AN INVESTIGATION OF MODELS OF COMMUNITY-BASED LOW-CARBON DISTRIBUTED ENERGY SYSTEMS IN NIGERIA

Author: Ibrahim Abubakar Sadiq

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University of Salford

School of Science, Engineering, and Environment

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BP	British Petroleum
BCO	Blue Camel Organisation
CES	Community Energy System
CDM	Clean Development Mechanism
CCRE	Climate Change and Renewable Energy
DER	Distributed Energy Resources
DC	Danjawa Community
DISCO	Distribution Company
DIREP	Danjawa Integrated Renewable Energy Project
ECN	Energy Commission of Nigeria
ESCO	Energy Service Company
EPC	Energy Performance Contracts
FRN	Federal Republic of Nigeria
FMP	Federal Ministry of Power
GC	Gnami Community
GHG	Greenhouse Gas
GSWHP	Guzape Solar-Wind Hybrid Project
GOSPP	Gnami Off-grid Solar Power Project
GD	Guzape District
HTC	Huawei Technologies Company
IMF	International Monetary Fund
IDS	International Development Association
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
SERC	Sokoto Energy Research Centre
SDG	Sustainable Development Goals Usma Water Board
LDS	Low-carbon Distributed Energy System
MLP	Multi-level perspective
NEPA	National Electicity Power Authority
NESCO	National Electiricity Supply Corporation Limited
NREEEP	National Policy on Renewable Energy Efficiency
PSHPP	Pleatue State Hyropower Project

SDR	Special Drawing Rights
SST	Social Shaping of Technology
UDU	Usman Danfodiyo University
UWB	Usuma Water Board
WEO	World Energy Outlook

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Declaration

I, Ibrahim Abubakar Sadiq, declare that this thesis is my original work, contribution to knowledge, and has not been submitted to elsewhere for any award. Any part, section, or phrasing idea that has been used or copied from literature reviews has been referenced at the point of citation as well as in the reference list of this thesis.

Abstract

This thesis undertakes research into community-based low-carbon distributed energy systems in Nigeria. It focuses the socio-technical factors of the development and operation of community energy systems, ranging from increasing population and economic growth to the issues of climate change and energy access as drivers for low carbon community energy systems.

The emergence of community low-carbon energy generation is an important factor for peripheral urban communities in Nigeria, addressing the key challenges to the energy system in Nigeria. The thesis explores the delivery of a low carbon energy system and the engagement with and impact on the participating community. This includes the social and cultural aspects and relationships between community key factors such as households, businesses, individuals, and national and local government involved in the development and operation of low carbon distributed energy systems. It also identifies the issues of innovative technologies, including the energy generation systems, energy storage systems, energy services and financial aspects, which should be adopted for the development and operation sustainable system. It examines distributed renewable energy technologies through a community ownership model to address the problem of the energy system in Nigeria.

The research is an empirical investigative study adopting a multiple case study approach to identify the impacts of socio-technical aspects, the actors and management of community energy system. Four main case studies and a pilot case study selected to explore the socio-technical aspects of different community energy projects in Nigeria. These community energy projects comprised the Usuma Solar project in Abuja (USP); the Guzape Solar-Wind Hybrid Project in Northern Abuja (GSWHP); the Gnami Off-grid Solar Power Project in Kaduna (GOSPP); and the Danjawa Integrated Renewable Energy Project in Sokoto (DIREP). The research explores how the different and similar factors and issues such as motives, funding sources, and benefits of the energy projects from different community energy projects are involved in relation to key actors.

The key findings of the research highlight the importance of effective capitalisation of the project, particularly with a view to the long-term sustainability of the project. It also highlights the issues of effective system governance and how failure can create technical issues for the system. It concludes that the structural model of community governance, both formal and informal at the local level facilitates providing better decisions for the supply of technical aspects. Additionally, energy access programmes for community energy systems would enable financial sustainability for the operation and maintenance of community energy projects. Finally, the research recommends to further study for local renewable energy generation and energy efficiency measures.

Chapter 1 : Introduction

1.1 Overview

This thesis presents exploratory research focusing on the development of community low carbon distributed systems in Nigeria, designed for the delivery of sustainable community-based energy as a response to issues of unreliable power supply, high dependency on fossil fuels, poor infrastructure. A community based renewable energy approach is considered for three main reasons: it could facilitate innovations for a low carbon community; it could enable a more decentralised energy system, which saves the costs of generating a centralised energy system; and it has the potential to improve the local economy. This chapter begins with a brief overview of the research background, and underlying motivations around important questions of community energy; exploring the issues of energy access and poverty, climate change, and institutions and infrastructures of energy systems used through the power sector paradigm, which may cause issues in terms of sustainable development. It also presents the research aims and objectives. The chapter will highlight the proposed contribution of the research. A summary description of the structure of the thesis will be presented.

1.2 Research Background and Justification

1.2.1 Research Background: Framing the Research Problem

The Nigerian government has sought to develop its energy policies through sustainable development goals (SDG), in which achieving universal energy access is the key issue that leads the country to change the mainstream governance structures of sustainable energy, which identifies energy targets, particularly for the adoption of renewable energy (Ayre and Callway 2013, von Stechow, Minx et al. 2016). SDG measures are part of a global energy transformation, putting forward measures designed for current and future sustainable development. The aim of these SDGs is to overcome any form of poverty, inequalities, and other related energy issues(von Stechow, Minx et al. 2016), including economic growth, access to energy, climate change and the governance energy system. This section starts with the key issues which will briefly explore the global energy issues that may underpin the adoption of community energy systems and justify the reasons why a community energy system is important for peripheral urban areas in Nigeria.

The Special Report of the IPCC on Global energy issues, such as climate change and energy security, indicates that (Roy, Tschakert et al. 2018) the way energy is produced and used by human activities caused the high level of global concerns. These concerns may be due to the large electricity demand in the building sector, particularly the resulting of economic growth and prosperity in developing nations, where there are relatively growing energy demand issues for electricity, heating, and cooling activities (Mitchell 2016). This is partly a question of sustainable development, strengthening the sense that the needs of present generations may be satisfied without compromising the ability of future generations in terms of needs and challenges, and the integrity of ecosystems no which human beings rely on survival(Ekins, Bradshaw et al. 2015, Roy, Tschakert et al. 2018). Global energy issues related these to challenges pose not only a threat to human health, the welfare of the humankind and the natural environment, but also raise the challenge of climate change.

1.2.1.1 Climate Change and Energy Consumption

Currently, energy use is growing at a higher level globally, particularly the use of electricity in the residential sector is projected to grow by 80% by 2050 (Roy, Tschakert et al. 2018), and this significantly contributes to global emissions (Johansson, Patwardhan et al. 2012) (Mitchell 2016). The contribution of carbon emissions through the burning of fossil fuels has been recognised as a large cause of anthropogenic greenhouse gases (GHG) emissions the main recognised drivers of climate change. Climate change reflects the rising cost of energy services and the severe consequences associated with GHG. This issue could likely cause a global average that leads to temperature rising over 2 0C.

The assessment report of the IPCC on global warming was (Pachauri, Allen et al. 2014, Roy, Tschakert et al. 2018, Maibach, Sarfaty et al. 2019) released in 2018 and concluded that the effect of climate change is the result of human activities and has steadily led to a serious threat to the human population. These effects include extreme weather events, soil moisture, contraction of glaciers, and a change of precipitation and sea levels, and they are likely to destabilise the water, food, and farmland on which humankind relies. This will have vulnerable effects if left without taking the costs of action in mitigation and adaptation, as a rise in greenhouse gas (GHG) into the atmosphere will result in increasing global average temperatures. The incidence of environmental catastrophes causes by climate change and leads to the question of what to do about the matter of climate change and searching for newer energy options. The meeting of international energy forums between the stakeholders around the world brought framework measures for climate change and reducing emissions, such as legally binding in 2008 as the Climate Change Act in the UK. This brought different responsibilities for many nations in reducing GHG emissions by 75% below 1990 levels by 2050. As a result of the 2016 Paris agreement and commitments, there are currently new national pledges among countries globally on the climate change measures of transitions in energy efficiency and the use of low carbon resources (Thorne and Mittal 2019). This action leads to the UK and other EU nations such as Spain and France increased collaborative commitments aimed by responding and reducing emissions by at least 100% of the 1990 level in the year 2050.

A community based low carbon energy system is a potential approach to increase the use of low carbon energy generation to accommodate embedded behavioural change through several stands of sustainability. It contributes to reducing emissions and the effects of global greenhouse emissions by using the various options of renewable energy.

1.2.1.2 Energy security

Energy insecurity is another global energy concern that includes the threat of fuel reserves and the relationships between the various nations regarding net energy exporters and importers. In addition, energy security is one of the important issues in relation to sustainable access to energy, ensuring a stable and abundant supply of energy. This issue is the response to economic growth and societal energy demand, which undermines the global efforts of mitigating climate change (IRENA, 2019). There is also examples of the consequent issue related to the issues in energy needs. Therefore, relying on fossil fuels will lead to a time where the world would not satisfy global demand due to limited energy supply, that leads to adverse impacts. This is what Dorian, Franssen et al. (2006) called energy insecurity, in terms of a finite supply. The consequent action due to the need for exploration and production fuels caused an incident in Blackpool (Hunter and Paterson 2014). Similarly, Igbinovia (2014) highlighted that there was a vandalization of oil and gas facilities in Nigeria; where pipelines remain the key challenge regarding energy security in the country. Additionally, energy insecurity has an impact on the geographical economy of regions (Mahmood and Ahmad 2018), and relationships between net importers and exporters. This considers that the effect of changing energy prices and crises disrupt the energy supply, particularly for countries who depend on energy imports. As stated in the previous section, the shifting the world away from the use of fossil fuels would be the reduction of energy use, due to the electrification of heating and efficiency measures in cooling use. Energy sector such as residential sector can be contributed more efficiency measures and the adaptation of renewable energy to supply the growing of energy consumption.

The instability of fossil fuels among countries creates the deterioration of financial markets and the weakening of relationships with countries promoting subsidy schemes (Ekins, Bradshaw et al. 2015). A decrease in prices in the global energy markets in recent years also led to difficulty for countries who were reliant on the mono fossil fuel economy (Al-Maamary, Kazem et al. 2017), and oil and gas exporting countries such as Nigeria, became vulnerable as a result of the dropping oil prices, which triggered significant reduction in the annual budget in planning for expected economic growth (Johansson, Patwardhan et al. 2012). IEE (2019) predicted the possible impacts on fossil fuel uncertainty on the global economy and estimated that the world economy could shrink by 9%.

There are technological measures in terms of diversifying and increasing energy production options, through the sustainable generation of low carbon energy, particularly regarding distributed community energy and renewable energy, which can be an important factor in addressing issues of energy security (Zong, Cao et al. 2018, Levenda, Richter et al. 2019). The development of new clean energy systems, the technologies that release less significant emissions, such as a combined heat and power and a tri-generation (power, heat and cooling), which commonly finds in UK as a part of the mix of technologies when implementing innovative technologies to their energy market where replacing fossil fuels helps in responding to energy security concerns. This includes benefits of efficient costs and effective solutions in the way community energy systems participate in the market, applying the systems, approaches of energy efficiency in buildings (Swan, Ruddock et al. 2013, Mourato and Bussler 2019), and local energy generation systems in order to scale up the issue of energy access concerns particularly in developing countries (Legros, Havet et al. 2009).

1.2.1.3 Access to energy

Energy access ensures social and economic improvements by means of energy services. There are a number of definitions of energy access, but they are generally limited to energy users having accessible, reliable, available and affordable access to energy services (Crousillat, Hamilton et al. 2014), in the sense that electricity can be delivered up to the level of electricity consumption over time, stabilising and reaching national average demands (Sokona, Mulugetta et al. 2012). This outlined by Sambo who identified that the provision of electricity for cooking and lighting by society, and the electricity reduces the use of biomass, which alleviates poverty, and increases economic development (Sambo 2016).

It is identified that there is an indication of the availability of energy and the use of renewable energy technologies, but the world commitment is slowing to meet SDG7 (Mulugetta and Agbemabiese 2019). This might be related to a report from the International Energy Agency, which suggested that over a billion people globally are deprived of basic electricity provision and need to scale up with energy access programmes (Adusah-Poku and Takeuchi 2019). Most of the people are confined to developing countries. Lack of access to energy generally indicates poor provisions in other areas such as health, education and food nutrition within the communities, and is defined (Adusah-Poku and Takeuchi 2019) as a poverty obstacle in sustainable development. One way to tackle the multi-dimensional aspects of poverty caused by the lack of energy access is to promote energy opportunities in the delivery of low-carbon distributed energy systems for community residents.

In 2017, the issue of energy development in the World Energy Outlook (International Energy Agency 2010) led to new policies in the International Energy Agency's plans, in order to achieve basic universal access to energy by 2030. This required an increase in additional electricity generation for a minimum capacity of 250 gigawatts (GW). The target is to be achieved within the framework of sustainable development goal 7 (SDG 7). Under this scenario, developing economies are required to have additional electricity generation because energy poverty is expected to remain a problem in these countries if they will not apply sustainable energy measures. To achieve this, the deployment of community renewable energy will be crucially ensured the availability of financial approaches, and technical and economic information for rural and urban communities in developing countries, where the lack of energy access limits people's progress.

1.2.2 Research Justification

Nigerian government action on universal sustainable energy has set a foundation within the framework of national energy efficiency and renewable energy policy of Nigeria. This has led to vision 20:20:20, which commenced in 2010, and the review was set up under the climate change policy and SDG7 strategy in order to achieve basic universal access to energy, in line with the International Energy Agency's policy. Nigeria has followed the path to achieving a global and national vision with the purpose of being among the 20 countries in the world with leading economies by 2020. The vision of this is to overcome key energy challenges such as financial constraints, which encourage businesses and shareholders to make investments, which limit the country's development.

One of the main measures the Nigerian government proposed was an energy mix strategy to meet the target of accelerating energy production capacity in order to promote sustainable economic development. The government's plan includes moving to the use of more renewable sources, diversifying for several energy supply options, meeting potential energy resources in the country, (Oyedepo 2012), thus Nigeria redefined its electricity plan 30:30:30, (shown in **Table 1:1**) to achieve the energy target by further increasing the use of renewable energy, which can contribute about 30% of energy capacity.

