EFFECTIVE MANAGEMENT AND SUSTAINABILITY OF RENEWABLE (OFF-GRID) POWER GENERATION PROJECT INRURAL COMMUNITIES IN NIGER STATE, NIGERIA

BY

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AUGUST, 2021

ABSTRACT

The study aimed to assess the impediments to the sustainable development and management of off-grid energy infrastructure in rural Nigeria. The methodology adopted was a descriptive survey involving the administration of structured a questionnaire to rural communities and power sector practitioners in Niger state. The result obtained shows that electricity accessibility, and demands in rural communities of Niger state are relatively low as 179 respondents representing 76.5% agreed that electricity demand in rural communities is generally low in Niger state. The study also identified key factors hindering the full implementation of off-grid power generation in rural communities as lack of awareness programs for the renewable energy consumption, corruption, and political barriers which ranked 1^{st}, 2^{nd}, and 3^{rd} with mean score of 4.11, 4.00, and 3.80 respectively. Additionally, lack of proper planning and designing challenges, high initial capital costs and higher perceived risks of the renewable energy technology with mean score 3.76, 3.63 ranked 4^{th}, 5^{th}, 6^{th} respectively. Results also showed the most significant factors to ensure sustainable off-grid power generation in Niger state are awareness on renewable off-grid power generation, knowledge of available off-grid energy, and proper planning and implementation with MS values 3.88, 3.84, 3.80 ranked 1^{st}, 2^{nd}, and 3^{rd} respectively. The study recommends that all tiers of government be duty-bound to implement off-grid projects to make the country attain its long-term plans of sustainable power supply, collaboration with the World Bank, United Nations (UN), NGOs and other institution to develop the power sector.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Access to electric power supply has significant role in promoting improvements in all societal sectors (Mandelli *et al.*, 2014). Adequate power supply is generally regarded as a prerequisite to any nation's development, and electricity generation, transmission and distribution are capital-intensive activities requiring huge resources of both funds and capacity (Sambo *et al*., 2009). Energy access policies are steadily yielding significant progress, as the number of people without access to electricity fell below 1 billion in 2017 (International Energy Agency, 2017) and 840 million people in 2019.

Major issues within the Nigerian power sector, principally concerning power outages and unreliable service lead to the privatization of the sector. Njoku (2016) while examining challenges of power supply in Nigeria in post-privatization era concludes that despite the privatization of the assets of the unbundled PHCN in 2013, the power sector still faces issues like lack of effective implementation of power policies and projects, impact of oil theft on the power sector, the effect of pipeline vandalism on the power sector, impact of gas flaring on the development of power sector, lack of regular maintenance of power equipment, the controversy over the billing system for power (electricity) consumers.

Access to clean, reliable, and affordable energy services for basic human needs for domestic and industrial use at household level to improve productivity represent the minimum levels required to improve livelihoods in developing countries. Although, access to electricity in the poorest countries has begun to accelerate, energy efficiency continues to improve and renewable energy is making gains in electricity sector (Sustainable Development Goal Report, 2019)

Energy is central to virtually every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential. Thus, the United Nations included access to affordable, reliable, and modern energy services, as it interlinks with other Sustainable Development Goals. Affordable and clean energy (Sustainable Development Goal 7) which focused on universal access to energy, increased energy efficiency and the increased use of renewable energy through new economic and job opportunities is crucial to creating more sustainable and inclusive communities and resilience to environmental issues like climate change. (Sustainable Development Goal Annual Report, 2019). Thus, the world must accelerate its transition to renewable energy in order to achieve the climate goals.

1.2 Statement of the Research Problem

The Nigerian power sector is marred with series of challenges and setbacks over the years. Efforts by the government to revive and stabilize this sector through countless interventions and partnerships with private investors have not completely improve electricity supply and access. A significant section of the Nigerian economy is largely powered by small-scale generators, and about 50% of the population have limited or no access to the grid. As a result Nigerians and their businesses spend almost $14 billion (₦ 5 trillion) annually for running and maintaining inefficient generation that is expensive, of poor quality, noisy, and polluting the environment (Rural Electrification Agency, 2017)

A lasting solution to these protracted problems could be the adoption and design of off-grid power generation for remote households and businesses facing difficulties of on-grid extension reach using the country's abundant renewable energy resource potential (Alao and Awodele, 2019). Apart from irregular and unreliable supply, high cost of connection, recurrent vandalism of the transmission facilities, and pressure on the national grid has led to constant system collapses. These necessitate for alternative electric power generation. Furthermore, these recurring issues have led to industrial sector players and a number of residential power consumers to solely rely on self-generated power for their operations (Ugwuanyi, 2018). From the foregoing, the epileptic power generation and distribution in Nigeria calls for a more sustainable solution.

1.3 Aim of the Study

The aim of the study is to assess the impediments to the sustainable development and management of off-grid energy infrastructure in rural Nigeria

1.4 Objectives of the Study

The objectives of the study are to:

1. To examine electricity demand in rural communities
2. To examine the accessibility to electricity in isolated rural communities
3. To explore the factors affecting the full implementation of off-grid power generation
4. To examine ways of sustaining renewable off-grid power generation.

1.5 Research Questions

1. What is the electricity demand for rural communities in Niger state?
2. How accessible to electricity are rural communities?
3. What are the factors hindering the full implementation of off-grid power generation
4. What are the ways of sustaining renewable off-grid power generation in rural communities?

1.6 Significance of the Study

The study has both theoretical and practical significance. Theoretically, this study will be beneficial to both students and scholars who wish to advance their knowledge on the concept, implementation and sustainability of renewable power generation in Nigeria. On the other hand, it also has a practical significance to the Nigerian government, power sector stakeholders, NGOs, local & foreign investors and policy makers. The findings and recommendations of the study will also improve the general awareness and understanding on the concept of renewable power generation, how the full adoption of renewable power generation can go a long way to solving the unending challenges facing the Nigerian power sector. In addition, government and policy makers will be in a better position to make suitable laws to create enabling and sustainable policies for renewable power generation projects across the country. This could be achieved subsidizing the adoption of renewable energy, as well as attracting foreign investors.

1.7 Scope of the Study

The scope of the study is to examine ways by which renewable off-grid power generation projects can be effectively managed using project management techniques and sustained for consumer satisfaction for rural communities in Niger state. The study was guided by four research objectives which were addressed with four research questions. The first objective of the study examines the rate of electricity demand in rural communities in Niger state. The second objective assesses the accessibility of isolated rural communities to electricity. The third objective of the study dwells on some of the factors affecting the full implementation of off-grid power generation. The forth objective concentrates on ways of sustaining renewable off-grid power generation.

1.8 Limitation of the Study

The limitations encountered by the researcher during the course of the study were as follows:

The first and major limitation of the study is accessibility to rural communities; Niger state is the largest state in Nigeria by land mass. Some of these communities are between 5-7 hours' drive from the state capital. There was also limited access to some of the rural communities in terms of mobility.

The second limitation of the study is the collection of the administered questionnaire from the respondents. Most of the respondents are illiterate, native languages was used for communication and in some cases a translator was used. This affected the time taken to retrieve the administered questionnaire and the return rate of the instrument was therefore low. Lastly, the research focuses mainly on rural communities in Niger state. Hence, data collated and analysis cannot be used for another state or used as a generalized representation for Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The first chapter of this research gave a background introduction of the study, stated the problem statement, and the research objectives. This chapter examines literature related and relevant to the study. Some of the major highlights include the Empirical, and Conceptual literature. Literature on the Nigerian power sector, power generation, transmission, and distribution was discussed. Additionally, extensive literature review was also conducted on renewable energy, off-grid power generation, as well as the prospects and challenges of off-grid power generation in rural communities.

2.2 Empirical Literature.

Harberl (2016) reviewed rural electricity programs and projects based on photovoltaic (PV) systems, including Solar Pico Systems (SPS) and Solar Home Systems (SHS) in developing countries (DCs). The aim of this study was to highlight the main multi-dimensional weaknesses that can limit the resilience of this system. This review addressed the four dimensions of sustainability (institutional, economic, environmental and socio-cultural). It was noted that institutional measures (such as lack of stability/stability and implementation of formal institutions, weak regulations or standards, decentralization/incomplete participation and lack of institutional adaptation) adversely affect the sustainability of rural electricity efforts in DCs. In addition, the lack of an effective subsidized system of electricity tariffs for poor people often makes electricity projects unacceptable. Furthermore, lack of environmental awareness and the lack of regulation or incentives often makes energy technology a supposedly environmentally friendly project. The study concludes that progress in social acceptance, timeliness and cultural justice is urgently needed to ensure the socio-cultural sustainability of rural electricity efforts in DCs. This review can help stakeholders identify and address (based on past experience) the most serious vulnerabilities that affect the sustainability of rural electricity efforts in DCs.

The study by Arowolo *et al*. (2019) identified the most densely populated consumer groups without access to electricity, creating estimates of load and size demand for PV and storage batteries that are technically optimized to achieve high power quality with multiple energy management. In addition, this study analyzes land requirements and availability to obtain a list of 233 7.2 million clusters that require a 3280 MW solar photovoltaic system for the proposed auction.

Bhattacharyya and Palit (2016) in their research suggest that cost-effective universal electricity services remain a challenge and that achieving the universal electricity target by 2030 will remain a challenge for less developed countries. Financial, organizational, and management weaknesses hamper the successful implementation of projects in many countries. The research provided ten (10) policy recommendations for promoting mini-networks as an additional way to develop networks to promote electricity access for successful results. These policy recommendations stated that a robust governance structure is a pre-requisite, as clear rules of the game are essential. Additionally, capacity development is required, link with rural development activities, among several others. This study also showed that power supply and development must be synchronized so that the delivery model that is designed meets the current conditions of development (and affordability) of the community. The study revealed that the main focus should be on the massive flow of pilot and demonstration projects regulatory certainty, strong local institutions with emphasis adequate institutional arrangements, access to soft financing, collection of projects and standard processes, and electricity supply indicators will be a good outcome for all major players to continue the universal energy access program.

According to Puglia *et al.* (2016), their study presents a methodology for the design and economic evaluation of hybrid power plants consisting of photovoltaic power plants, electricity storage and emergency power systems for diesel generators in remote villages in Ntoroko, Uganda. The results of this article show that the use of rechargeable batteries is very important economically, especially in areas with low daily power consumption and in the morning and evening increase peak loads when solar radiation is lower and photovoltaic networks reduce production energy. The results of this study indicates that the optimal configuration of a hybrid system (photovoltaic diesel generator) is an economic advantage despite high investment costs. This conclusion makes the authors argue that electricity storage is an important tool for the use of renewable and non-programmable energy sources, which can dramatically reduce energy production costs by 22.2% and fuel consumption by 77%, especially in each region, in where excess energy cannot be put into the grid and lost.

In a more recent study by Yadav *et al.* (2019), the research provides an overview of the emergence and potential of solar power plants that are not network dependent and network independent of infrastructure. It outlines the specific problems of the last mile population in rural and remote areas, which remain closed by centrally distributed policies. Access to electricity for low and remote income communities must go beyond traditional centralized practices and typologies and provide more opportunities for locally generated and decentralized solar power. The study concludes that, given the geographical, demographic, environmental and technological challenges facing rural and remote populations, the energy transition requires sustainable cooperation and coordination of public order policies and private participation. The energy poverty cycle cannot be solved by a single solution, but must be supported by an embedded and future-oriented ecosystem.

