Rural electrification in Africa: a case study of Yebu community solar minigrid

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Abstract

Using field observation and focus group semi-structured interviews, we explored rural electrification dynamics within a rural community setting. We investigated the issues surrounding the emergence, deployment, operation and management of solar minigrid technology within Yebu community in the Federal Capital Territory, north-central Nigeria, and the associated issues that emerged over time. The study revealed that: (1) many solar minigrid energy access interventions do not have a viable business and sustainability plan that guarantees long term impact; (2) a lack of participatory decision making by all concerned stakeholders (from the project conception stage) has hindered the potential of many solar minigrid energy access projects to achieve their intended developmental and economic benefits. The paper concludes by highlighting the key recommendations that can help address these challenges.

1. Introduction

Energy is at the heart of the sustainable development goals (SDGs) and it is the prime mover of the global economy [1–3]. It powers and sustains many economic and development initiatives and processes aimed at improving livelihoods and human wellbeing. Access to energy is an important component of the SDGs. It is the thread that links virtually all the SDGs since the attainment of most of the SDGs depend on energy. Improving health and education services, eradicating poverty and hunger, reducing inequality and the provision of water and good sanitation, among others, are important for the integral wellbeing and development of all [4, 5].

Access to energy is important for integral and inclusive development. The International Energy Agency (IEA) argues that Africa is the region with the least access to energy [6]. According to the IEA, about 600 million people in sub-Saharan Africa lack access to electricity and approximately 690 million people in the region lack access to clean cook stoves [6, 7]. This challenge has slowed down the pace of development in the region [8].

In Nigeria, about 45 percent of the population (amounting to over 90 million Nigerians) lack access to electricity [9, 10]. About 60 percent of those without access to electricity are in rural areas [1]. Nigeria has one of the lowest net electricity generation rates per capita in the world, with grid-connected electricity generation installed base of about 13 000 MW but with an average actual generation output of 4000 MW [11, 12]. This creates a challenge (but also an opportunity) to drive initiatives that addresses current and future energy needs that incorporates climate friendly technologies [13].

The Nigerian government, through various initiatives established programmes to address the energy access challenge. Some examples include the rollout and implementation of the Transmission Rehabilitation and Expansion Programme of the Transmission Company of Nigeria which kicked-off in early 2018 aimed at improving the reliability of the transmission infrastructure while improving the wheeling capacity to evacuate more electric power generated [14–16]. Another initiative was the establishment of the Rural Electrification Agency (REA) in 2006, tasked with the responsibility of addressing electricity access in rural and peri-urban centres through the use of grid and off-grid electricity infrastructure [17]. Indeed, owing to the huge politics around grid infrastructure decisions, many energy access projects across various communities implemented or financed by the REA have focused on the use of decentralized electricity sources (mainly renewables).
An important component in addressing energy access challenges is stakeholder engagement and an inclusive decision making process that involves the various stakeholders [18]. Issues around ownership, public perception, tariff, security of infrastructure, provision of land for the infrastructure, empowerment, among others, needs to be addressed before deploying an infrastructure [17]. Addressing these issues requires a more democratic process in energy decision making that helps to guaranty a certain level of inclusivity [16, 19]. Indeed, how democratic are the processes leading to the provision of an energy infrastructure at the community level? What does the consultation process look like? Who are the stakeholders and how are their interests met? Who are the winners and losers of such processes? What are the (un)intended outcomes of some of these decisions? In this paper, we delve into these issues in an attempt to answer these questions using Yebu community as a case study.

In structuring this paper, we provided the research context within which the study was carried out (Yebu community) and the key economic activities of the community in section 2. In section 3, the materials and methods used were presented. In section 4, the key findings on the dynamics of solar minigrid infrastructure provision in Yebu community were presented. Section 5 discusses the lessons learnt while the concluding thoughts and recommendations for policy and practice were presented in section 6.

2. Research context

In this section, we provide some background about Yebu community that proffer some important context of the dynamics and everyday life of the people in Yebu.

2.1. About Yebu community

Yebu community is located in the Kwali Area Council of the Federal Capital Territory, Abuja Nigeria. It is a community surrounded by neighbouring villages and other agglomeration of buildings where people live and work. It is predominantly an agro (farming) community that grows mainly grains such as: sesame seed (also known as benne seed), maize, sorghum, guinea corn and cassava. It is a tropical savannah wetland with latitude and longitude of 8.6675, and 7.121 11 respectively. According to the National Population Commission, Yebu has a total population of about 39 567 (following the last census figures of 2006), with women accounting for about 41 percent of the population (as shown in figure 1).

With respect to social infrastructure, Yebu has a primary school, a primary health centre, a police post and a network of unpaved mud roads. The community operates the traditional market day’s system where traders buy and sell their goods and produce on specific market days that follows some traditional cycles (every four calendar days). The market days physically convene traders, craftsmen and women, service providers, etc, for transactional purposes. The community is not connected to the national electricity grid and there is still a heavy reliance on biomass by the people of the community to address their basic energy needs (particularly cooking).

Yebu has a 40 kWp solar minigrid infrastructure installation with a storage capacity of 144 kWh that powers some parts of the community. The solar infrastructure was installed in 2017 at a project cost of N40 million (forty million naira—the equivalent of $200 000 following the prevailing exchange rate at the time) funded by the REA and implemented by Havenhill Synergy Limited (a solar installation and management company based in Abuja Nigeria). The plant currently has a utilization capacity of over 99.9%. With over 5000 users in the community, the installation has improved basic lighting applications in households. It has also supported a few micro businesses and a community primary healthcare centre. Table 1 shows a panoramic summary of
Table 1. A Panoramic summary of Yebu Community.

| Name and location of community       | YEBU Community, Kwali LGA, Abuja |
|--------------------------------------|----------------------------------|
| Longitude and latitude (Dec):         | 8.671 867, 7.050 117             |
| Major economic activities            | Farming and agro-processing      |
|                                      | The community grows produce such as: yam, maize, guinea corn, sesame seed, cassava, rice, millet, beans, soya beans, oil palm, fruits and vegetables |
| Ethnic groups in the community       | Gbagi, Ganagana, Bassa, Hausa, Tiv, Igbo |
| Total population (based on 2006 census) | 39 567 inhabitants               |
| Approximate actual population (2022) | Male population—23 328. Female population—16 239 |
|                                      | Over 80 000 inhabitants           |
| Electrification status               | Not connected to the national electricity grid |
| Solar minigrid capacity              | The community is connected to a solar minigrid infrastructure |
| Infrastructure installer/manager     | Havenhill synergy limited         |
| Year of provision/installation       | 2017                              |
| Project financier                    | Rural electrification agency (REA) |
| Project cost                         | N40 000 000:00 ($200 000 at the time of implementation) |
| Actual number of people connected to the solar minigrid | Approximately 5000 people |

Figure 2. Satellite maps of Yebu community.

the some vital information about Yebu community while figure 2 shows the satellite maps of Yebu community point the location (with respect to other communities) and the area map.

2.2. Economic activities in Yebu Community

For a better understanding and contextualization of everyday life in Yebu community, we now provide below the major economic activities in that community.

(a) **Logging**: a major economic activity in Yebu is the felling of trees in the deep forest of the community targeted at several uses. This includes; construction, marketing and sales of firewood, and a host of other uses in and around the community. This is a trade carried out by men and women alike. Women are more involved in logging for firewood marketing and sales. Logging constitutes a huge part of the economy of Yebu, accounting for about 10% of the economic activities of the community.

(b) **Agriculture**: agriculture is the mainstay of community. They cultivate root and tubers, cereals and tree crops including yam, cassava, maize, millet, guinea corn, sesame seeds, pepper, tomato, vegetables, groundnuts, mangoes, cashews etc. The percentage of men, women and children involved in agriculture is 50%, 40% and 10% respectively. Figure 3 shows two agro-processing kiosk where some agricultural produce are processed.

(c) **Sand mining**: business activities around sand mining in Yebu are quite considerable. It is predominantly carried out by men, with women participation of about 10%. Sand mined is sold to builders, contractors, businessmen and women, and individuals. The mining takes place in the community river (river Gaye, shown in figure 4).

