigeria's framework for addressing electricity access.

This project's scope is centered around rural populations, as persons dwelling in rural communities experience the greatest degree of deprivation (Luiz, Beria, Koo, Rysankova, and Portale, 2020). Other areas where electrification deprivation is present include urban poor populations and Nigerian firms (Doing Business, 2019). These areas are also deserving of attention.

While rural electricity-access definitions and policies are studied in this project, little discussion is given to electricity sources. A body of literature already exists that addresses electricity generation sources, specifically in Nigeria (Enongene, Abanda, Otene, Obi, and Okafor, 2019; Aliyu, and Tekbiyik-Ersoy, 2019). Every generation source is associated with its costs and benefits. A valuable tool undiscussed in this project is an energy database provided by the REA (https://database.rea.gov.ng/). This tool maps existing infrastructure, community information, natural resources, and potential off-grid and solar home system opportunities. This tool enables the private sector to identify optimal places for new electrification projects.

Focusing strictly on electricity access neglects other fundamental mechanisms that alleviate poverty. Total energy access and access to clean cooking are closely related topics that deserve attention. While extensive research exists in each of these fields (Anon, 2020), continued robust analysis will improve our understanding of the problems and solutions at hand. Additionally, poverty can be alleviated by improving services that are indirectly reliant on energy. Gains in access to clean water, roads, healthcare, and education provide examples of spaces where multilateral involvement can better people's lives and bolster development (Nussbaumer, Nerini, Onyeji, and Howells 2012).

Methods used to answer RQ2 are subject to interpretive limitations. Nigeria's methodology for publishing electrification statistics is assumed to be congruent with the IEA's method for defining electricity access. This assumption is based on a 5% difference in published electrification statistics for 2018 and an absence of transparent methodological practices. If a 5% difference is valued to be significant, then a rejection of congruence would follow. Secondarily, RQ2 was answered broadly by identifying ten recurring components found in Nigeria's overall framework for assessing electricity deprivation. Giving the somewhat arbitrary nature of this component identification, other scholars might select different components that describe Nigeria's overall framework.

The "fulfillment of goods" methodology contains assumptions and informational sources that could limit the approach's accuracy. Expressions used to execute the fulfillment model relied on the standardization of provided statistics. Statistics were standardized to achieve common units of "per year" (annual) and "per person" (individual). Individual standardization was reliant on dividing household statistics by the number of people per household. A household size of five was used for IEA thresholds following the IEA 2020 methodology (IEA, 2020). For MTF thresholds, a household size of seven was used, following the assumed household size provided by the RESIP (RESIP, 2016). Variance in utilized household size is a potential source of error. This potential source of error could be mitigated using "per household" units, although variations in assumed household size would persist. Statistics such as "national per capita electricity consumption and capacity" were manipulated to represent "national per capita electricity consumption and capacity within the electrified population." This manipulation informed a better understanding of the electrified population's access to electricity services. Due to the size of Nigeria's unelectrified population, statistics such as "per capita electricity consumption" misconstrue the average consumption of the electrified population. Nigeria's total installed capacity statistic came from trade.gov, a source that might lack accuracy. Another limitation of comparing power capacity stems from a lack of transparency. Of the total installed Nigerian power capacity, a fraction of that capacity is available, a feature not reflected in the "fulfillment of goods" methodology. For statistics on RESIP planned power capacity, it is unclear what fraction of the 6,000 MW generating capacity is planned to be available. It is also unclear if the capacity attribute for the MTF allocates tiers based on installed capacity or available capacity (Bhatia, and Angelou, 2015). For consistency purposes, MTF capacity tier allocation was based on installed capacity and not available. For the fulfillment methodology, all power capacity comparisons derive from generating capacity and not available capacity. Using total generation capacity is likely to overestimate the fulfillment of electricity access definitions based on power capacity statistics due to available capacity frequently being less than generating capacity.

Answering RQ3 is partially reliant on graphs 1-3, which comprise their own limitations. Graphs 1-3 track consumption rates published by the UN over time. These graphs can not conclude electrification policy effectiveness, as many external factors obscure this relationship's exact nature. Moreover, graphs 1-3 rely on binary access definitions that provide a limited understanding of the state of deprivation. Multifaceted access definitions can not be graphed over a decadal period due to a dearth of long-term data.