The study by Diemuodeke and Briggs (2018) outlined the main barriers to sustainable electrification of rural areas in the Niger Delta and proposes appropriate policies to eliminate obstacles to the aggressive use of renewable energy technologies in the Niger Delta. Barriers to the entry of renewable energy technology into the Niger Delta have been divided into institutional, technical, data and information, socio-cultural and behavioral, economic and financial policies and surveys, political and market barriers, and inadequate scope for decision making. The proposed policy path is based on energy and accessibility aspects. They identify potential stakeholders with their different qualities and roles as the main drivers in political ways. It has been proven that the positive energy policy of the Nigerian federal government for the introduction of renewable energy and the support of oil and related companies for its use will lead to an aggressive takeover and absorption of renewable energy technologies to meet energy needs to cover the Needs of the Niger Delta. This document also serves as a guide for policy makers who want to address energy problems in coastal communities.

According to Alao and Awodele (2018), their study provided an overview of Nigeria's energy sector and its challenges, focusing on the transmission network. It analyzed the current level of electrification in various geopolitical regions of Nigeria and suggests the use of off-grid solar photovoltaic in northern Nigeria as the fastest way to increase electricity access in the country. In addition, this paper examined the relative success of rural electrification programs in Kenya, Peru and Chile and draws lessons from these countries to make recommendations for accelerating rural electrification rates through off-grid development.

This section critically reviews 6 relevant and related literatures as summarized in Table 2.1 below. They are contemporary studies carried out within and outside the shores of the country. These publications were selected because they align with the various construct studied in this research.

Table 2.1 Reviewed Literatures

S/NO	Author	Topic	Country	Year
1	Haberl H	Sustainability of Off-Grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review	NA	2016
2	Puglia, G;Moroni, M; Fagnani, R;Comodi, G.	A design approach of off-grid hybrid electric microgrids in isolated villages: a case study in Uganda	Uganda	2016
3	Alao O. and Awodele K.	An overview of the power sector, the challenges of its National grid and off-grid development as a proposed solution', Institute of electrical electronics engineer power and energy society	Nigeria	2018
4	Diemuodeke E. O. and Briggs T. A.	Policy pathways for renewable and sustainable energy utilization in rural coastline communities in the Niger Delta zone of Nigeria, Energy report	Nigeria	2018
5	Arowolo, W;Blechinger, P;Cader, C;Perez, Y	Seeking workable solutions to the electrification challenge in Nigeria: Minigrid, reverse auctions and institutional adaptation Energy strategy reviews	Nigeria	2019
6	Yadav, P;Davies, P.J;Palit, D.	Distributed solar photovoltaic landscape in Uttar Pradesh, India: Lessons for transition to decentralized rural electrification. Energy strategy reviews	India	2019

Source: Author

2.3 CONCEPTUAL FRAMEWORK

2.3.1 Nigeria Power Sector

According to Claudius (2014), the history of electricity generation in Nigeria dates from the end of the 19th century, when the first power plant was installed in Lagos in 1898, fifteen years after it was introduced in England. The total generator output used at the time was 60 kW. That is, the peak demand for 1898 did not exceed 60 kW (Onochie *et al.*, 2015).

In 1946, the public works department no longer controlled the operation of power plants and distribution systems in the country. As a result, the Nigerian Electricity Government Undertaking (NGEU) was established under the responsibility of the Public Works Department (PWD) to be responsible for electricity supply in the state of Lagos. Five years later, a head office was established to handle various power plants in the country. The authority was directed to the Electricity Corporation of Nigeria (ECN) and was established in 1951 by Parliamentary law (Olugbenga *et al.,* 2013). When electricity demand increased, several projects were implemented at power plants in Iiora, Oji, Kano and Ibadan to increase the availability and quality of electricity supply (Claudius, 2014).

In 1962, a decade after the founding of the ECN, the Niger Dam Authority (NDA) was formed, which was responsible for dam construction after discovering the many benefits that would be generated from the dam. This led to the construction of the Kanji dam in 1962 and was completed in 1968 (Claudius, 2014). Electricity from NDA is sold to the

ECN for distribution and sales. However, the second merger was carried out in 1972 by the National Electricity Authority (NEPA). According to Olugbenga *et al*. (2013) electricity demand increasingly exceeds population supply, which causes a decrease in power generation capacity. As a result of the government's efforts to revive the energy sector, NEPA was renamed the Nigeria Energy Holding Company (PHCN) by the 2005 Electricity Reform Act.

2.3.2 Generation

The Nigerian power sector in is sub-divided into power generation, transmission and distribution. The Electric Power Sector Reform (EPSR) Act was signed into law in March 2005, enabling private companies to participate in electricity generation, transmission, and distribution. The government unbundled PHCN into eleven electricity distribution companies (Discos), six generating companies (Gencos), and a transmission company (TCN). The Act also created the Nigerian Electricity Regulatory Commission (NERC) as an independent regulator for the sector. According to NERC, at present, the Federal Government has fully divested its interest in the six Gencos while 60% of its shares in the eleven (11) Discos have been sold to the private operators. The Transmission Company still remains under government ownership (Nigerian Electricity Regulatory Commission, nd). The generation companies after the unbundling of PHCN are shown in Table 2.2.

Table 2.2: Gencos created after the unbundling of PHCN

Genco	Installed Capacity (MW)	Type	Privatisation Status
Afam Power Plc	776MW	Gas	100% Sold
Sapele Power Plc	414MW	Gas	51% Sold
Egbin Power Plc	1,020MW	Gas	100% Sold
Ughelli Power Plc	900MW	Gas	100% Sold

Kainji Power Plant	760MW	Hydro	Long Term Concession
Jebba Power Plant	578MW	Hydro	Long Term Concession
Shiroro Power Plc	600MW	Hydro	Long Term Concession

Source: Nigerian Electricity Regulatory Commission (NERC), (nd)

The generation sub-sector currently consists of 23 grid-connected electrical installations with a total installed capacity of 10,396 MW (available capacity of 6,056 MW) for thermal production with an installed capacity of 8,457.6 MW (available capacities of 4 996 MW) and 1,938.4 MW of total hydropower installed capacity with 1,060 MW available. These are privatized Gencos, Independent Power Producers (IPPs) and the National Integrated Project Power (NIPP). To increase electricity generation, the Federal Government launched the Niger Delta Power Generation Company (NDPHC) in 2004 as a publicly funded emergency program. The company is tasked with managing the National Integrated Project Power (NIPP), which basically consists of developing critical infrastructure identified in the generation, transmission, distribution and natural gas supply sub-sectors of the electric power value chain. Several NIPP power plants have been privatized and planned to be sold to other investors who are interested in increasing the involvement of the private sector, thereby strengthening the government's reform agenda.

To support the reform program, the Nigerian Electricity Regulatory Commission (NERC) has in the past approved several Independent power producers (IPPs), some of which are at various stages of project development. The Commission has also established guidelines for the procurement of groups that will ensure efficient and appropriate large capacity production in the future. In this way, the Commission can effectively estimate the amount of capacity that can be added to the network each year. In addition, the Commission has developed an integrated production scheme that allows electricity generation (including renewable energy) to be connected and evacuated directly through the distribution network. This also offers investors, states and cities the opportunity to produce, sell or use energy without having to go through a transmission network. It also provides a way for disco to increase available sales capacity while eliminating the tariff transfer component.

Nigeria aims for a capacity of 40,000 MW in 2020 to implement reforms, and to spend around $ 10 billion per year on the energy sector over the next 10 years to achieve this. In the privatization sector, the Nigerian Electricity Wholesale Company (NBET) from Gencos, IPP, and NIPP buys energy at a negotiated price, as stated in the Electricity Purchase Agreement (PPA), and sells it to Discos that produces end-user energy.

2.3.3 Transmission

The Transmission Company of Nigeria (TCN) operates the electricity grid in the country. It is one of the 18 companies that was unbundled from the defunct Power Holding Company of Nigeria (PHCN) in April 2004 and is a product of a merger of the transmission and system operations parts of PHCN. The company was founded in November 2005 and issued a transfer license on July 1st, 2006. TCN is currently 100% owned and operated by the government. As part of the government's reform program, it needs to be reorganized and restructured to increase its reliability and expand its capacity.

TCN licensed activities include: power transmission, system operation, and power trading. It is responsible for the evacuation of electricity produced by the power generation company (Gencos) and its distribution to distribution companies (Discos). This provides important infrastructure for transmission between Gencos feed stations and Discos.

Nigeria's transmission network consists of high voltage substations with a total (theoretical) transmission of 7,500 MW wheel drive and more than 20,000 km of power lines. At present the cogs (5,300 MW) are above the average operating power of 3,879 MW, but far below the total installed production capacity of 12,222 MW. The entire infrastructure is basically radial without redundancy, creating inherent reliability problems. The average transmission loss is very high, at 7.4%, compared to 2-6% in emerging markets. The number of system crashes has decreased in recent years from 42 in 2010 to several years. All of this reflects critical infrastructure and operational challenges in the industrial transportation subsector. TCN consists of three operational departments:

1. Transmission Service Provider (TSP)

TSP manages the development and maintenance of transmission infrastructure. It is responsible for the national substation transmission system for substations and power lines and offers open access transmission services. Their job is to preserve the physical infrastructure of the transmission network and expand it to new areas.

2. System Operations (SO)

SO manages the flow of electricity throughout the power system from generation to distribution companies. He leads the Grid Code for the Nigerian Electric Industry (NESI). The SO is responsible for ensuring the reliability of the transmission line and ensuring the technical stability of the network by planning, sending and controlling electricity in the network. Specifically, the responsibilities of SO are:

i. Frequency and voltage regulation;

ii. Electricity distribution during sub-production;
iii. Design, installation and maintenance of supervision control and data acquisition (SCADA) and communication facilities for efficient network operations;
iv. Economical generator delivery
v. Provision and management of additional services;
vi. Strengthen network code and operating procedures
vii. Coordination of all planned interruptions for maintenance of system equipment;
viii. Perform analysis after all major network failures occur.

3. Market Operations (MO)

The MO administers the market rules of the NESI. It is responsible for the administration of the Electricity Market and promoting efficiency in the market. Specifically, the roles of MO include:

i. Implementation and administration of electricity market rules in Nigeria;
ii. Preparation and implementation of market procedures;
iii. Management of commercial measurement systems to ensure that each point of sale has an appropriate measurement system;
iv. Market settlement system management;
v. Payment system management and commercial organization of the energy market, including ancillary services;
vi. Supervising Electricity Market Participants' compliance with and enforcing the Market Rules and the Grid Code;
vii. Periodic reporting on the application of market rules;

viii. Increasing the capacity of market participants through market rules and procedures and trade agreements;

At the long-term stage of the electricity market, ensuring and promoting competition among market participants will be a key function of the MO.