(d) **Fishing**: this business flourishes more in the wet (or rainy) season when there is an appreciable rise in water levels in river Gaye (see figure 4). Fishing is done by men while the trading of the commodity is dominated by women.
(e) **Local brewing:** this business is predominantly carried out by women. They produce local alcoholic malted drink called *Burukutu* which is predominantly consumed by men. It is a thriving business which does not require much electricity consumption, except for the energy required for grinding and processing of sorghum or millet used in producing it.

(f) **Trade:** trade is an integral part of the community. Agricultural produce, household items, electrical items, carpentry items, medicines, drinks, clothes, shoes etc are all traded in the community predominantly by women. Figure 5 shows the traditional market setting where trade activities take place in the community.

(g) **Haulage:** this business is dominated by men, with practically no woman involved. They haul foodstuff, timber, sand, firewood etc, to the city. It is a major economic activity

(h) **Education:** Yebu has a big functional primary and secondary school in the town, owned and controlled by the local government with teachers at all levels. Electricity is connected to the schools to aid teaching. The higher proportion of teaching and ancillary staff in both schools is dominated by women, constituting about 70% of the school’s staff population. Figures 6 and 7 shows the pictures of the community primary school and the school’s playground.

(i) **Health:** there is a functional primary health care (PHC) in the community. It caters for maternal and child health issues and offers PHC to the sick and elderly. Most of the nurses and ancillary staff are women. Malaria, typhoid fever, snake bites and other infectious diseases are treated there. They also act as contact tracing agent for infectious diseases like cholera, Covid-19, etc. Yebu can boast of the presence of a medical doctor, nurses, laboratory scientists and other ancillary staff.

(j) Yebu have five (5) major functional grinding mills and several saw mills that are independently powered by diesel engines. Women are more involved in the operation and processing of cereals at the mills. The mills operate for more than 10 h a day. Most operators are males while the women handle the other aspects of the processing.
3. Materials and methods

This section provides the rationale for the choice of Yebu community and the data collection and analysis instruments used in this study.

3.1. Rationale for the choice of Yebu community

In Nigeria, about 60 percent of rural population have no access to electricity [20]. By geography, this low electricity access is more pronounced in northern Nigeria. This is mainly because most communities in the northern region of Nigeria are dispersed, unlike the concentrated nature of settlements in most parts of southern Nigeria. Since historical rural electrification strategy centred on electricity grid expansion, it was easier and cheaper to connect more concentrated settlements to the national grid than to connect communities that are highly dispersed. This unintended factor greatly contributed to the worsening state of electricity access in most rural communities in northern Nigeria.

Since 2017, there has been a more aggressive rural electrification strategy by the REA that partially decouples itself from the national grid in order to drive rural electrification at a faster pace [21]. This new approach involves using decentralized electricity infrastructure that utilizes the energy source that is most dominant in each region [17]. For example, utilizing gas fired power plants in the Niger Delta region (since it is closer to more sources of gas) and utilizing solar hybrid solutions in most parts of northern Nigeria due to its great solar irradiation. Indeed, Yebu falls within the geography where the use of solar energy offers more advantages.

We chose Yebu community for the following reasons:

(a) It is a community that was never connected to the national grid prior to the provision of its first ever source of electricity, a 40 KWp solar minigrid infrastructure.

(b) There seemed to have been something that had a semblance of stakeholder engagement in the decision making process that led to the provision of the solar infrastructure. This enabled us to explore the decision making dynamics (and some energy democracy principles) that led to the provision of the solar infrastructure and to further explore if the systems of provision was really participatory or not.

(c) It provided us the opportunity to explore the geographical nuances and the geographies of energy (within a northern Nigerian community context) and the issues that shape energy provision, demand and use.

3.2. Data collection and analysis instruments

In carrying out this study, two important data collection instruments were used. These are:

(a) Field observation

(b) Stakeholder focus group interviews
Field observation is a type of field research that attempts to observe a group or a person in their natural environment in order to gain insights into their activities and processes in an uninfluenced manner [22]. This method of data collection was used loosely in order to understand the energy use patterns of the people of the community and what they actually use (and need) energy for. We three rounds of field observations: in March 2021; July 2021; and March 2022.

During the field observation, we focused on exploring the social practices of people in Yebu community to understand what kept people busy and how it influences their energy needs and use. In March 2021, we had a two-day field trip to the community and three days each in June 2021 and March 2022 respectively. Among the observers was someone who had a good knowledge of the language, culture and workings of the community who served as our guide. During the third field observation, we had the assistance of a guide (a locale of the community) who provided explanations to some issues we observed but could not fully comprehend on our own. On the last day of each field trip, we had focused group interviews that targeted different stakeholder groups within the community.

Three rounds of stakeholder interviews took place in the form of focused group interviews of some members of the community. The focus group interviews took place in March 2021; July 2021; and March 2022 respectively. Those represented include different types of end users, including those that use electricity for micro businesses and those that simply use it for lighting, community youths, among others. The focus groups held were composed as follows:

(a) Women group made up of those with micro-businesses around the home and agro processing businesses
(b) Youth groups made up of young people involved in trading and farming
(c) Professional services groups made up of police officers and health care givers living in the community
(d) A group representing young secondary school students and out-of-school (post-secondary) youths.

The number of persons in each focus group interviews varied between three and eight persons. The people of the community were very cooperative and were willing to share their thoughts on the subject. We gathered data by taking notes of the conversation since we observed that some of them were not comfortable with us taking audio recordings. The interview notes were later transcribed which aided the development of the key findings. Having the focus group interviews with different groups helped us to confirm or refute certain points that other groups had raised so as to ensure that the final output truly reflects the position of the participants.

Data analysis of the focus group interviews was done using thematic data analysis to ascertain the issues that impacted on the provision and use of the solar minigrid infrastructure [23, 24]. The themes that emerged from the analysis served as the basis for the issues presented in subsequent sections.

4. Key findings

In this section, we present the key findings based on the field observation and interviews conducted in Yebu community as presented in subsequent sub-sections. It is interesting to note that there was a common voice among all the groups interviewed as they all stated the same joys and frustrations in different ways. They saw the focus group interviews as an opportunity to vent their true position on the minigrid infrastructure in their community.

4.1. Stakeholders and their role in shaping energy decision

Three groups of stakeholders were involved in the decision process that led to the provision of the solar minigrid infrastructure. These are:

(a) Methodist missionaries: this is a group of missionaries from the methodist church on an evangelizing mission to Yebu and neighbouring communities. They were very instrumental in galvanizing support from other stakeholders that led to the success of the solar infrastructure provision.
(b) REA: the REA was the agency of government responsible for the project financing and mobilization for execution. They are the project financier.
(c) Havenhill Synergy Limited: this is a company whose business centres on solar infrastructure installation, operation and maintenance. They are the infrastructure provider and manager
(d) Yebu Community: this is the community where the solar minigrid infrastructure was situated. They are the project beneficiary.

4.2. Description (and the emergence) of a solution

The history of the provision of the solar minigrid infrastructure started in 2015 with the intervention of some methodist missionary group that engaged with the people of Yebu (and neighbouring communities) on an
In the course of their missionary work, they discovered that the communities around Yebu lacked some basic amenities. They started engagement with members of the Yebu community to seek ways that they might be of help. The first intervention was the provision of a hand-pumped water borehole for the community in late 2015.

During one of the subsequent visits of the methodist missionaries in 2016, they discovered that water borehole infrastructure was already damaged due to increased pressure on the facility since the entire community depended on it. Prior to the provision of the borehole, the community depended on a nearby river (river Gaye) for their water needs. The missionaries intervened by fixing the borehole and other broken pipes. They also saw the need to provide more water boreholes in the community, powered by electricity. However, to achieve these objectives, they also saw the need to get some form of electricity infrastructure in place since the community had no access to the national grid.

The methodist missionaries took the initiative and made contact with someone at the REA. They discussed with the REA on the possibility of helping Yebu (and neighbouring communities) through funding and provision of solar minigrid infrastructure that could power some important social amenities in those communities as well as in individual homes. This was how the REA got involved. The missionaries were able to convince the REA of their willingness to provide more water boreholes once the REA agreed to provide and fund the solar minigrid. Indeed, this was how the minigrid project (and other associated infrastructure) emerged.

Havenhill Synergy Limited was the solar energy provider that did the energy audit for the community to ascertain their energy needs as well as establishing those members of the community that were willing to connect to the solar infrastructure. Havenhill prepared and made the official bidding for the project funding by the REA. In summary, Havenhill designed, procured, installed and are now maintaining the solar infrastructure; REA provided the funding; the community provided in-kind support and land for the infrastructure; and the methodist missionaries linked these three stakeholders in providing the solution. In addition, the methodist missionaries provided more water boreholes for the community powered by electricity. All of these interactions took place for most part of 2016. Figure 8 shows the solar minigrid infrastructure comprising the solar panels located at the Yebu community.

**4.3. Positive impact of the solution. Who were the winners?**

The provision of the solar minigrid infrastructure led to some meaningful impacts. New micro and small businesses around the homes selling cold beverages (including sodas) and other perishable commodities that could easily be stored in a refrigeration system powered by electricity sprang up. Other businesses include barbers shop, hair dressing salons, phone charging and repairs businesses, among others.

The Primary Health Centre in the community was connected to the solar infrastructure which enabled the proper storage of vaccines and medicines. This has also improved medical care delivery and the introduction of medical consultation at night in the clinic.

The community have experienced improved education and computer literacy skills due to the provision of electricity to the community schools and the introduction of Information and Communication Technology (ICT) literacy courses in an ICT centre that was established in the community. There was also an increase in the number of enrolments in the schools (particularly among the girls).

The provision of electricity has greatly enhanced night life activities such as night market and a greater sense of security since most part of the community is lit at night. It has also encouraged a greater community spirit through greater interaction with other members of the community during the night activities when many are around their homes. Certain energy services (such as grinding) could now be provided within the community.
without the additional transport cost of getting those services in other communities, thus, reducing cost of living.

Indeed, the project benefitted the following groups:

(a) The financier, i.e., the REA, through the good will they enjoyed from the people of the community and the mileage this project offers in supporting and financing other projects.

(b) The infrastructure installer and manager, i.e., Havenhill, through the continuous business operations the project provides them and the mileage for the execution of future projects.

(c) The community, who are the beneficiaries of the project. The project has enabled the provision of certain energy services and the establishment of micro-businesses around the homes powered by electricity.

4.4. Infrastructure management challenges and the emergence of losers

As with many projects, there were great expectations on some key deliverables the solar minigrid project was to deliver. However, after three (3) years of stable electricity supply, some major infrastructure management issues started erupting. These issues, which were sufficiently considered during the conception, planning and implementation phase, started manifesting during the project operations and management phase. The core themes that emerged during the focus group interviews and corroborated by the field observations are summarized in the following paragraphs.

4.4.1. Erratic power supply due to battery failure

Members of the community started experiencing erratic power supply due to battery failure of the power plant. The batteries became too weak to provide the much needed power backup at night and reliable power availability was limited to the peak period during the day when the Sun was available.

4.4.2. Low vending and patronage due to power outages

Erratic electricity supply resulted in reduced revenue for the facility management company. We found, through the interviews, that the average monthly revenue dropped from ₦300,000 to ₦50,000 (from $750 to $125).

4.4.3. Inadequate plant capacity to meet growing consumer needs

The provision of the solar minigrid infrastructure led to an increase in the number of micro businesses around the homes that depended on electricity. Hence, electricity consumption increased. However, the infrastructure managers failed to make adequate plans for future demand and expansion. Indeed, the initial installation became grossly inadequate for the requirements of the grain millers, saw mills, and other businesses requiring heavy machineries. As such, many of such businesses started pulling out of the grid to go back to their diesel powered engines.

4.4.4. Inadequate plant capacity and supporting hard infrastructure

Some vital infrastructure such as adequate number of connection poles that could have helped in expanding the grid connection was insufficient. A good number of the poles (at least 20% of them) were either weak or were bad which posed some safety risks (particularly in windy or rainy weather). Metering was also a challenge. Inadequate metering supply was a major factor that led to low connectivity to the grid because the infrastructure management company failed to provide the necessary meters. The capacity of the plant was also deemed as low and could not cater for the energy needs of many members of the community.

4.4.5. Lack of a viable sustainability plan

There are very vital aspects of the project that could have had a greater impact on the sustainability of the project if they had been jointly considered by the infrastructure providers and members of the community ahead of time. Some of them include issues around efficient use of the solar facility, population stabilization and growth forecasts, growth in economic activities, among others. These factors impact on energy demand and use which could have helped in future energy forecasting and planning to meet the rising energy needs of consumers. The members of the community argued that these factors were not considered before and after the project implementation.

4.4.6. Poor community/customer relationship and a lack of trust among parties

The lack of commitment on the part of the infrastructure managers to address some of the salient issues and a lack of communication led to a breach of trust among the parties. Members of the community complained about poor customer care and oftentimes the infrastructure managers were either not reachable by telephone or in their office or both. This led to a loss of trust with the company which has allowed for the potential development of harmful actions, or emotions such as negative attribution and suspicion.

Indeed, the aforementioned challenges led to the emergence of losers which include:
Table 2. Scorecard of salient issues at the various stages of the project in Yebu community.

| Key issues                        | Idea | Design | Implementation | Management |
|-----------------------------------|------|--------|----------------|------------|
| Addressing energy poverty         | X    | X      | X              | ✓          |
| Protecting ethnic (minority) groups | X    | X      | X              | X          |
| Educational needs of children    | X    | ✓      | ✓              | ✓          |
| Economic empowerment              | X    | X      | ✓              | ✓          |
| Women participation              | X    | X      | X              | X          |

(a) The infrastructure manager, i.e., Havenhill that have not been able to reach their revenue potential due to some pending infrastructure related issues as already highlighted

(b) The community, made up of energy end users and small businesses who could no longer power their electrical equipment for their businesses and students who now have limited time for study at night due to battery failure.

4.5. Inclusivity and participatory governance: how democratic was it?
The participation of various stakeholders and inclusive decision making in infrastructure provision is important in ensuring proper governance and sustainability of any project. It helps in ensuring a sense of shared ownership in the project which largely affects every aspect of the project life from idea conception, design, implementation and management.

Participatory governance in decision making also provides a platform for some salient issues (that could easily skip the minds of people at the conception stage) to be brought forward and addressed. In Yebu community, issues around addressing energy poverty, educational needs of children, economic empowerment, women participation and protecting ethnic (minority) groups were top on the list of priorities. Table 2 provides a summary of the scorecard on the salient issues regarding the Yebu community project.

Addressing energy poverty for the people of Yebu was of utmost importance. However, this was not fully considered at the project conception, design and implementation phase. It only came as an afterthought during the management stage when (at the initial stage) there was low utilization of the electricity generated. This challenge is also closely linked to economic empowerment. Considerations about possible economic activities that the project could enable only started at the project implementation stage. Addressing issues of low utilization of electricity generated was what led the infrastructure managers to provide some funding facility to acquire energy assets that promotes greater consumption of electricity and enables the establishment of micro businesses around the community.

Right from the design stage, provision of electricity to support educational needs of children was given a priority. This led to the provision of electricity in the community schools and hospital. Other issues such as protecting minority groups and women participation were not considered at any stage of the project. Everything done regarding these points was all afterthoughts. Indeed, the people of Yebu felt that the project was not inclusive enough due to the exclusion of certain groups in participatory governance of the project.

5. Discussions and lessons learnt

5.1. Institutional aspects
To guarantee the success of such a project, it is important to work with and through other partners that can help facilitate project acceptance, design, and implementation phases. In the case of Yebu community, some stakeholders (such as some women and youth groups) felt excluded at the planning stage. This led to problems at the implementation and operations stage of the project.

There is also a need to establish and nurture a maintenance infrastructure support system that addresses maintenance needs for community level infrastructure projects since nothing is maintenance free. In Yebu, the company managing the solar minigrid infrastructure had personnel on ground to address maintenance issues.
and improve reliability of supply. However, they lacked the requisite skills to address more challenging infrastructure issues. Addressing this may require both upfront and refresher trainings of the maintenance personnel and the effective documentation of the maintenance schedule to help address issues around infrastructure failure.

Since traditional rural electrification tariffs are highly subsidized, there is a need to have a tariff structure that reflects both actual cost and quality of service. After many years of the infrastructure provision, the people of Yebo expressed concerns that the infrastructure have not yielded all the benefits it promised at inception. There is also a greater need for development coordination in addressing linkages in rural development programmes around education, economic empowerment, health, among others [27, 28]. This is important as the provision of one infrastructure may have the potential of reaping multiple benefits as experienced in Yebo.

There is a need to match administrative stress and emphasize the value of quality of service that electricity infrastructure confers and teach people in those local communities how this can be achieved. This can help the people of the community to understand and embrace energy efficiency and conservation. However, this was not the case in Yebo.

5.2. Implementation aspects and operational issues
There is a need to focus electricity intervention projects in communities where there is local support/interest. Focus on evaluating and presenting the various rural electrification options based on locally available resources and needs while allowing the locals to participate and select the appropriate solutions. Ensuring that administrative procedures and systems aligns with local circumstances of the people of the community is also important [29, 30]. This was rather done in a hurry in the case of Yebo.

Ensure meters are provided to energy consumers so as to guarantee revenue collection, curb uncontrolled growth in demand and reduce inequalities in electricity use. Demand-side energy efficiency and load management is important in rural energy systems [31] as seen in the case of Yebo.

5.3. Technological and development needs
There is a need for the development of low-cost prepayment meters targeting rural communities. The current metering infrastructure in Yebo increases the initial sunk cost due to its unaffordability. Development of resource data is important in order to develop and provide the best rural electrification solution based on the available resources in a community [32, 33].

6. Conclusion and recommendations for policy
This study has some practical implications for diverse stakeholders, particularly the Rural electrification Agencies, project managers and installers, financiers, among others. For the REA:

(a) They need to reconsider energy access financing not to have a 100% grant element in order to force project managers to think of a viable business plan that guarantees project sustainability through a long term repayment plan.

(b) They should make it mandatory that all project bidders must provide a business and sustainability plan (that includes infrastructure maintenance/renewal plan—such as replacement of batteries) that guarantees long term impact of such projects.

For project managers and installers, there is a need to consider issues around economic empowerment (for men and women), education and poverty alleviation through participatory decision making right from the project conception and design stage in order to address possible implementation and operation challenges.

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‘The authors have confirmed that any identifiable participants in this study have given their consent for publication’.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).
Ethical compliance
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its amendments or comparable ethical standards.

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Conflict of interest
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References
[1] Roche M Y, Verolme H, Agbaegbu C, Fischedick M, Oladipo E O and Fischedick M 2019 Achieving sustainable development goals in Nigeria’s power sector: assessment of transition pathways Clim. Pol. 20 846–65
[2] van Gevelt T, Canales Holzéis C, Fennell S, Heap B, Holmes J, Hurley Depret M, Jones B and Safdar M T 2018 Achieving universal energy access and rural development through smart villages Energy Sustain. Dev. 43 139–42
[3] Masuda H, Kawakubo S, Okitasari M and Morita K 2022 Exploring the role of local governments as intermediaries to facilitate partnerships for the sustainable development goals Sustain. Cities Soc. 82 103883
[4] Bhurcuw A, Joshi M, Khosla R and Dubash N K 2019 More priorities, more problems? Decision-making with multiple energy, development and climate objectives Energy Res. Soc. Sci. 49 183–57
[5] Buonocore J J et al 2019 Metrics for the sustainable development goals: renewable energy and transportation Palgrave Commun. 5 1–14
[6] International Energy Agency International Energy Agency (IEA) 2014 Africa Energy Outlook—A Focus on Energy Prospects in Sub-Sahara Africa International Energy Agency (Paris, France)
[7] International Energy Agency (IEA) 2019 Africa Energy Outlook 2019 www.iea.org/africa2019%0Ahttps://www.oecd-ilibrary.org/energy/africa-energy-outlook_2120ab250-en
[8] Schlerer R 2012 Reforming the Energy Sector in Africa: the Case Study of Nigeria (African Development Bank)
[9] Edomah N 2017 Modelling future electricity: rethinking the organizational model of Nigeria’s electricity sector IEEE Access 5 27074–80
[10] Edomah N 2020 Electricity and Energy Transition in Nigeria 1st edn (London: Routledge)
[11] Ogunrinde O, Shittu E, Bello M and Davidson I E 2019 Exploring the demand-supply gap of electricity in Nigeria: locational evaluation for capacity expansions 2019 IEEE PES/IAS pp 587–92
[12] Edomah N 2019 Governing sustainable industrial energy use: energy transitions in Nigeria’s manufacturing sector J. Clean. Prod. 210 620–9
[13] Dioha M, Edomah N and Caldeira K 2022 Fixing the Disconnect Around Energy Access Issues Sci. Technol. 38 51–6 https://issues.org/fixing-disconnect-around-energy-access-dioha-edomah-caldeira/
[14] Transmission Company of Nigeria 2017 Strategy for rehabilitation and expansion, to achieve grid expansion stability and reliability Transmission Rehabilitation and Expansion Plan (Abuja Nigeria: Transmission Company of Nigeria)
[15] Transmission Company of Nigeria 2019 Implementation Milestones of Transmission Rehabilitation and Expansion Program (Abuja Nigeria: Transmission Company of Nigeria)
[16] Edomah N 2021 The governance of energy transition: lessons from the Nigerian electricity sector Energy Sustain. Soc. 11 1–12
[17] Edomah N, Ndulue G and Lemaire X 2021 A review of stakeholders and interventions in Nigeria’s electricity sector Helyon 7 e07956
[18] Hearns A X 2022 Positive energy district stakeholder perceptions and measures for energy vulnerability mitigation Appl. Energy 322 119477
[19] Stephens J C 2019 Energy democracy: redistributing power to the people through renewable transformation Environ.: Sci. Pol. Sustain. Dev. 61 4–13
[20] Ugwoke B, Gershon O, Becchio C, Corgnati S P and Leone P 2020 A review of Nigerian energy access studies: the story told so far Renew. Sustain. Energy Rev. 120 109646
[21] REA 2017 PROJECT STATUS—Total Completed Projects in 2017 (Rural Electrification Agency) https://rea.gov.ng/projectstatus/ (accessed 26 May 2020).
[22] McCullough R 1984 Systematic field observation Annu. Rev. Sociol. 10 263–82
[23] MacQueen K and Namay E 2012 Appl. Themat. Anal. (SAGE) pp 3–20
[24] Fereday J and Muir-Cochrane E 2006 Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development Int. J. Qual. Methods 5 80–92
[25] Leduchowicz-Municio A, López-Gozález A, Domench B, Ferrer-Martí L, Uldaet Ñ M E M and Gimenes A L V 2022 Last-mile rural electrification: lessons learned from universalization programs in Brazil and Venezuela Energy Pol. 167 113080
[26] Edomah N, Bazilian M and Sovacool B 2020 Sociotechnical typologies for national energy transitions Environ. Res. Lett. 15 111001
[27] Meyer E L and Overen O K 2021 Towards a sustainable rural electrification scheme in South Africa: analysis of the status quo Energy Rep. 7 4273–87
[28] Wassie Y T and Adaramola M S 2021 Socio-economic and environmental impacts of rural electrification with solar photovoltaic systems; evidence from southern Ethiopia Energy Sustain. Dev. 60 52–66
[29] GIZ 2014 The Nigerian Energy Sector: An Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification (Abuja Nigeria: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ))
[30] Edomah N 2016 On the path to sustainability: key issues on Nigeria’s sustainable energy development Energy Rep. 2 28–34
[31] Bhandari R, Sessa V and Adamou R 2020 Rural electrification in Africa—a willingness to pay assessment in Niger Renew. Energy 161 20–9
[32] OECD/IEA, IRENA 2017 Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (International Energy Agency)
[33] Lee J and Yang J S 2019 Global energy transitions and political systems Renew. Sustain. Energy Rev. 115 109370