Much time is spent in this paper arguing for multifaceted electricity access definitions. However, these definitions comprise communicative challenges. Multifaceted definitions are typically simplified into an index or overall tier ranking, making their interpretation less intuitive. In contrast, simple statistics (such as binary access rates and per capita consumption) have been collected over decades and tend to be more intuitive (World Energy Outlook, 2002).

Throughout this project, access to electricity services is likely underestimated. Electricity services provided by diesel generators are uncaptured by the IEA and MTF electricity access definitions. Reliability assessed by system disturbance metrics also likely underestimates total electricity service reliability by excluding diesel generators' electricity services. Although diesel generators are a non-optimal electricity source technology, their presence in Nigerian communities is extensive. Thus, failing to capture diesel generators' use provides a limited understanding of the true state of access to electric-services, regardless of the many downsides to generators (World Bank, 2014).

5.2: Summary

This project sought to provide two new informational sources to the literature. One informational source has provided an informational summary of Nigeria's political landscape for national rural electrification policy. Rural electrification institutions and policies have been coordinated into relationship flowcharts to speak to the political structure. Goals, policies, and operational proceedings have also been identified for each national institution related to rural electrification. These goals and policies contributed to the formation of an implied rural electrification framework to address electricity deprivation. This framework features metrics that can track progress. Progress can be studied, alongside goals and policies, to learn more about each components' effectiveness.

The second informational source has attempted to challenge preconceived assumptions of "what it means to have electricity access" by contrasting different approaches to defining electricity access. This project's literature review provides ample scholarly literature with differing perspectives on electricity access and its definitional components. This project also chose to broadly define Nigeria's electricity access definition to paint a larger picture of methods that can be used to describe the state of electricity deprivation. This paper also provides a methodology used to compare different electricity access definitions to existing and planned energy system features. An aggregate fulfillment score across multiple definitions could be implemented to track electricity access progress, with a multi-definitional index.

Around 67,000,000 rural Nigerians have no access to electricity whatsoever. Furthermore, many of those with access face problems with availability, reliability, affordability, safety, and legality (Luiz, Beria, Koo, Rysankova, and Portale, 2020). The way we talk about, measure, and track electricity access has implications for the actions that we take to reduce deprivation (Jain, and Shahidi, 2019). Many scholars have sought to better understand and define the multi-faceted nature of electricity access (Amatya, 2010). This project provides information to the multilateral community with the hopes of encouraging better decision-making and conceptual understanding at any relevant level. Contributions from this project include a summary and snapshot of Nigeria's national rural electrification landscape, an assessment of Nigeria's framework for addressing electrification deprivation, a methodology to compare different access methodologies, references to scholarly literature, governmental resources, and intergovernmental resources.

6: Conclusion

6.1: Areas for future research

-Extend a similar analysis to another case study country.
-Execute an expanded fulfillment methodology for a population.
-Research Nigeria's grid codes to identify an operational framework, or resilience plan.
-Research Nigeria's market rules and tariff orders to identify a financial framework.
-Research Nigeria's urban and industrial electrification policy and connect it to rural policy.
-Research Nigeria's regional electrification policy and connect it to national policy.
-Research International political structure and connect it to Nigeria's national policy.
-Research the effectiveness of Nigeria's policy instruments and electrification programs.
-Research the fulfillment of Nigeria's electrification goals and policies.
-Survey stakeholders on perceptions of minimum attribute thresholds.
-Survey stakeholders on attribute preferences.
-Survey households in Southern Nigeria and compare results to NW Nigeria's MTF report.
-Perform a thorough evaluation of the NW Nigerian MTF report.
-Orchestrate program to meter households in Nigeria.
-Orchestrate program to directly measure energy used by appliances in Nigeria.
-Orchestrate program to directly measure energy system disruptions in Nigeria.
-Simulate the process of identifying, funding, and implementing an electrification project in Nigeria using the REA energy database.

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Appendix 1: Table of legislative documents studied in minimal detail

Year	Document Name	Location
2016	NERC Regulation for mini-grids	http://rea.gov.ng/wp-content/uploads/2018/07/NERC-Mini-Grid-Regulation.pdf
2013	Renewable Energy Master Plan	https://www.iea.org/policies/4974-nigeria-renewable-energy-master-plan
2020	Project Implementation Manual for the Nigeria Electrification Project	https://rea.gov.ng/wp-content/uploads/2020/10/PROJECT-IMPLEMENTATION-MANUAL_Revised_09102020.pdf
2005	Energy Master Plan (Draft)	Unlocated, referenced in RESIP section 2.3
2014	National Energy Master Plan (Revised)	https://www.energy.gov.ng/Energy_Policies_Plan/Draft%20(Reviewed)%20NEMP%20-%202014.pdf
2015	Nigerian Electricity Supply and Installation Standards Regulation	https://nepawahala.ng/Uploads/article10014.pdf
2003	National Energy Policy	http://rea.gov.ng/wp-content/uploads/2017/09/National_Energy_Policy_Nigeria.pdf
2018	National Energy Policy	https://www.energy.gov.ng/Energy_Policies_Plan/National%20Energy%20Policy.pdf
2018	Nigeria Electrification Project	https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/PESR_NG_NIGERIA_ELECTRIFICATION_PROJECT_CORR_EN-final.pdf
2015	NEMSA Act	https://nemsa.gov.ng/act/
1979	Energy Commission of Nigeria Act	https://www.energy.gov.ng/ecn_act.php
2014	NESI Market Rules	https://nerc.gov.ng/index.php/library/documents/Tariff-Charges--and--Market-Rules/NESI-Market-Rules/
2018	Grid Code	https://nerc.gov.ng/index.php/library/documents/Codes-Standards-and-Manuals/Grid-Code/ https://nbet.com.ng/wp-content/uploads/2018/05/Grid-Code-Final-Version-before-Approval.pdf
2017	Power Sector Recovery Implementation Program	https://rea.gov.ng/download/power-sector-recovery-implementation-program-2017-2021/
2008	Nigerian Electricity Health and Safety Standards Manual	https://nerc.gov.ng/doclib/codes-standards-and-manuals/26-nigerian-electricity-health-and-safety-standards-manual-08-06-08-part1-1/file
2020	Revised Multi-year tariff order	https://nerc.gov.ng/index.php/library/documents/Revised-MYTO-2020/Revised-MYTO-2020-for-IBEDC_Effective-Nov-1-2020/

Appendix 2: Table of policy databases from Nigerian Government websites

Institution	Website URL	Status at the time of project completion
ECN	https://www.energy.gov.ng/databank.php	Unavailable
NEP	https://rea.gov.ng/nepresources/	Available
REA	https://rea.gov.ng/power-sector-policy-documents/	Available
NERC	https://nerc.gov.ng/index.php/library/documents	Available
MOP	https://www.power.gov.ng/e-tender/	Unavailable

Appendix 3 provides an experimental template for an expansive fulfilment methodology. Attributes are listed in red. Approaches and metrics are listed in orange, some of which are inspired from the literature base, others of which are hypothetical examples. Definitional electricity access thresholds are provided in yellow and represent entirely senseless thresholds not intended to be reflective of a reasonable threshold to define electricity access. Fulfillment of definitional thresholds is provided in green, and values are entirely hypothetical. The first two green columns could be aggregated vertically to assess the degree of fulfillment of universal tier 1 and universal tier 2 access definitions against real measurements. These columns could be aggregated individually or in unison, where the singular aggregation would include 1 definition per approach across all attributes, and the unified aggregation would include 2 definitions per approach across all attributes. The third green column could be vertically aggregated to assess the fulfilment of contextual Tier 2 definitions against measurements from an electrification plan. Individual or groups of attributes could be aggregated horizontally to assess the degree of fulfillment of multiple access definitions along the similar attributes or following the simplified or minimalistic attribute mix. Theoretically, the number of attributes used, types of approaches used, types of metrics used, number of definitions (thresholds) used is limitless. However, these things would need to be validated by critical review, and the more expansive the framework, the more data is required.

Appendix 3: Experimental template for expansive fulfillment of access methodology with senseless thresholds and fulfillment ratios