2.3.4 Distribution

The third sub-sector which is the distribution comprises of eleven electricity distribution companies (DISCOS). Their responsibility is to facilitate the supply of power using its distribution network to provide electricity to customers within their area of operation. They are also responsible for the operation and maintenance of the distribution network, installation, connections, reading of meters, billing, etc. The 11 DISCOS include;

1. Kaduna Distribution Company
2. Kano Distribution Company
3. Jos Distribution Company
4. Yola Distribution Company
5. Abuja Distribution Company
6. Ibadan Distribution Company
7. Ikeja Distribution Company
8. Eko Distribution Company
9. Benin Distribution Company
10. Port Harcourt Distribution Company
11. Enugu Distribution Company

Figure 2.1: Nigeria national grid

Source: Nnonyelu and Madueme (2013)

2.4 The National Grid of Nigeria

The national electricity grid presently consists of 14 generating stations (3 Hydro and 11 thermal) with a total installed capacity of about 8,039 MW (Oyedepo, 2012). Figure 2.1 shows the grid network in Nigeria as presented by Nnonyelu & Madueme (2013). The transmission capacity is made up of about 5523.8 KM of 330 KV lines and 6801.49 KM of 132 KV lines (KPMG, 2016). According to Oyedepo (2012), 23 of 330/132-kV substations, with a combined capacity of 6,000 or 4,600 MVA at a utilization factor of

80%. In turn, the 91 of 132/33-kV substations have a combined capacity of 7,800 or 5,800 MVA at a utilization factor of 75%. The distribution sector is comprised of 23,753 km of 33-kV lines, 19,226 km of 11-kV lines, and 679 of 33/ 11-kV substations. The transmission system is the weakest link in Nigerian's Electricity Network, with the capability to evacuate only about half of the currently installed generated capacity (Sambo *et al.*, 2012). The transmission system has been plagued by system collapse resulting from negligence from the TSP. Some of the challenges of the TCN are radial design of the system which makes it vulnerable to outages, ageing substation equipment, overloaded transmission lines and lack of cost reflective transmission tariffs, amongst others (Sambo *et al.*, 2012). From Figure 2.4, it can be observed that most of Nigeria's electricity is generated in the South. More so, according to (Gesellschaft flir Internationale Zusammenarbeit (GIZ), 2016), many transmission loops within a region increases the reliability and strength of the system, as also observed in the Southern region.

At present, the national electricity grid consists of 14 power plants (3 hydroelectric power plants and 11 thermal power plants) with a total installed capacity of around 8039 MW (Oyedepo, 2012). The transmission capacity covers around 5523.8 km of the 330 KV line and 6801.49 km of the 132 KV line (KPMG, 2016). According to Oyedepo (2012), 23 of 330/132-kV substations, with a combined capacity of 6,000 or 4,600 MVA at a utilization factor of 80%. Also, 91 of 132/33 kV substations have a total capacity of 7,800 or 5,800 MVA with 75% utilization. The distribution sector consists of 23,753 km 33 kV lanes, 19,226 km 11 kV lanes and 679 33/11 kV substations. The transmission network is the weakest link in the Nigerian electricity network, with the potential to evacuate only about half of the currently installed production capacity (Sambo *et al.*, 2012). The transmission network was affected by a system crash due to TSP negligence. Some of TCN's challenges are the radial design of the system, which makes it vulnerable to interference, obsolete substations, congested transmission lines and the lack of cost-based transmission costs (Sambo *et al.*, 2012). Figure 2.2 shows that most Nigerian electricity is generated in the south. In addition, according to GIZ (2016), many shipments in one region increase the reliability and power of the system, as seen in the South.

In terms of the consumption of electricity, a classification into three groups has been proposed (industrial, residential, and street light consumption). In 1970, the total electricity consumption stood at 145.3 MW/h; this increased to about 536.9 MW/h in 1980. However, in 2005, the total electricity consumption had increased to 1,873.1 MW/h Central Bank of Nigeria (CBN), 2006). On the generation side, these values of 176.6 MW/h in 1970 increased to 815.1 MW/h in 1980. By the end of 2005, the achieved total electricity generation was 2,997.3 MW/h (CBN, 2006). Comparing the per capita power generation to that of other countries, Nigeria has the lowest among the countries, as shown in Table 2.3, while the USA has the highest per capita electricity generation.

In spite of the contribution of electricity to the total gross domestic product, it is evident that Nigeria is facing several problems. The incapacity of the electricity subsector to efficiently meet the demand for electricity in the country has been caused by a number of problems, which have been detrimental to economic growth.

Table 2.3: Country statistics of electricity generation and per capita

Continent	Country	Population (million)	Generation Capacity (MW)	*Per Capita* consumption (kW)
North America	USA	250	813,000	3.2
South America	Cuba	10.54	4,000	0.38
Europe (central)	UK	57.5	76,000	1.1
Europe (eastern)	Ukraine	49	54,000	1.33
Middle East	Iraq	23.6	10,000	0.42
Far East	South Korea	47	52,000	1.1
Africa	Nigeria	140	<4,000	0.03
	Egypt	67.9	18,000	0.27
	South Africa	44.3	45,000	1.02

Source: Oyedepo, 2012

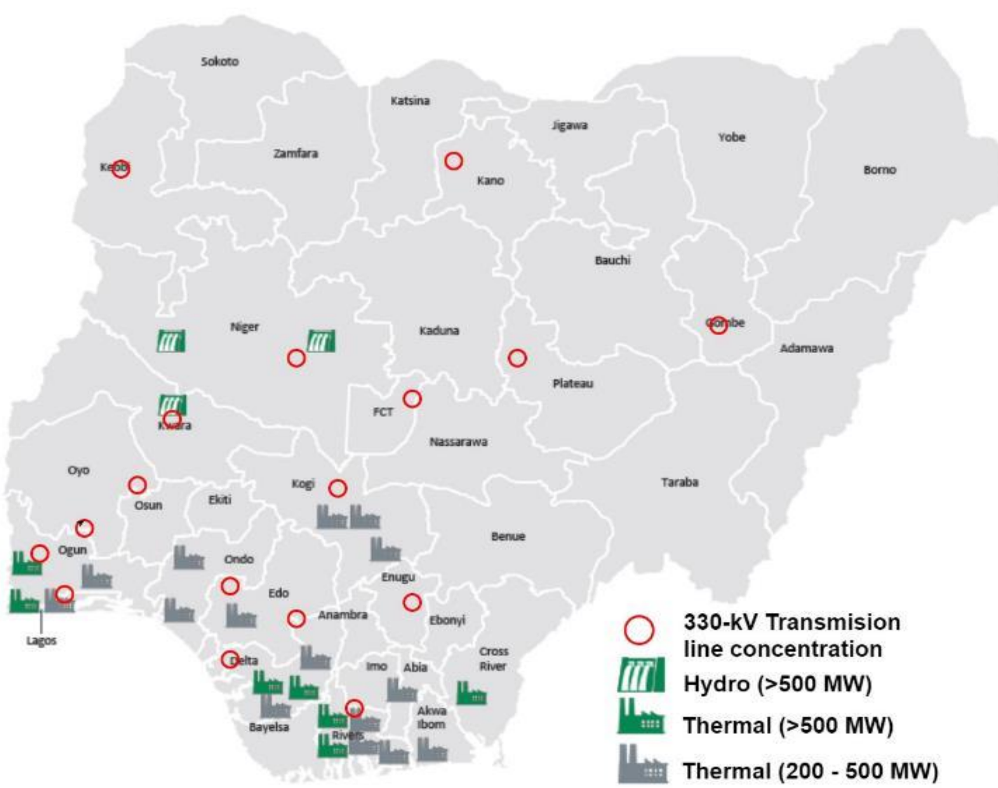


Figure 2.2: Location of the 23 on-grid power plants and 330-kV transmission line concentration in Nigeria

Source: Alao and Awodele, 2018

2.5 Renewable Energy

The term 'Renewable energy' simply means an energy collected from renewable resources. These resources could be in the form of sunlight, wind, rain, tides, waves, or geothermal heat (Ellaban *et al.,* 2014). Renewable energy plays an important role in meeting future energy needs in rural and urban areas (Hui, 1997; Oyedepo, 2012). The development and use of renewable energy sources must be given high priority, especially given the increasing awareness of the adverse effects of fossil fuel production on the environment. Demand for sustainable energy is increasing rapidly throughout the world. Widespread use of renewable energy is important to achieve sustainability in the energy sector, both in developing and industrialized countries.

The renewable energy resources in Nigeria are as enormous as they are diverse. The summary of the renewable energy potentials are given in Table 2.4 which, if fully developed and used, will lead to poverty reduction and sustainable development.

Table 2.4: Renewable energy resources

Renewable Energy Source	**Capacity**
Small Hydropower	3500MW
Large Hydropower	11,250 MW
Wind	2 – 4 m^2 annually at 10m height
Solar Radiation	3.5 – 7.0KMh/m^2/day
Fuel Wood	13,071,464 hectares of forest and woodland
Biomass Animal Waste	61 million tons/year
Crop Residue	83 million tons/years

Source: Vincent and Yusuf (2014)

Renewable energy resources and technologies are a key component of sustainable development for the following primary reasons (Oyedepo, 2012):

i. They generally cause less environmental impact than other energy sources. Implementation of renewable energy technologies will help overcome environmental problems caused by greenhouse gas emissions such as carbon dioxide (CO_2), nitrogen oxides, sulfur oxides (and particles from oil, gas and natural gas production). Various renewable energy sources offer a variety of flexible uses.
ii. They cannot run out. Renewable energy sources, with careful use in appropriate applications, can provide an almost unlimited and sustainable supply of energy. Conversely, fossil fuels are reduced through extraction and consumption.
iii. They advocate systemic decentralization and local solutions that are largely independent of national networks, thereby increasing system flexibility and providing economic benefits for isolated small populations.

According to Oyedepo (2012) Nigeria needs to create a renewable energy market and expand its experience with renewable energy technology to take advantage of the opportunities offered by renewable energy sources for sustainable development. Barriers and restrictions on the distribution of renewable energy must be overcome. It is important to create legal, administrative and financial infrastructure to facilitate the planning and implementation of renewable energy projects. Governments must play a useful role in promoting renewable energy technologies by starting studies to identify their potential in urban and rural areas.

Renewable energy resources are constantly being replenished by natural resources, which is unlike fossil fuels. Non-renewable energy like fossil fuels are often negotiated on international markets and exposed to international competition, they have security of supply which sometimes even leads to war and congestion. They have important advantages which can be stated as follows:

i. The level of use does not affect its availability in the future; therefore they are endless. In general, resources are well distributed throughout the world, despite significant spatial and temporal changes. In this way, all regions of the world have adequate access to one or more forms of renewable energy supply.
ii. They are clean and environmentally friendly and hence a form of natural energy that is sustainable.
iii. They can be mined cheaply and continuously and are therefore a sustainable source of energy.

2.6 Sustainable Energy Development

Sustainable energy includes the provision of sustainable energy services, which in turn requires the provision of energy services for all in a way that is sufficient now and in the future to meet basic needs, can be accessed, without damaging the environment and can be accepted by all communities and people (Lior, 2008). The use of renewable natural resources, combined with the supply and use of efficient fossil fuels with cleaner technology, can help reduce the environmental impact of energy use and help Nigeria replace inefficient fossil fuel technologies that pollute the environment. As a further step, the wise use of energy resources is important to drive economic growth, protect ecosystems, and secure sustainable natural resources (Oyedepo, 2012).

Energy sustainability thus includes sustainable use of energy throughout the energy system. This system includes methods and technology to extract and convert energy sources into energy forms that are useful for providing energy services such as the operation of communication systems, building lighting and cooking (Hammond, 1998). Energy sector reform is very important for sustainable development in Nigeria. This includes reviewing and reforming subsidies, creating a sound regulatory framework, developing a policy framework through regulatory interventions, and creating market-based approaches such as emissions trading (Sims *et al.*, 2007). Countries around the world are developing strategies and strategies to enable the sustainable development of their energy resources, thereby contributing to economic and social development while reducing air pollution and greenhouse gas emissions (Oyedepo, 2012).