Table 1:1: Nigerian Renewable Energy Targets

Technologies and energy resources	**Short term target**	**Medium-term target**	**Long term target**
Large Hydropower	1097 MW	2,540MW	4,700
Small hydropower	15 MW	265MW	1,200MW
Solar projects	-	2,050MW	6,000MW
Biomass project	-	300	1,100
Wind turbines	-	1700MW	800MW

It has also targeted the extension of on-grid renewable capacity through large hydropower and other renewable energy technologies, with the provision of 5,300MW and 13,800MW in the years of 2020 and 2030, respectively.

The level of national ambition for energy access is confined to the approach of grid extension through gas thermal infrastructures to homes as the key energy strategy. But there are several measures of how to use renewable technologies have been implemented specifically (Edomah 2019) the use of off-grid solutions, including standalone and mini-grid projects across cities and rural areas in Nigeria. These measures are the deployment of small solar and technologies expanding the energy system. A target was set up to complement the SDG, where the number of people living without electricity access could be improved from 60% in 2015 to less than 10% by 2030 (ICREEE 2016), by changing the use of energy 50% of firewood and food waste consumption and replacing it with improved technologies. For this reasons, an increase of energy access remained a priority to meet energy demand, considering that only 40 % of the population living in Nigeria could benefit from this electricity, while most people (65%) live in urban areas, with 28% of people situated in peripheral urban communities (ICREEE 2016).

Most of the plans were set up by the Energy Commission of Nigeria (Khaleel and Chakrabarti 2019), the government agency which is responsible for the planning and coordination of the National Energy Strategy. Adopting new models to extend the energy plan in the energy sector disrupts the prevailing energy structure. Addressing universal access and affordable energy issues are significant challenges for the system. The policies and strategies had stretching energy targets created in National Policy on Renewable Energy Efficiency (NREEEP) (ICREEE 2016), in which the liberating and privatising of the centralised energy sector increased the numbers of multiple actors responsible for renewable energy and energy efficiency activities. In 2017, the federal government signed a private partnership to extend 1,200MW of a solar energy project, which was to be implemented by 2018 (Adetiloye, Babajide et al. 2019, Khaleel and Chakrabarti 2019). The approach of institutional frameworks for the supporting energy policies should involve sharing responsibilities between local and federal governments, but federal government agencies dominated the action of contribution to energy activities (Adetiloye, Babajide et al. 2019). However, energy infrastructures and systems in the delivery of energy need to be transformed, due to the questions of energy governance mechanisms and long-term political commitments (Ogunleye 2017).

The diversification of renewable energy technologies for the delivery of sustainable energy such as the use of solar and wind turbines is expected to help Nigeria achieve its energy targets. However due to certain issue such as the failure of linked renewable energy programmes in the energy sector, it has been difficult for the country to achieve a reliable electricity supply. A report by Ogunleye (2017) stated that a lack of incentives to promote renewable energy limits stakeholders' commitment to the production of energy capacity. An OECD report published in 2018 *Financing Climate Futures,* indicated that Nigeria is predicted to be one of the nations with the lowest level of average annual clean energy technology deployments by the year 2050. Reviewing resources and capacity building, Elum Z.A and Mjimba V. (2020) argue that renewable energy represents a a potential energy resource that might be tapped, creating opportunities for high-level deployment. These deployments of technology could be realised in relation to local energy and renewable energy community systems, with approaches that would provide solutions to the issue of access to energy in Nigeria.

Thus, this outlines the importance of institutions involved in energy communities, rethinking of managerial frameworks and strengthening of governance to support innovation. Community energy could be a force for social cohesion and drive sustainable energy development. It is the governance approach which is described as the establishment of a distinct actor making grassroots initiatives to realise change, creating the opportunity to benefit from a variety of systems such as shared benefits, democratic control and active participation at the centre of the project.

The target of increasing access to electricity through solar and wind renewable technologies so that 75% of Nigerian population have access to energy has not been achieved. Ogunleye, (2017) stated that around 60% still lack connections to electricity services. The current measures introduced by the Nigerian government, including the adoption of improved stoves to reduce the consumption of tradtional firewood, have not reached the population living in peripheral urban communities. Rural electrification projects were commissioned by the federal government of Nigeria to extend the electricity supply, especially in some villages in Adamawa, Bauchi, Jagawa, and Katsana states. However, many of these projects are incompleted due to the high capital costs of installing the infrastructures. The mixed energy targets set for 2015 of a 40% increase in electricity access should be reviewed. Instead, natural gas and renewable energy sources for a reliable energy supply should be proposed aiming to account for at least 90% of Nigerian's total energy by 2030. This research has identified a framework integrating economic, and socio-technical factors; delivery targets, community groups, and distributed low carbon energy systems.

Therefore, in addition to the extension of grid electricity supply through power plant installations, there are various other options that could be implemented. These should focus on distributed low carbon energy installations in order to facilitate the adoption of sustainable renewable energy systems in local communities. Such systems can potentially contribute to energy generation in Nigerian energy systems. Low carbon and renewable energy generation have been achieved in European countries through the use of strategies to encourage and promote sustaible energy generation. The use of distributed low carbon can be drivers for energy efficiency with renewables accounting for at least 30% of the energy supply.

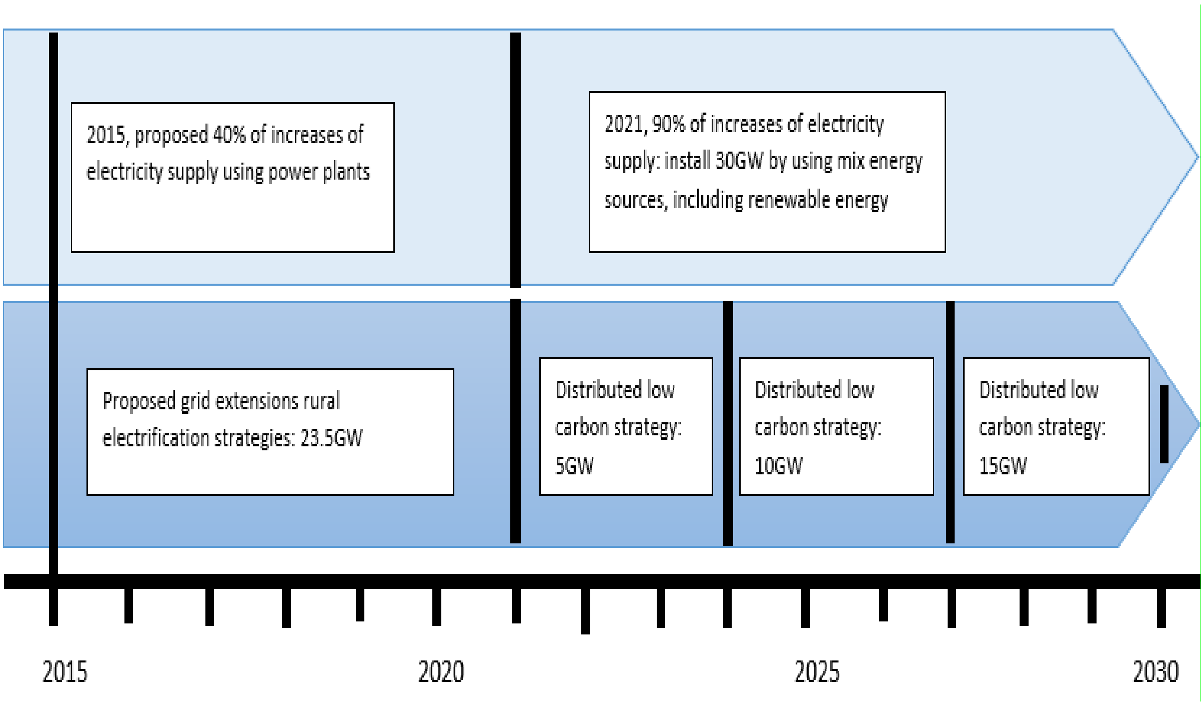

Figure 1:1 The framework for potential input on distributed low carbon energy systems

Figure 1:1 above shows a reablity framework and its potential impacts on distributed low carbon energy systems: community-based sysyems incorporating the use of solar PV, wind, pump heating and geothermal energy. Cogeneration could be one of the methods used to address the problem of energy supply in Nigeria. Implementing appropriate models of community distributed energy in each five year phase would help to meet the national energy targets by the year 2030.

1.2.2.1 Community-based low carbon energy system

The previous sections discussed issues around the nature of the energy system in Nigeria associated with factors of increasing energy demand due to an increasing population. They highlighted some of the approaches and measures required to meet the challenges of energy security, climate change and energy access.

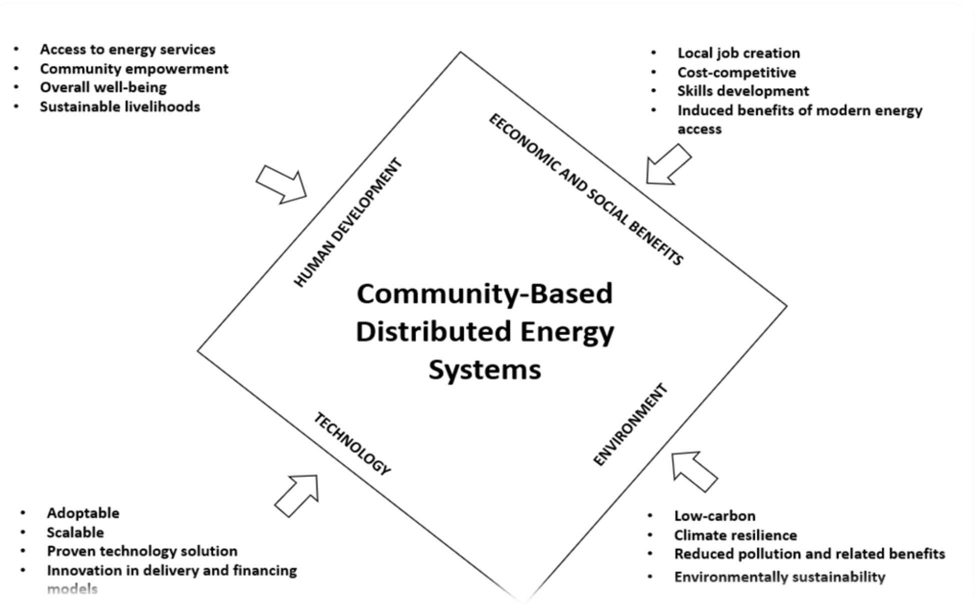

Figure 1:2: The impacts of the community-based distributed energy system.

This section briefly provides a working definition (shown in Figure 1:2) of a community energy approach and discusses the motives and factors for investigating community energy ownership as an energy solution to the problems of energy access. The approach is a complex issue, involving the use of various technologies, structural change, and institutional relationships and socio-cultural change (Seyfang, Park et al. 2013).

The section considers community energy actions and initiatives that form the basis of community energy projects, including the use of innovative distributed energy technologies such as digitalisation, decentralisation and electrification, changing the power energy system paradigms to address the energy issues of energy efficiency, energy conservation and renewable energy generation (CD, 2016).

The term community energy applies to those projects where the engagement of the local community exhibits a high degree of ownership and control of the energy projects, through which there is an impact on community people (Avelino, Bosman et al. 2014). The concept of self-organising, community-led groups of individuals includes not only community energy projects that are typically developed in rural areas, but also low-carbon distributed energy on a community energy scale at specific geographical areas, which include urban and city districts in terms of the delivering of energy generation and energy efficiency to local community groups (Seyfang, Hielscher et al. 2014), but also benefit the local economy, and importantly, creating public support for the energy transition (CD, 2016).

1.2.2.2 Community energy structure

Community-based energy has been recognised to play an important role in taking practical actions around energy generation systems that solve the local energy problems, while communities are allowed to participate in the distribution of energy and resulting leadership and control of the system. The community energy approach uses a number of relationships: the networks of non-governmental organisations, national and local government and local businesses actors all invest in the establishment and operation of energy activities (Walker, et al. 2013). The structures involved are likely to be complex due to many actors and interests to the related issues of climate change, and instability in the fossil fuel supply, encouraging the implementation of decisions for community energy. By formatting the community energy system, this approach provides important issues to the structural institutions, which may be organised to improve and maintain infrastructure through financial sustainability. RENA (2017) stated that institutional changes enable the structural energy system to engage flexibly when interacting with other stakeholders, particularly when the actors at local levels such as small local governments and community energy producers included for the future of governance energy system (Parag, Hamilton et al. 2013). Therefore, community energy projects, as an example in industrialised countries, develop due to national programmes and support the planning and process of community energy development.

1.2.2.3 Distributed energy systems (DESS) and renewable energy community models

A community distributed energy system is an important issue in terms of generating electricity and reducing energy consumption. The approach includes the deployment of distributed energy resources, such as small pumped hydropower, and a decentralised and stationary battery storage system, ensuring the adequate and flexible operation of extended use of the power system for reliability and absorbing capacity of variable benefits from renewable energy (Hain, Ault et al. 2005). This could be provided through low carbon and renewables-based power generation capacity mainly in the construction of small generation capacity, which could be fuelled by solar and wind generators, replacing the use of wood, waste and other fuel pollutants (Walker and Devine-Wright 2008). The use of decarbonisation technologies for community energy requires not only technological options in terms of the reduction of the effects of fossil fuels and carbon emissions but also solutions for the community-based energy systems in the delivery of energy efficiency projects (Anda and Temmen 2014). Integrating an approach for resilience is an important aspect for improving the overall reliability and stability of the community energy system.

However, there are renewable energy technologies that provide little intermittency and resilience in supplying energy generation, which cannot match energy consumption (Kalkbrenner and Roosen 2016). As an example of the challenge of delivering energy, the matter of a steady supply of energy is a concern, particularly through the use of wind and solar technologies, which vary unpredictably for energy users looking to meet the constancy of energy demand (Anda and Temmen 2014, Bauwens, Gotchev et al. 2016). Smart meters, smart grid technologies and energy storage are also key factors for building community acceptance and support for the improvement of technologies (Koirala, Koliou et al. 2016).