Simplified (X = included) Minimalistic (XY= included)	Attributes	Relevant Inspiration	Approaches	Metrics	Universal Tier 1 threshold	Universal Tier 2 threshold	Contextual Tier 2 threshold	Universal Tier 1 demand / existing measurements	Universal Tier 2 demand / existing measurements	Contextual Tier 2 demand / measurements from an electrification plan
	Power Capacity	(Bhatia, and Angelou, 2015)	Generation capacity per person	Watts per person	80 W	160 W	150 W	.6	1.2	1.1
		N/A	Available capacity per person	Watts per person / available watts per person	0.6	0.8	0.7	.7	.8	.75
XY	Supply Capacity	(IEA, 2020)	Annual Per capita electricity consumption	Watt-hours per person per year	150 kWh	500 kWh	400 kWh	.4	.6	.5
		(Bhatia, and Angelou, 2015)	Electricity consumption required for bundle of electricity services	Electric consumption demanded by bundle of electricity services	Consumption provides TV, phone charger, 4 lights for 5 hours a day	Consumption provides refrigeration, air conditioning, and tier 1 services	Consumption provides refrigeration, TV, phone charger, and 4 lights for 6 hours	.5	.7	.6
XY	Reliability	(Ayaburi, Bazalian, Kincer, and Moss, 2020)	Average system outage duration and frequency	SAIDI and SAIFI	SAIDI max < 40 SAIFI max < 20	SAIDI max < 20 SAIFI max < 10	SAIDI max < 30 SAIFI max < 5	1.4	1.1	1.5
		(Vugrin, Warren, and Ehlen, 2011)	Absorptive Capacity	ability of the system to absorb the disruptive event (Low = 1, High = 2)	Low	High	Low	0	0	1
	Resilience	(Willis, and Loa 2015)	Level of resilience plan robustness	Level of resilience plan robustness (Low = 1, High = 2)	Low	High	High	1	1	.5
		(Yeddanapudi et al., 2008)	Percentage of transmission lines that are underground	Transmission lines above ground / transmission lines below ground	20%	40%	50%	.9	1.8	2.2

	Availability (Daytime)	(Bhatia, and Angelou, 2015)	Number of hours electricity is available	hours	6 hours	9 hours	9 hours	.5	.6	1.3
		(Metadata, 2020)	Time required to get electricity	days	60 days	20 days	15 days	.5	.6	.7
X	Availability (Nighttime)	(Bhatia, and Angelou, 2015)	Number of hours electricity is available	hours	4 hours	7 hours	6 hours	.2	.7	1.2
		N/A	Day to Night power capacity difference	(Day power capacity - night power capacity) / night power capacity	20%	5%	10%	.05	.21	.2
	Quality	(Bhatia, and Angelou, 2015)	Voltage fluctuations	Damaged appliances per year	4	1	2	.5	1.5	.9
		(Das, Bera, and Biswas, 2019)	Composite Reliability Index	Composite Reliability Index ranking (Worst=1, Best=2)	Worst	Best	Best	1	1	1
X	Monetary Affordabilit y	(Metadata, 2020)	cost to get electricity (% of income per capita)	Cost to get electricity / per capita income	4%	2%	3%	.7	.9	.8
		(Metadata, 2020)	Cost to acquire appliances as a share of total personal expenditure	Cost to acquire appliances / total personal expenditure	6%	3%	2%	.6	.7	.9
	NonMoneta ry Affordabilit y	(Metadata, 2020)	Time spent paying electricity bill	hours	4 hours	1 hour	2 hours	.4	.5	.5
		N/A	Time required to acquire appliances	hours	48 hours	24 hours	24 hours	.5	.6	.6
	Health	N/A	Risk presented to respiratory system	Low, Medium, High (Low=1, Med=2, High=3)	Medium	Low	Low	.33	1	1
		N/A	Average	meters	60m	160m	100m	.66	.88	.99

			height of smokestacks							
	Safety	N/A	Annual number of major injuries and fatalities per 10,000 customers	Annual injuries and fatalities / 10,000 customers	2/10,000	1/10,000	2/10,000	.43	.54	.66
		N/A	Number of major injuries and fatalities per 1 MWh.	Injuries and fatalities / 1 MWh	4 / 1MWh	2 / 1MWh	2 / 1MWh	.71	.98	1.5
XY	Sustainability	(Štreimikienė, and Balezentis, 2016)	Energy efficiency	Primary Energy / GDP	x	x-20%	x-15%	0.5	1.3	1.2
		(Štreimikienė, and Balezentis, 2016)	Emission intensity	CO2 emissions / Primary Energy	y	y-20%	y-15%	2.1	2.34	1.99
	Legality	(Bhatia, and Angelou, 2015)	Percentage of customers informally connected to the grid	Informal connections / total connections	20%	10%	15%	.64	.45	.99
		NEMSA	Collection rate	Bills paid / Bills sent out	75%	95%	90%	.22	.45	.55
XY	Societal Electrification	EEI	Percentage of healthcare facilities electrified	Electrified healthcare facilities / total healthcare facilities	70%	95%	100%	.33	.55	.7
		EEP	Percentage of primary schools electrified	Electrified primary schools / total primary schools	75%	99%	100%	.44	.65	.88