According to the United Nations (UN), sustainable development (SD) without sustainable energy is not possible. Therefore, the problem is prioritized by establishing an independent SD Goal (No 7) to Sustainable Energy, which implies universal access to modern energy sources that are affordable, reliable and environmentally friendly, modern energy (Assembly, 2015). Although there is no universal definition of energy access and data is often scarce, the International Energy Agency (IEA) defines access to energy as households that have access to electricity and cooking media that are relatively clean and safe (IRE, 2015). With regard to electricity, the IEA methodology provides a minimum annual household consumption of 250 kilowatt hours (kWh) in rural areas and 500 kWh in urban areas. According to this definition, 1.2 billion people still do not have access to electricity throughout the world, especially from rural areas (Harberl, 2016)

Although not the only alternative (see Figure 2.3), a feasible solution to achieve the goals of seventh SD goal of the UN in rural areas that are not yet connected is to use renewable technology outside the network. One of these off-grid technologies is the photovoltaic system (PV system), which is installed in many developing countries (DCs) and serves to provide power for people whose connections will take years with the national electricity grid.

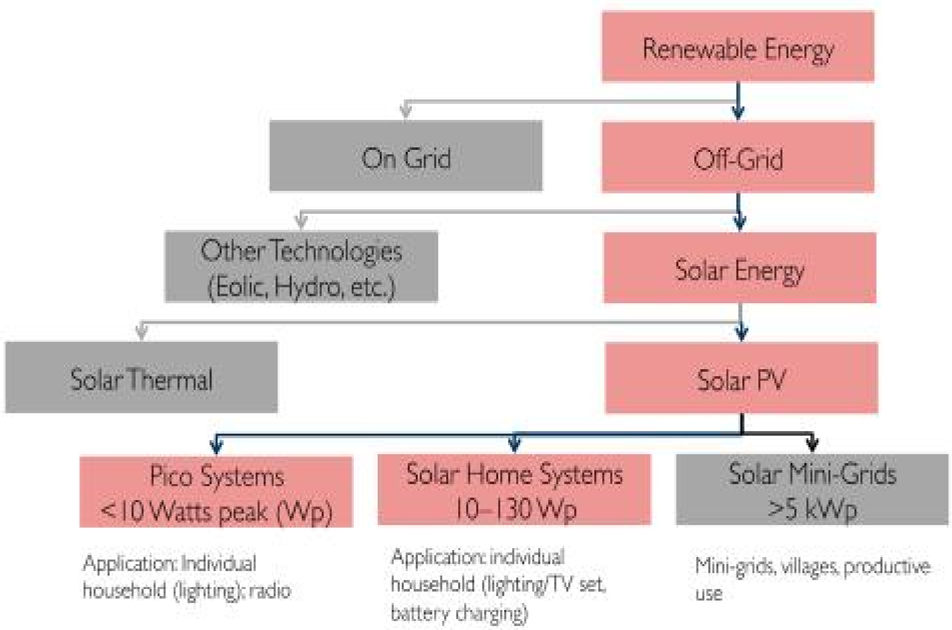


Figure 2.3: Types of solar PV system

Source: Haberl, 2016

Photovoltaic systems can be used in a variety of ways: technological solutions range from very small applications such as Solar Pico Systems (SPS) (that is, one to 10 watts used to replace kerosene lamps with lightning) to medium-term solutions such as Solar Home Systems (SHS); The latter usually has a peak power of 10-130 watts (in some households, up to 250 watts installed) (Lysen, 2013). SHS can provide some artifacts such as lights, radio and TV. In addition to photovoltaic cells, other accessories needed are batteries, inverters (to convert DC to AC) and charge controllers (to convert charges from solar panels to deep discharge batteries) making more expensive system. It is estimated that there are currently around six million SHS installed worldwide (compared to 1.3 million systems in 2002), although a significant data gap only allows estimated figures (International Renewable Energy Agency, (IRENA) 2015).

PV systems have also been installed in large-scale projects, such as hospitals or whole communities. For that purpose, hybrid solutions (including, e.g., diesel generators or eolic systems) are combined and fed into a local mini-grid, which can provide energy to a whole community (Roland, 2011).

2.7 Off Grid Power Generation

Around 55% of the Nigerian population does not have access to electricity networks that are connected to the network. Access to electricity in rural areas is around 35% and in urban areas around 55%. However, in recent years, the federal government has focused more on researching other off-grid sources of electricity generation to reduce pressure on network supply. In addition to irregular and unreliable shipments, pressure on the national network has caused permanent system failures. These events have made entrepreneurs playing in the industrial sector, and some private electricity disconnected from the national electricity grid in order to rely on self-generated energy for their operations (Ugwuanyi, 2018). Off-grid production can be described as a standalone or mini-grid power generation system, which usually powers smaller communities through independent power distribution networks (Zubair, 2016). Off -grid supply is power supply that does not go through the national grid. Minigrids are often deployed in remote rural areas as a cost-effective means of electrification than traditional extension of the main grid. They offer more reliable power than the main grid in many settings, including much of rural Nigeria. Mini grid only exists in nine state in Nigeria which includes; Sokoto, Niger, Kaduna, Abuja, Plateau, Ogun, Edo, Cross River, and Rivers State as shown in the Figure 2.4.

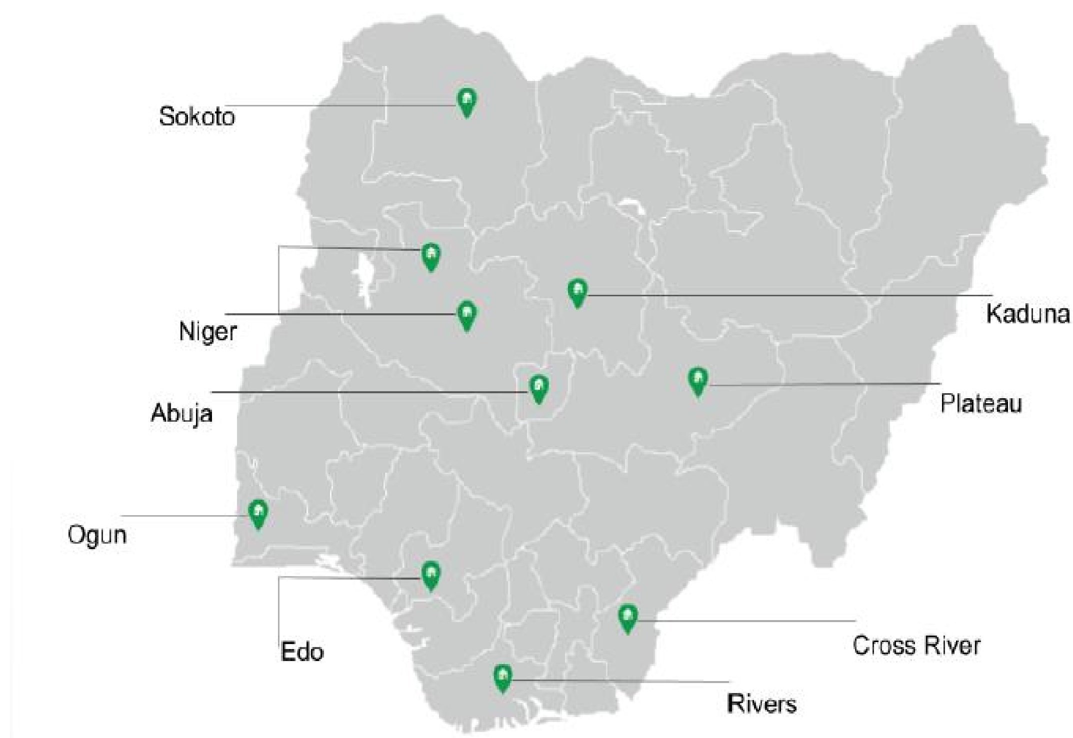


Figure 2.4: Mini-grid sites across Nigeria

Source: Rocky Mountain Institute (RMI) (2018)

It is estimated that a growing economy requires around 1000 MW per million people to meet their electricity needs. Nigeria will always need more than 160,000 MW to achieve the desired power generation capacity. According to Punchng (2015), the total network capacity approved by the Nigerian Electricity Regulatory Commission (NERC) is still below 500 MW. Significant investment is needed to produce off-grid power; given Nigeria's plans to increase its generation capacity in the coming years.

Figure 2.5 illustrates the minigrid value chain, as presented by RMI, (2018). This includes the three fundamental phases of project development, construction, and operations.

Figure 2.5: The mini grid value chain
Source: RMI, (2018)

The project development phase, which is very crucial is completed within the first three months. This phase involves activities such as; site identification and assessment, system design and planning, and customer acquisition. The construction phase, which can take between two to 12 months, includes equipment procurement, system installation, and commissioning. Finally, the operations phase can continue indefinitely (depending on reinvestment—although minigrid project lifetime is typically estimated at 20–25 years) and comprises ongoing maintenance, metering, billing, and collections, and decommissioning or grid integration.

Off-grid power is mainly for solar home systems (SHS) and is available in small systems with power between 10 W and 500 W and especially for rural communities, while SHS for systems greater than 500 W to 15 KW for urban and suburban areas. Off-grid systems for SMEs and companies range between 500 kW and 1 MW, enabling complete control of the rural energy industry (REA). Mini grids range from 15 kW to 10 MW for industry, real estate, educational institutions and markets, solar agriculture and solar irrigation (Ugwuanyi, 2018).

2.8 Off-Grid Power Generation in Rural Communities

The Nigerian government is developing solar and wind energy projects through the Ministry of Energy, Construction and Housing, in collaboration with private operators, to supply residents without access to electricity. The Rural Electrification Agency (REA) is another important government tool to push forward with rural development projects in the country's rural areas (Ugwuanyi, 2018). The REA was established by the 2005 ESPR Law for Promotion of Rural Electricity in Nigeria. It was closed by the Federal Government in

2009 and opened in 2011. For a densely populated country like Nigeria, off-grid generation is very important, especially in the country's rural areas (Audu and Diugwu, 2019).

Rural areas in Nigeria suggest parts of the country with populations less than 20,000 people are more than 10 km the city area is at least 20 km from the nearest 11 kV line and with a population density of less than 200 km² (Elusakin *et al.*, 2014). As part of a strategy for Rural Electrification Implementation Plan (RESIP), (2015), Mini network solutions for remote billing are usually more expensive effective from network extensions. This shows that for rural settlements, many people do not access to electricity in Nigeria, an off-grid system at a different scale such as Mini networks, micro networks or isolated systems will be the most numerous an economically and technically feasible security approach Electricity (Alao and Awodele, 2018).

Renewable energy (RE) technologies such as solar photovoltaic and terrestrial wind turbines are often suitable for rural electrification applications (Ajayi, 2010; Elusakin *et al.*, 2014) and have been proven feasible in Nigeria. Nigeria has an average irradiation of 4.0 - 6.5 $kWh/m^2/day$ and an average duration of sunshine of 4 - 7.5 hours per day (Ajayi, 2010). Solar electricity may be used for power supply to remote villages and locations not connected to the national grid. It may also be used to generate power for feeding into the national grid. Other areas of application of solar electricity include low and medium power application such as: water pumping, village electrification, rural clinic and schools power supply, vaccine refrigeration, traffic lighting and lighting of road signs (Sambo, 2009). The yearly average of daily sun in Nigeria is shown in Figure 2.6.

It is estimated that wind has a potential of 14,399 MW with a capacity factor of 20%, provided that 0.25% of land is available (Elusakin *et al.*, 2013). However, the geophysical and demographic characteristics of each settlement differ from country to country and play an important role in informing about sources of electricity that are viable and financially feasible.

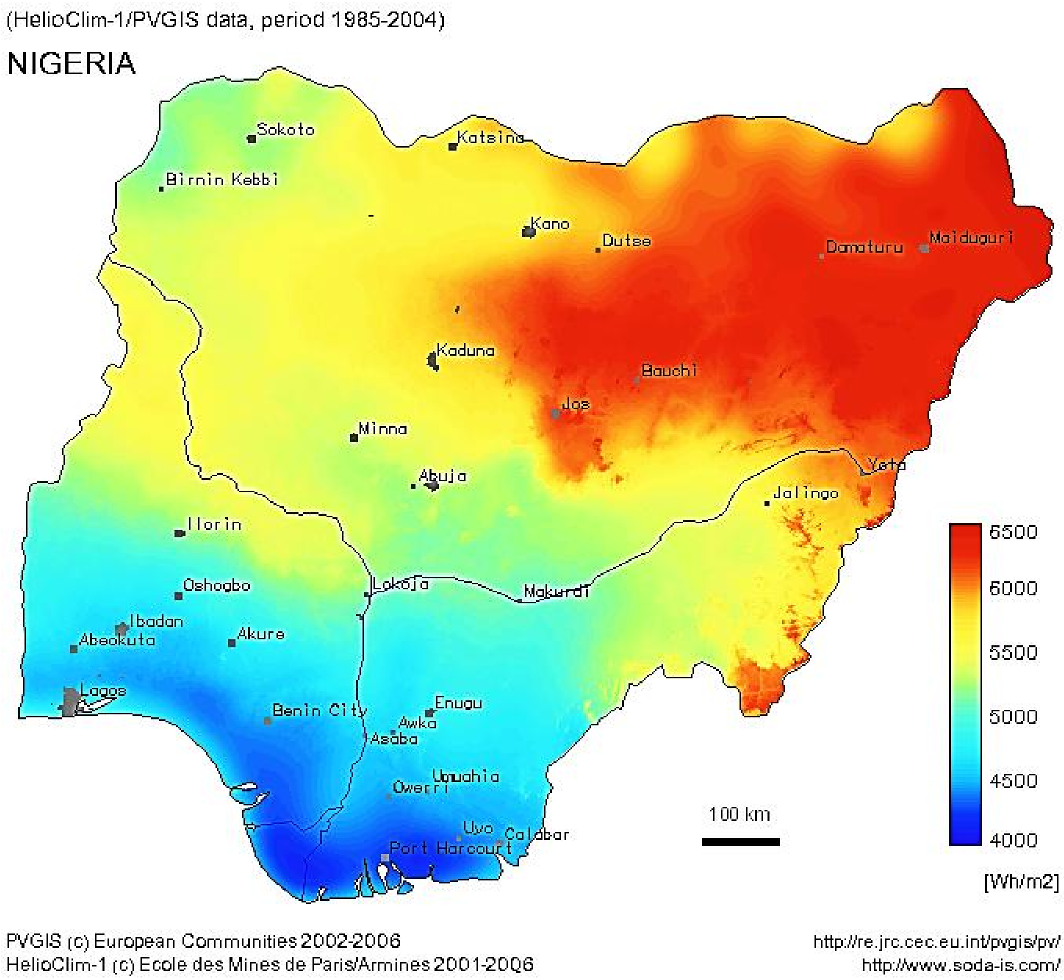


Figure 2.6: The yearly average daily sun in Nigeria (1985-2004)

According to Mustapha (2017), there are two mini-grids and one facility unit solar projects in the state. They include the Bisanti Project funded by the bank of industry, Abdus-Salam

Abubakar General hospital, and the Tungan Jika solar mini grid as shown in Plate 2.1. The latter is a 100KW capacity to supply the Agrarian community with a population of about 600 households with 300 signed on (2,100 people), 27 productive users, and 52 commercial users. 2 schools, 2 hospitals, 2 mosques, 2 churches, 23 Mill sand Agricultural Workshops, 2 Metal Welders including 1 filling station and 2 Bakeries

Plate 2.1: Tungan Jika solar mini-grid

According to Ediri Report (2019), solutions implemented for renewable energy can be a fundamental change in the energy supply of remote rural communities and businesses that are not served by traditional infrastructure. Lessons learnt from other countries that have had relative success in implementing off-grid projects are as follows: According to Alao and Awodele (2018), Kenya has become a regional star, increasing electrification from 23% in 2013 to around 50% in 2016. Before that period, the speed of rural electrification was low. The establishment of the Rural Electricity Authority (REA) in 2006 was the main driver for this latest leap. Much of Kenya's success in this sector was due to large investments through subsidies and careful planning. In Kenya, a GIS-based minimum-cost analysis was adopted to implement a rural electrification planning framework, which mainly assesses and evaluates the cost effectiveness of implementing off-grid projects compared to network expansion (Lee *et al.*, 2016).

Bangladesh, for example, is one of the most populous countries in the world, with more than one hundred and fifty-six million inhabitants, and has a rich history of implementing off-grid electricity solutions. In 2003, the Government of Bangladesh began a rural electricity program based on solar energy through micro credit development companies with limited responsibilities. In 2002, only 7,000 Bangladeshi households used solar panels. But so far, around 2 million SHS have been installed in this country (Zubair, 2016).

2.9 Mini-grid Success Factors and Best Practices

Mini-grid projects just like any other type of project also follow the generic project life cycle as shown in Figure 2.7 and Table 2.5. Off-grid power projects factors for success include site selection, community engagement, demand stimulation, ownership, and regulatory support. Based on these factors, developers are already implementing best practices to lower costs, improve customer satisfaction, and achieve economic viability in new projects.

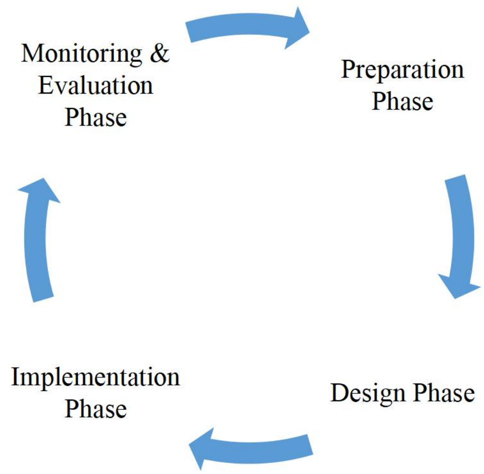


Figure 2.7 Project life cycle

Table 2.5: Mini-grid success factors.

Preparation Phase	Design Phase	Implementation Phase	Monitoring & Evaluation Phase
Community building	Strategic project planning	Diligent tariff collection	Energy service reliability check:
Local actor identification	RE technology selection & sizing	Final user education	Level of user satisfaction
Sense of ownership	Operator model selection	On-going O&M and troubleshooting	Tangible health, social and economic benefits
Capability building measures	Technical operation planning		
Continued engagement measures	Financial and commercial viability		

Source: Adapted from Rolando *et al*., (2015)

2.10 Prospects of Off-Grid Power Generation

According to the Minister for Power, Works and Housing in Nigeria, Fashola (2016), Elusakin *et al.* (2014) the following were some of his prospects for off-grid power generation in the country:

Potential to grow industrial clusters and small cottage industries: Most industrial clusters and some small cottage industries require uninterrupted power supply to function optimally. The power supplied could be generated through fully off-grid power plants or embedded within distribution networks. This could potentially transform the economy of these areas; increase profitability for the existing businesses; create jobs; and breed a crop of customers who are willing to pay for electricity supplied.

Opportunity to expand and refurbish distribution networks of the DISCOs:

In line with the NERC Regulation for Independent Electricity Distribution Networks (IEDNs), 2012, off-grid generation plants require Independent Electricity Distribution Networks (IEDNs) to supply electricity to end users, save for eligible customers upon declaration by the Minister of Power, who can be supplied to directly. This creates opportunities for investors who may wish to create off-grid projects with their own IEDN. This could potentially be a win-win situation for DISCOs who could either collaborate with developers to expand or refurbish their network; add to their number of paying customers; or acquire the developer assets given the right regulatory framework.

Access to other fuel alternatives: Most of the power plants in Nigeria are gas fired thermal plants. Given the current constraints with gas, off-grid power plants are able to take advantage of diverse and hybrid fuel sources like renewables (solar, wind, biomass) and because the power is not generated on-grid, transmission constraints with renewables are eliminated. This would be particularly more useful in areas where there is limited gas supply, e.g. the northern part of Nigeria where solar, wind, and hydro sources are prevalent.

Opportunity for rural electrification: Off-grid solutions are also useful in Nigeria in view of some topographical or geographical challenges in the rural areas which have made it uneconomical to extend the grid to such areas. Rural electrification in Nigeria is currently in a weak and dilapidated state; hence there is a dire need for investments. Recently, bids were requested by the Rural Electrification Agency (REA) for several rural electrification projects across Nigeria, and were to be submitted to the Agency by 27th November, 2015. It is expected that many rural electrification projects will spring up this year. A priority for the REA should be the sustainable development of rural mini-grids that are targeted towards the economic development of these rural communities so that the communities can learn the culture of paying for electricity (Zubair, 2016; Audu and Diugwu, 2019).

2.11 Challenges of Off-Grid Power Generation in Rural Communities

There are numerous challenges facing the off-grid power generation in rural communities. Table 2.6 presents these challenges

Table 2.6 Barriers to sustainable energy utilisation in the rural communities

S/NO	Reference	Barriers
1	Diemuodeke and Briggs (2018)	1. Policy and institutional barrier. 2. Technical barrier 3. Socio-cultural and behavioural barrier. 4. Economic and financial barrier. 5. Political and market barrier **6.** Inadequate decision space
2	Kumar *et al.* (2018)	7. Technical challenges 8. Non-technical challenges 9. Data access and ownership 10. Data privacy 11. Cybersecurity **12.** The role of renewable energy and fully distributed generation
3	Tariqul and Imtiazul (2014)	13. Lack of idea about renewable energy resources 14. High initial capital costs and higher perceived risks of the renewable energy technology 15. Unavailability of information 16. Lack of awareness programs for the renewable energy consumption 17. Financing challenges 18. Natural disasters are one of the barriers for promotion of sustainable energy.
4	Elusakin *et al.* (2014)	19. Lack of proper planning and designing challenges 20. Corruption 21. Political instability 22. Adulteration of the off-grid equipment and low off-grid Technology.

Technology gap: Due to the fact that many of the off-grid equipment are sophisticated and advanced, Nigerians need to develop the adequate technological know-how for installation, operation and maintenance. It is common to find that many solar PVs (photovoltaic) installed pack up shortly after installation. Also, renewables such as wind and biomass have not been fully explored in Nigeria, and would require adequate know-how for Nigerians to operate.

Objections from Existing Monopolies: There are possibilities that there would be objections to the granting of off-grid licenses from DISCOs over the areas where their DISCO licenses currently cover. NERC also maintains a balance to ensure that the DISCO's market share will not be destroyed by the grant of an off-grid license (Zubaira, 2016).

Improper planning: Inadequate planning is an impediment to the success of off-grid development in Nigeria. Off-grid projects are not well planned such that the viability of the projects are not being considered in each location before the implementation.

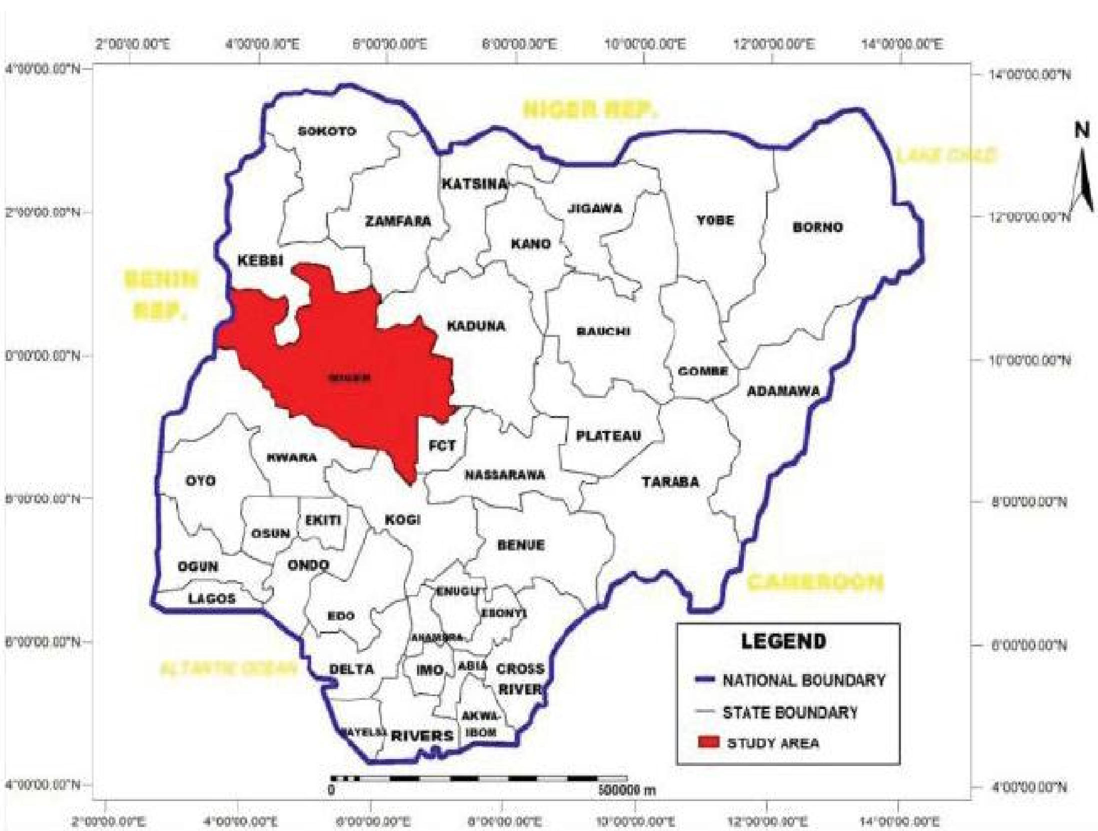
Lack of monitoring the implementation of off-grid projects: Off-grid projects when awarded to contractors are well monitored. Due to corruption in the REA, project fund are misappropriated and this leads to non-implementation of off-grid projects (Alao and Awodele, 2018).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Area of Study

Niger state is one of the seven North-central states in the country. The name was derived from the third longest river in Africa (River Niger). It was created in 1976 lying on latitude 3.20 E and longitude 11.30N. By land mass, Niger state is the largest in the country with 76,363km^2 with estimated population of 3,950,249 (2006 estimate). Figure 3.1 shows the



map of Nigeria showing Niger state

Figure 3.1: Map of Nigeria showing Niger state

Source: Oguh *et al*., (2019)

The state is populated by mainly by Nupe people in the south, the Gwari in the East, the Busa in the West, and Kamberi, Hausa, Fulani, Kamuku, and Dakarki in the North spread across the 25 local government areas.

The state also houses three major hydro-electric power stations in Nigeria namely; Kainji, Jebba, and Shiroro stations collectively producing 2000MW of electricity to major cities across the country (Odesola and Ale, 2019).

3.2 Study Design

Research design refers to overall strategy chosen to ensure effectiveness in addressing the research problems logically and as ambiguously as possible (De Vaus, 2001). This research adopted a mixed survey research design to achieve the aims and objectives of the study. Survey research is simply defined as the collection of information from a sample of individuals through their responses to questions (Check and Schutt, 2012). This method was selected because it can cater for larger census surveys to obtain information showing demographic and personal characteristics of individual respondents. For this study, the method was adopted so that relevant information would be gathered from the respondents to achieve the objectives of this research. Hence, a structured questionnaire was used to collect primary data targeted at rural community dwellers and power sector practitioners.

3.3 Population of Study

The population of this study constitutes one hundred and thirteen randomly selected rural communities, and 120 power sector practitioners in Niger state. In order to give a good representation, this study randomly selected 113 rural communities across the 25 local government area of the state. The name of the selected 113 rural communities and their representative respondents which makes up the population of this study is shown in Appendix 1. For uniformity, the research purposively sampled six number of respondents each from the 113 rural communities to enable sample size determination.

3.4 Sample Size

The sample size is a significant feature of any empirical study in which the goal is to make inferences about a population from a sample (Hamed, 2018). Thus, since the study population is 798 as shown in the Table 3.1 above, it is therefore necessary to select samples from the population upon which the study was based. Thus, this research adopted the Guilford and Fruchter (1973) formula for estimating finite sample.

This is shown below

Guilford and Fruchters formular

$$n = \frac{N}{1+(e^2)N} \quad (3.1)$$

Where:

n = Desired sample size
N = Total Population
e = level of significant (0.05)

$$n = \frac{798}{1+(0.05^2)798}$$

$$= \frac{798}{2.995} = 266$$

Therefore, the sample size is 266 numbers of respondents.

3.5 Sampling Method

In order to ensure equal population of all the categories of respondents illustrated above, a stratified random sampling technique was used. This was determined by achieved dividing the total number of the sample size which was 266 across the 113 rural communities and power sector practitioners to ensure equal proportion. The equal proportionate calculation is illustrated below. Table 3.2 shows the total sample size of the research.

To have the proportionate sample size for Rural communities

$$n = \frac{\text{Total number of respondents in each rural community}}{\text{Sample population}} \times \text{Sample size} \qquad (3.2)$$

$$= \frac{6}{798} \times 266 = 2$$

Therefore, 2×113 for 113 rural communities

$$= 226$$

To have the proportionate sample size of Power sector practitioners

$$= \frac{120}{798} \times 266 = 40 \qquad (3.3)$$

Table 3.2: Proportionate sample size from each of the study population

Proportionate Sample size	Number of respondents
113 Rural communities	226
Power sector practitioners	40
TOTAL	**266**

Source: Researcher's Field survey, 2019

The implication of the calculations above is that two number of respondents in each of the selected rural communities will be randomly selected

3.6 Instrument for Data Collection

Both primary and secondary data were used for this study. Primary data were be collected through structured questionnaire. The questionnaire was divided into four sections. Section A ask about the respondents' biodata, and section B examines the perception on accessibility and demand of electricity in isolated rural communities. Section C asked questions concerning factors affecting the full implementation and ways of sustaining renewable off-grid power generation. The respondent were to identify and rank these factors. In order to ensure that the respondents give accurate information, the researcher through interaction, got approval and willingness to participate in the survey. Again, privacy, and anonymity of the respondent were ensured to encourage honest response without any fear of consequences.

3.7 Administration of Questionnaire

The study's population of interest included 6 community representative from the 113 rural communities, several industry practitioners including electrical engineers, mechanical engineers, project managers, technicians. These professionals work in MDAs, professional consultancy firms, generation, transmission, and distribution sub-sectors, etc. located in Niger state, Nigeria. The questionnaire titled 'The Management and Sustainability of Renewable Off-Grid Power Generation Questionnaire' was distributed by the researcher and four helpers. The four helpers have helped the researcher to distribute the questionnaires in five of the twenty-five local government area of the state, while the researcher distributed the questionnaires of the remaining five local government and industry professionals to the respondents in their communities and places of work respectively. Instructions on how to fill the questionnaire was made simple so that the respondent will fill the questionnaire and return it back to the researcher. The researcher spent 18 days before he could retrieve back the administered questionnaires from the one hundred rural communities and industry practitioners.

3.8 Method of Data Analysis

The valid questionnaires were collected and analyzed using Statistical Package for the Social Sciences (SPSS) 20.0. Results were presented using descriptive statistics. Percentage, frequency and charts were used to present the results of the demographic data while mean, standard deviation, and relative importance index (RII) was used to present the results obtained from the research questions.

CHAPTER FOUR

4.0 RESULTS AND DICUSSION

4.1 Introduction

This chapter of this research work deals with the presentation and analysis of data collected from various sources. The collected data were analyzed using descriptive statistic, which enable the researcher summarize the quantitative data. The descriptive statistic described the sample in terms of the responses to the questions using frequency table, percentages, means and standard deviation. Frequency and percentage tables were used to present the demographic data, while mean, standard deviation, and relative importance index (RII) were used to analyze the data obtained from the research questions.

4.2 Returns Rates/Responses

The representative sample size of this research, which is 266 respondents from representative rural communities (RRC) and power sector practitioners (PSP) was arrived at by the proportionate stratified random sampling methods as detailed in the methodology section of this study. The return rate of the 266 administered questionnaires is 242. Out of the 242 questionnaires that were retrieved, 234 questionnaires were considered valid for analysis. This figure represents 88% response rate.

Table 4.1: Gender Distribution of Respondents

Gender	RRC	%	PSP	%
Male	116	58.6	31	88.6
Female	82	41.4	4	11.4

Total	198	100	35	100

Source; Researcher's Field Survey, 2019

Table 4.1 depicts the gender of the respondents of the representative rural communities, and power sector practitioners in Niger state. The former account for 58.6% & 41.4% of male and female respectively, while the latter constitute 88.6% & 11.4% male and female respectively.

Table 4.2: Age Distribution of Respondents.

Age range	RRC	%	PSP	%
20 – 24	15	7.6	1	2.9
25 – 29	34	17.2	4	11.4
30 – 34	65	32.8	9	25.7
35 – 39	54	27.3	13	37.1
40 – above	30	15.2	8	22.9
Total	198	100	35	100

Source; Researcher's Field Survey, 2019

Table 4.2 reveals the age distribution of respondents for the study. The summation of respondents with less than 40 years of age is 195 representing is 83.3%. The summation of respondents above 40 years of age is 38 which is 16.2%.

Table 4.3: Highest Academic Qualification of Respondents

Edu. Qual.	RRC	%	PSP	%
None	114	57.6	-	-
Primary Edu.	58	29.3	-	-
SSCE	26	13.1	-	-
HND	-	0	12	34.3
BSc/BEng/BTech	-	0	17	48.6

MSc/MEng/MTech	-	0	6	17.1
PhD	-	0	-	-
Others	-	0	-	-
Total	198	100	35	100

Source; Researcher's Field Survey, 2019

Table 4.3 presents the highest qualification of the respondents from the representative rural communities, and power sector practitioners. The Table shows that only 84 respondents in the rural communities, representing 42.4% are educated having a minimum of Primary School Certificate and maximum of Secondary School Certificate Education (SSCE). Whereas, 34.3%, 48.6%, and 17.1% of power sector respondents have HND, Bachelors' degree, and Masters' degree respectively.

4.3 Presentation and analysis of results obtained from research questions

This sub-section of the chapter presents results obtained from the research questions. This research will report the mean score along with the rank.

Objective 1: To examine the accessibility to electricity in isolated rural communities

4.3.1 Accessibility of rural communities to Electricity in Niger state

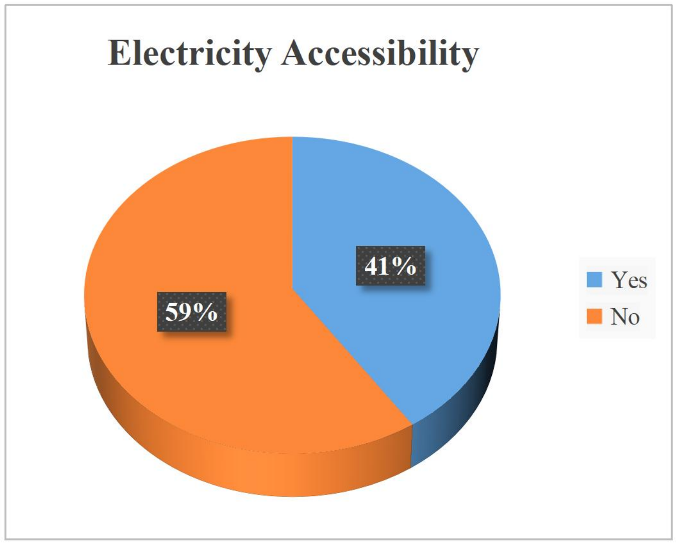


Figure 4.1 Electricity accessibility in Rural Communities
Source: Researcher's Field Survey, 2019

From Figure 4.1, respondents expressed their views concerning the accessibility of electricity in rural communities in Niger state. One hundred and thirty-nine (139) of the respondents, representing 59% agreed that rural communities are accessible to electricity. The other 41% are of the opinion that rural communities are accessible to electricity in Niger State.

Objective 2: To examine electricity demand in rural communities

4.3.2 Electricity demand in rural communities

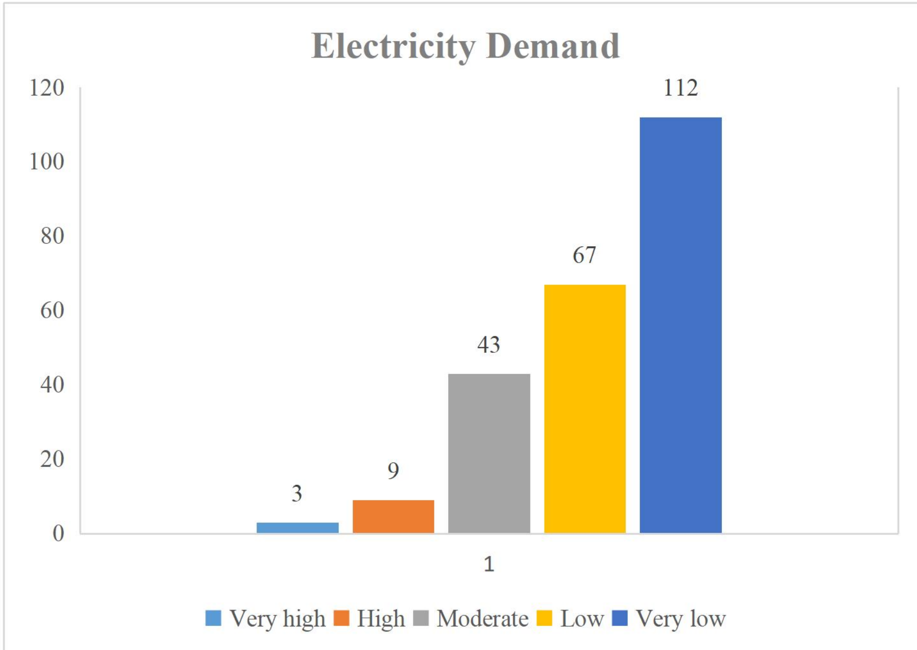


Figure 4.2: Electricity demand. ***Source; Researcher's Field Survey, 2019***

Electricity demand is the amount of electrical energy consumed at a given time, measured in KiloWatt hour (KWh). Data was obtained from both primary and secondary source to efficiently analyze this aspect. Primary data source was deployed to ensure conformity and the authenticity of with the secondary data. Appendix 2 shows the electricity demand of 113 rural communities randomly selected for this study. However, field survey results shows that 179 respondents representing 76.5% agreed that electricity demand in rural communities is generally low in Niger state. This is mostly due to the fact that unlike the urban dwellers, majority of these rural community dwellers do not have appliances with high power ratings.

Objective 3: To explore the factors affecting the full implementation of off-grid power generation

4.3.3 Factors hindering the full implementation of off-grid power generation

Table 4.5: Factors hindering the full implementation of off-grid power generation

S/NO	Factors	1	2	3	4	5	Weighted Point Total	MS	RII
1	Lack of technical know-how	12	14	42	85	56	786	3.76	4
2	Socio-cultural and behavioural barrier.	64	43	38	40	35	599	2.72	10
3	Political and market barrier	8	15	48	78	61	799	3.80	3
4	Economic and financial barrier	20	43	45	63	32	653	3.22	7
5	Policy and institutional barrier.	28	18	34	94	57	827	3.58	6
6	Data access and ownership	44	46	54	46	41	687	2.97	8
7	High initial capital costs and higher perceived risks of the renewable energy technology	18	24	46	83	62	846	3.63	5
8	Inadequate decision space	51	43	51	38	47	677	2.94	9
9	Lack of awareness programs for the renewable energy consumption	5	7	41	80	95	937	4.11	1
10	Natural disasters.	70	63	55	15	12	481	2.24	
11	Lack of proper planning and designing challenges	11	21	58	67	76	875	3.76	4
12	Adulteration of the off-grid equipment and low off-grid Technology.	27	18	38	77	70	835	3.63	5
13	Corruption	4	8	57	78	84	923	4.00	2

Source: Researcher's Field Survey, 2019

Table 4.5 presents the factors hindering the full implementation of off-grid power generation in Niger state. These factors were assembled from literature and presented to respondents. The mean score (MS) of the factors was calculated using the weighted point total (WPT) value for ranking. Lack of awareness programs for the renewable energy consumption, corruption, and political barriers ranked 1st, 2nd, and 3rd with mean score of 4.11, 4.00, and 3.80 respectively. Lack of proper planning and designing challenges, high initial capital costs and higher perceived risks of the renewable energy technology with mean score 3.76, 3.63 ranked 4th, 5th, 6th respectively.

Objective 4: To examine ways of sustaining renewable off-grid power generation.

4.3.4 Ways of sustaining renewable off-grid power generation in rural communities

Table 4.6: Factors for sustainable off-grid power generation in rural communities

S/NO	Factors	1	2	3	4	5	Weighted Point Total	MS	RII
1	Technical training on renewable off-grid power generation	12	23	47	67	57	752	3.65	4
2	Awareness on renewable off-grid power generation	12	18	37	76	81	868	3.88	1
3	Knowledge of available off-grid energy	11	15	47	71	75	841	3.84	2
4	Financial Analysis	15	32	39	53	74	778	3.65	5
5	Policy and institutional barrier.	21	27	43	52	71	767	3.58	6
6	Proper planning and implementation	15	13	45	66	73	805	3.80	3

Source: Researcher's Field Survey, 2019

The essence of sustaining renewable off-grid power generation for rural communities is to ensure continuative in operation of such projects if eventually implemented. In addition sustaining such projects may include strategic planning and policies to ensure quality project delivery, operation, and maintenance. Table 4.6 shows the enabling factors to ensure sustainable off-grid power generation in Niger state. These factors were extracted from literature and ranked using the mean score (MS) values. Awareness on renewable off-grid power generation, knowledge of available off-grid energy, and proper planning and implementation with MS values 3.88, 3.84, 3.80 ranked 1st, 2nd, and 3rd respectively. This is an implication that; with increased awareness and knowledge of off-grid energy, coupled with proper planning and implementation policy for off-grid power projects, sustainability of these projects can be assured.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary

This research investigated the effective management and sustainability of renewable off-grid power generation project in Niger states. The research examined electricity demand in rural communities. The second objective of the research is to examine the accessibility to electricity in isolated rural communities, while the third objective is to explore the factors affecting the full implementation of off-grid power generation. The fourth is to examine ways of sustaining renewable off-grid power generation. To achieve the research objectives, the researcher designed a questionnaire aimed to source out the data required for the complete execution of the research. The questionnaire was divided into sections and each section deals with single research objective. The multistage random sampling was used to select one hundred and thirteen rural communities randomly selected across the twenty-five local government area of the state. The stratified proportionate random sampling was used to obtain 242 respondents out of the 266 population made up of representative rural communities and power sector practitioners. The questionnaire was a close ended one which collected data using the five scale Likert form which starts from 1 (very little) to 5 (very much).

Descriptive statistic was used for data analysis. Frequency tables and percentage were used to present the demographic information. Weighted point total, mean score and relative importance index were used to present the results obtained from the research questions.

5.2 Conclusion

Findings from the first two objectives of the research revealed that electricity accessibility, and demand in rural communities of Niger state are relatively low. The low demand is due to the fact that majority of the rural community dwellers do not use appliances with very high power ratings. The finding of the third objective of this study highlighted some of the most common factors hindering the full implementation of off-grid power generation for rural communities. These factors based on their relative important index (RII) values are:

1) Lack of awareness programs for the renewable energy consumption
2) Corruption
3) Political and market barrier
4) Lack of proper planning and designing challenges
5) High initial capital costs and higher perceived risks of the renewable energy technology
6) Adulteration of the off-grid equipment and low off-grid Technology.

Finally, the last objective examined ways of sustaining renewable off-grid power generation. Findings identified some factors responsible for sustaining off-grid power generation. These factors based on their relative important index (RII) values are;

1) Awareness on renewable off-grid power generation
2) Knowledge of available off-grid energy
3) Proper planning and implementation
4) Technical training on renewable off-grid power generation

5.2 Recommendation

- To emphasize the need for increase in awareness on renewable power generation through trainings, workshops. This will deepen knowledge and competency in the area.

- To encourage further investments in off-grid solutions, it is important that the government ensures an enabling environment for renewable energy generation to thrive.
- Projects for rural electrification should be adequately funded, efficiently planned, and effectively executed to ensure prolonged design life.
- Collaboration with the World Bank, United Nations (UN), NGOs and other institution to develop the power sector.
- All tiers of government be duty-bound to implement off-grid projects to make the country attain its long-term plans of sustainable power supply.
- Need for a vigorous review of power sector professions curriculum to lay a strong foundation for improved knowledge of renewable energy.

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Appendix 1: Population of selected rural communities in Niger state

S/N	Rural Community	LGA	Sam le Pop atio
1	Tagagi	Agaie	6
2	Boku	Agaie	6
3	Baro	Agaie	6
4	Magaji	Agaie	6
5	Dauaci	Agaie	6
6	Etsugaie	Agaie	6
7	Kutiriko	Agaie	6
8	Papiri	Agwara	6
9	Dugga	Agwara	6
10	Papiri	Agwara	6
11	Gallah	Agwara	6
12	Agwata	Agwara	6
13	Kashini	Agwara	6
14	Dugga	Borgu	6
15	Karabonde	Borgu	6
16	Konkoso	Borgu	6
17	Malale	Borgu	6
18	Kabe/pissa	Borgu	6
19	Wawa	Borgu	6
20	Garatu	Bosso	6
21	Shata	Bosso	6
22	Maikunkele	Bosso	6
23	Kodo	Bosso	6
24	Mambe	Edati	6
25	Gaba	Edati	6
26	Jima	Edati	6
27	Etsu tasha	Edati	6
28	Sakpe	Edati	6
29	Gaba	Edati	6
30	Edozhigi	Gbako	6
31	Batagi	Gbako	6
32	Etsu audu	Gbako	6
33	Batako	Gbako	6
34	Sammajiko	Gbako	6
35	Edokota	Gbako	6
36	Kurmin sarki	Gurara	6
37	Kabo	Gurara	6
38	Kwaka	Gurara	6
39	Diko	Gurara	6
40	Shako	Gurara	6
41	Lambata	Gurara	6
42	Edotsu	Katcha	6
43	Edotsu	Katcha	6
44	Gbakogi	Katcha	6
45	Sidi saba	Katcha	6

S/N	Rural Community	LGA	Sample Population
46	Bakeko	Katcha	6
47	Essa	Katcha	6
48	Bisanti	Katcha	6
49	Badeggi	Katcha	6
50	Gurdi/zago	Lapai	6
51	Takuti/shaku	Lapai	6
52	Evuti/kpada	Lapai	6
53	Birnin maza	Lapai	6
54	Lefu	Lapai	6
55	Lagun	Lavun	6
56	Gbangban	Lavun	6
57	Dabban	Lavun	6
58	Egbako	Lavun	6
59	Tukunji	Lavun	6
60	Nassarawa	Magama	6
61	Auna central	Magama	6
62	Ibelu north	Magama	6
63	Ibelu north	Magama	6
64	Kumbashi	Mariga	6
65	Bobi	Mariga	6
66	Galma	Mariga	6
67	Kakangi	Mariga	6
68	Warari	Mariga	6
69	Kontokoro	Mariga	6
70	Mazakuka	Mashegu	6
71	Dapangi	Mashegu	6
72	Kwatachi	Mashegu	6
73	Mashegu	Mashegu	6
74	Mashegu	Mashegu	6
75	Kasanga	Mashegu	6
76	Kaboji	Mashegu	6
77	Saho-rami	Mashegu	6
78	Etsu tasha	Mokwa	6
79	Muregi	Mokwa	6
80	Rokota	Mokwa	6
81	Kpaki	Mokwa	6
82	Kudu	Mokwa	6
83	Gbajibo	Mokwa	6
84	Rabba	Mokwa	6
85	Fuka	Muya	6
86	Kuchi	Muya	6
87	Sarkin pawa	Muya	6
88	Ishau	Pailoro	6
89	Chimbi	Pailoro	6
90	Kwagana	Pailoro	6
91	Ishau	Pailoro	6

S/N	Rural Community	LGA	Sample Population
92	Bishini	Pailoro	6
93	Gwam	Pailoro	6
94	Jere	Pailoro	6
95	Manta	Rafi	6
96	Manta	Rafi	6
97	Kagara gari	Rafi	6
98	Kakuri	Rafi	6
99	Inkwai	Rafi	6
100	Shambo	Rijau	6
101	Danrangi	Rijau	6
102	Bassa	Shiroro	6
103	Gurmana	Shiroro	6
104	Gayam	Shiroro	6
105	Zuma east	Tafa	6
106	Dogon kurmi	Tafa	6
107	Garam	Tafa	6
108	Akare	Wushishi	6
109	Sabon gari	Wushishi	6
110	Kodo	Wushishi	6
111	Tukunji	Wushishi	6
112	Akare	Wushishi	6
113	Zungeru	Wushishi	6
	SUB-TOTAL		**678**
	Industry practitioners		120
	GRAND TOTAL		**798**

Source: Field survey, (2019)

Appendix 2: Electricity Demand in Rural Communities in Niger state

S/NO	Rural C	Demand
1	Tagagi	584
2	Boku	139
3	Baro	120
4	Magaji	112
5	Dauaci	209
6	Etsugaie	66
7	Kutiriko	94
8	Papiri	169
9	Dugga	134
10	Papiri	102
11	Gallah	833
12	Agwata	85
13	Kashini	146
14	Dugga	694
15	Karabonde	358
16	Konkoso	115
17	Malale	261
18	Kabe/pissa	523
19	Wawa	94
20	Garatu	85
21	Shata	183
22	Maikunkele	107
23	Kodo	79
24	Mambe	69
25	Gaba	328
26	Jima	278

S/NO	Rural C	Demand
27	Etsu tasha	119
28	Sakpe	128
29	Gaba	83
30	Edozhigi	72
31	Batagi	277
32	Etsu audu	136
33	Batako	86
34	Sammajiko	81
35	Edokota	295
36	Kurmin sarki	121
37	Kabo	208
38	Kwaka	149
39	Diko	135
40	Shako	102
41	Lambata	147
42	Edotsu	151
43	Edotsu	80
44	Gbakogi	156
45	Sidi saba	76
46	Bakeko	155
47	Essa	81
48	Bisanti	155
49	Badeggi	117
50	Gurdi/zago	171
51	Takuti/shak	140

S/NO	Rural C	Demand
	u	
52	Evuti/kpada	129
53	Birnin maza	101
54	Lefu	122
55	Lagun	185
56	Gbangban	76
57	Dabban	64
58	Egbako	178
59	Tukunji	179
60	Nassarawa	73
61	Auna central	656
62	Ibelu north	141
63	Ibelu north	92
64	Kumbashi	142
65	Bobi	146
66	Galma	105
67	Kakangi	87
68	Warari	75
69	Kontokoro	234
70	Mazakuka	113
71	Dapangi	117
72	Kwatachi	65
73	Mashegu	102
74	Mashegu	147

S/NO	Rural C	Demand
75	Kasanga	125
76	Kaboji	170
77	Saho-rami	120
78	Etsu tasha	183
79	Muregi	85
80	Rokota	98
81	Kpaki	99
82	Kudu	115
83	Gbajibo	331
84	Rabba	6662
85	Fuka	81
86	Kuchi	206
87	Sarkin pawa	166
88	Ishau	217
89	Chimbi	138
90	Kwagana	89
91	Ishau	231
92	Bishini	116
93	Gwam	214
94	Jere	73
95	Manta	112
96	Manta	337
97	Kagara gari	206
98	Kakuri	87
99	Inkwai	101
100	Shambo	72
101	Danrangi	85
102	Bassa	386
103	Gurmana	401
104	Gayam	130
105	Zuma east	331
106	Dogon kurmi	256
107	Garam	1081
108	Akare	265
109	Sabon gari	76
110	Kodo	102
111	Tukunji	95
112	Akare	140
113	Zungeru	445

Source: Nigeria Rural Electrification Plans (NESP) (nd)

APPENDIX 3

INTRODUCTION LETTER

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STAE

DEPARTMENT OF PROJECT MANAGEMENT TECHNOLOGY

SCHOOL OF ENTREPRENEURESHIP AND MANAGEMENT TECHNOLOGY (SEMT)

Sir/Ma

REQUEST FOR FILLING THE MANAGEMENT AND SUSTAINABILITY OF RENEWABLE OFF-GRID POWER GENERATION QUESTIONNAIRE

I am AUDU DANGANA BAKO, a postgraduate student of Federal University of Technology, Minna Nigeria from the Department of Project Management Technology. I am carrying out a research on "*Effective Management and Sustainability of Renewable Off-Grid Power Generation in Nigeria*". Please kindly help me provide answers to these questions and note that your cooperation and contribution to this questionnaire is important for the success of this study. This information will be kept in the strictest confidence and use for statistical purposes only.

Yours sincerely,

AUDU DANGANA BAKO

M.TECH/SEMT/2017/7464

APPENDIX 4

SAMPLE OF THE RESEARCH QUESTIONNAIRE

Section A: Bio data

Instruction: Please tick **[√]** the appropriate box as it applies to you

1. Sex: Male [ ] Female [ ]

2. Age: 20 – 24 [ ] 25 – 29 [ ] 30 – 34 [ ] 35 – 39 [ ] 40 – above [ ]

3. Level of Education:

   HND/BSc [ ] MSc/MEng/MTech [ ] PhD [ ] Others [specify]……

4. What is your area of specialization?

   Electrical Engineer [ ] Mechanical Engineer [ ] Project Manager [ ]

   Technicians [ ] Others [specify] …..

5. What is your year of experience?

   1 – 5 [ ] 5 – 10 [ ] 10 – 15 [ ] 15 – above [ ]

Section B

This section evaluates your perception on accessibility and demand of electricity in isolated rural communities.

NB

Metrics for the ranking of probabilities are as follows:

Very high = 5

High = 4

Moderate = 3

Low = 2

Very low = 1

Instruction: Please tick **(√)** the appropriate box as it applies to you or give your comment if necessary.

1. Are rural communities accessible to electricity in Niger state?

   Yes [   ]   NO [   ]

2. What is the electricity demand in the rural communities?

	1	2	3	4	5
Electricity Demand					

Section C

This section identifies the factors affecting the full implementation and ways of sustaining renewable off-grid power generation.

3. What are the factors hindering the full implementation of off-grid power generation?

S/NO	Factors	Please, tick as appropriate
1	Lack of technical know-how	
2	Socio-cultural and behavioural barrier.	
3	Political and market barrier	
4	Economic and financial barrier	
5	Policy and institutional barrier.	
6	Data access and ownership	
8	High initial capital costs and higher perceived risks of the renewable energy technology	
9	Inadequate decision space	
11	Lack of awareness programs for the renewable energy consumption	
12	Natural disasters.	
13	Lack of proper planning and designing challenges	
14	Adulteration of the off-grid equipment and low off-grid Technology.	
15	Corruption	
	Others, please specify	

4. On a scale of 1(lowest) -5(highest), rank the challenges limiting the full adoption of off-grid power generation? (Please, tick as appropriate)

S/NO	Factors	1	2	3	4	5
1	Lack of technical know-how					
2	Socio-cultural and behavioural barrier.					
3	Political and market barrier					
4	Economic and financial barrier					
5	Policy and institutional barrier.					
6	Data access and ownership					
7	High initial capital costs and higher perceived risks of the renewable energy technology					
8	Inadequate decision space					
9	Lack of awareness programs for the renewable energy consumption					
10	Natural disasters.					
11	Lack of proper planning and designing challenges					
12	Adulteration of the off-grid equipment and low off-grid Technology.					
13	Corruption					
14	Others, please specify					

5. What are the ways of sustaining renewable off-grid power generation in rural communities?

S/NO	Factors	Please, tick as appropriate
1	Technical training on renewable off-grid power generation	
2	Awareness on renewable off-grid power generation	
3	Knowledge of available grid energy	
4	Financial Analysis	
5	Policy and institutional barrier.	
6	Proper planning and implementation	
	Others, please specify	

6. On a scale of 1(lowest) -5(highest), rank the ways of sustaining the adoption of renewable off-grid power generation in rural communities (Please, tick as appropriate)

S/NO	**Factors**	1	2	3	4	5
1	Technical training on renewable off-grid power generation					
2	Awareness on renewable off-grid power generation					
3	Knowledge of available grid energy					
4	Financial Analysis					
5	Policy and institutional barrier.					
6	Proper planning and implementation					