In terms of energy storage capacity, there is evidence that this technology is one of the physical tools to achieve community resilience. Energy users can reduce their energy bills through the opportunity to benefit from innovation through demand flexibility (Anda and Temmen 2014). Energy storage involves technologies and processes having a capacity to capture energy for consumption at other times (Gupta, Bruce-Konuah et al. 2019). Gupta, Bruce-Konuah et al. (2019) highlighted that the use of this technology offers the ability to balance energy demand and supply, responding to the issues of disruptions and blackouts in the electricity supply. It also reduces demand from the grid in the case of the existing, ageing infrastructure of generated energy. Similarly, smart grid technology in the community energy development is an important factor, in terms of adjusting the supply of electricity to the users' demand(Gupta, Bruce-

Konuah et al. 2019), where the energy demand could be tweaked to balance the peaks. This model enables the cutting of power to energy users' devices and appliances in order to smooth out variations in the energy load.

The fact remains that sustainable community energy projects are adopted to satisfy local energy needs, creating wide-ranging energy objectives, which may involve the use of multiple technologies, the change of institutional structure, business models, actors and goals (Wirth 2014). There are community renewable energy approaches, such as the development of business models, which promote sustainable development. These approaches and models have been identified in developed countries, where community energy projects are a key priority, in addressing national energy problems.

Examples of community renewable energy approach studies include Seyfang and Haxeltine (2012); Maruyama, Nishikido et al. (2007); Denis and Parker (2009); and Walker, Hunter et al. (2007), indicating that there are greater applications of small-scale community business models used to reduce resource use and create markets across the EU. These studies stated that community energy projects are generally more focused on the business project model, such as those of Baldwin (2010) and Middlemiss and Parrish (2010). Some studies are focused on the more specific technology, such as those of Hain, Ault et al. (2005): small hydro in Scottish rural community; and Rogers, Simmons et al. (2012); Social impacts of renewable energy technologies: a study of community wood fuels.

In recent years, much of the research (Walker, Hunter et al. 2007, Hielscher, Seyfang et al. 2011, Seyfang and Haxeltine 2012) has indicated that there is a flourishing of community-based energy projects, due to the growth and spread of community energy access programmes such as feed-in tariff in Germany and in UK used to address energy issues. For example, about 910 cooperative community projects are operational in Germany, and more than 5,000 community groups have been working in the UK in order to develop low-carbon communities and systems. While Canada has a vision planned to achieve the largest number of community energy projects by 2050 (Koirala, Koliou et al. 2016). As stated before this can be seen as having a varying degree of numbers, success rates and strategies related programmes to prevailing community-based energy structures (Seyfang, Park et al. 2012). Little research to date has explored the potential as well as the wider scope of potential community-based innovations that influence the practical community energy in the energy system, especially in developing countries.

Therefore, community energy using renewable energy sources and distributed technologies in the delivery of sustainable energy needs such as electricity, cooling and heating can form important energy solutions to the problems of energy access and climate change in Nigeria. This research emphasises the institutional factors, particularly community energy capacity issues, and socio-cultural, technical and administration skills in Nigeria, using specific innovative systems that have an impact on the evolution of sustainable community energy systems. This outlines the important factors that represent the contribution of social cohesion, economic regeneration and support for renewable energy.

1.3 Research Aims and Objectives

The two key aims of this research are to understand:

1) Whether the adoption and implementation of models of community-based low-carbon distributed energy systems may establish solutions to the problems of peripheral urban communities in Nigeria.
2) The model of low-carbon distributed energy systems can improve quality of life and sustainable development for the residential community.

The following objectives will be addressed in order to achieve the research aims include:

- Explore community-based distributed low carbon energy and its potential application in Nigeria,
- Explore and identify specific economic and socio-technical factors related to the community-based low-carbon energy systems,
- Apply a case study-based approach to explore economic and socio-technical factors in existing community energy projects in Nigeria,
- Identify key successful elements and barriers for community distributed energy projects in Nigeria,
- Make recommendations based on the elements of economic and socio- technical factors of community energy systems in Nigeria.

1.4 Research Question

The energy issue, energy inequality is the most energy issues between the rural-urban areas in Nigeria. The lack of access to electricity affects 90 million Nigerians. Due to poor policy and initiatives to upgrade energy supply capacity or incorporate and foster the deployment of renewable energy technologies. It might be due to the high cost of infrastructure. The situation is different in some areas where the urban residents account for 17 million, while the rural residents account for 73 million is the most prevalent issues on need electricity. The use of energy fuels is predominant in these areas for residents to light and cook their foods. This causes air pollution.

In late 2018, couple special reports about the global energy issues released by the Intergovernmental Panel on the issues related to Sustainable Development and Climate Change (IPCC, 2018). These reports highlight the impacts that undermine welfares of human being, due to the growing effect of climate change such as air pollution, health problems and the impacts related to poverty and inequality.

The decisions from global forums conclude that the adoption of low-carbon distributed energy resources included solar, wind, energy storage, small district heating and cooling and energy efficiency measures. This is an important factor to achieve the aspects of sustainable development (IRENA, 2019). A number of approaches and actors, including a community approach, has been identified to utilise the adoption of sustainable development (IRENA, 2019, IEA, 2019). This issue raises the question of

- Why is the investigation of community energy approach vital in Nigeria for sustainable energy?
- What are the key drivers of and challenges to sustainable community energy projects?
- What are the practical actions, processes and impacts of a community-based energy project in the delivery of low carbon distributed energy?

1.5 Proposed Research Contribution

This research is concerned with the particular energy problem in Nigeria, the issues of energy access and climate change and the potential of community energy systems this fits within the original contribution of this thesis. This is because a community project presents a new niche strategy of a complex approach.

It also contributes to a literature study in relation to the issues of community energy often practised in developed countries, and the review of the perspective on the elements of socio-technical aspects of a community low-carbon energy system could provide a basis to understand the factors of community energy projects.

This research contributes by applying the case study approach in Nigeria, where the research adopted to study a community-based energy system. This study will contribute to knowledge in terms of its unique investigation of the potential community energy system. The findings of the research can be used in developing countries, with similar issues regarding energy systems, involving processes, technical and financial factors, and governance and social actors in the specific context of local energy generation systems, solving the issues of community energy systems.

1.6 Research Structure

The thesis is organised into the following chapters to address the research aim and objectives.

Chapter 1 begins with a brief background of the framed research problem in terms of global energy issues driving and proposes the idea of using community energy systems to address climate change, energy security and energy access. It specifically describes these energy issues in the context of the Nigerian energy system as a research justification focussing on accessibility, affordability, and reliability, and governance and infrastructural management of energy systems. It highlights various findings related to community energy projects across the world. It also states the aim and objectives of this study. It will provide the proposed research contribution.

Chapter 2 explores a detailed and synthesised literature review on the sociotechnical elements of community energy and energy issues ranging from the political, economic and social-cultural issues, regarding the aspects of community energy. It specifically focuses on issues such as scales, technical factors, management, and financial sustainability in the way that community energy engages for operation and maintenance. In addition, it outlines the outcomes and benefits of the adoption of community energy projects. It explores the various socio-technical and scales local approaches and theories, which help to formalise the conceptual framework of community energy, used for understanding and identifying the drivers and barriers in the context and location of the research study.

Chapter 3 introduces a research methodology identified as a case study (shown in Figure 2, approach. It starts with epistemological approaches in order to explain and justify the research design adopted: case-based approach, comparative case design and data collection and analysis. It concludes with the analysis of the pilot case (PSHPP), was tested before the main data collection and analysis

Chapter 4 presents the analysis of adopted case studies and identifies the key findings including drivers and barriers to community energy obtained across individual cases: 2, the Usuma Solar project (USP); 3, the Guzape Solar-Wind Hybrid Project (GSWHP); 4, the Gnami Off-Grid Solar Power Project (GOGSPP); 5, the Danjawa Integrated Renewable Energy Project (DIREP). It concludes the issues involved in successful community energy projects in Nigeria.

Chapter 5 discusses the key issues and themes such as governance and institutions, finance, motives and operation and maintenance which were results from case studies. The discussion of this chapter will provide successful factors and the issues that prevent the development of community energy. It outlines these issues in order to draw a conclusion for better community energy practice in Nigeria.

Chapter 6 summarises key issues which the thesis addresses around the research aim and objectives. It highlights the original contribution of this research to knowledge. It states limitations in relations to the difficulty of data collection and highlights various approaches to take with regard to prospective techniques in conducting research. It concludes with a reflection based on the research process. Finally, it mentions the number of approaches that could be used in this research for further work.

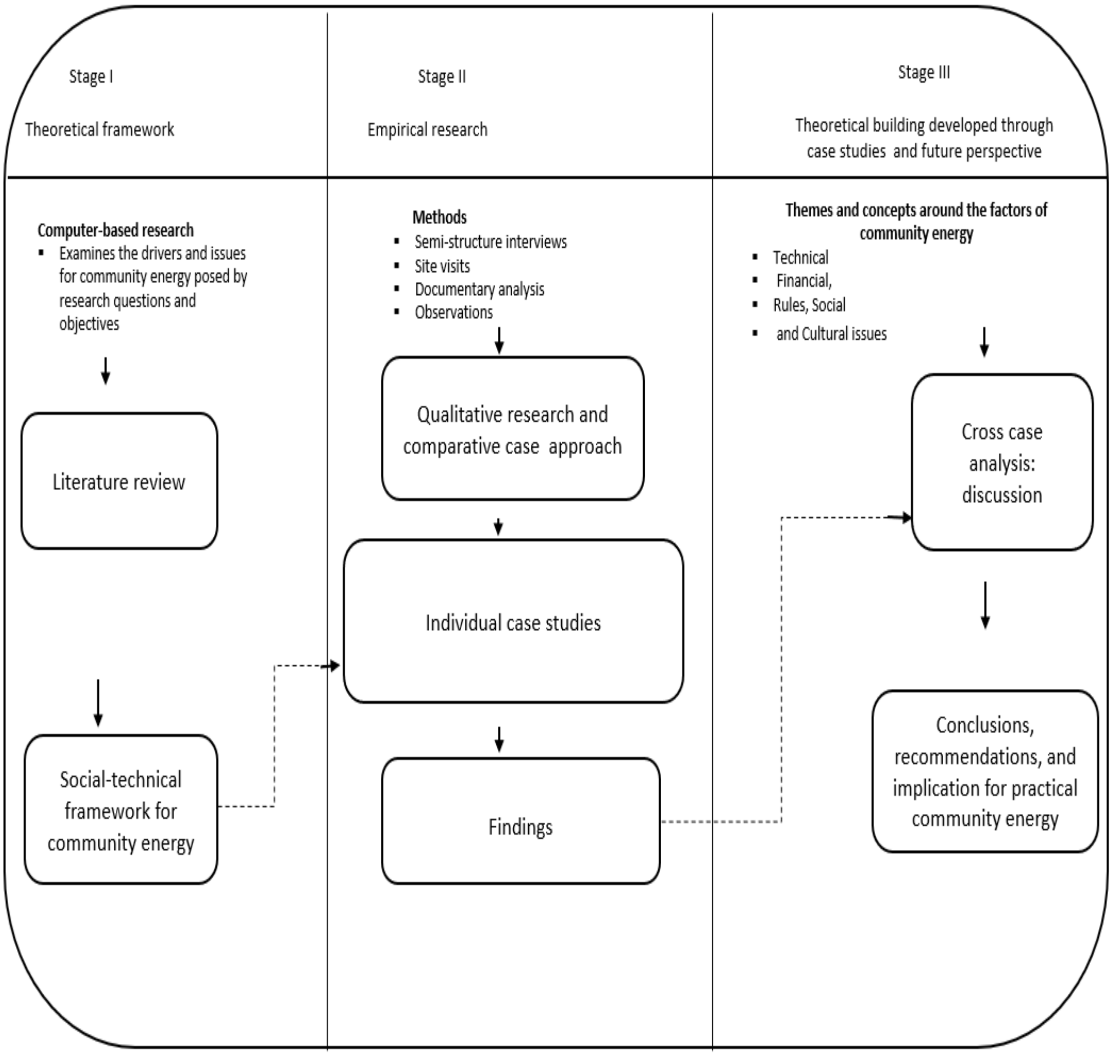

Figure 1:3: The adopted theoretical framework and empirical research

Figure 1:3 shows the three-flow process of research design. The first stage is to understand issues and factors related to the community through the reviews and theories from the literature. For the second stage, the empirical research, this thesis uses qualitative research by the design of comparative case studies to identify the key findings. Finally, the research discusses the cross-case analysis to draw the conclusions for successful factors of community energy in Nigeria.

Chapter 2 : Literature Review

2.1 Introduction

The purpose of this chapter is to provide a review of the literature in relation to key issues and drivers for community-based distributed energy systems and to address the research question and objectives of this research. The literature focus is on identifying some of the issues that include fuel poverty, energy security, climate change and energy equality in the world as well as the specific challenges of affordability and reliability of electricity generation and management concern in developing countries. The aim of this research is to investigate factors related to the community-based energy system, which as a potential approach for the delivery of low carbon distributed resources and energy efficiency measures in Nigeria. A number of researches into community-based energy exist for some developed countries (Hain, Ault et al. 2005, Maruyama, Nishikido et al. 2007, Seyfang, Park et al. 2012, Anda and Temmen 2014, Wirth 2014, Bollinger, van Blijswijk et al. 2016), but there are few kinds of this study carried out to investigate community-based low carbon distributed energy systems, and also there is no evidence of research having been undertaken for community-based energy systems in Nigeria.

The research that is being undertaken is not only addressing the energy issues for community energy in Nigeria, but it applies to countries with similar problems of energy access specifically in the developing countries, as it seeks to make a series of contributions by exploring the roles and factors of community-based energy systems in governing sustainable energy (Seyfang and Haxeltine 2012), evaluating the appropriate grassroots technology innovations for addressing local energy problems, implementing energy efficiency policy by using community-based energy (Ince 2019), and it contributes to the existing knowledge base. This chapter begins by exploring how energy supply and demand and other factors influencing the adoption of community energy and challenging the use of energy sustainability. It also investigates community energy models which have been adopted in developed countries and looks at various components of community energy for the purpose of applying them in Nigeria. Finally, the chapter identifies and discuss a range of the theoretical frameworks of sociotechnical perspectives for the understanding of the complexity of elements and issues involved in studying community energy in Nigeria.

2.2 Demand for and Supply of Energy

This section will start with exploring the issues of energy-related climate change., concerns over energy security and fuel poverty that (Johansson, Patwardhan et al. 2012) are challenges around the global threats such as the welfare of the human population, due to demand for and supply of energy, likely causing and increasing the consequences associated with greenhouse gas emissions. It also includes the important issue of increased population and the influence of economic growth to increase the likely energy consumption in the building sector, resulting in the increase of total energy consumption worldwide (Li 2018). It further explains the issue of energy use facing the countries globally and the implications for sustainable development. This issue would be examined in the context of the literature with an intention to identify and apply the roles for communities in adopting the use of low carbon energy and the application of energy management system for the self-community energy needs.

2.2.1 Supply of Energy

It is commonly acknowledged that the use of energy in various economic activities such as capital, labour, and natural resources leads to the change of economic development. Also, it improves social services and comfort for residential sectors and contributes to living standards (Apergis, Aye et al. 2015). While there is a major issue of the use of energy where the world now relies on the supplying of fossil fuels, coals, oils and gas for burning to obtain the necessary energy to satisfy a range of human needs including foods, hot water, electricity and cooking (Pachuari and Rao 2014).

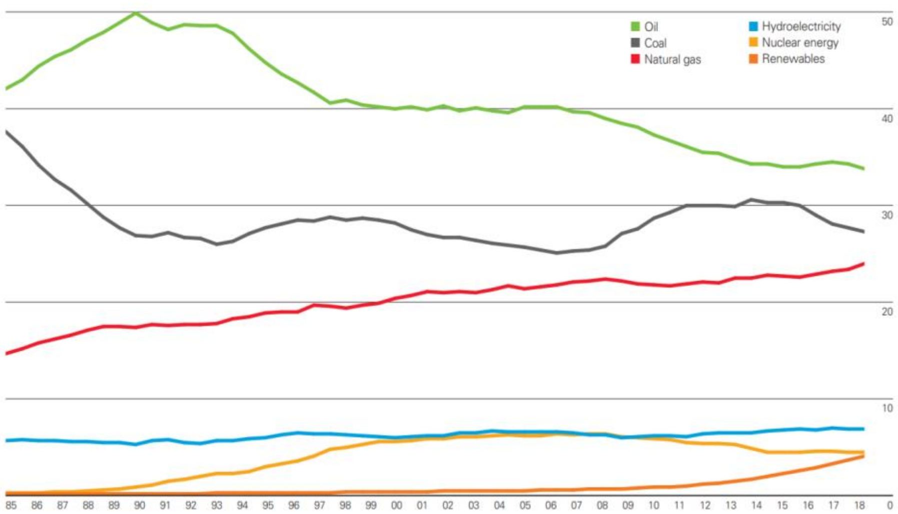

Figure 2:1: The contribution of Primary Energy by Fuel in the World (BP, 2019).

As stated earlier there is a need for energy to shape global energy demand for economic and human development. Sambo (2016) states that fossil fuels are the most dominant main energy sources in most countries, which include, biofuel, waste and other carbon sources find in developing countries. Figure 2:1 from the British Petroleum (BP), the report shows a billion tonnes of the world energy consumption is coming from both renewable and non-renewable energy as the primary energy use. With a clear indication, the report reveals the contribution of the fossil fuels as the primary energy as continuous up to 2040, and it classifies the main energy contributors into gas, coal, oil, and renewable energy which has the lowest contribution.

It is identified that the gas contributed 27% of primary energy in 2010 but expected to grow by 46% in 2040. This increase is faster than oil and coal consumption. The coal contributes approximately 36% as the second contributor, oil provides approximately 41% of total primary energy use, a low carbon source such as nuclear contributes 6%, hydro contributes 8%. Other renewable energy sources which comprise solar and wind contribute 2% of the total primary energy consumption. This is a couple of challenges of energy demand at the same time, increasing the issues of carbon emissions (Finnerty, Sterling et al. 2017).

Consuming of the fuels has risen unsustainably and would likely to increase over the years due to rapid economic growth and population growth in developing countries. This issue is driven by high levels of improvements in the gross domestic product driving use of energy to levels similar to the progress seen in developed countries (EIA, 2012), in the way of the development of environment and building sectors, in which the use of a substantial portion of the energy consumption.

However, the consumption of energy is varied between countries and the level activities of the country such as economic development, the availability of energy resources, political and social influences determine how the energy is used (Miroux, Hamdi et al. 2011). The contribution of deposited carbon energy sources is significantly higher to global energy production in Nigeria.

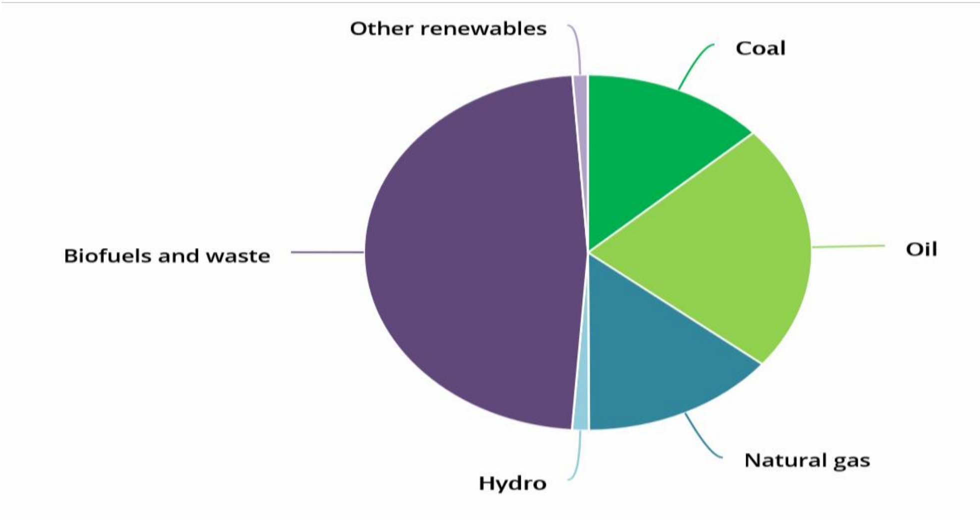

Figure 2:2: Primary energy consumption in Nigeria (IEA, 2019).

Figure 2:2 shows that biofuels and wastes contributed a higher percentage to world energy consumption and environmental effects, mostly due woods in the rural homes and a low GDP per capita (Ogunleye 2017).

Energy from low carbon energy sources such as wind and solar energy can contribute to sustainable development. Their contribution will be needed for sustainable energy use, facilitating the reduction of energy demand and the effects related to carbon emissions, particularly from the domestic sector. Using distributed energy sources through innovative renewable technologies and the adoption of solar thermal heat, lowing temperature processes, provide a positive impact on energy demand for the future. This can be essential for closing the gap for the protection of environmental effects and meeting the energy demand in the domestic sector.

2.2.2 Use of Energy in the Domestic Sector

It is important to understand the important role of energy consumption in the domestic sector, the community energy sector where the use of heating, lighting and cooling is considered as the important factor for social and economic of human development, and the undertaking of sustainable objectives that may address the poverty, inequality and environmental degradation. There is an indication that community energy could be a driver as the potential energy savings through the use of low carbon and the encouragement of improvements in the energy efficiency in domestic sectors. Ramachandra, Subramanian et al. (2000) argued energy use pattern, in the environment, is different around the world and is related to social-economic and efforts to reduce the issues of climate change and the impacts of energy security. In the UK there is a range of measures and programmes such as Community Saving Programme, Energy Company Obligation adopted, aiming to improve the use of energy in domestic sectors.

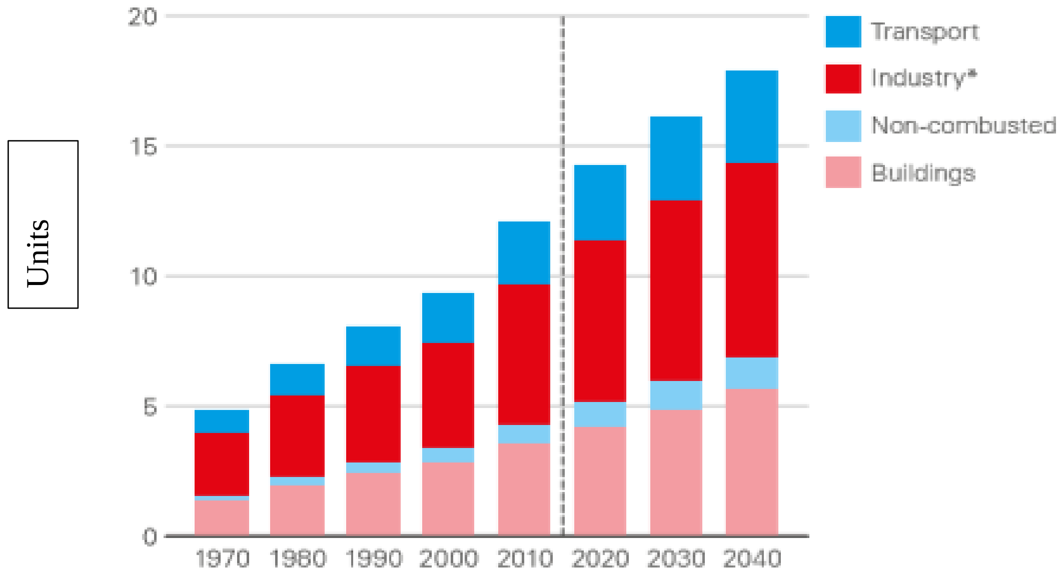

Figure 2:3: Energy use in the various sectors of economy BP (2019).

Figure 2:3 shows various sectors use of primary energy, which include to a broad-based across global economy: an industrial, a transport, and a building sector. The buildings sector contributes 29% of energy consumption, which is greater than the other sectors. The industrial sector has a higher energy consumption despite the fact that it gains in energy efficiency. A study conducted by (Mielli 2011, Carlén, Rosenqvist et al. 2016) explained the use of a central and visual room and the metering system for generating data for real-time actions facilitate the industries to monitor the energy demand and improve the performance to the equipment and loads. Transport accounts for 21% of energy.

Given the characteristic of energy use in the residential sector for lighting, heating and cooling and other home activities, a number of reports and Data from World Energy Statistics reveal domestic energy consumption continues to increase globally. But the recent report of the Department for Business, Energy and Industrial Strategy states the use of energy consumption in the UK homes decreased due to sustainability, use of low carbon fuels and the change of weather to warmer average temperatures. The use of energy in residential buildings accounts for about 28% in 2017 which is a decrease from 29% in 2016. There is evidence that a lot of decentralised energy such as rooftop solar and microgrid being consumed in residential homes in Nigeria, there also has increased significantly using biofuels and wastes for cooking, lighting and electricity. These account for, at least, 49% of final consumption. The residential sector used more than other economic sectors in 2015 (Goldemberg 2000, Oyewunmi and Iwayemi 2016).

Considering the use of fossil fuels as discussed in the previous section, many explained their implications in the built environment where social and economic activities such as individual houses, businesses, and appliances increase for the use of high energy consumptions that may mark by modernisation and the adoption of a new lifestyle. Thus, (Bilgen 2014) considers that the growth of energy use has surged in developing nations where the growth of prosperity in the nation leads to the residential sector expanding significant proportions of energy consumption in the world.

Many studies have identified the issue of global energy implications (Kennedy-Darling, Hoyt et al. 2008, Miles and Kapos 2008, Hannon, Foxon et al. 2013, Ekins, Bradshaw et al. 2015, Emodi and Ebele 2016), suggested that fossil fuels are no longer viable as an energy source in future times, considering the global energy demand increased by 2.3% as an indication in 2018, and from 2.2% in 2017. In this situation, energy use needs to be diversified in order to sustain for the future. There are important factors such as technological innovations (Breschi and Malerba 1997, Nakata, Silva et al. 2011, United Nations Conference on and Development 2011), and changes of governance energy systems for stabilising the residential energy sectors (Smith 2007, Foxon, Hammond et al. 2009, Avelino, Bosman et al. 2014).

Sathre (2014) argued that the impacts of using innovative technologies, while replacing the systems of coal, petroleum and gas, which are relatively higher in expense, especially in term of installations, maintenance costs and extension. This is likely the use low-carbon distributed energy technologies such as innovative systems dominated by wind and solar PV, which have long-lasting of energy generation, effective costs, significant upfront capital investments (Sarkodie and Strezov 2019)and use for sustainable energy sources free from the issues and difficulties of fossil fuel-based power models, producing pollution, health hazards and higher costs, driven fuel consumptions (Bazmi and Zahedi 2011).

2.2.3 Investigating Issues of Energy Use in the Wider Perspective for Adopting Community Energy Models

In order to understand the main roles of communities in delivering the energy activities such as low carbon distributed systems and energy management system for achieving the social, economic and environmental benefits, it is important to investigate the wider issues and drivers of energy use. This is to understand the causes of energy use within the environment and the particular challenges facing developed and developing nations include Nigeria motivating communities to engage in sustainable energy systems.

Sustainable energy aims are the use of new innovative technologies, changing policies and strategies and adopting innovative market models (Sørensen 2002, Song 2006, Seyfang and Smith 2007, Wilson et al., Macgregor et al. 2009, Sambo 2016, Leal, Dal et al. 2018), are important measures to tackle energy issues that include energy equality, energy security, and climate changes by integrating local energy system. The community energy system can be provided for sustainable energy requirements through generation renewable energy and efficiency activities by developing distributed energy systems.

This section aims to identify the various literature discussions of the global factors that drive sustainable energy use. In the previous section, the literature discussed the growth of energy demand for heating and cooling in the residential sector, stressing the widespread use of fossil fuels. However, there are a number of factors that drive for challenges of sustainable energy use. There are also different understandings of technologies such as low carbon distributed energy systems used to adapt to sustainable energy. Pachuari and Rao (2014) state the social and economic factors; which Russ, Ciscar et al. (2009) elaborate on. These issues relate to population size, longer-term fertility, and demographic transition as well as income growth and income convergence, and the energy price difference that influences the use of energy consumption. Similarly, urbanisation and resource use efficiency, as well as technological factors, are identified in the literature studied by (Hennicke 2004, Barbato, Capone et al. 2011).

The studies suggest the importance of renewable energy resources and technologies having an impact on energy consumption. Additionally, Russ, Ciscar et al. (2009) discussed the stabilisation of energy of policies related to exogenous input such as emission price and the scale of emission reduction drives for sustainable issues (Gurney, Ahammad et al. 2009). Importantly, energy emission and vulnerability issues (Carter, Fronzek et al. 2004, Grübler, Nakicenovic et al. 2004, Moss, Edmonds et al. 2010) are the global energy concerns essential to the ecological environment and human health.

The above factors can be summarized by the following four thematic drivers; population growth, energy security, economic growth and climate change for investigating energy issues in order to identify methods for sustainable energy generation, the approaches that will be needed for managing renewable energy technologies. Community-based ownership approaches might be integrated for utilising low carbon energy resources

2.2.3.1 Climate Change

It is recognised the important role of atmospheric CO_2 on the planet regarding how the inhabitants and plants depend on CO_2 as the carbon sources for their photosynthesis and food production. There is a change in climate occurring as a result of natural processes such as changes in the output of the sun, and slow changes in ocean circulation. As a result, the world's climate is changing far above the historical average. It is understood to be a warning based on a broad scientific IPCC consensus (Pachauri, Allen et al. 2014). It is understood that much of the warming is caused by human activity. In Figure 2.4a (left), under Figure 2:4 which is the Antarctica ice core data, shows that (Mitigation 2011) the change was increased from 280ppmv in 1850 to 295ppmv in 1900. The change kept increasing up to 315 ppmv in 1950 and then 390 ppmv in 2000 above preindustrial level (Patz, Engelberg et al. 2000, Song 2006) until the change in the atmospheric CO_2 has reached the level which causes concerns throughout the world.

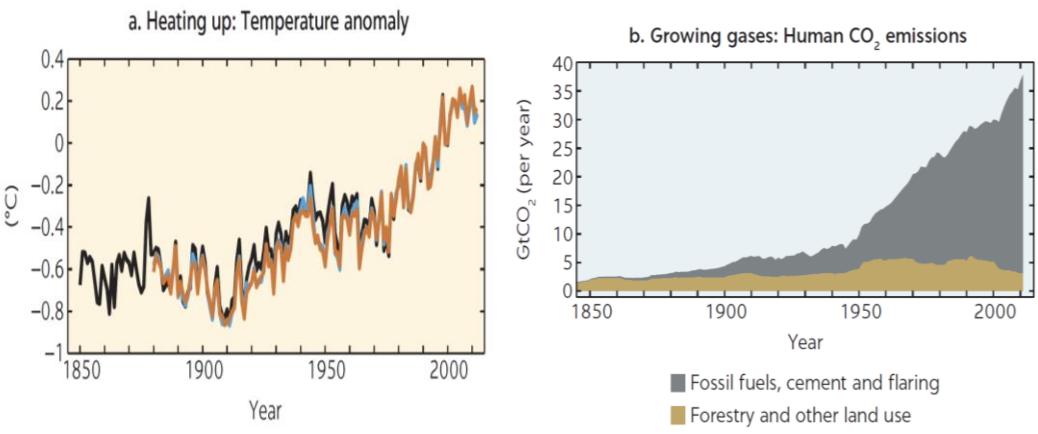

Figure 2:4: Growing temperature and the issues related to CO_2 emissions

Human activity such as deforestation and burning of the fossil fuels results in emissions of greenhouse gases especially the emissions coming from fossil fuels shown in Figure 2:4b (right), under Figure 2:4 (Miles and Kapos 2008, Baccini, Goetz et al. 2012). In 2018 fossil fuels contributed to the global CO_2 emissions by 1.7% compared to 1.2% in 1999. Emissions are also expected to grow by 27% in 2030 (Ruehl and Giljum 2011) which will globally continue to cause an increase in global temperature. A variety of research literature has identified severe and irreversible impacts for populations and ecosystems as a result. The increase in global temperature pose threats not only the welfare of the humankind, the rising cost of energy services, but also the vulnerable climate (McCarthy, Canziani et al. 2001) this, latter, is to be defined:

"the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. The vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."

Negative impacts from the environmental changes include extreme weather events (Anderson, de Leon et al. 1998), air pollutions such as ozone, sulphur dioxide, nitrogen dioxide, and particles as identified by (Anderson, de Leon et al. 1998, McMichael, Campbell-Lendrum et al. 2003), the pollutions have significant impacts associated with asthma. Severe storms (Parmesan, Root et al. 2000), droughts, and floods (Deschenes and Greenstone 2007, Lobell, Burke et al. 2008, Hanjra and Qureshi 2010) will diminish the quality of life on this planet.

There are many options for changing the methods of using fossil fuels for lowering carbon emissions through the energy system at the same the global demand for energy is satisfied. These options include renewable energy technologies, energy efficiency, and conservations (Boomsma, Goodhew et al. 2016), (EU 2006, Mielli 2011, Apergis, Aye et al. 2015), (Boyle 1996, Hain, Ault et al. 2005, Sadorsky 2009, Twidell and Weir 2015, Al-Maamary, Kazem et al. 2017), low-carbon technologies and batteries storage systems (Sorrell 2005, Gibbins and Chalmers 2008, Nakata, Silva et al. 2011, Peterson, Stephens et al. 2015) and similar, all of which suggest the possibility of sustainable development.

The sustainable energy system is used to measure the issues of energy equity and energy insecurity by using community-based low-carbon distributed energy resources in order to adopt sustainable energy and the sustainable technologies techniques to manage energy system. Seyfang and Haxeltine (2012) considered that the community-based distributed energy system is applied to undertake sustainable energy activities to address issues. This section will discuss the technical issues and related energy activities with which communities engage. It focuses on important aspects and issues by using energy efficiency and low carbon energy generation (renewable energy), which play the most important roles in sustainable development for community energy.

2.2.3.2 Economic Growth

In the subsequent section, the influence of the population on the use of energy due to high energy demand and the likely implications of fossil fuels in the world due to the increase of energy demand for provision services was explained. This section is related to the issue of a growing population, but it will identify the consequences of economic growth. Economic growth refers to energy use per a unit of Gross Domestic Product (GDP) (IEA, 2018).

The report of IPCC (2014) mentions China, India, and Africa countries as the current energy drivers indicating that their growing energy demand is more in the domestic sector for living standards that raise the level of energy consumption. Understanding the structural changes developed for economic growth, Rudl, (2019) described the energy consumption of economies through a series of stages where the use of energy initially dominates in agricultural production, moves to the industrial sector in which characterised by the heavy and energy-intensive industries, before the final stage of the energy services sectors. Sadorsky (2009) illustrates the possible effects between the scale of production and the high consumption of energy and specifies that the emissions may rise to a certain level where the environment can be degraded. The domestic energy sector driven by the growing prosperity in the Middle East, Asia and Africa (BP, 2018) is one of the factors accounting for economic growth.

It found that there is a clear link between the impact of economic growth and energy consumption causing a threat to ecosystems and ultimately, to human beings (Rudl, (2019). This issue discussed in section 2.2.3.3. as the high increased demand using fossil fuels contributes the global CO_2 emissions. However, sustainable energy measures will need to be taken into account not only for available resources but for the future energy demand caused by the introduction of the new modern energy system and the increase the use of these energy systems. Jacobson and Delucchi (2011) suggested that low carbon technologies can facilitate the positive actions of economic growth by providing a sustainable energy system.

Considering the impacts of fossil fuels leads to a market for new innovation of renewable energy sources (Jewell, McCollum et al. 2018). For energy price solutions, Olabi (2017) describes the important roles of renewable energy sources being suitable, multipurpose, and flexible in use. Miroux, Hamdi et al. (2011) looked at the wind and solar appropriate technologies and innovations replacing the use of oil and gas energy(Miroux, Hamdi et al. 2011). Bennett (2018) recognises the effective integration of technologies by using a small scale model that includes the storage energy capacity for unlocking the value of new energy technology (Ammer 2017). Sovacool (2017) identified the opportunity to adopt the use of new technologies through the digitalisation technologies for energy-related services, promoting new business models that serve active market players and further explains that the model can be comprised of a decentralised energy system combined with a storage system and smart network in order to integrate new price models (Sovacool 2017). Community energy distributed systems can also adopt technologies and renewable energy sources through digital transformation models to stabilise electricity prices for future challenges.

2.2.3.3 Population Growth and Income Disparity

The population is one of the key factors driving energy consumption currently in the world. It is considered the issues that will cause the growth of energy demand affecting energy sustainability in the future. In the International Energy Agency Report 2011, the world population was estimated at 6.8 billion in 2005. It concluded that the world's population is expected to grow approximately 8.6 billion by 2035 (Jewell, McCollum et al. 2018) with an average growth rate of 0.9 per annum. Lizunkov, Politsinskaya et al. (2018) considered that population growth is, likely, derived from urbanisation issues in developing countries, which make higher demands on energy use (Lizunkov, Politsinskaya et al. 2018). Bilgen (2014); Gazder (2017) and Mitigation (2011) suggest that the importance of sustainable energy by using large-scale renewable energy technology to overcome the increased demand caused by population growth. Sustainable modernisation, however, is another issue for promoting the degree of urbanisation (Sharma, Dua et al. 2018).

Widening the disparity issue in economic development and unequal investment in human capital leads to inequalities in relation to social stratification and the distribution of energy consumption within and across the countries due to income level. Looking at the global economy. The implication of this issue in the global market is that the nature of the economy is prevented by unemployment, in which capital and labour produce goods and services that, economically, influence the changes of various factors in the economy including the income level of the households. It is energy consumptions increases that give the total change of structural development. Therefore, effective information and economic development limit the widening gap for the amount that individuals have to spend on their energy consumption. Otherwise low level of capital investment, information and technologies in connection to the economy means relying on intensive labour which results in a fragmented collection of low income among individuals. The geography and people are left concerned struggling to attain access to clean and sustainable energy. On the whole, the level of capital and income is one of the key determinants for economic development and prosperity. This is caused by sustainable energy consumption as in the Sadorsky (2009) study which shows that there is a positive relationship between the energy consumption of energy and sustainable economic growth as well as Gross Domestic (GDP) income.

Considering the income levels of households for the extent of sustainable energy supply, Cherp, Adenikinju et al. (2012) considered that access to energy services is access electricity use for each person living in specific areas. Any point below this capacity is defined as an energy poverty level. However, research show changes in policies for capital investment to be improved (Pachuari and Rao 2014), adopting clean technologies and improvements in labour capacity (Nakata, Silva et al. 2011) and environmental management practices(Rahman and de Castro 1995, Kahn and Fritz 2006, Bilgen 2014, Towler 2014, Sarkodie and Strezov 2019) helping to achieve sustainable energy change (Sarkodie and Strezov 2019). Most importantly, the policy on fuel energy subsidies, Heffron and McCauley (2017) consider that it provides the impacts for energy equality and economic growths while balancing the issues of income inequity and offering the opportunity for the application of community-based low carbon energy systems.

2.2.3.4 Energy Access in Developing Countries

The decreasing energy disparity for social and economic objectives is understood (Behera and Ali 2017) as an impetus to create strategies for sustainable energy. Because energy is one of the key factors for social and economic development, it is essential to provide access to poor communities. Report on Climate Change and Renewable Energy highlight (Adib, Murdock et al. 2015, by IRENA and DESA 2019) that energy access must be reliable, safe, affordable, and sustainable in order to achieve social equity and sustainable development. Investment in energy management strategies and initiatives are key tools in facilitating access to energy in developing countries (Franco, Shaker et al. 2017). According to Mathur and Mathur (2005) prioritisation of energy, provision is a political issue and needs to be addressed.

Although it has been found (Mathur and Mathur 2005) that there is a rise of living standards due to the improved access to electricity in some parts of the World , however, provisions of energy infrastuctures access to energy are still daunting for energy improvements in african countries. There is an urgent need for reliable and affordable electricity. As the International Energy Agency (IEA) report for Energy Access states that a large number of people in developing countries lack access to clean energy use depend on the traditional biomass fuels (Mathur and Mathur 2005). An estimation number of these people is around 1.6 billion population, who do not have access to electricity and the large number of 2.4 billion people relies on unclean fuels such as agricultural residues, wood waste, dried animals dung, charcoal, and fuelwoods for cooking (Sokona, Mulugetta et al. 2012). This statistic suggests that nearly one in five households in the world is deprived of access to energy that is clean and environmentally friendly.

Repeatedly about energy access but this relates to continents in the world, much of the literature refers to (Crousillat, Hamilton et al. 2014, Jairaj, Martin et al. 2016, Organization 2018, Shahsavari and Akbari 2018) the more than 2.7 billion world peoples from Asian and African countries using traditional biomass fuels and other solid fuels for cooking and electricity. In Asian countries, almost 1.9 billion people rely on solid fuels, with a high proportion using kerosene for lighting. Whereas, in the African countries, it has been determined that 80 per cent of the population relies on biomass and that approximately 600 million people are deprived of energy services (Agency 2016, Organization 2018, Shahsavari and Akbari 2018). In Nigeria, it has found that most homes do not have a constant electricity supply (Edomah 2019). Of the total of 197 million population, more than 95 million people rarely secure reliable energy. (Agency 2016) concludes that by 2030, 700 million Africans will not have a reliable resource of energy unless the situation is addressed immediately.

2.2.4 Understanding the Energy System Issues in Nigeria

In terms of global energy issues, access to energy is one of the predominant problems in Nigeria, particularly in isolated rural areas where communities are deprived of energy services. These are prioritised for urban homes and businesses due to the more prosperous and economic density (Cherp, Adenikinju et al. 2012). Providing energy security and access to environmental and public health for poor and rural areas is essential for sustainable development (Köppinger 2007). There are a number of sources both from academic researches and government sources that discuss and make recommendations about these issues. (Khennas 2012, Dörr, Wahren et al. 2013) propose that institutional arrangements, technology, and infrastructure, and energy price, and equity concerns must be identified to address the complexity and constraints threatening Nigerian energy systems. The aim of this section is to understand how the various resources and literature identify the challenges for understanding the issues which limiting energy access in Nigeria: emphasis on-grid energy generation to address the issue of energy access; Issues of availability and unreliability of energy services provision; introduction of subsidies: misappropriated and misdirected, and Vested interest favouring the affluent in the delivery of energy.

2.2.4.1 Emphasis on-grid energy generation to address energy access

Currently, energy generation in Nigeria is structured mainly around fossil fuel generation and centralised grid systems (Aina and Akinrebiyo 2015). In the structural energy system, the physical infrastructure of the network characterised by many points of generated energy flow from centralised energy generators to millions of Nigerian homes. Figure 2:5 shows how the generated energy transports over distances through transmission and distribution lines from generators to deploy load in the areas for energy services.

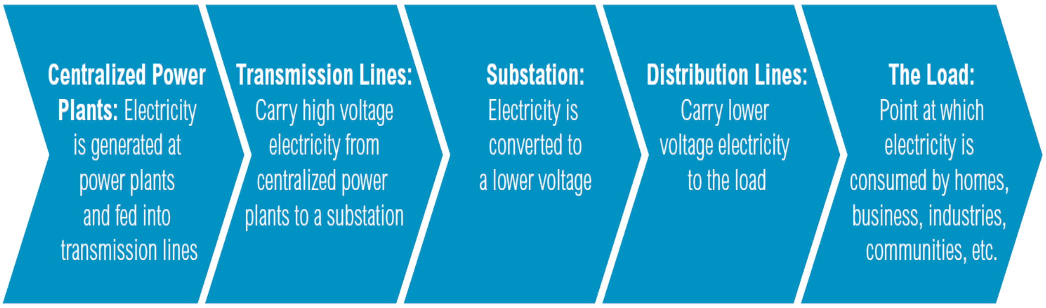

Figure 2:5: Characteristic features of the power plant energy generation system (Singh, 2008).

Looking at the energy governance body, the main objective of policymakers and regulators and the utility companies regarding this system structure is to ensure that energy can be accessed by all Nigerians wherever and whenever they need it. Grid energy generation and its extension are considered the way of energy access. Singh (2008) explaines the use of the electricity grid system as it maintains a constant balance between supply generation and demand loads. This highlights the moving of electricity from the generation source to the energy users, where the amount of electricity consumed is not always the same as its use. Willis (2013) indicates that the system used depends on the time, day, weather and has said that electricity must be produced at the time it is consumed. Small and Frantzis (2010) identified that the efficiency and safety of the Nigerian energy generation system is a key issue. To address the energy system issues, the approach and policy supporting mechanisms in the delivery energy for the equality energy access are clearly incompatible (Edomah 2019).

Regarding the electricity distribution across the country, (Leal, Dal et al. 2018) looked at the energy situation in the African regions in term of electricity access in order to make a comparison with the issues in developed countries such as the UK, who have 100 per cent urban-rural energy access to electricity compared with 35% as the average for African countries (Szabo, Bódis et al. 2011, Ogunleye 2017). Figure 2:6illustrates the number of people who have unequal distributions of energy provision between urban and peripheral rural areas (NBS, 2016).

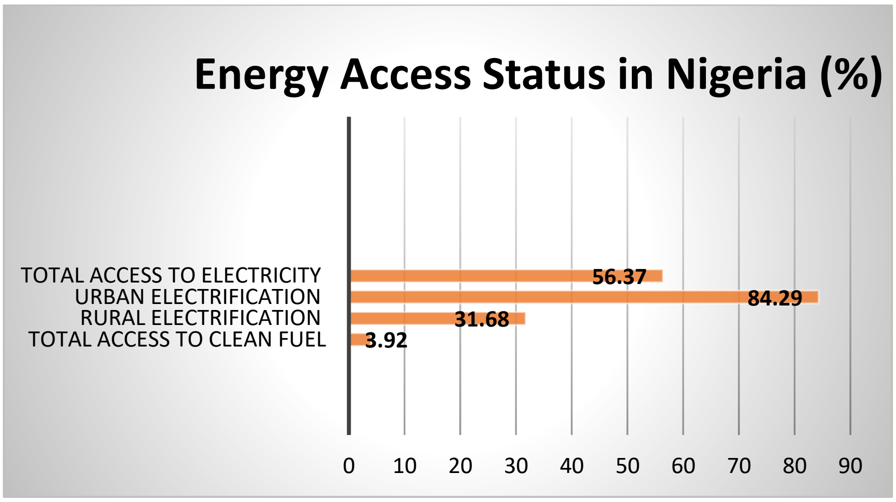

Figure 2:6: Energy access in Nigeria (NBS, 2016)

The Figure shows that the urban area in Nigeria approximately 85% access to energy compared to the rural population which has less than 32%: this is a significant difference. However, even in the urban energy access to clean fuels that described as natural gas by (Ogunleye, 2017) for cooking services is significantly lower by 3.9%. The deficit of energy access coupled with insufficient energy sources may lead to an increase in the use of low-quality biomass sources which results in high air pollution and contributes to the greenhouse gas emissions.

In recent years, the efforts have made for large innovative technologies such as thermal gas plants (National Council on power) (Ogunleye 2017). This includes the 30000MVA capacity 132/33kv transformers installed in the new substation points, 986.5km of 330KV Lines and 705.3km of the 132kv line all on-going construction. These, along with the overload transmission station are being upgraded to reinforce the capacity for energy generation. Thus, energy inequality still is the most prevalent issues between the rural-urban areas. The new report discloses the lack of access to electricity which affects 90 million Nigerians. Due to the high cost of infrastructure, the urban areas account for 17 million, while the rural areas account for 73 million.

Many types of research about local innovations (Geels 2004, United Nations Conference on and Development 2011, IRENA 2012, Mez 2012) contribute with approaches to business models, new technologies and policies to support energy access creation with the motivation of building a sustainable energy system not only to mitigate climate change but, also, to reduce the impact of poverty, improve health quality, empower women. These issues are also experienced in China (Ying, Hu et al. 2006). Grassroots innovations as the decentralised generation reflected in the UK energy system (Seyfang, Hielscher et al. 2014) Seyfang, Hielscher et al. (2014).

2.2.4.2 The delivery of energy through a governance system

As discussed, the issues of the centralised grid distribution system in Nigeria in section 2.2.4.1, the governance system which delivers energy infrastructures and manages the distribution of the energy system should be the key factors to the access of energy. The system overcomes inequality in terms of the provision of new and stable energy infrastructure. In this case, the provision of energy access has remained relatively poor over the decade (Aina and Akinrebiyo 2015), and it seems that this is the result of the management system: planners, regulators and system operators. Emodi and Ebele (2016) described how the energy system is operated by planning and implementation, but also lack of clear roles and responsibilities among relevant stakeholders.

Ihuah and Eaton (2013) have identified a characteristic feature which is that energy delivery is governed by centralised incentives for facilitating infrastructural expansion. This arrangement is considered to be because the failure of the energy targets is not taken into proper account. Jairaj, Martin et al. (2016) looked at economic consequences by accommodating the national grid system.

In terms of energy delivery, there are licences presented to private energy providers authorised by the government, as it did not consider financial viability and affordability in some rural areas the government simply focus about revenues in order to make up incomes inflow. This concludes that the central management approach, which is positioned by political expediency, reflects the arrangement of expenditure on physical access to energy through grid extension, thus providing doubtful hope to deprived areas (Kennedy-Darling, Hoyt et al. 2008, Ihuah and Eaton 2013). The strategies on infrastructure expansion adopted for rural communities to benefit the real needs of available energy services as national measures, however, most of the periperial urban communities have been identified with limited energy access and the use of electricity services is in favour of higher incomes and wealth people. Studies on renewable energy have identified that there are many rural areas in Nigeria have easy access for free and potential energy sources, flexible technologies installation.

The issue of transmission losses also reflects as inefficacies of distribution systems which adversely impacted both costs of affordability, in terms of the quality and viability of the energy services, (Aina and Akinrebiyo 2015, Edomah 2019) mention deficits, that lead an unpleasant to the energy users. Deficits such as free provisions organised by government schemes, illegal grid connections resulting in poor quality supply, and frequent power cuts. As well, the deficits might contribute to the high costs to the governance energy financial accounts (Ohiare 2014). In a 2014 report (Crousillat, Hamilton et al. 2014), it was noted that the grid capacity was extended with a growth rate of energy supply for many energy users, but it was revealed that the managing the grid system in the country is one of the distribution energy problems, where about 17% losses in transmission and distribution energy.

2.2.4.3 Challenges of availability and reliability of energy services provision

As stated in the previous sections, access implies that the physical infrastructures and supply chain mechanisms are structured with the key objectives for households who are put on the right track to use energy services (Leal, Dal et al. 2018). Without the basic electricity distribution infrastructure in place, households cannot access the energy, despite their willingness to pay the energy services. AGECC (2010) argued the importance of reliability and availability of energy services, highlighting not only lighting, heating and cooking activities but also other services which comprise health, education. In addition to these benefits, income generation may improve when energy services facilitate small scale business and agriculture improvements for local productivity. For example, political upheaval in 2016 caused a shutdown of the electricity system in some urban areas in Nigeria. The rural electrification programme, however, was created for the people who were deprived of energy services. The programmes formulated in order the peripheral urban areas to provide infrastructures and energy connectivity to the national grid for rural residents, but the reliability of energy supply was not provided. The report by the UN found that Nigeria was one of the African countries that had one highest power outages in 2015.

2.2.4.4 Introducing subsidies to improve energy access

BV (2010) suggested the provisions of incentive in order to prevent market chains becoming limited in supplying energy for business purposes. lower payment capacity and the lower densities of the population might lead to uncertainties with reference to f capital investment returns. Subsidies are an important factor considering that it delivers through government programmes (CEE 2017). In the other hand, it can be shaped as effective measures for people who cannot pay for energy because they are relatively poor, through economic policies such as tax reductions or from economic development and the transition to new energy technologies (Khennas 2012). Sovacool (2017) Identifies the impact of subsidies for the advantages of health benefits by using decarbonisation energy access to reduces air pollution.

In Nigeria, access to energy for rural homes is restricted due to the lack of integration plans within energy access programmes. Thus, the infrastructure is not adequate to allow for energy access or even, to freedom of choice in term of a different kind of energy available. Homes on the periphery of the grid system will have not the choice of energy options, where those within the grid can choose what they want. IRENA (2012) outlined the structural barriers of energy systems around justifiable subsided tariffs, the extension of capital costs, the lengthy period for authorisation and incoherent policy and regulations (BV 2010, Ohiare 2014). In addition to barriers, Rohdin and Thollander (2006) mentioned the challenge of opportunities for peripheral areas to get connection and access. This issue discourages capital investment in the energy system because of the complexity of logistics revenue collection.

2.2.5 Exploring the Wider Understanding of Distributed Low-Carbon Energy Resources and Energy Efficiency Measures for Community Energy

2.2.5.1 Energy efficiency measures

Energy security, as understood earlier, is the key issue that faces global challenges. Energy efficiency is among energy policy options positioning the significant role for energy security (EU 2006). It is important for energy saving within the built environment. Energy efficiency defined, (Apergis, Aye et al. 2015) as the useful outcomes produced from a unit of energy use the various indicators used to measure such useful outputs. Erbach (2015) mentioned the important impact numbers for adopting of energy efficiency such as, but not limited to, energy costs for energy users can be lowered, air pollutants and other adverse impacts of emissions can also be significantly lowered.

Using energy more efficiently may be a significant factor in saving energy on a global scale. However, (Mielli 2011) identified that the challenge of practical use of energy efficiency must consider policy implementation. Sarkodie and Strezov (2019) add that further challenges include investment failures and the uses of less efficient technologies. In the investigation of community energy activities, it is important to understand local energy initiatives for the purpose of this research. Much of the literature related to energy policies, technologies and markets solutions also identified localised and small-scale concepts of energy reduction and efficiency.

Energy-efficient refurbishment as studied by Hong, Gilbertson et al. (2009), aims for the improvement of the thermal comfort for low-income dwelling in England, Reeves, Taylor et al. (2010) designed the Peabody modelling case study in existing social housing to achieve carbon emission savings. In the study that Dörr, Wahren et al. (2013) conducted about the approach of energy efficiency measures related to the management of energy activities in organisations found that there are misconceptions due to a lack knowledge and skills for using the introduced technologies. Swan, Ruddock et al. (2013) studied the adoption of sustainable retrofit technologies within social housing identifying issues and factors of strategic attitudes, behaviours and readiness toward the adoption of an energy-efficient retrofit. They considered the use of low carbon energy sources or upgrading properties to promote energy efficiency in the built environment. The energy-efficient upgrade of homes is a method used to improve the physical characteristic of buildings aiming to improve a desirable social and economic output. It could be either adopted by using fabric materials or changing systems of the buildings for energy uses reductions or behaviour.

The approaches include the sustainable retrofit (Swan, Ruddock et al. 2013) used to address energy poverty, eco-design, energy labelling to improve performance standards processes (EU 2006), but approaches are understood the important measures used to apply across the UK and some European homes, in terms of assessing the relative energy efficiency (EU 2006, BV 2010). The measurement processes, which is the about labelling technologies, constructions and materials, can either remove or maintaining the products to be distorted from the market by using policies to regulate the minimum energy performance of material products or management engagement to assess the energy performance of products for the energy users through a means of standardised energy labels. Example of this eco-design for energy performance include household appliances such as stoves, heaters washing machines, and lights. The use of energy standardisation labels applies to heavy appliances such as refrigerators and dishwashers. labelling provides an energy efficiency ranking in an attempt to raise awareness about energy-efficient products, particularly in the EU this also applies to buildings.

There is also a study conducted by in the UK homes, where the use of energy efficiency is identified as measures in terms of visual interventions, which promote energy conservation (Goodhew, Pahl et al. 2015). The study shows the important tools of innovative technologies such as efficient boilers, low energy consumed light bulbs, and the potential energy resources savings of householders' behaviours particularly from technical energy efficiency measures and interventions to encourage the reduction of energy use (Goodhew, Pahl et al. 2015). There is also a study that looked at energy efficiency interventions into two approaches in the delivering of energy efficiency measures: tailoring interventions and visual information. The visual information could be applied in several new homes including residential communities, while the tailoring interventions are the approach measures used for certain houses, which need to apply skills and capital resources in order to upgrade the home's performance (Boomsma, Goodhew et al. 2016).

Research of Anda and Temmen (2014) finds that it is more successful to encourage behavioural change in the public by using social marketing rather than using the more intensive and formal approaches of appealing to economic interest, opportunities, and the advantages of improving energy use. Sarkodie and Strezov (2019); BV (2010) have argued the investments in energy efficiency do not, directly, benefit the investors. Thus, the introduction of smart metering serves as a multi-tool for residential energy efficiency induces the behavioural changes. The technology is used as social marketing for behaviour change, introduced for smart grid connections (BV 2010), and the approach can accommodate both energy users and investors benefits as it uses the meter system to facilitate the positive economic assessment and benefit, providing detailed information regarding energy use and connected technologies. Anda and Temmen (2014); Ehrhardt-Martinez, Donnelly et al. (2010) highlight the roles of the meter system for use in the communities for energy efficiency. This reduces the costs of the solar PV system, direct load control for devices such as air conditioners, provision of an in-home-display (IHD) and it also determines a time of use pricing product. Communities with real ambition and a long-term energy strategy can apply energy efficiency activities for sustainable energy use using distributed systems.

2.2.5.2 Low carbon energy and distributed energy system

Low carbon energy technologies have been recognised to date as simple models of distributed low caenergy systems, that incorporate district heating, combined heat, electicity generation, and cooling technologies. These models can deploly both renewable energy sources and low carbon sources such as natural gas for low carbon emissions. It is acknowledged that low carbon energy technologies are typically better installed in local communities and they can be an opportunity for local communites to explore their local energy sources. Likewise renewable technologies described by (Al-Maamary, Kazem et al. 2017) as the use of renewable energy resources such as hydro, wind, solar, biomass and geothermal are used as substitute for fossil-based fuels and nuclear power plants, which are denger to the environment. Renewable energy can significantly contribute to the reduction of energy use. This will reduce greenhouse gas emissions while increasing energy sources. Lake, Rezaie et al. (2017) identified the benefits of renewable energy such as decreasing energy costs and increasing the chances of introducing technological innovations such as energy storage. Olabi (2017) supported the ability of low carbon energy to increase energy production and transform forms of energy to storage for future energy use. In spite of the contributions of low carbon energy sources in the energy supply, the use of these sources varies by region or country. This is because each region has different technologies, policy strategies and markets, drivers and barriers and levels of social acceptance (Callaway, Fowlie et al. 2018). These various technologies need to be assessed so that each region can adopt appropriate technological installations.

Community energy practitioners and stakeholders can be employed to evaluate the potential renewable technologies within specific local areas. This assessment will be adopted if the technologies are feasible and can be practically operated for the desired overall results and ease for energy users. Critically, (Al-Maamary et al. 2017), energy dvelopers can take adventages of available energy resourse to install renewable technologies either on a small scale or for community users or large scale commercial businesses. There are issues of constraint related to to planning, constructions, the physical environment, and policy and regulations. All of these are important factors that need to be considered when developing renewable technologies.

The studies by AGECC (2010) and Erbach (2015) found physical barriers to practical actions related to of renewable energy installations such as large scale wind turbines on roads. There is also a set of constraints reflecting health and safety concerns such as air and water quality and environmental protection. Hong, Gilbertson et al. (2009 highlighted economic factors, for example the costs of technologies and the prices users pay for energy as being critically important to decisions made about development technologies. Renewable energy technologies such as solar PV, heat pump, wind generators and small hydropower can have advenetages and disadventages depending on variable factors such as the specific site, the costs of installation, how easily the technologies can be used and the economic benefits related to payback periods and overall outputs.

One of the merits of solar technologies is that solar installations can easily convert solar radiations into electrical and thermal energy throughout the day. For instance, solar thermal systems produce energy and they convert energy by capturing the solar radiadion as heat. This can be used for the purposes of producing electricity, heating residential spaces or heating water. Solar PV has the capacity to produce significant amount of electricity by converting solar radiation through the PV cells. Jairaj, Martin et al. (2016) stated that with 1 kW/m^2 a maximum incident solar energy on Earth, solar cells can provide the entire energy needs for many households including energy storage duinng the night. However, one of the disadvantages of solar PV in terms of the production of electricity is that the energy price is much more expensive than fossil fuels technologies.

Wind is one of the clean renewable energy sources that the world will potentially rely on in the future. The natural energy from the wind can be easily harnessed by simply driving a wind turbine generator to produce electricity. Research has been identified that wind turbine technologies have substantial adventages over solar energy technologies in terms of installation spaces. Wind energy technology can be an individual generator installed on a community - based energy scale. It can also be installed in a large area for the purpose of commercial generation and supply using the configurarion of groups of wind generators connected to a grid. When assessing potectial wind energy technologies, the abilities of technology to harness wind resources is an important factor in the initial stage of the development projects. The main elements that need be considered are specially turbine sizes and their efficiency and installation requirements. Jairaj, Martin et al. (2016) also described vital information regarding average annual wind speed in terms of a 1sq km grid, which indicates wind energy availability (m/s). Wind turbine also plays an important role when it comes to investment decisions in renewable energy technologies. The large wind turbine technoilogies are potentially mature and cost effective energy energy generation. Energy output from wind technologies will increase drastically by turbine size. For instance, an individual medium wind tubine with the size of 76 tip heigh can generate equally or more than a fifty small size of 25m heigh turbines, therefore having to the larger area of a rotor is the better wind resource available at height.

Hydropower is generate electricity with higher energy efficiency than other renewable energy technologies such as solar energy and wind turbines. In hydropower, water is used as an energy sources when electricity is required. The process of energy generation involves the use of a turbine to produce electricity by harnessing the power of flowing water. There are a number of adventages to hydropower such as economic benefits and robustness in terms of operation and maintenance. It also has few advese effects on the enviormnnt compare to geothermal energy.

Geothermal energy is an environmental friendly technology and it is a simpler project than fossil power plants. This technology does not include the complex compoments of generation systems. However, there are technical challenges related to geothermal energy systems where non-condensable gases cannot be removed from the condenser. The technology still has certain adventages over other energy sources in terms of its fluid, which emanates from the interior of the Earth, and carries a number of substances including solids and gases. Heat pumps basically work by using the sources of air, water and ground heat to generate heat energy or to reverse the pump heat in to cool a building. The heat pumps transfer heat from one place to an other unlike the use of fuels to convert heat from one form to another.

The ability of clean and low carbon energy resources to provide community' s energy needs has been identified in a number of projects and studies Al-Maamary, Kazem et al. (2017), AGECC (2010), and Erbach (2015). Factors such as energy costs and payback are addressed for developers to understand the feasibility of dopting sustainable energy systems. Although there is an indication that some renewable energy technologies have a limited lifetime in terms of their manufacturing, they have great oppotutiny for a rapid payback. An initial investment in renewable nergy projects must be recovered as receipt or income within a particular period of time. In an average calculation for solar PV sytems, for example, the energy payback period is expected to be between three and four years. The quality of the technological installations is one of the factors determining a faster payback. Ground mounted solar panels can also be placed in secure open areas such as agricultural land areas and landfill sites. Using this ground mounted approach, solar panels generate electricity from solar radiation without moving installation parts.

Table 2:1 Assessment of potential energy technologies

Clean and low carbon energy technologies						
						
Technology	5WM solar PV	15kW small wind turbine	500 kW medium sized wind turbine	50kW small hydropower	500 kw small-scale geothermal	100kW ground source heat pump
Capital cost	£3.75m	£75k	£1.6m	£300k		£125
Annual revenue potential	£390k	£5,5k	£170k	£35k		£1.2
Return on investment	9%	7%	9%	12%		10%
Development complexity	Medium	Low	High	High	Medium	Medium
Performance risk	Low	High	Low	Low	Medium	Medium

Key: High Medium Low

Table 2:1 above indicates five projects that local communities could consider when considering and assessing the use of clean and low-carbon technology. For each technoilogy capital cost, initial investment, and social and technical risks for development are assessed.

In the use of low carbon technologies, there are different understandings about the effective use of technology in some geographical regions. Sims, Rogner et al. (2003) see the policies playing an important protective role in existing energy industries and infrastructures. Monopolising of technologies through policy protection for energy production and distribution is that, in some cases, the policies now protect the monopoly technologies creating becoming centralised systems, preventing new technologies from entering the markets (Ekins, Bradshaw et al. 2015). Walker (2008) study states that market failure is frequently noted when the market is underinvesting in research and development and in new technologies. As a consequence, the investors have little hope to meet the requirement of technologies that may lead to the investor's failure to benefit from the right term.

The local information is considered to be valuable when considering the deployment of renewable energy. Callaway, Fowlie et al. (2018) consider the location driver of technologies being deployed and also the technical information such as solar, wind turbine, and geothermal as vital for the technologies to operate and perform sufficiently. Jacobson and Delucchi (2011) noted the potential issues that could happen in terms of solar energy when solar radiation information is not available. The wind turbine which is installed on a high hill topography provides more outputs compared with a similar wind turbine installed at low topography even with the same hub height. There are a number of case studies which look at the issues of social-cultural and environmental factors within the geographical regions regarding the installation of renewable technologies (Jacobson and Delucchi 2011, Team 2012, Al-Maamary, Kazem et al. 2017, Lake, Rezaie et al. 2017). Al-Maamary, Kazem et al. (2017) give an example of the hydropower project that was constructed in Papua New Guinea where villages were saved due to floods and the solar PV were installed on the roofs of the urban areas in order to minimise the costs of land compensation. Studies such as Anderson, Wulfhorst et al. (2015); Kaunda, Kimambo et al. (2012); Rosa and Dunlap (1994); and (Watts 2012) show the slowing in the adoption of renewable energy or even halted uptake such technology in the built environment some in buildings others in boundaries scales. Peterson, Stephens et al. (2015) narrated the history and developments of poorly considered and planned hydropower and nuclear power which was undertaken by stakeholders who should be engaged in the decision-making processes for these technologies. This might be a learning issue concerning environmental safety so that a disaster such as Chernobyl (Cambray, Cawse et al. 1987) does not occur again. The distributed energy system is considered as one of the promising technologies regarding sustainable and costs effective energy generation.

Wouters, Fraga et al. (2016) recognise that a distributed energy system has the advantages of the exploitation of local renewable energy on a small scale as well as the potential in increasing the overall efficiency of the system. Distributed energy systems include small sized technologies for energy generation and the technological storage of energy which can be used locally to provide safe electricity and thermal energy for energy users (Yi, Feng et al. 2014). The incorporation of distributed energy systems in the built environment is the way of the introducing low carbon markets that are favourable for the development of low carbon energy resources while restricting the high risk of the use of deposited carbon energy (Rong and Lahdelma 2016). Community-based organisations can be a catalyst to deploy renewable energy through distributed systems, even on a small-scale, to achieve social and environmental goals. This may contribute wider impacts to local economies and substantial benefits through the reduction of social costs.

In recent years, research and reports on the use of low carbon energy resources using community energy systems have been encouraged with the intention to provide information about low carbon technologies instead of fossil fuel. Studies on environmental sustainability reviewed the advantages of renewable energy (Wilson et al., Macgregor et al. 2009). These include aspects of market regulation, social and technical innovation (Bennett , Marino, Bertoldi et al. 2011), and the new regional and local governance systems in England (Smith 2007). Nigeria needs a distributed energy system to an energy solution. The use of low carbon energy distributed through communities can be vital to addressing the energy access, air pollutions and the problems caused by climate change in Nigeria.

2.2.6 The Rationale for the Adoption of Models of Low-Carbon Distributed Energy Systems in Nigeria

In the previous sections, it is understood that various issues and challenges relate to population and economic growth drivers expanding production capacity for generation, which are part of energy use and supply concerns, climate change and these issues can be found in the literature. Inequality in energy access and distribution, particularly in Nigeria, are also highlighted, understanding a few energy programmes such as incentives, electrification of mini-grids were important factors targeted to achieve sustainable development goals with relation to inequality issues including energy for health, water, education and economic development. Identifying the wider ranges of energy efficiency, renewable energy and policies measures to address such energy insecurity and climate change problems for curbing emissions and a change for sustainable energy use are also found in the literature.

Much of the literature concluded that energy demand in Nigeria is still a concern. The impact of energy capacity and extension remains challenging. The African Progress Report (2015) compared over a 17,519MW the current power demand in Nigeria with 5,300MW peak generation capacity. This means that there is a need for substantial changes in the delivery of energy systems in order to meet Nigerian energy demand. The linear technology which is shaped by a top-down energy system tends to use for shaping the implementation of infrastructural technologies programmes which always encounters many challenges and barriers, considering existing policies which lack a holistic approach to providing energy access and meeting the SDGs. This section aims to investigate collective ownership and management of energy-based renewable energy models, as (shown in figure 2:8) and its components and activities within the literature will be reviewed to answer the research questions as well as to meet the research objectives.

The role of community ownership energy groups in the energy system will be necessary for the expansion and use of sustainable energy and can provide a broad scale of contribution to Nigeria's energy generation system. The benefits that are derived from local community energy include greater energy efficiency, reduced carbon emissions and energy access will impact the general population. Community-based low carbon distributed energy systems through a community's economic and operational participation are the key factor for the building of low carbon societies and can contribute to energy use in a sustainable manner (Becker, Kunze et al. 2017).

2.2.6.1 Models of community energy and the use of distributed energy systems

2.2.6.1.1 Corporate model for community groups

Distributed energy which is delivered by local energy organisations has been advocated by the actors of innovative technologies and sustainable activists. The approach would be grown as a result of low carbon models supporting and resourcing the development skills of self-sufficiency and local energy businesses (van Veelen and Haggett 2017). But a business idea from researchers such as Okay, Okay et al. (2008), Hansen, Langlois et al. (2009), Hielscher, Seyfang et al. (2011), Hannon, Foxon et al. (2015) highlight and discuss community energy models such as the Energy Service Company (ESCO), which provides wider energy services benefits to customers, where the energy services which the ESCO provides delivers wider energy benefits to customers. According to Hannon and Bolton (2015), the energy service that the ESCO provides is not only related to the physical benefit, goods or utilities, but also to general energy management services (EU 2006).

The energy services include the transfer of decision rights over main items of energy equipment facilitated under the terms and conditions provided. These services can be offered via energy service contracts which usually last between 5 - 25 years (Sorrell 2005). Hansen, Langlois et al. (2009) identified the energy service contracts that ESCO can deliver to its customers, categorising them into two approaches; Energy supply contracts (ESC) and Energy performance contracts (EPC). Although the importance of the corporate energy model in providing energy services is identified (Ren, Zhou et al. 2011), the approach has also opportunity to offer self- renewable energy businesses particularly in the development process where procurements and capital investments could be provided loans. In the corporate models, there are issues related to the purchase aspect of unbundling attribute certificate, which could be barriers to sourcing energy (Ren, Zhou et al 2011). This issue needs to be considered in the delivery of energy for successful energy generation and management.

Community energy has been considered an important factor, particularly by established policy frameworks for delivering low carbon energy and operations for broader positive local impacts. The formation of community energy organisations who deliver the energy systems is another significant factor enhancing and driving the influence of local energy change by the creation of social value to address managerial control and financial issue and tackling energy poverty and health problems (Bardsley, Büchs et al. 2019).

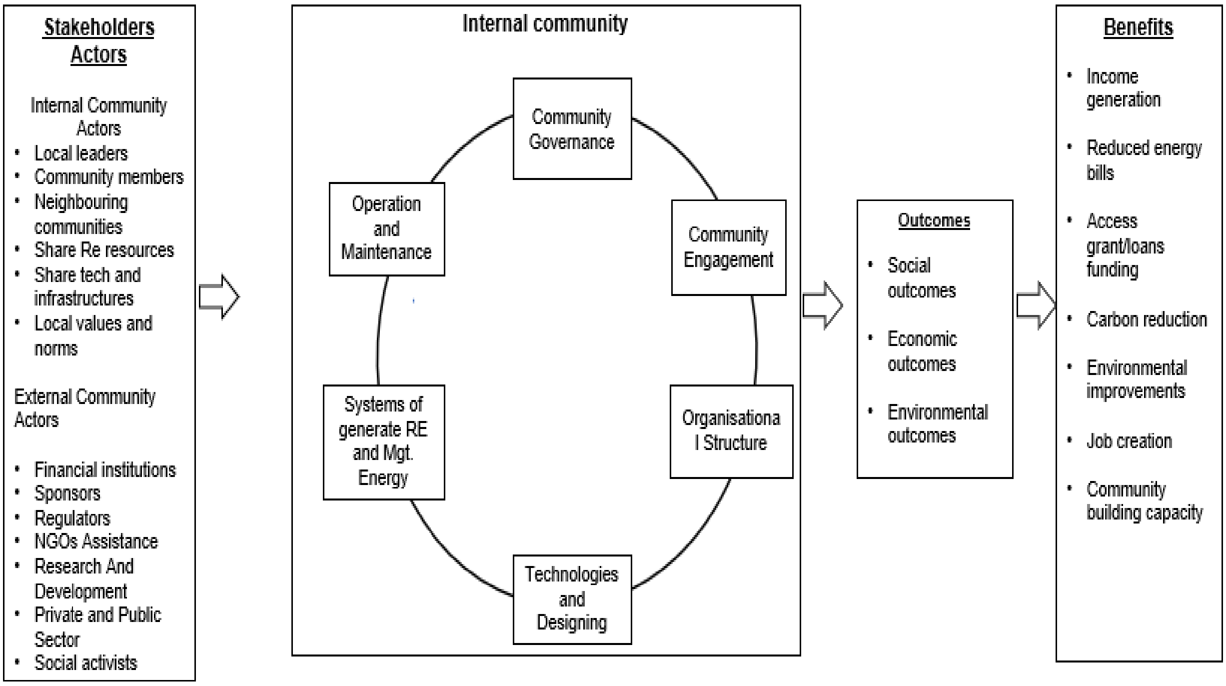

Figure 2:7 Community-based energy framework.

2.2.6.1.2 Community energy ownership Model

When considering community energy systems, there is a need to consider the sociotechnical issues that make up the complex systems (shown in Figure 2:7) that are driving for the development of community energy. Koirala, Koliou et al. (2016) look at how the people of communities engage and gain expertise in legal administrative and management structures for community energy success. Denis and Parker (2009) highlight the vital aspects of financial approaches and support mechanisms in developing community energy. In the following section, the aim is to identify the key components of community energy and factors driving the success or barriers for delivering community-based energy. It starts with one organisational structure of the community energy, the key activities that the communities are involved in, what are the instruments facilitating the community energy, further investigation of energy outcomes and impacts for the community energy.

To understand the concept of community-based system and energy activities two distinct themes are conceived making a clarity for this research: energy communities' ownership and the use of small distributed energy resources and energy efficiency measures. The community ownership refers the group of people who are involved in one or more activities in energy-related assets such as energy generation, energy storage, demand reduction, or energy efficiency, while these distributed energy systems, which use the approach of small scales renewable energy such as wind and solar technologies owned either managed by individual members (Walker and Cass 2007) from a community or by those individuals participate in such operations and management activities for the benefits of a defined community area or group of people.

The Department of Energy and Climate Change Report (2014) on Community Energy Strategy described the meaning of community-based energy as community initiatives or projects that place an emphasis on the use of energy reduction and better management systems. But the emphasis of this definition should be placed on the inclusions of generating and purchasing energy for the communities of place or communities of interest with the projects sharing a focus on community ownership for the benefits of the community. Therefore, the models of community ownership can be developed in the defined community area where geographical boundaries or mutually dispersed community interest (van Veelen and Haggett 2017), which includes social benefit groups or economically value orientation companies.

2.2.6.1.2.1 Types of community ownership models

Some of the research identifies the ranges of structures commonly used for implementing a distributed energy system. (Walker and Cass 2007) identify types of authories management responsibility for delivering energy include public utilities, private suppliers, communities, households and business structures. Community structures which function to generate electricity or heat for local consumption or onto the grid can be macro and micro in size (Middlemiss and Parrish 2010). These would include community benefit societies, co-operatives, and community interest companies all of which have been mentioned above but depending legal issue and financial models of ownership to be adopted. The community benefit societies are a similar organisation to those to be found in the UK. They include community benefits funds, approaches which seek to stimulate the local economy by ownership of the public assets as community energy shares(Becker, Kunze et al. 2017). There are examples of projects, such as, High winds community energy society (shown in Table 2:2**Table 2:2**) and Baywind, which cooperatively owned wind generation systems, after years later, people in the local area involved in the cooperation through buying shares to finance the system.

Table 2:2: High winds community energy society

Commencement of community	2014, High Winds Community Energy Society
Location	Ulverston, Cumbria
Community organisation structure	The partnership includes Energy4All Co-operative, Baywind Energy, and Energy Prospects
Type of technology	Two wind turbines
Total capacity	4.6 MW
In 2017 generated	Over 11MWh
The project brought benefits such as	Three community organisations to form mutual support, reducing the development burden on communities

The High Winds Community Energy Society is a partnership community energy project between three community organisations established to develop wind turbine technologies. The project provides multiple benefits including energy generation. Community energy systems in Nigeria can be facilitated to generate electricity a similar the capacity of generated energy in the UK and they can be used to address energy access issues, which are challenging the Nigerian energy policy. As cited in the earlier section, the financial scheme is one of the community energy issues. The development and promotion of community renewable energy in the UK are related to the introduction of the feed-in tariff that developed through renewable energy programmes over the last decade.

There is greater adoption of community-based projects in Denmark, where over 150,000 household ownerships managed wind turbines (Lauber 2004). Approximately about 350,000 households owned shares in wind community energy organisations (Sawin and Flavin 2006) across in Germany. Significantly, these organisation forms of community have structures which suggest a preference for a mission-led to democratic and social enterprise structures engaging in energy activities in order to address environmental actions or promote the local economy.

Community energy organisations can be created to govern local energy activities for the development of human capacity within an organisation. Therefore, the success of community energy can be found in many community organisations who form the legal structures necessary for governing an energy system. As a range actions of the myriad processes through which the group of people must go in order to enforce the rules that needed for these groups to enable them to achieve their desired outcomes (Florini and Sovacool 2009). This means that the governance for community energy organisations consists of people with the structures and networking skill to meet local needs and priorities. Additionally, this provides a focal point for local energy decisions, while the communities have a local leadership role enabling them to lead themselves taking an action to promote inclusion such as developing social and capital values (CEE 2017). In England, for example, more than thirty-seven community energy groups reported that they had received £7.4m feed-in tariff subsidies since the programme was introduced in 2010 (Warren and McFadyen 2010, Trust 2015).

2.2.6.1.3 Key energy activities

Community energy organisations could adopt various renewable energy resources, technologies and aggregated initiatives to achieve their objectives. Hoicka and MacArthur (2018) revealed that the broadening practice of community energy activities across England in terms of engaging renewable electricity generation and actions in energy efficiency by using low carbon technologies. It appears that the community participates in using energy storage systems in the most of island societies. These include rural areas in developing countries.

2.2.6.1.3.1 Community small scale energy generation

Community-owned energy systems can produce capacity by using renewable energy that may meet annual energy demands while, at the same time, reducing the annual carbon emissions. Walker, Hunter et al. (2007) found that technological sizes and varying scales capacity installations within communities played a significant role in driving the growth of energy capacity. There has been a range of studies (Lund, Möller et al. 2010, Walker and Simcock 2012, Lake, Rezaie et al. 2017, England 2018) on community electricity and heating regarding the use of solar power, wind power, hydropower, biomass, ground sources heat pumps, and air source heat pumps by the community energy organisations to generate energy. The CEE (2017) report revealed that the operational energy generation through community organisations in the UK installs the various of technologies types and sizes Table 2:3 shown generated capacity (small-scale and large with 5 MW capacity) at least contribute energy capacity to the UK renewable energy sector.

Table 2:3: Community electricity generation capacity (%) in the UK 2017

Technologies	Capacities
Solar PV	135MW
Wind Turbines	30.5MW
Hydropower	1.47MW

The table above shows how the UK energy community (including England, Wales and Ireland) have adopted renewable energy, not only reducing the threats and severe impacts of global warming on the environment but also promoting the use of energy capacity in much better for sustainable energy services. Most importantly, this capacity contributed to energy generation adding 202 GWh of electricity in the UK and reducing CO_2 emissions by 71, 000 tonnes (%) in 2017. It was proposed that community energy would provide a significant energy contribution to meet the energy demand of 67,000 (%) UK homes annually CEE (England 2018). The high winds community energy society is one of the community energy case studies in the UK, generating 4.6MW energy capacity (see Table 2:2).

2.2.6.1.3.2 Community and energy efficiency

Recent years have seen a growth in pressure to increase energy efficiency and management activities by community engagement mostly found in some OECD countries (Apergis, Aye et al. 2015, Carlén, Rosenqvist et al. 2016). This suggests the importance of energy efficiency activities in providing multiple benefits such as the reduction in energy use and the risks of carbon emissions (Sarkodie and Strezov 2019). Several technologies use through metering systems, improved energy bills are developed to improve energy efficiency and reduce emissions from fossil fuels (Abrahamse, Steg et al. 2007, Steg 2008, Ehrhardt-Martinez, Donnelly et al. 2010, Polimeni, Mayumi et al. 2015, Bardsley, Büchs et al. 2019). These studies sought to address energy efficiency and demand management issues, including: advice and support; improved energy services; and utility demand management. Callaway, Fowlie et al. (2018) recognised the design of energy efficiency as an important factor through the community organisations' emphasis on the benefits of lower energy costs and improved quality of life. Facilitating and enabling services such as energy monitoring, energy audits or energy efficiency upgrade activities are community energy efficiency tools (EU 2006). Energy services and information campaigns are the dominant community intervention actions. Swan, Fitton et al. (2013) viewed this intervention as any activity that controlled the risk using effective communication, useful information in connection with the community or the delivery of the clearance services approach which enables the energy users to monitor household properties by removing the risk.

Community Energy England's report (2018) on energy efficiency assessed interventions by community energy groups, where it identified that energy initiatives in terms of addressing households' behaviours, which include energy audits, innovative meters and facilitated billings contributed to shifting residential loads. All are these important approaches, parts of community initiatives, which promote energy savings. It identified that advice on energy appliances accounted for 55 per cent of sustainable energy use. For energy café and awareness campaigns 25 per cent. Educational events are of increasing interest due to their wide impact on sustainability and low costs are important aspects in community organisations due to the low cost and expertise required to carry out the tasks. The example of community energy efficiency, Carbon Co-op is a case study of community energy engaging in energy efficiency in Manchester shown in **Table 2:4**.

Table 2:4: Energy efficiency adopted through Carbon Co-op.

Commencement of community	2008, Carbon Co-op
Location	Greater Manchester
Community energy structure	Community interest members
Type of technology and services	Technical consultancies such as retrofit energy efficiency measures or detailed training workshops
Energy activities by Carbon Co-op	Focus on the whole-house approach
Benefits	Cost-effective for members
	Reduction in energy use, and capacity building

The carbon Co-op is focusing on the whole-house approach to save energy use using retrofitting energy measures. Also, the community organisations engage their energy activities by using battery storage systems (Bauwens 2013) that often save energy generation and make the communities use renewable energy more efficiently. Studies have identified studies the importance of battery storage as a technology for lowering costs and the opportunity of installation for island societies, this can also be improved the quality life of rural community, who does not access to energy grid (Koirala, Koliou et al. 2016, Becker, Kunze et al. 2017, Bardsley, Büchs et al. 2019), which addresses the intermittency issues associated with renewable technologies. The table below Table 2:5 shows a pilot case study of community energy using battery storage for a degree of flexibility, in the case of weak grid issues and deployment without support.

Table 2:5: Energise Barnsley: a pilot of batteries and solar installations.

Community Energy Name	**Energise Barnsley – a pilot of batteries and solar installations**
Location	Barnsley
Community organisation structure	Partnership with District Network Operator (Northern Powergrid), Barnsley Council, Energy Storage Company (Moixa)

Community-owned project	321 council-owned homes, 16 council buildings include schools and housing blocks
Technology type	Smart batteries, thermal stores and air source heat pumps
Capacity	7MW stand-alone battery on council-owned land
Benefits of the projects	Free solar PV panels, a bond from Charity Bank, focus on those vulnerable to fuel poverty

The case study deployed a 7MW stand-alone battery in Barnsley for community homes and buildings Table 2:5. The purpose of this project was to use battery storages to help Bsansley communities to eradicate fuel poverty. It also encourages the impacts of social and economic benefits in the community.

2.2.6.1.3.3 Incentives and barriers to community energy

There are number factors such as financing and supporting installation encouraging for community end-users to engage the handling of energy activities, otherwise, lack of these factors could be barriers to the community energy. Community energy systems through a proper structure can take financial advantages, depending on the motivations the communities involved in energy activities (Muthoora and Fischer 2019). Seyfang, Park et al. (2013) indicated the real action of practices through implementation of the community energy systems, as an economic policy is an important driver such as incentives through tax reliefs and subsidies for different actors, including the shareholders and investors who can actively participate in community energy. Financial aspects are a key issue in the situation for established community energy.

There are two financing approaches mentioned, which are the most common for the development of community energy in the UK (Hoicka and MacArthur 2018, Muthoora and Fischer 2019): funding and investment. