UKRI – GCRF SIGMA Project

Sustainability, Inclusiveness and Governance of Mini-grids in Africa

NIGERIA FIELDWORK REPORT

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This report was compiled by Unico Kalu Uduka of the International Center for Energy Environment and Development (ICEED), Abuja, Nigeria.

DISCLAIMER

The views expressed in this report are those of the authors and do not necessarily represent the views of the institutions they are affiliated to or those of the funding agencies.

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Contents

ACRONYMS

DisCo	Distribution Company
ECN	Energy Commission of Nigeria
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
FGD	Focus Group Discussion
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICEED	International Center for Energy, Environment, and Development
KM	Kilometer
KVA	Kilo-volt-amperes
KW	Kilowatt
kWh	Kilowatt hour
MW	Megawatt
NEPA	Nigeria Electricity Power Authority
NGN	Nigerian Naira
PV	Photovoltaic
REA	Rural Electrification Agency
REF	Rural Electrification Fund
SIGMA	Sustainability, Inclusiveness and Governance of Mini-grids in Africa

1.0. INTRODUCTION AND BACKGROUND

The International Center for Energy, Environment, and Development (ICEED) participated in the implementation of the three-year research project titled "Sustainability, Inclusiveness, and Governance of Mini-grids in Africa (SIGMA)." The UK Research and Innovation - Global Challenges Research Fund funded this project. It involved collaboration with other researchers from the University of Surrey, the Open University, De Montfort University and the University of Huddersfieldin the United Kingdom, TaTEDO in Tanzania, the Center for Frugal Innovation in Kenya, and the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in Cape Verde.

The objectives of the project were to:

1. Develop a comprehensive evidence base on the performance of mini grids in sub-Saharan Africa.
2. Establish an analytical framework for scrutinizing the political economy of energy access and a sustainability framework for mini grids.
3. Conduct in-depth case studies on the sustainability, inclusiveness, and governance of mini-grids in four sub-Saharan African countries, namely Kenya, Nigeria, Senegal and Tanzania.

Within the scope of this collaborative effort, ICEED was tasked with providing data specific to the Nigerian context. This contribution has ensured a nuanced and contextually relevant perspective within the broader SIGMA project.

1.2. Research Questions

The SIGMA project sought to answer the following questions:

1. Which business models have succeeded to deliver financially and technically viable mini-grids in Africa?
2. Who and what have been the key beneficiaries of mini-grids in the case study countries and in what way?
3. Who drives or hinders the proliferation and the speed of adoption of mini-grids in East and West Africa?
4. What governance, regulatory and policy frameworks for decentralised systems of electricity provision exist in each case study country, how successful have they been and how do they differ?

2.0. METHODOLOGY

2.1. Research design

To effectively address the above research questions, the study adopted an embedded case study design.[1] Nigeria was considered a case study, with a focus on multiple units of analysis. This

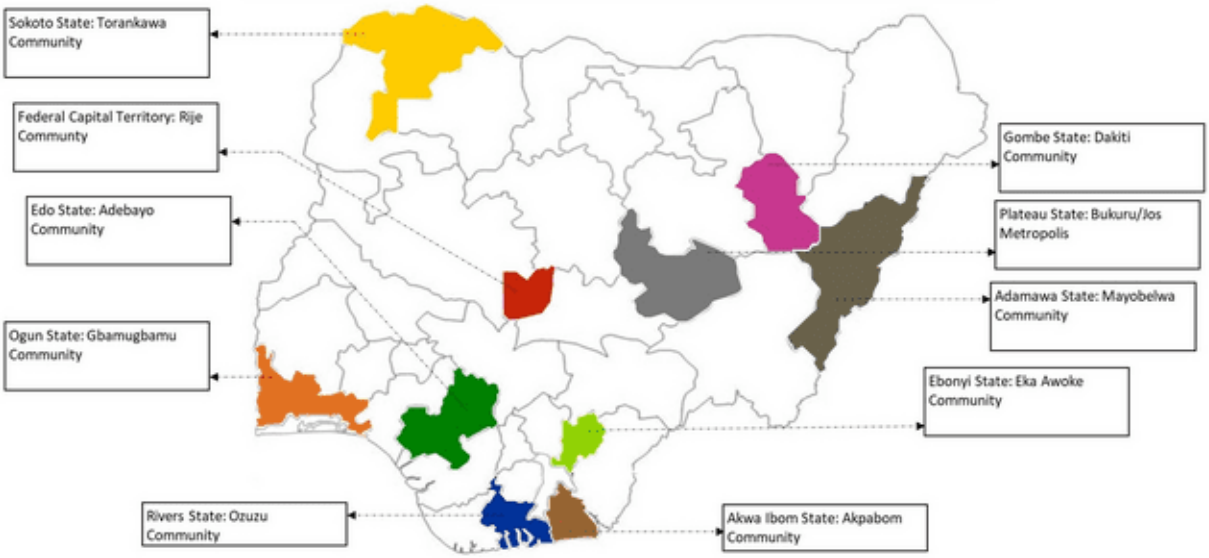
[1] Robert K. Yin. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage

design provided a nuanced and complex understanding of the case by comparing and contrasting the sub-units within it.

2.2. Research area

The field visits encompassed mini-grid communities and sites distributed across all six geopolitical zones of Nigeria.[2] These visits were complemented by key informant interviews with relevant stakeholders from government, development agencies, and private sector actors within the Nigerian electricity supply industry.

Figure 1: Mini-grid sites visited



2.3. Data collection plan

During our fieldwork, we purposively collected data from mini grids across all six geopolitical zones in Nigeria. We ultimately visited ten mini-grid communities, showcasing a range of three different technologies. Additionally, we held key informant interviews with 15 stakeholders from government, industry, and development who are involved with mini grid initiatives in Nigeria. Table 1 provides a breakdown of the communities visited, detailing their respective technologies and locations. Table 2 delineates the stakeholders that participated in the key informant interviews.

Table 1: Mini-grid location and composition

Mini-grid site/Community	Technology	Geographical Zone
Akpabom	Solar hybrid	South South
Adebayo community	Solar Hybrid	South South

[2] Nigeria is politically divided into six geopolitical zones, each comprising several states and reflecting the country's geographical characteristics. The geopolitical zones are North-West, North-East, North-Central, South-West, South-East, and South-South

Ozuzu	Solar Hybrid	South South
Eka Awoke	Solar hybrid	South East
Gbamugbamu	Solar Hybrid	South West
Rije Community	Biogas	North Central
Bukuru	Hydro	North Central
Torakanwa	Solar Hybrid	North West
Dakiti	Solar PV	North East
Mayo Belwa	Solar PV	North East

The team conducted household and key informant interviews as well as focus group discussions. The key informant interviews involved national government officials representing pivotal stakeholders in the electricity sector, including individuals from the Ministry of Power, the Nigerian Electricity Regulatory Commission, the Energy Commission of Nigeria, the Rural Electrification Agency, mini-grid developers and operators, development organisations, and electricity distribution companies.

Mini-grid users, such as households and small enterprises, were interviewed at the community level using semi-structured questionnaires. In each community, the team interviewed 10 households that were connected to the mini grid and five households that were not. Where available, we interviewed the owners of five small businesses per community, focusing on different types of business (e.g., general shops, barber shops, salons, betting shops, video halls, petrol stations, welding workshops, and pharmacies). Operators of community facilities such as schools and health centres were also interviewed where possible. To further enrich our understanding, focus group discussions were carried out with mini-grid users in each community, providing a platform for in-depth exploration of their perspectives and experiences.

Table 2: Key informant interviews

Institution	**Position of Interviewee**	**Gender**
Energy Commission of Nigeria	Managing Director	Male
Nigeria Electricity Regulatory Commission	Deputy General Manager, Research	Male
Ministry of Power	Chief Electrical Engineer, Chief Engineer (x2)	Male
Rubitec Solar Nigeria Limited	Operations Manager	Male
GVE Projects Nigeria Limited	Operations Officer	Male
Gen Sustainability Solutions	Managing Director	Male
Havenhill Synergy Limited	Managing Director	Male
Abuja Electricity Distribution Company	Head Regulatory Affairs	Female
Benin Electricity Distribution Company	Head Regulatory Affairs	Male
Ibadan Electricity Distribution Company	Head Regulatory Affairs	Male
Nayo Tropical Nigeria Limited	Managing Director	Male
Heinrich Boell Foundation	Programme Manager	Male

Community Research and Development Centre	Executive Director	Male
Renewable Energy Association of Nigeria	President	Male
World Bank	Energy Specialist	Male

2.4. Questionnaire development and data collection

Semi-structured questionnaires and interview guides were developed for the stakeholders interviewed, including government departments, owners/operators, organisations and productive users, private investors and financiers, project developers, regulators, utilities, and households. While there were general templates for each of the categories of questionnaires and interview guides from the broader SIGMA team, the Nigeria team adjusted the templates to fit the context and needs of the stakeholders in Nigeria. This ensured the questions were relevant and tailored to gather the most helpful information from each group. For example, the household questionnaires collected views on energy use and expenditure, ease of payment, tariffs and affordability, community engagement, energy source and electric service quality, mini-grid impacts, etc.

The key informant interviews were conducted using Zoom and Microsoft Teams (depending on the interviewees' preferences). Using these virtual platforms for the key informant interviews provided a convenient and efficient way to gather information from participants, regardless of their location. It also allowed for easy recording and transcription of the interviews, ensuring accuracy in data collection. At the community level, data collection was done using a combination of audio recorders and note-taking. The recorders were responsible for documenting responses during face-to-face interviews, while note-taking was used to capture observations and additional information. It is crucial to highlight that the data collection process adhered strictly to ethical guidelines, as outlined by both De Montfort University (DMU) and the University of Surrey. These ethical approvals from DMU and Surrey were taken and the procedures outlined there were followed.

It is imperative to underscore that the data collection process adhered rigorously to ethical guidelines outlined by both De Montfort University (DMU) and the University of Surrey. These ethical approvals from both academic institutions were obtained, and the prescribed procedures followed throughout the entire data collection process.

2.5. Planning and implementation of key informant interviews

The SIGMA Nigeria team created a list of key contacts and shared this with the Rural Electrification Agency (REA), with whom we had established an official partnership for our study. The REA then composed an introductory letter encouraging the identified stakeholders to participate in interviews with the SIGMA team. The letters were sent out, followed by phone calls to confirm availability. Respondents were free to suggest suitable times and dates, and the team arranged interviews accordingly. All interviews were conducted online, except for the one with the Ministry of Power, which utilised a hybrid format combining virtual and physical attendance. This approach was necessary due to the geographic distance between a SIGMA team member and the meeting location, which required virtual participation.

2.6. Planning and implementation of FGDs

The planning process for conducting focus group discussions (FGDs) involved developing questions that elicited diverse perspectives from mini-grid users. The FGDs covered the process of setting up the mini grid, its impact on different segments of the population, views on mini-grid management, and overall satisfaction levels. FGDs were held in all the communities visited, and the participants were carefully selected to represent various community segments. Although the number of discussants ranged from 10-20, in some instances, more people showed up than expected. An example is the Rije community in Abuja, where the biogas mini-grid was not operational and any meeting regarding the system attracted interest from the community members. The sessions included men, women, youth, community leaders, as well as individuals (both those connected and those not connected to the mini grid). This latter group was included so the team could gain insight into why they were not connected to the mini grids in their respective communities.

We spent two days in each mini-grid community, except for Gbamu-gbamu, where we had made prior arrangements before trip, making sure to observe the appropriate community entry protocols on the first day. We informed the traditional rulers and gatekeepers of our mission and sought their permission to conduct the assessment. Once approved, we conducted household interviews and notified the traditional ruler(s) that we would return the next day for the FGD. We also requested the gatekeepers' assistance in mobilising participants for the group discussion.

Table 3: Schedule of mini grid communities/sites visitation

Mini-grid location/community	**Geographical Zone**	**Date(s)visited**	**Mini-grid developer**
Adebayo	South South	March 4th and 5th, 2022	Fani Frank Global Resources Nigeria Limited
Ozuzu	South South	March 7th and 8th, 2022	Darway Coast Nigeria Limited
Akpabom	South South	March 12th and 13th, 2022	GVE Projects limited
Eka Awoke	South East	March 15 to 16, 2022	Cloud Energy Nigeria Limited
Gbamu Gbamu	South West	March 23, 2022	Havenhill Synergy Limited
Rije	North Central	February 4th and 5th, 2022	Ajima Farms
Bukuru	North Central	March 30th and April 2022	NESCO
Torankawa	North West	March 24th and 26th, 2022	News Engineering Nigeria Limited
Dakiti	North East	March 6th and 7th 2022	Leading Diagonals Engineering Nigeria Limited
Mayo Belwa	North East	March 10th and 11th	OG Fortune Limited

3.0. Observations and findings

It is important to note that the information presented here provides a concise overview of our observations and findings and does not delve into the detailed outcomes of the fieldwork. A comprehensive analysis will involve transcribing each interview and coding the data in alignment with agreed themes for a thorough examination. The recorded community engagements will also undergo targeted analysis to extract specific insights.

3.1. Mini-grid site visitation and community engagement

3.1.1 Rije Community Mini-grid

This was the first mini-grid visited by the Nigeria research team on 4th and 5th of February, 2022. Rije is a community located in the outskirts of Abuja metropolis, about 67 kilometers from the city center. The mini grid was developed by Ajima Farms and General Enterprises Nigeria Limited with support from the United States African Development Foundation Off-Grid Energy Challenge in 2016. After development, it was handed over to the community for management.

Rije community, despite having existed for over 80 years and being located under high-tension wires, had never had any form of grid connection before the arrival of the mini grid.
The mini grid is a 20kWp mini grid powered by two 100 kVA biogas generators and a 2KM distribution line. The power system, when it was functional, was originally connected to 66 households and served about 500 community members. New barbing salons sprang up in the community, as well as stores that were selling cold beverages and drinks. However, during our visit, the system was not operational due to lack of feedstock to fire up the installed generators. According to the interviewees, the last time the biogas plant distributed electricity was about a year prior to the date the SIGMA team visited in 2022.

The mini grid is situated on community land that was freely donated for the project. The land donation was part of the community's contribution to making sure that the project succeeded. In the build-up to the development of the mini grid, the developer engaged with the community through the community leadership who were well-acquainted with the project. Respondents also said the community publicly deliberated the project in a general assembly and agreed to its setup. To keep the plant running, the developer initially installed subsidised prepaid meters. The meters, according to respondents were not working properly, and users started paying a flat fee of N500[3] per month for each household accessing power from the plant. This arrangement was to be managed by a committee set up by the community.

[3] This is an equivalent of $0.92 at an exchange rate of 600 Naira to I Dollar

Figure 2. Rije Community biogas mini grid and community

Challenges faced at the mini grid:

- Bypassing of installed meters by households. This mostly caused overloading, and it affected power stability, as the system was always tripping off once there were illegal connections.
- Availability of feedstock to power the mini grid. The mini grid depended on feedstock from two medium-scale poultry farms operating in the community, including Ajima farms, which evacuated their poultry wastes to the plant. Due to logistics and an inability to continue with the farms, the poultry closed and feedstock became a problem for the power station. Therefore, operators had to travel long distances to get feedstock and had to compete with other feedstock users. The cost of transportation also added to the overall running cost, and the mini-grid eventually stopped operations.
- Users were reluctant to pay even the monthly flat rate because there were complaints that the number of hours they had light in a day (4 to 5hrs) was not satisfactory to them. Some also complained that a flat rate was not a just tariff because households had different appliances at home.

- There is a prevailing perception among users that the provision of electricity should transcend mere profit maximization and be viewed as a social responsibility of the government, rather than a purely business-oriented endeavor. This perception gains strength from the stark reality that within less than a kilometer from the community, a national grid is already connected to homes, and users in this location pay significantly lower electricity bills. There is therefore a reluctance to pay by the mini-grid users.

3.1.2. Adebayo Community Mini grid

Adebayo community is located more than 10 kilometers off Lagos- Benin expressway in Edo State Nigeria. The community consists mainly of farmers, for whom farming is the primary source of income. Even those who engage in other businesses find time to farm. The community has existed for over 60 years, and for all those years, it has never had any form of grid electricity except for those who could afford to buy generators. In 2020, Fanny Frank Global Resources Limited developed and commissioned a mini grid. The mini grid has an installed power plant capacity of 100 kW, with 294 solar panels, 72 batteries, and a 27-kilometer distribution cable. It also has a 100 kW generator. The system connects 320 homes and businesses.

Community engagement: According to the interviews, consultations were held with the local community leadership to initiate the process of mini-grid installation. Before the project development, community members were consulted and informed about the type of power system they would receive, and they were also told that they would be paying a certain amount of tariff per kilowatt-hour. However, technical terms were not broken down for them to understand. For example, they were unfamiliar with jargon like "kilowatts," and they did not understand how the tariff came to be what they were paying. They were not adequately educated on the mini-grid system and how it differs from the national grid. However, they were engaged in all aspects of the project development, including participating in the non-technical aspects of mini-grid construction, including clearing the construction sites, fetching water for the construction of battery and inverter house. A Village Power Committee (VPC) was formed as an institutional

arrangement to interface between the developer and the community on all aspects of running the mini-grid.

Figure 3: Adebayo community mini grid

The community reported that the quality of electric service was excellent in the first year, with no complaints. However, that was no longer the case at the time of fieldwork as community members complained that the lights had started going off at 7 pm daily and did not come back on until the following day. Respondents stated that while the mini grid was not perfect, it was still reliable compared to when the community was not electrified.

Figure 4: Focus group discussion with community members at Adebayo

Mini-grid impacts on the community:

Social impacts: Community members agreed that the mini grid had improved their lives. For example, before the mini grid, only a few households and commercial businesses had power because they were the only ones who could run on a petrol generator. However, at the time of our fieldwork, the majority of houses were connected to the mini grid. There were solar streetlights that illuminated the entire community. Also, the mini grid was used to pump the communal borehole at no cost to anyone, so residents come to the public tap to fetch water free of charge. There was also a general viewing center in the community. While the center existed even before the arrival of the mini grid, community youths were now able to extend their viewing time as the operator no longer needed to ration fuel to run the generator that previously powered the centre.

Economic impacts: Some businesses in the community said they benefited from the mini grid. Some benefited from business expansion due to the new availability of power. For example, a welder established a new business in the community after the mini-grid power arrived. A carpenter also reported that his works were now better appreciated by the community members, which translated into more commissions for him. This was because the new mini-grid connection allowed him to showcase his skill using the electric saw, improving his work quality.

Challenges faced by the mini grid:

Reduced quality of electricity supply: Community members reported that towards the end of 2021, they observed a decline in the mini grid's performance, with the system tripping off promptly at 7 p.m. daily, plunging the community into darkness. Community members involved in managing the system identified weak batteries incapable of delivering optimum capacity as the cause. They expressed concerns that the maximum power supply was only effective from morning until around 6 p.m. due to many users switching off their connections while attending to farming activities and only reactivating them in the evening.

High tariff: Respondents complained that the tariff charged by operators was high. They paid NGN 208[4] per kwh, which they said was exorbitant for an agrarian community. Many users complained of spending NGN 3000[5] every 2-3 days, which could go as high as NGN 30,000 [6]monthly, especially for commercial users.

Unilateral decisions by the developer: Community members stated that in the agreement they saw, which they did not even have a copy of, it was noted that both parties (the developer and the community) should discuss any cost increments. However, community members reported that the developer had been unilaterally making decisions. According to them, the village power committee (VPC) was set up to interface between the developer and the community on any price increment. However, the VPC had been rendered useless in that regard. For example, they said the developer never sought their consent when the connection fee was raised from the initial sum of NGN 5000[7] to NGN 10000.[8]

Meter unavailability: Community members also stated that prospective users could only connect to the power if they were able to latch on to neighbours with existing meters. They complained that they had asked the developer several times to get separate meters for new customers, but he had not obliged them.

[4] This is an equivalent of $0.35 at an exchange rate of 600 Naira to I Dollar

[5] [5] This is an equivalent of $5 at an exchange rate of 600 Naira to I Dollar

[6] [6] This is an equivalent of $50 at an exchange rate of 600 Naira to I Dollar

[7] This is an equivalent of $8.33 at an exchange rate of 600 Naira to I Dollar

[8] This is an equivalent of $16.67 at an exchange rate of 600 Naira to I Dollar

Figure 5: A carpenter who uses power from the mini grid

Figure 6: Poles waiting to be energised

3.1.3. Ozuzu Community Mini grid

Ozuzu is a community situated in the Etche local government area of Rivers State, Nigeria, approximately 5 kilometers from the central city of Port Harcourt. Recognised as the state's food basket, most of its residents are engaged in agriculture. Prior to the installation of the mini grid, Ozuzu was never connected to the national grid and lacked public power supply. The community had previously experimented with a community power-generated unit using a diesel generator, but this could not be sustained due to the high cost of diesel.

The Ozuzu mini grid, established in 2020, is a 28 kWp hybrid system powered by 78 solar panels, 52.8-volt batteries, a 28 kVA inverter, and an 80 kVA generator. The mini grid is located on private

land leased out to the developer, and as part of the agreement, the landowner utilises power free of charge. According to respondents, the mini-grid connects 142 households, businesses, and institutions, with 80 households receiving flat-rate unmetered connections. During the development phase, respondents highlighted a deep level of community engagement. Two developers, Darway Coast Nigeria Limited and Renewvia, visited the community to discuss mini-grid construction. Both developers met with community leaders, and a formal presentation of their proposed projects was requested. One developer, Darwaycoast, attended the community meeting, while the other provided excuses for not attending. Subsequently, another meeting was scheduled, and the developer who participated in the initial meeting attended, while the other declined. At this point, the community selected Darway Coast as their preferred developer due to the company's respectful approach.

Figure 7: Ozuzu community mini grid plant

Ozuzu has a community development committee (CDC) chaired by a retired employee of Nigeria's public power company (NEPA). Committee members were drawn from the six communities benefiting from the power system. This committee was the community's representative in the mini-grid development negotiations. Before signing any agreements with the developers, the CDC chairman (who retired from the then public power company Nigeria Electricity Power Authority NEPA) insisted on a series of meetings and question-and-answer sessions. For instance, the developer had to demonstrate their ability to deliver power to the community by installing a few pieces of equipment and operating for three to four months before the community could sign their

Power Purchase Agreement (PPA). The equipment brought to the construction site underwent testing and certification. Certification for metres and poles at the site was requested, and an impact assessment was conducted.

According to respondents, the tariff was discussed with the community before it was implemented. When the mini grid became operational in 2020, the agreed tariff was NGN100[9] per kwh, but it has now been raised to NGN 138.8[10] per kwh, which the community also said was discussed.

Mini-grid impacts on the community:
According to respondents, the mini grid has had the following impacts:

Economic: The mini grid has had a significant impact on businesses operating in the community. The manager of a petrol filling station in the community that uses power from the mini grid reported substantial savings on diesel costs whenever the energy from the mini grid is constant. The community development chairman, whose eatery and beer joint closed due to the COVID-19 effect, said he was renovating his business premises due to the presence of the mini grid, and he intended to expand the place to include air conditioners.

Social: The various streetlights that illuminate the major community roads provide more security to the community. Some respondents also said that the presence of the streetlights extended the community's nightlife.

Health: The presence of the mini grid in the community has contributed to the location of a pharmacy in the area. The mini grid will not only assist in preserving drugs and vaccines for use by members of the community; it will also make available essential drugs to the community members.

Figure 8: Filling station powered by energy from the mini grid in Ozuzu community

[9] [9] This is an equivalent of $0.17 at an exchange rate of 600 Naira to I Dollar
[10] [10] This is an equivalent of $0.23 at an exchange rate of 600 Naira to I Dollar

Challenges:

System overload: At the time of fieldwork, the mini grid was facing an overload issue caused by an excessive number of connections, surpassing the capacity of the mini grid. As a result, power rationing was being implemented during the day, affecting various households and businesses. Certain areas were experiencing power outages for a duration ranging from 4 to 8 hours on a daily basis.

Unfair billing system: In addition to the overload problem, there were complaints from users on flat-rate connections who felt that they were being charged at a rate higher than what metered customers were paying. This issue caused dissatisfaction among some users.

3.1. 4. Akpabom Community Mini grid

Figure 9: Akpabom Community Mini-grid

Akpabom, situated in Akwa Ibom State within the South-South region of Nigeria, is a community primarily sustained by fishing and agriculture, with minimal petty trading activities. The community, comprising approximately 250 houses, endured more than 15 years without power after its connection to the national grid was severed due to road construction damaging the power infrastructure.

In 2019, GVE Limited developed a 100kWp solar PV mini-grid system powered by 270 solar panels, inverters, 36 batteries, and distributed to homes and businesses through a 5.5-kilometre cable. The mini-grid is located on community land donated free of charge.

According to respondents, when fully operational, the mini grid offers users continuous 24-hour power supply, except for faults caused by thunder or trip-offs due to illegal connections.
The mini grid is connected to approximately 77 homes and businesses in the community, but only 44 are energised. The remaining 33 homes only have their wires connected to the electric poles but have not been energised because they do not have meters.

Respondents said the mini grid was facilitated by a political representative in the state legislature, whose constituency includes the Akpabom community. According to them, the representative initiated discussions with the developer, GVE Projects, inviting community participation. However, respondents highlighted that the engagement needed to be more comprehensive. For instance, although the developer verbally informed the community that the project would be operated by the company for ten years before being handed over to the community, this agreement was not documented. The community claimed they had not seen any such document, and they emphasised the absence of post-development engagement. According to the community, the developer, GVE Projects, had not returned to the community for any discussions since the project's commissioning in 2019, despite complaints of faults lodged by the mini grid users. Instead, proxies needing more technical knowledge about the power station handled communication with the community.

Figure 10: Akpabom mini grid battery bank

Mini-grid impacts on the community:

Economic: Regarding the economic impact of the mini grid, it is worth noting that while it has had an overall positive effect, the community's use of power for productive purposes and economic activities is still limited. Most power users are households using it for basic needs like lighting, television, and fans. Commercial users are few and far between, with only a handful of small shops utilizing the power to refrigerate beverages for sale. While this has resulted in a modest reduction in fuel costs for these businesses, there is one notable exception. One store, which previously did not have a deep freezer, was able to acquire one thanks to the development of the mini grid. This expansion led to a significant increase in sales and income.

Social: Respondents said the mini grid had contributed positively to societal bonding and bridging within the community. Providing a central location for people to gather, such as a cold drink joint, fosters healthy relationships and bridges social gaps. Additionally, installing street lights and security bulbs on houses had improved human security by illuminating the community.

Challenges:

- Technical personnel were unavailable to promptly address system-related issues. Regrettably, the mini grid lacked a resident technician to handle minor community and system complaints. Consequently, certain individuals had been waiting for over a year to be connected, despite having already paid for the service. Moreover, some individuals had faced challenges with their meters but lacked the necessary support to resolve these issues. This situation compelled some individuals with malfunctioning meters to illicitly connect their homes to their neighbors' electricity or use power without a meter.
- A noticeable disconnect existed between the mini-grid developer and the community. Community members complained about the lack of formal communication channels for connecting with the developer. Consequently, users were left to address any technical difficulties related to utilizing the mini grid independently of the developer. Regrettably, no one in the community was trained to resolve minor technical issues resulting from the mini grid.

3.1.5. Eka Awoke Community Mini grid

Figure 11: Eka Awoke mini-grid system

Eka Awoke is a rural community located in Ebonyi State in the southeastern part of Nigeria. The community has existed for over 100 years and has never been connected to any form of grid electricity. The mini grid was developed and commissioned in 2020 by Cloud Energy Limited and connected to 75 households and commercial points.

The mini grid is located on land donated by the community to facilitate its development. The developer gave the community a monetary offering as a token of appreciation. The mini grid is a 100kWp solar hybrid system with batteries and a 100kVA diesel generator, which was functional at all times - 24 hours a day, seven days a week – at the time of fieldwork.

However, according to the site operation assistant, the system operated at only 20% of its installed capacity, indicating it was being underutilised. As part of their business development model, the mini-grid developer had begun taking steps to increase demand by offering energy-efficient electrical appliances such as televisions, light bulbs, and refrigerators. The plan was for these appliances to be sold to users under mutually agreed terms to boost demand for the system.

Community members said they were engaged during the pre-development phase. According to them, the community chief briefed the community on the government's approval to install a solar mini grid, and the developer was introduced. The developer consulted the community in different ways, including conducting feasibility studies to determine appliance usage and willingness to pay. The community members agreed that the developer consulted them at every phase of the development process.

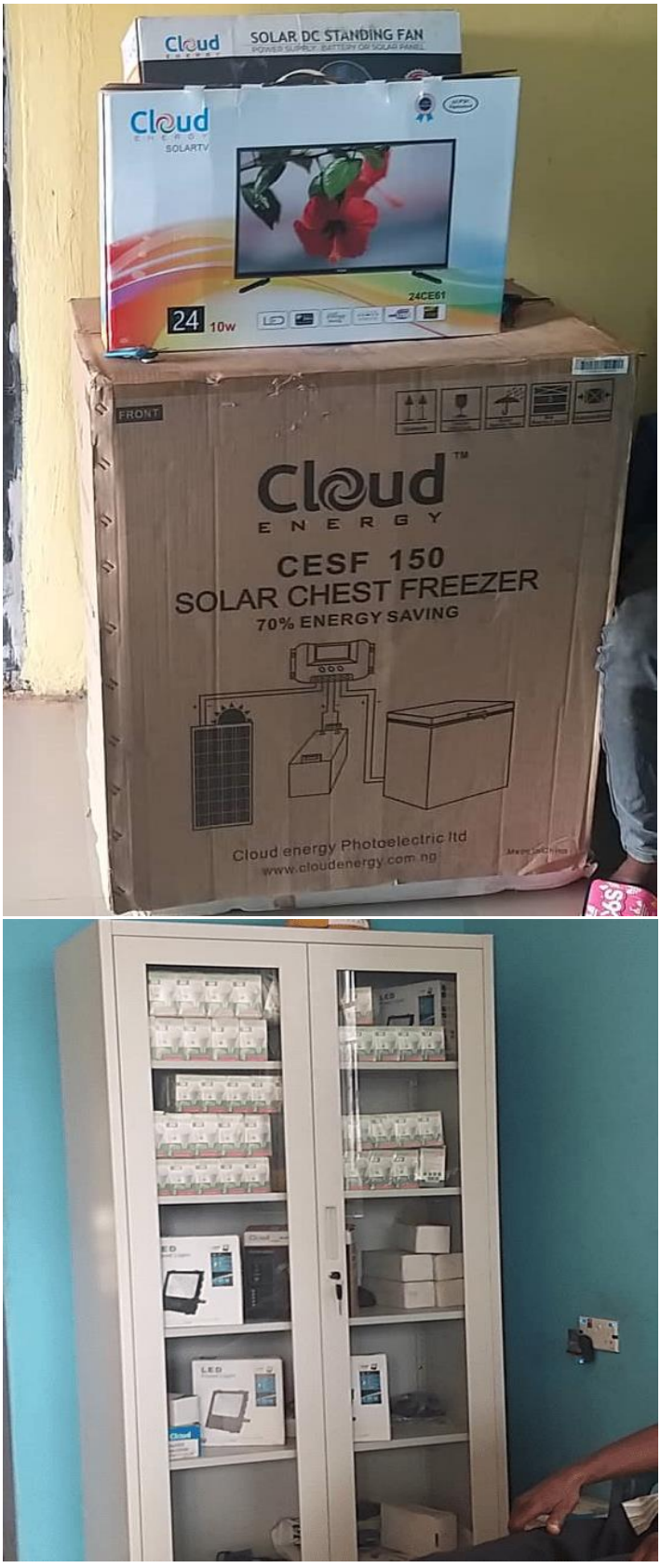


Figure 12: Some electrical appliances offered by the mini-grid developer and operator

Mini-grid impacts on the community:

Economic: The local market night hours had been extended to accommodate those returning late from their farms. The market was now open until late at night and was illuminated by floodlights powered by the mini grid and placed in strategic positions. This increased economic activity within the community as it attracted buyers and sellers from neighbouring communities. Moreover, the mini grid also positively impacted individual businesses. For instance, a respondent who owned a mini-cold room had seen increased customers and sales for frozen foods and cold drinks. The store had become a popular destination for those looking to buy iced fish, which previously had to be purchased from traders in Abakaliki (an urban centre more than 15 kilometers away) due to the lack of power supply in the community. Other businesses that saw a boost in sales include those selling satchet drinking water, resulting in increased income. A few barbershops also opened in the community.

Social: According to the respondents, the streetlights served the dual purpose of illuminating the market and enhancing the surrounding environment. This, in turn, promoted security and fostered societal connections within the community, as individuals were afforded more opportunities to engage and discuss communal concerns.

Challenges:

Underutilisation: The mini grid is a 100kWp power system with a 100kVA diesel generator. The power was connected to only 75 households and businesses at the time of fieldwork. According to the site engineer, only about 20% of installed capacity was being utilized, leaving 80% unutilised.

Developer's low capacity for expansion: The customer base of the mini grid was insufficient to provide the necessary income for expanding operations. In one FGD, many people raised concerns that their areas were not receiving power. The community development chairman himself reported that his residence was still without power.

3.1.6 Torankawa Mini grid

Torankawa is an agrarian community situated in Yabo, a local government area of Sokoto State in the northwest region of Nigeria. The community comprises 350 households with a population of approximately 1,750 people. Located about 10km from the local government headquarters and 70km from Sokoto, the state capital, Torankawa primarily engages in agricultural activities, producing food crops such as maize, millet, sorghum, beans, and vegetables.

The Torankawa interconnected solar hybrid mini grid was inaugurated for use in 2019. Financed by the Green Bond, the Federal Ministry of Power executed the project through a contract awarded to News Engineering Nigeria Limited. Before the mini grid was installed, the community received electricity from Kaduna DisCo. However, a lack of electricity plagued the community for about five years before 2019, which was attributed to the destruction of distribution lines by strong winds.

The solar installation in the community, housed in a generation/distribution station, consists of 200 units of 300W solar panels, 180 units of 2V 600A deep-cycle batteries, one unit of 120kVA inverter and one unit of 120kVA backup diesel generator. The interconnectivity consists of an

11kVA Kaduna DisCo distribution line which is stepped down through a 300KVA transformer to the generation/distribution station. A meter installed in the station records monthly supply from Kaduna DisCo which is paid by the community through tariffs charged by the management of the installation. Changeover switches installed in the station switches supply from Kaduna DisCo to the solar and vice versa. Low-tension distribution lines with cumulative length of about 2km are installed along the roads in the community from where step-downs are made to households. Each house is supplied with a prepaid meter.

From the very beginning of the project, the community was consulted and actively involved. Community members provided both land and logistics support during the installation process. Furthermore, the Contractor ensured that three individuals from the community were trained in essential maintenance and troubleshooting, ultimately becoming the skilled management personnel who took over when the Contractor's involvement concluded.

Figure 13: Focus group discussion in Torankawa community

Mini-grid impacts on the community:

Economic: According to the respondents interviewed, the mini grid had positively impacted the community's economy. Those previously using petrol generators and incurring high expenses had seen significant savings. This resulted in increased liquidity, allowing them to address other issues. A few new businesses had emerged while existing ones had expanded to offer additional services such as cold drinks and film rental.

Social: The mini grid electrified the mosques and public places within the community. Nighttime activities had been greatly enhanced, and the community no longer went to sleep at dusk. Means of worship had also been greatly improved, and the illuminated mosques and other public places had now become conducive for after-dark social gatherings. Also, better human security was achieved by illuminating the community with streetlights and house security bulbs.

Challenges

- The mini grid was regarded as one of the most successful interconnected systems in Nigeria. However, during the field visit, it was observed that the interconnectivity was not functional as the Kaduna DisCo lines to the community had been destroyed again by strong winds. The community confirmed that the utility supply had not been available for over two years.
- The revenue profile of the mini grid system is poor; it stands between NGN100,000[11] and NGN150,000[12] monthly. Once management personnel and other maintenance costs were settled, the net revenue dwindled to less than NGN50,000[13] monthly. The pressing concern revolves around financing the battery replacement, incurring a substantial cost of NGN10,000,000.[14] The Secretary of the Technical Committee emphasized the critical need for external support to address this challenge, expressing that without it, there's a looming possibility of abandoning the installation. The committee was optimistic about receiving additional support from the Federal Ministry of Power in the coming years. Unfortunately, the pool of productive users capable of bolstering the revenue remains limited.
- The lack of adequate skilled personnel was also a significant problem. The mini grid operators did not know how to test for dead batteries and isolate them. During fieldwork, the SIGMA team observed that the community was relying on the contractor, who had been providing pro-bono service since the installation's completion, to assist with battery testing. Moreover, the community was i8unsure how many batteries were affected and how to finance their replacement. Due to the drop in supply, the connection of additional customers beyond the initial 100 were been put on hold until the battery issues could be resolved.

[11] This is an equivalent of $166.67 at an exchange rate of 600 Naira to I Dollar
[12] This is an equivalent of $250 at an exchange rate of 600 Naira to I Dollar
[13] This is an equivalent of $83.33 at an exchange rate of 600 Naira to I Dollar
[14] This is an equivalent of $16, 666.67 at an exchange rate of 600 Naira to I Dollar

3.1.7. Dakiti Community Mini grid

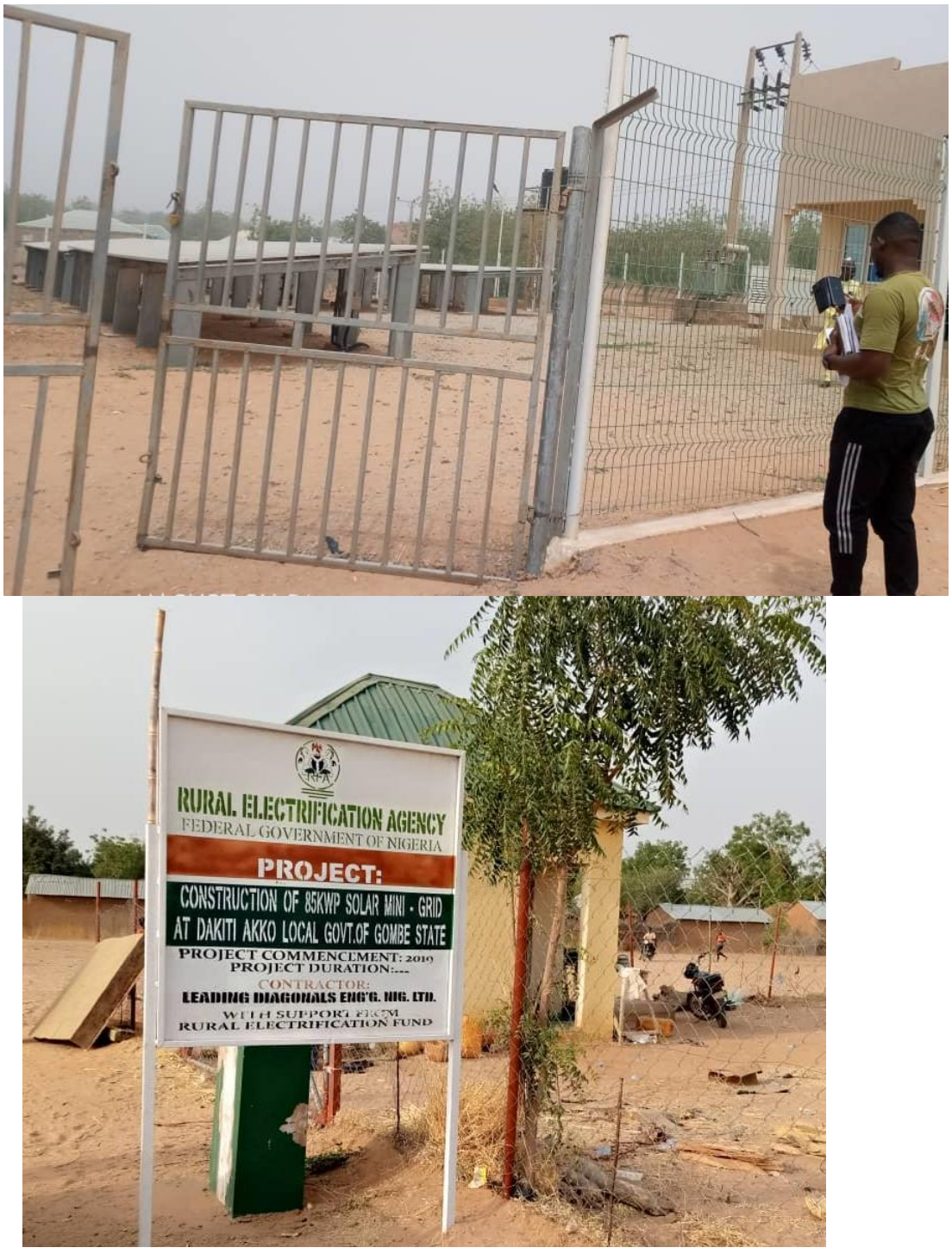


Figure 14 : Dakiti community mini grid

Situated in the Akko Local Government Area of Gombe State, Dakiti is a predominantly agrarian community with a population of over 3,000 residents distributed across more than 500 households. The community is approximately 20km from Gombe and 6km from the nearest national electricity

grid. Dakiti is renowned for cultivating diverse crops, including millet, sorghum, and soybeans, alongside animal husbandry.

The Dakiti mini grid, a project developed by Leading Diagonals Engineering Nigeria Limited in collaboration with the Rural Electrification Fund (REF), was completed in March 2020 and commissioned in March 2021. The system comprises 282 solar panels, 74 batteries, and various other solar components, including approximately 6km of distribution lines. The power system had successfully energized 253 residences and businesses within the community at the time of fieldwork. In addition to the solar components, a 60kVA backup diesel generator is housed in the power station. This generator functions to recharge the battery bank in the rare event that its power level descends below 40%. Since its installation, the battery bank had consistently maintained a capacity above this threshold, rendering the generator unnecessary.

Community involvement played a pivotal role in the development process. According to respondents, the mini-grid project was initiated by an official from the Transmission Company of Nigeria (TCN), who owned farms near the community and had a positive rapport with the residents. When the Rural Electrification Fund (REF) call was announced, this official advocated for the community's electrification, given its distance of approximately 6km from the nearest electricity grid. Community members affirmed their willingness to accept the electricity. They expressed their commitment to covering the associated costs during consultations, which were reported to have been attended solely by men.

The land on which the Village Head generously donated the mini grid stands at no cost to the developer. Local mini-grid management was entrusted to a technician trained by the operator in essential maintenance and troubleshooting. Additionally, two local guards were employed to ensure security for the installation, receiving monthly compensation from the company. The local technician undertook routine maintenance tasks and called upon the company for more complex maintenance services when necessary.

Mini-grid impacts on the community.

- **Economic:** While the respondents agreed that the mini grid had a positive overall impact, the community's use of power for economic activity and productive use was very low. The majority of electricity users were households, of which only a few had used petrol generators prior to the installation of the mini grid. Contrary to expectation, only a couple of businesses had been added since the mini grid was installed. Notwithstanding this, the reduction in energy costs for those previously using petrol generators was quite significant, according to respondents.

Figure 15: Sample electricity meter at Dakiti community

Challenges:

During our fieldwork, there were no operational challenges with the mini grid. This was corroborated by the respondents, who reported no issues. However, upon closer analysis, a

potential future challenge emerged concerning replacing the battery bank. Insights from the local technician revealed that the average monthly revenue generated was approximately NGN100,000.[15] Projections indicated that the installation's anticipated battery lifespan was six years, with replacement costs exceeding NGN14,000,000.[16] Based on the current revenue stream, the gross revenue over the six years amounted to approximately NGN7,200,000.[17] Unfortunately, these financial calculations indicate that the mini grid may not generate sufficient funds to cover the replacement of the battery bank in the future. This concern was raised with the local technician, who regrettably could not provide insights into the operator's strategy for financing the replacement when needed.

3.1.8. Mbela Lagaje Mini grid

Mbela Lagaje is a rural community in the Mayo Belwa Local Government Area of Adamawa State. The community has an estimated population of 1,500 inhabitants and is situated about 15 kilometers away from the local government headquarters. Mbela Lagaje is known for its agricultural activities, particularly the cultivation of sorghum and soybeans.

The Mbela Lagaje solar hybrid mini-grid was completed in December 2020. The installation has a 60kVA diesel generator that is supposed to provide a backup electricity supply to the community. Since it was installed till when the SIGMA team visited, respondents said the generator had only been used once to power the community overnight. They said they could not continue using the generator due to the high cost of diesel. As of the time of visit, the mini grid was not operational. However, of the 147 houses in the community, only 80 households were connected, and out of the connected households, only five had been connected by the contractor. The other 75 households had had to purchase their own poles and cables for connection. Households unable to buy their own materials were left out of the connection.

During the process leading up to the installation of the mini grid, the community said they were never consulted. They confirmed that a member of the House of Representatives facilitated the development of the mini grid. Respondents said they were only called for a briefing when the developer mobilized to the site. According to the respondents, the developer and REA officials told them that the government had decided to bring them electricity, which was why the developer was there. They were urged to keep the mini grid secure after it was installed.

After the development of the mini grid, the REA established the Rural Electricity Users Cooperative Society (REUCS) to be in charge of the mini grid's operation, maintenance, and security.

[15] This is an equivalent of $166.67 at an exchange rate of 600 Naira to I Dollar

[16] This is an equivalent of $ 8,420.53 at an exchange rate of 600 Naira to I Dollar

[17] This is an equivalent of $ 4,332.22 at an exchange rate of 600 Naira to I Dollar

Figure 16: Mbela Lagaje mini-grid site

Mini-grid impacts on the community:
Economic: Respondents said when the mini grid was working, it boosted economic activities in the community. Shops and barbing salons witnessed enhanced service delivery and cost savings. Only one respondent who operated a phone charging shop reported having negative growth in business when the mini grid was working.
Social: When it was working optimally, the mini grid improved social life in the community. The mosque and other public areas in the community were illuminated and enhanced nighttime for the inhabitants. The mini grid also improved relations with neighboring communities as they visited and enhanced friendships with the Mbela Lagaje inhabitants so they could charge their phones, torch lights and rechargeable radios.

Challenges:
When the SIGMA team visited the generating site and observed the distribution lines, the following technical deficiencies were noted:

- The solar panels were a mixture of monocrystalline and polycrystalline, with more of the latter in the mix. It is very likely that the system was delivering lower-than-designed output
- All the labels in the solar panels had been removed so the power rating could not be determined without using a test meter.
- The inverters were also being used as chargers instead of having separate charge controllers. This put a lot of pressure on the inverters.
- The electric poles supplied were metal based instead of concrete or wood. This is not good practice.

Figure 17: Mbela Lagaje mini-grid lines

Figure 18: Mbela Lagaje mini-grid lines

3.1.9. Nigeria Electricity Supply Company (NESCO), Jos

Plateau is the twelfth-largest state in Nigeria. Located in the centre of the country, it is geographically unique in Nigeria due to the boundaries of elevated hills surrounding the Jos Plateau, its capital, and the entire plateau itself. Plateau State is described as "The Home of Peace and Tourism." With natural formations of rocks, hills, and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million. The Jos-Bukuru Metropolis, which comprises much of NESCO's customer base, was previously considered two separate metropolises. Over time, however, the city of Jos has merged with the town of Bukuru to form the Jos-Bukuru metropolis.

Jos Plateau has a rich, industrious heritage. The people are engaged in different economic activities, but their primary occupation is agriculture and trading; the people farm a lot of fruits and vegetable crops such as carrots, cucumbers, okra, tomatoes, potatoes, onions, rice, beans, groundnuts, maize, watermelon among other things. Besides agriculture, the metropolis has witnessed very rapid commercialization and industrialization. New markets, industries, and institutions are growing and expanding at almost every corner of Jos City, making Jos a metropolitan city. Some of these commercial and industrial centres include Jos primary market (Terminus), Bukuru market, Rukuba market, Faringada market, Coca Cola Bottling Company, NASCO Group, Naraguta Leather Works, Swan Bottle Water Industry, Jos University Teaching Hospital, aluminum roofing industries, NTA Television College. Other important establishments in this city include the National Veterinary Research Institute, the National Institute of Policy and

Strategic Studies (NIPSS), the Jos National Museum, the Airport, the College of Accountancy, the Zoo, Eateries, Relaxation parks, and a host of other industries.

NESCO was originally a British Company established in 1929 with the colonial administration's support. The first 4Megawatt hydropower plant was installed in Kurra Falls. The plant was upgraded to 8 Megawatt: Jekko 1 and 2, each with a capacity of 4 Megawatt, were installed in 1937 and 1954, respectively. Ankwil 1 was established in 1961 with a capacity of 1 Megawatt, while Ankwil 2 was installed in 1963 with a capacity of 2 Megawatt. The first hydropower station built by the Tin miners in 1919, Kwall 1, with a capacity of 2MW, was taken over by NESCO some years after it started operations. Kwall 2, with a capacity of 4MW, was installed in 1968. These are small hydroelectric systems situated across different river networks.

The original operating license was for providing electricity for tin miners who operated in the area during the colonial era. Following the 1962 decline of the tin-mining industry and the subsequent loss of its key customers, NESCO shifted focus to the communities and towns surrounding the mines. The operating license was then expanded in later years to include selling electricity to the defunct Electricity Corporation of Nigeria (ECN). Subsequent reviews included servicing customers whom the ECN could not reach then.

By 1970, NESCO had electrified 27 towns in the Benue-Plateau region and was the sole electricity supplier to Jos. When the defunct Nigerian Electric Power Authority (NEPA) took over electricity supply in the city in 1978, the government permitted NESCO to operate independently of NEPA due to the former's reputation for reliability and superior service.

When it started operations, NESCO was financed by the colonial administration because of the latter's interest in tin mining. When Nigeria gained independence in 1960, financing by the colonial administration stopped. In 1975, when the Nigerian government was promoting the indigenization of foreign-owned companies, the then Benue/Plateau State (now Benue, Plateau, and Nasarawa States) first bought shares in the company. The Federal Government followed suit the following year. Presently, its operations are financed through revenue generated from the sale of electricity.

NESCO's main franchise area is the Plateau area. It supplies electricity to Jos Metropolis, Bukuru, and all the communities along the 107km road from Jos to Kurra and beyond. Its customer base is 7,860, comprising domestic, commercial, industrial, and institutional users. NESCO has not conducted a recent enumeration to get the number of customers in each category, but the most extensive customer base is in the R2 band[18].

All the respondents the SIGMA team asked about levels of community engagement said they were not part of the pre-power system development in the communities. There was no community engagement before its establishment, as the original focus was the tin mines. Surplus electricity was extended to communities surrounding the sites for a fee. From its inception to date, NESCO has been a commercial enterprise and solicits customers like any other electricity utility company. However, during its expansion phase, in addition to obtaining the necessary permits from the government, NESCO engaged with communities in its franchise area on the electricity supply, tariff, and benefits. Today, NESCO still engages with the communities it services on the safe use of electricity and cost recovery.

[18] These are household customers with consumption above 50 kilowatt electricity.

Mini-grid impacts on the community:

Economic: According to respondents who use NESCO's power, NESCO's electricity supply is much more stable than Jos DISCO's. This has led to very significant and sustained growth in economic activities. The few industries NESCO serves enjoy much lower production costs, according to the NESCO personnel interviewed.

Social: Because NESCO's supply is much more stable than that of Jos DisCo, the persons interviewed said they enjoyed a much more social life than most parts of Nigeria. Nighttime recreational activities and gatherings were usually fun before insecurity became a problem in the region. Also, better human security has been achieved at the community level by installing street lights and security bulbs on houses.

Environmental: NESCO's operations have not had any significant negative impact on the environment, according to the personnel interviewed. Even though a substantial area of land was set aside for the reservoir, not much agricultural land was condemned. Secondly, the dams were constructed in such a way as to avoid significant distortions to aquatic life. Water flow through the river is maintained at all times, though at different levels depending on the season. The personnel said this has boosted fishery and agriculture around the dam and downstream. Also, no case of flooding has occurred in the dams. Beyond the spillways, each dam has an underground tunnel that channels excess water downstream and helps maintain natural river flow.

Further, because the dams are earth dams, they have equipment that measures seepage. Where detected, any seepage is quickly plugged. Finally, the respondents said reduced dependence on petrol generators positively impacts their health and the environment.

Challenges:

- **Financing constraints:** Currently, NESCO generates just enough money to finance its operations but not enough to finance its expansion plans. NESCO said it has tried to get a loan from the Bank of Industry (BoI), but it wasn't successful due to the difficult terms proposed by the bank, including the provision that NESCO hand over the Certificates of Occupancy of its facilities as collateral to access a loan.
- Low revenue generation - While the NESCO tariff is much lower than that of Jos DISCO, customers still complain that the amount is high. This has affected its revenue. According to NESCO, bill collection compliance, at the time of engagement, stood at about 70%.
- Illegal connections are one of its biggest challenges. NESCO estimates its losses to be close to 50% of unlawful connections. Where detected, the offending customer is disconnected and must pay a penalty before reconnection. However, most offenders have found ways to continue illegal connections and do this mostly at night.
- About 25% of NESCO's customers are in the rural areas. Recovery of bills in rural areas is quite challenging as it requires significant logistics to get to the rural communities. This is not helped because NESCO operates a post-paid metering system.
- Since the last power plant was installed in 1968, NESCO has not expanded its generation capacity. Most of the turbines now operate at reduced efficiency. Lack of finance has hampered its plans to upgrade the aged turbines. This and the rising customer base have forced NESCO to adopt a load-shedding program. Currently, daily electricity supply varies

depending on location and class of customer. In some areas, supply is done every other day, i.e., one day on and one day off. Some areas have only a few hours of disruption per day. High-value customers such as industrial users and public institutions, enjoy 24-hour supply.

- Changes in climatic conditions, which are increasingly becoming unpredictable, have also significantly impacted generating capacity. Water levels in their reservoirs are progressively dropping, according to NESCO personnel. The drop in water level is usually most felt during the dry season and has threatened NESCO's operations severely.
- Insecurity has severely impacted NESCO's operations. The company has lost a couple of staff to attacks by insurgents operating in the region. Maintenance is greatly affected. The 33KV lines from the power stations to the control stations pass through areas where insecurity is rife. Maintenance teams now go with military escort. This has affected the schedule of their maintenance. Also, all their power stations now have military personnel guarding them. These have substantial financial implications.

3.1.10. Gbamu Gbamu Mini grid

Gbamu Gbamu, settled by farmers from Owu-Ijebu (Ijebu East L.G.A.) of Ogun State, was established over two decades ago. The settlers were drawn to the area's fertile land, peaceful surroundings, and trade opportunities offered by the renowned Gbamu Gbamu market. Over the years, the community has attracted people from different parts of Nigeria, including Cross River, Osun, Sokoto, and Lagos States. The Ogun state government initially designated the land as a forest reserve, where nature was preserved by allowing crops like Gmelina, trees, and animals like elephants to thrive.

Before the introduction of the solar hybrid project, a significant development had already occurred in Gbamu Gbamu. Nigeria's most extensive network service provider, M.T.N., had installed a telecommunications mast seven to eight years prior in the area. This development was instrumental in selecting Gbamu Gbamu as a potential site for a solar mini grid, as it allowed for real-time communication necessary for the plant's effective daily operations. Additionally, the community's distance from the national grid was crucial. The absence of electric poles miles before the community meant that the national grid would not have been accessible anytime soon.
The Gbamu Gbamu 85kWp Solar Hybrid Mini-Grid Project, initiated in 2018, was still functioning at the time of fieldwork in 2022, albeit at reduced capacity. The mini-grid operator, Rubitec Utilities, views the project as its most significant undertaking, and GIZ provided the funding. Before the establishment of the mini grid, the approximately 500 households and businesses in the community had no electricity, and only a few of them could afford to run petrol or diesel generators sets to meet some of their energy requirements.

Figure 18: Gbamu Gbamu mini-grid site

Figure 19: Gbamu Gbamu mini-grid battery bank

At its inception, GIZ tasked Rubitec with the role of seeking potential sites that were suited for mini grid solutions which effectively led to the final selection of Gbamu Gbamu amidst five other communities identified by the operator. The operator, knowing the importance of government inclusion, encouraged GIZ to interface with the Ogun state government before further

engagements were made with the community through the traditional ruler and his governing council.

However, due to various unrealised schemes and projects proposed by external bodies to the community in the past, the villagers and their leaders initially considered the mini grid project another hoax. This did not deter the operator from carrying out feasibility studies and energy needs assessment of households and businesses about five years before the project commenced in 2017. This included proper sensitisation of the community on how stable electricity can induce socio-economic growth and development. Nonetheless, a number of interviewees admitted that they didn't fully believe the developer's promises until the first set of electric poles and connecting cables were installed.

With proper understanding of the benefits the community stood to gain from the project much later, the traditional ruler and his governing council of 14 members (comprising a secretary, a treasurer, a public relations officer, two women and eight other male members) selected a suitable location for the mini grid installation beside the telecommunication mast. The land in question was formerly used by a member of the community for cocoa farming, and he was duly compensated for it by the mini grid operator. Proper documentation (in the form of an MoU) was also put in place and signed by the representatives of the community and the mini-grid operator. The MoU primarily outlined the roles of the community and the mini-grid operator and the initial tariff structure, as pre-determined by the mini grid operator and regulated by the REA.

Mini-grid impacts on the community:
The villagers acknowledged that the mini grid had directly impacted the community's socio-economic life in the following areas:

1. Improved productivity levels especially by businesses that were reliant on constant power supply such as barbing, tailoring, vulcanizing and hotel/motel businesses.
2. Migration of people from neighbouring villages or communities to Gbamu Gbamu to carry out productive activities, relax and sometimes settle with their households. This led to an increase in housing units from an estimated 500 houses to over 1500 houses within 4 years of commissioning the mini grid.
3. Improved academic performance by students in the early days of the mini grid's operation. However, it was gathered from the village school head teacher that constant electricity hadn't necessarily led to improved performance of students in the long term, as some were distracted by excessive consumption of TV shows and videos. An exception would be the introduction of information technology instruction (done with one laptop on Fridays) by the school's PTA as a result of improved electricity access.

   On the part of healthcare workers, since the storage's efficiency declined, they have had to rely on rechargeable lamps and lights from their mobile phones for delivery of pregnant women at night. They have also resorted to storing their vaccines with cold-drink retailers in the local market. This indicates that for social users such as schools and health centres, electricity access has not been much of a game changer.

Challenges:

- The challenges faced by the mini-grid operator were mostly financial and operational. This specifically has to do with managing the backup solutions deployed to help keep power supply round-the-clock. Since solar is an intermittent energy source solely dependent on the sun's availability, the mini grid has a battery storage backup (96 batteries) and an 80kVA diesel generator which has to be constantly maintained and serviced. The high cost of diesel and the reduced efficiency of the batteries after 4 years of operation had reduced power supply for the community from 24 hours daily to around 18 hours daily.
- Out of more than 600 houses currently connected to the grid, over 400 are believed to be household users. This category of users are primarily night-time users who rely on power for lighting and entertainment, consuming around NGN200[19] worth of electricity daily. Therefore, their complaints are tied around recent outages and reduction in the number of daily hours of power supply – especially during evening time when batteries have been drained and the diesel generator is rested. This, coupled with the perceived poor communication from the operator to notify them ahead of power outages and status of their tariff (resulting in sudden power cuts even when there is electric supply) affects their ability to secure their homes and surroundings at night and is seen by them as the opposite of what was promised them at the beginning – 24/7 power supply.
- Another major challenge pointed out by household owners is that of the social conflicts that are generated in situations where a meter is shared by two or more households. While the operator is ensured of zero energy theft since every household is metered and only one electrician is authorised to attend to electrical faults, customers are sometimes left unhappy because others are free-riding on the power they purchase. The monopoly enjoyed by the electrician and the power vendor also raised doubts among some users (including productive and commercial users) regarding the efficiency and transparency of the complaints resolution system.

3.2. Key informant interviews

3.2.1. The Energy Commission of Nigeria (ECN)

Our interview was with a member of the top management team of the Energy Commission of Nigeria. The ECN was established in 1979 and started operations ten years later in 1989. This was after Economic Community of West African States (ECOWAS) heads of state decided in Cotonou in 1985 that each member state should establish a government agency to serve as its energy commission. The respective commissions were expected to be in charge of the surveillance, development, monitoring and coordination of energy in each state. The ECN's key functions involve collecting data, producing periodic master plans, and coordinating national energy policies.

[19] Equivalent of $0.33 with the exchange rate of N600 to a dollar.

According to the respondent, the ECN has participated as a critical stakeholder within the mini grid sector. For example, during the development of the 2016 Mini-grid Regulation driven by Nigeria Electricity Regulatory Commission (NERC), the ECN was part of the energy stakeholders in Nigeria that took part in the process. According to him, preceding the regulatory framework, the ECN actively engaged in pilot mini-grid projects, exemplifying diverse technologies aimed at enhancing energy access for rural communities. Those initiatives included the installation of 5kWp and 10kWp capacity mini grids. To date, the ECN still implements mini-grid projects budgeted for by the National Assembly under the banner of so-called constituency projects.

The respondent underscored a substantial impediment to the sustainability of mini grids in Nigeria, specifically, their placement within communities where users do not remit payments, with politicians mainly utilizing constituency projects to garner popular support.

3.2.2. Renewable and Rural Policies Department (Ministry of Power)

Our respondents were three senior officers of the Ministry of Power. The ministry is responsible for overseeing power sector policies, program formulation, and intervention development as needed. The ministry has a specific department, the Renewable and Rural Power Sector Department, dedicated to renewable energy. This department manages the formulation and implementation of renewable energy policies, including the Renewable Energy Policy, Energy Efficiency Policy, National Renewable Energy Action Plans, Sustainable Energy Action Agenda, and other related policies. Overall, the ministry is actively involved in shaping and executing initiatives to advance the power sector, particularly in the realm of renewable energy.

The respondents pointed out that the Ministry of Power plays a pivotal role in coordinating the electricity sector as a whole, including the development and regulation of mini grids. This strategic involvement ensures that the expansion and management of mini-grid systems align with national policies and standards.

The respondents identified two major challenges in the development of the mini-grid sector in Nigeria. Firstly, the prevalence of impatient investors poses a significant hurdle, with some individuals seeking quick returns within unrealistically short timeframes. Secondly, the issue of double-digit interest rates in the country adds financial pressure on developers. Beyond these challenges, the respondent highlighted the need to address changes in lifestyle among electricity consumers, particularly those encountering electricity for the first time. The shift in daily routines and the lack of awareness about electrical gadgets affect the consumption patterns and financial viability of mini-grid projects. They also emphasized the importance of incorporating productive use strategies to stimulate energy consumption and ensure the success of mini-grid projects in the unique context of Nigeria.

3.2.3. Heinrich Böll Stiftung (HBS)

The team interviewed a senior member of HBS staff. HBS is an international development organisation and has been in Nigeria since 1999. According to the respondent, HBS works on increasing energy access, and started its work in mini grids with mapping of the solar energy sector in Nigeria where a lot of solar players were identified and grouped into what roles they played in the solar sector. HBS's strength on advocacy has resulted in collaboration with other energy sector stakeholders including the Nigeria Economic Summit Group (NESG), and Rocky Mountain

Institute. Utilising its strength, the HBS looked into reforming renewable energy by organizing a roundtable discussion with many government officials. They discussed import duties, harmonized systems (HS) codes throughout the value chain, and how to interact with Nigerian customs, all with the goal of lowering the costs of renewable energy, mini grid, and solar home solutions

As an organisation that has conducted much advocacy and research on energy access in Nigeria, HBS sees the following as barriers to mini-grid growth and success in Nigeria.

- Undersizing issues arise during project deployment, where initial plans for delivering a certain capacity of, for example, 50 megawatts may fall short upon assessment, often due to technical malfunctions or performance degradation. Inefficiencies in load carriage capacity have been observed, leading to disconnections and a reliance on backup generators. Sustainability is a broader concern, particularly in government-led projects, where value for money and long-term viability are questioned.
- The lack of formalization and training in the industry has hindered the growth of the formal sector, despite widespread informal adoption of solar solutions. The industry's relative infancy, less than five to six years old, has resulted in a learning curve for institutions, banks, and experts.
- The absence of suitable incentives, coupled with the government's focus on revenue generation, further challenges the establishment of a robust sustainability framework.

3.2.4. The World Bank

The team spoke with an energy specialist at the World Bank. The respondent asserted that the Bank actively engages in transformative initiatives, participating in market reforms, regulatory enhancements, and the development of sustainable systems in countries like Nigeria that face energy deficits. Despite the considerable challenges posed by energy deficits, the Bank is committed to designing and implementing effective programs that effectively address and bridge these gaps in energy supply.

The respondent emphasised that the Bank's dedication lies in meticulously assessing ongoing initiatives, scrutinising existing policies and regulations to identify potential gaps, and integrating global expertise to enhance efficiency in implementation. A notable instance of this commitment occurred in 2016, when the Bank played a pivotal role in supporting Nigeria's development of the Mini-grid Regulation. This initiative not only proved successful in Nigeria but also served as a benchmark for numerous African countries, receiving positive acclaim for its effectiveness.

Following a comprehensive evaluation of the Bank’s support, the respondent highlighted a critical concern regarding size in the current regulatory framework. Specifically, the regulation restricts mini-grid capacities to 1Megawatt, hindering developers with ambitions beyond this limit. In response, the Bank is actively pursuing the revision of the existing regulation, advocating for an increase to 5 Megawatt. Additionally, there is a concerted effort to provide heightened support, both in terms of funding and regulatory facilitation, for interconnected mini grids to further catalyse their development.

3.2.5. Renewable Energy Association of Nigeria (REAN)

The team engaged with a top official of REAN to gain insights into the association’s perspective on Nigeria's burgeoning wave of mini-grid development. REAN, an industry association

comprising renewable energy professionals, project developers, and practitioners, is dedicated to advancing the interests of the private sector in Nigeria's renewable energy domain. As a private sector-led association, REAN prioritises considerations of the economics of scale and commercial viability in selecting technology for developing mini grids. According to the president, developers within the association invest in technologies that offer swift deployment and rapid scalability. Hence, solar power is prevalent in the mini-grid landscape in Nigeria. The emphasis is on choosing technologies that enable efficient and quick rollout, aligning with the economic considerations within the sector.

Addressing challenges in the sector, the president underscored a noteworthy observation. Many of the developed mini grids have benefited from some concessional funding, whether through grants or subsidies. There is a legitimate concern about the commercial viability of these mini grids in the absence of such concessional funds, so this highlights the delicate balance between sustainability and financial feasibility.

The president identified security as another prominent challenge. Most mini-grid communities are rural, necessitating deep penetration into off-grid communities. Security concerns become particularly pronounced in these remote areas, posing additional complexities for the development and maintenance of mini grids. He also mentioned that customs duty is a big issue for players in the sector and it creates a situation where end users will have to pay a higher tariff. He urged for an enhanced enabling environment, and called the for both development and commercial finance to be injected into this market.

3.2.6. Havenhill Synergy Limited

The team spoke with one member of the top management team of Havenhill Synergy Limited, who shared insights into the company's operations. According to him, Havenhill is positioned as a clean technology micro-utility company specialising in harnessing solar energy to generate clean, safe, cost-effective, and sustainable electricity in rural and urban Nigeria.
The company predominantly employs solar technology in rural areas to energise commercially viable off-grid rural communities. This includes serving a diverse range of customers, encompassing residential, commercial, and productive segments. At the time of fieldwork, the company had four mini grids in operation and was planning to commission 26 more, bringing their total to an impressive 30. This expansion is poised to provide electricity to approximately 200,000 people across these 30 communities. The commitment to sustainable energy solutions and community impact is evident in Havenhill's strategic and operational endeavours. On how the company has sustained revenue from some low income customers, the respondent said they infused a social enterprise model where farmers were helped to grow their productivity.

The company has implemented an innovative initiative in its demand stimulation strategy. In 2017, when it constructed its first grant-funded mini grid, the company went beyond energy provision: they established a barbing salon for a barber, created a viewing centre for another individual, and opened a provisions store for yet another person. The provisions store, equipped with a refrigerator, allowed the owner, a woman, to sell cold beverages. The respondent also spoke of a demand creation model in which the company formed groups of five farmers, each cultivating 3-5 hectares during a farming season. These farmers were provided improved seedlings, tractors, and access to

capital. Surprisingly, with this support, the farmers significantly expanded their cultivation to 13 hectares, a notable increase from the 3 hectares they would have managed without assistance. During the harvest, Havenhill purchased the yield from these farmers, providing a market for their products and enabling them to generate income to cover their energy usage expenses. These community-driven endeavours not only showcased Havenhill's commitment to holistic development but also significantly contributed to an increase in energy consumption within the community.

3.2.7. Community Research and Development Center (CREDC)

The team spoke with the one member of the top management team of the CREDC. According to the respondent, CREDC is a sustainable development organisation that has been actively involved in renewable energy and energy efficiency since 2006. He explained that the organisation's journey commenced with advocacy and evolved to implementing small standalone solar home systems (SHS) projects in various communities. Over time, CREDC transitioned to microgrids and subsequently to mini grids. Notably, the organisation has successfully developed three mini grids, with the first one initiated in 2013—all embracing a social enterprise model.

The respondent emphasised the relevance of the social enterprise model, stating that it aligns with the current needs of many communities in Nigeria. Going fully commercial might not be viable, and the respondent highlighted the fact that commercial electricity is subsidised in Nigeria. In his view, the government should also subsidise mini grids, emphasising that this approach is crucial for sustaining numerous communities. He argued that adopting a purely business-oriented model could jeopardise the survival of many rural mini grids and developers because the business activities in those communities cannot sustain them. Therefore, with necessary subsidies, the social enterprise model is the key to ensuring the long-term success and sustainability of mini grids in Nigeria.

The respondent highlighted the paradox of promoting commercial mini grids in local communities. He questioned the logic behind charging residents in wealthy cities, where many people are above the poverty line, N50[20] per kilowatt-hour, while those in local communities, often living below the poverty line, are charged N100[21] per kilowatt-hour. In his view, it defies logic that the government subsidises electricity for those in the city and does not extend similar support to those who need it the most.

3.2.8. Rubitec Nigeria Limited

At Rubitec Nigeria, the team spoke with a staff of the company's project team. According to the respondent, Rubitec is a renewable energy company specialising in solar, small hydro, and biomass energy systems. The company has been actively involved in developing mini grids. One of the company's projects, an 85kWp installation at Gbamugbamu, had been operational since February 2018. Additionally, at the time of fieldwork, the company was participating in an interconnected mini-grid initiative funded by grants from the European Union and the German government, implemented by GIZ, and supported by the Rural Electrification Agency. The interconnected mini-grid project, in collaboration with the Ibadan Distribution Company (DisCo), aimed to provide

[20] Equivalent of $0.8 with the exchange rate of N600 to a dollar.
[21] Equivalent of $0.17 with the exchange rate of N600 to a dollar.

electricity to three communities simultaneously. The system was designed to generate 447 kilowatts at peak capacity, facilitating over 3100 connections. However, when discussing the challenges of mini-grid expansion, the respondent highlighted a significant hurdle: the regulatory restriction limiting mini-grid size to 1 megawatt.

According to the respondent, this limitation discouraged potential investors interested in larger systems. He expressed the view that Nigeria has surpassed the stage of building 50kWp and 30kWp mini grids, deeming them sustainable only for small communities with minimal power consumption needs. He emphasised the necessity of accommodating large-scale renewable energy integration to foster industrial growth. Furthermore, he identified Nigeria's foreign-exchange volatility and high inflation rates as additional drawbacks to mini-grid development. These economic factors contribute to the complexities and uncertainties companies involved in renewable energy initiatives face.

3.2.9. GVE Projects

The team spoke with one of the field staff of the GVE Projects Limited. GVE is a leading renewable-energy solution provider in Nigeria and has a presence in four of Nigeria’s six geopolitical zones. At the time of fieldwork, the company had 14 functional mini grid sites, and another 50 were in the works, at either the construction or pre-construction stage. Further, the company was in the process of developing an interconnected mini grid at Wuse Market in Abuja, in collaboration with the Abuja Electricity Distribution Company. On what the developer did to keep tariffs relatively low and still maximise profits, the respondent stated that the company encourages productive uses of electricity, leverages equity and grants, and minimises operational and maintenance costs. However, he also pointed out that tariffs depended on the funding dynamic of particular mini grids. Grant-funded mini grids reduce the project's payback period and, most significantly, reduce the tariffs to end users.

On the challenges of navigating the complex landscape of mini-grid development, the respondent identified the imposition of value-added tax on photovoltaics and storage equipment as a significant impediment. Another challenge he identified had to do with the potential ramifications for existing mini grids when the primary grid expands into a community, with foreign investors expressing apprehensions about perceived ambiguities in that aspect of regulatory provision. Beyond fiscal challenges, the respondent highlighted logistics problems where security operatives on the road encumbered the seamless movement of mini-grid equipment from one location to another. The respondent further underscored challenges relating to the disruption of entrenched norms within specific communities by the introduction of mini grids. In one instance, for example, a particular community declined to have a mini grid installed by the company on the basis that their ancestors would not want them to have electricity.

3.2.10. Nayo Tropical Technologies Limited

The team spoke with a lead executive officer of Nayo Tropical Technologies Limited. The respondent described the organisation as a vertically integrated renewable energy company, offering a comprehensive spectrum of services ranging from product development, system design, and product design to equipment procurement, construction, utility establishment, and the operation of micro utilities. At the time of fieldwork, the company had been in the space for over 23 years. The company pioneered the first metered mini grids in 2010 in Onitsha, Anambra State,

with support from the United Nations Development Programme (UNDP). In discussing the mini-grid landscape in Nigeria, the respondent pointed out three major development programs: The Mini-Grid Acceleration Scheme (MAS) and the Interconnected Mini-Grid Acceleration Scheme (IMAS) supported by the Nigeria Energy Support Programme (NESP) of the GIZ; the Nigerian Electrification Project (NEP) supported by the World Bank; and the Rural Electrification Fund (REF).

On raising finance, the respondent noted the unfavourable macroeconomic conditions in Nigeria, which deter foreign direct investment and lead to a reluctance among local banks to invest in mini grids. This, the respondent emphasised, remains a significant obstacle across various mini-grid projects in the country. Despite these challenges, the respondent acknowledged that when considering capital expenditure and incentives as key indices, the incentives offered by the NEP outweighed those of MAS and REF. He underscored the necessity for mini grids to secure a unique form of capital characterised by low interest rates. Drawing a parallel with infrastructure development, the respondent lamented the unavailability of longer-tenure, single-digit funding from Nigerian banks for such ventures.

3.2.11. Gen Sustainability Solutions Limited

The team spoke with one of the lead directors of the organisation. Gen Sustainability Solutions supports stakeholders (private and public) in the mini-grid sector in training, research, and market expansion. The organisation was part of the team that developed Nigeria's mini-grid site selection criteria and provided training to REA Directors in that capacity. Reflecting on the challenges faced by pioneer developers of mini grids in Nigeria, the respondent emphasized the historical issue of site selection. According to him, in the early years of mini-grid implementation, poor site selection contributed significantly to project failures, accounting for 80% of the setbacks. The introduction of site selection criteria proved instrumental in alleviating this challenge, streamlining the process, and enhancing project viability.

The respondent underscored a contemporary challenge in the Nigerian mini-grid landscape, that of the disproportionate emphasis on solar PV technology. While acknowledging the importance of solar energy, the respondent highlighted the need for a more balanced approach, expressing concern over the neglect of alternative technologies such as bio-ethanol and hydro. He stressed the importance of diversifying the focus within the mini-grid development sphere to ensure a more inclusive and sustainable energy landscape.

3.2.12. Rural Electrification Fund (REF)

The team spoke with one of the lead directors of the Rural Electrification Fund. According to the respondent, the Rural Electrification Agency (REA) is committed to supporting underserved areas and those without access to electricity. As a crucial outcome of privatisation reforms, the REA was established with a mandate to enhance access for citizens not connected to the grid and those who are underserved. This involved infusing private sector finance and capacity and introducing various technologies to enable swift deployment to villages far from the grid. While mini grids have currently taken precedence, the REA continues grid extension initiatives, transformers, and related projects, partly driven by political pressures and influence. The Rural Electrification Fund (REF) operates within the REA as a distinct department. The respondent highlighted that the REF

explores innovative approaches to reach isolated areas, going beyond solar to embrace emerging technologies. Additionally, the REF encourages contributions from academic and research actors.

On the subject of political influence, the respondent acknowledged the substantial impact of the legislature on the REA's activities, particularly in non-donor-funded projects. While the National Assembly maintains reporting and oversight obligations over the REA, its influence on donor-funded projects like the World Bank's Nigeria Electrification Project is somewhat limited. However, a dedicated committee within the National Assembly oversees domestic and foreign loans, ensuring funds are utilised as intended. The respondent highlighted a central bank-managed government loan facility worth about N140 billion[22] to support local content and drive sector expansion. This facility is strategically designed to encourage local companies to invest in renewable energy technologies by establishing local assembly plants.

3.2.13. Nigeria Electricity Regulatory Commission (NERC)

The team spoke with one of the top officers at the research department of the NERC. According to the respondent, as the regulatory body in the power sector, NERC works toward ensuring that Nigeria's electricity sector reform succeeds by enabling a level playing field for all market participants through regulation. NERC's mandate is to set the rules and guidelines and ensure that all stakeholders play according to those rules. NERC provides entry and exit permissions through licencing and other regulations and determines what conduct is permissible within the market, including tariff determination to ensure the market is sustainable. NERC also creates standards that actors must abide by to ensure that consumers get value for the money they pay in terms of access to electricity, the quality of power, and the safety of installations and humans.

The respondent revealed that the development of the 2016 Mini-grid Regulation did not initially have the blessing of the distribution companies, who thought that their respective franchise areas would be balkanized and shared with smaller entities. However, the proviso in the regulation that a mini grid cannot be situated in any community that is within the five-year expansion plan of a distribution company doused the tension.

3.2.14. Abuja Electricity Distribution Company (AEDC)

The team spoke with a leading member of the regulatory team at the AEDC. The utility is one of the 11 electricity distribution companies that emerged after the privatisation of the power sector in Nigeria in the 2000s. AEDC holds the franchise for the distribution and sale of electricity in the Federal Capital Territory, Niger, Kogi, and Nassarawa States. According to the respondent, AEDC recognises the value that mini grids bring to the mix in terms of helping to achieve the business objective of delivering electricity to customers. Accordingly, at the time of fieldwork, the company was working with two mini-grid developers toward the establishment of interconnected mini grids.

The respondent acknowledged that a proactive approach was essential to maximise the advantages that organisations such as AEDC can gain from mini-grid development. The respondent underscored the importance of providing incentives to catalyse the expansion of mini-grid projects. She specifically advocated a review of the 1 megawatt capacity limit that NERC set for licensing and suggested increasing the limit to support further growth. Additionally, the respondent

[22] Equivalent of $ 233,333,333.33 with the exchange rate of N600 to a dollar.

advocated for fostering collaborations in executing mini-grid contracts, emphasising that such cooperative endeavours would play a pivotal role in propelling the nation towards meeting its energy access targets.

3.2.15. Benin Electricity Distribution Company (BEDC)

The team spoke with a leading member of the regulatory team. Like AEDC above, BEDC is one of the 11 power distribution companies that emerged after the privatisation of the power sector in Nigeria. BEDC is responsible for the retail distribution of electricity in Delta, Edo, Ekiti, and Ondo states. At the time of the interview, BEDC did not have any existing collaborations with mini-grid developers in its franchise zone; however, serious plans one for one were underway, with the utility because already in advanced talks with mini-grid developers.

When asked about the factors that could pique the interest of distribution companies in mini-grid development, the respondent highlighted the significance of transaction size. He noted that certain mini-grid transactions might not be lucrative enough to entice DisCos to participate actively. According to him, DisCos were primarily focusing on mitigating losses within their existing networks and might hesitate to invest in creating isolated islands that would require additional oversight.

3.2.16. Ibadan Electricity Distribution Company (IBEDC)

The team spoke with a leading member of the regulatory team. Like AEDC and BEDC, the distribution company is one of 11 that emerged after the privatisation of the power sector in Nigeria. The respondent stated that IBEDC was aware of the mini-grid wave, especially the REA's efforts to promote interconnected mini grids. At the time of fieldwork, IBEDC was had received requests from contractors under the REA's IMAS initiative, and it had a couple of projects to showcase its readiness in the mini-grid sector.

The respondent mentioned infrastructural and liquidity challenges as issues that have constrained IBEDC and influenced its reaction to mini-grid development within its franchise. According to the respondent, this is the case because ability to pay is a major consideration for IBEDC's involvement in the electricity sector. This means that a DisCo will strongly consider its ability to recover expenditure in any area of energy investment because there is a stipulated amount that it is required to remit to NERC monthly. The upshot of this, according to the respondent, is that local communities with low productivity levels are not good areas for DisCos to invest.

4.0. Cross-cutting findings

4.1. Energy access and use

In all the communities we visited, before the advent of the mini grid, households' major energy uses were for lighting, mobile phone charging, radio, television, and cooking. Lighting technologies included rechargeable battery torches and gasoline generators, while cooking was predominantly done using firewood and charcoal stoves. While household energy needs remained more or less constant, a significant technological shift occurred following the introduction of mini grids to those communities. All connected households had transitioned to using mini-grid

electricity for lighting, phone charging, television, fans, and radio. However, in certain areas like Ozuzu community in Rivers State, some households still relied on petrol generators and rechargeable lanterns. Interestingly, cooking energy patterns and technologies remained consistent. The introduction of the mini grid did not influence cooking preferences, as households expressed concern about the cost of purchasing energy units for cooking.
However, in Dakiti community, Gombe State, there was a remarkable surge in energy usage, with most households expanding their loads. A local technician confirmed that at least 10 consumers had purchased televisions since the arrival of the mini grid. Furthermore, four households had acquired fridges, while at least five households owned electric irons. Notably, one consumer acquired an electric stove. Commercial users in the area, specifically five shops, had also invested in fridges since the introduction of the mini grid. This indicates a positive trend in increased energy consumption and improved access, particularly in Dakiti community.

4.2. Tariffs and affordability

The 2016 Mini-grid Regulation stipulates a negotiated tariff agreement between developers and communities. While this was effectively executed in numerous communities, including Eka-Awoke, Ozuzu, Akpabom, and Torankawa, some communities found it difficult to understand this process. In Adebayo community in Edo State, for instance, members acknowledged the inclusion of a tariff in the initial agreement with the mini-grid developer. However, they lacked understanding, having never experienced power supply before. Consequently, they accepted the tariff provision without complete comprehension.

In the actual implementation, developers set varied tariffs. In Adebayo community, the tariff for private households commenced at NGN140[23] per kWh, while commercial entities paid NGN160[24] per kWh. After three months, the tariff was surreptitiously increased to NGN172.40[25] per kWh for commercial entities and NGN208[26] per kWh for private households. The community also reported an initial fixed connection cost of NGN5000[27], which was later raised to NGN10000.[28] Despite these increases, users, especially those transitioning from petrol generators, found the costs affordable.

In Ozuzu community, users initially paid NGN100[29] per kWh, which was later increased to NGN138.8[30] per kWh after community discussions. Notably, there was no customer segmentation in this community, as all customers paid the same tariff per kilowatt-hour, with household and commercial customers paying N3000 and N5000 connection fees during connection, respectively. Regarding affordability, the initial subscription was as low as NGN50[31] per kWh, but it had now been raised to NGN100, the minimum amount of power a user could purchase. Users expressed satisfaction, affirming they did not face difficulties paying this amount.

[23] Equivalent of $0.23 with the exchange rate of N600 to a dollar.
[24] Equivalent of $0.96 with the exchange rate of N600 to a dollar.
[25] Equivalent of $0.29 with the exchange rate of N600 to a dollar.
[26] Equivalent of $0.35 with the exchange rate of N600 to a dollar
[27] Equivalent of $8.3 with the exchange rate of N600 to a dollar
[28] Equivalent of $16.67 with the exchange rate of N600 to a dollar
[29] Equivalent of $0.17 with the exchange rate of N600 to a dollar
[30] Equivalent of $0.23 with the exchange rate of N600 to a dollar
[31] Equivalent of $0.08 with the exchange rate of N600 to a dollar

In Gbamu Gbamu community, the tariff structure was grouped into residential, commercial, productive and social. While the initial average tariff was around NGN160/kWh, the average tariff across these user categories at the time of fieldwork stood at around NGN190/kWh, after consulting with the regulators. Tariff reviews at Gbamu Gbamu did not seem to be frequent, as the tariff had only been reviewed upward once as of the time of our visit. Also, the tariff was set to encourage more daytime usage by ensuring that daytime users got charged lower compared to night-time users.

Akpabom community's tariff structure included fixed and variable components. Users paid a connection fee of NGN7,500, covering the meter and cables from the pole to the house. However, an unstructured tariff design existed: early connectors paid NGN270 per kWh, while later users reported receiving 4.3 kWh for an NGN1000 credit unit. This discrepancy led to a shop owner leaving the community, citing excessive energy costs as being detrimental to her business profitability.

In Eka Awoke community, NGN2500 was the lowest tariff for users to purchase 20 kWh of electricity. Users complained that this was usually insufficient unless used solely for lighting and phone charging and could not last more than four weeks. Additionally, there was a one-time connection fee of NGN10,000, excluding the cost of wires. Those costs posed challenges in a community where subsistence farming is the predominant productive engagement, affecting households and effective users. A welder in the community even voluntarily disconnected from the mini grid, stating that spending over NGN20,000 monthly on power units did not contribute to his business profitability. Though some users acknowledged that the electricity from the mini grid was cheaper for them than that from generators, overall affordability remains a significant concern.

4.2. User perception of mini grids

In nearly all the communities we visited, the respondents expressed overall satisfaction with the mini grid's performance, particularly when the systems were functioning optimally to meet their energy needs. Some users also considered the tariff they were paying to be reasonable. However, these positive sentiments are rooted in the fact that several of those communities had gone years without electricity, making the current situation an improvement on their previous conditions. This context may explain why, despite their contentment, all the communities visited advocated for a reduction in the tariff.

Amidst this widespread approval, there were users who remained unconvinced of the significance of the mini grid. For instance, many users in Torankawa exhibited indifference towards the mini grid. From their perspective, there was minimal distinction between the period when they had power supply from the main grid and period since the mini grid became functional. The only noticeable difference for these users was the improved street illumination at night.

5.0. Lessons learned and limitations

- Collaborating with the Rural Electrification Agency (REA) on the SIGMA project proved to be beneficial. The agency assisted with drafting introductory letters, which we subsequently sent out to prospective key informant interviewees in government and the

private sector. This approach yielded positive results for our key informant interviews, as we successfully engaged with all the individuals we intended to speak to. However, the effectiveness of this strategy was limited in opening doors to engage with mini-grid developers. The challenges arose because it proved difficult to obtain access to respective mini-grid installations. Most developers are not physically present at their facilities in the communities, instead delegating responsibilities to operators or facility caretakers. Unfortunately, those individuals were often instructed not to grant interviews or permit the taking of pictures of the installations. Compounding this issue, only a few operators were willing to allow their technicians to provide information on the technical makeup of the mini grids. Most developers found it very difficult to disclose information about their mini-grid systems. Consequently, the gathering of detailed information, especially regarding the technical aspects of many mini grids (mostly for the data envelopment analysis undertaken by the team), was hindered.

- Most of the mini grids we visited are situated in remote villages several kilometres from main roads. For example, it takes approximately 30 minutes to travel from the nearest highway to Adebayo community by motorbike, which is the fastest option. Travelling by motorcar would entail waiting patiently at the motor park for about an hour, given the paucity of inbound traffic to the community. This is also the case for Eka Awoke in Ebonyi State. Our trips to those communities proved physically demanding, especially as we had to make multiple trips to each community to ensure we could engage with all the relevant stakeholders.
- Security emerged as a significant concern, particularly in the northern part of the country where insurgency is prevalent. The mini grids in Dakiti, Torankawa, and Mbela Lagaje are situated in regions marked by insurgency and banditry. Although we successfully conducted interviews in these areas, the engagements were characterized by a heightened awareness of risk. Our interactions in those communities were not as relaxed as they might have been in more peaceful environments.
- Language posed a significant barrier in some communities, particularly during focus group discussions and household interviews. The majority of the villagers did not speak or understand English, which was the working language of the SIGMA team. To surmount this challenge, we adopted the strategy in each community of recruiting a local villager as an interpreter. This individual facilitated communication by conveying our questions to the villagers and, in turn, articulating their responses. Although this approach proved effective for data collection, it extended our engagement time in the communities beyond the initially budgeted field duration. Further, the approach increased the possibility of some details of the exchanges in those communities being lost in translation.

References:

Robert K. Yin. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage.

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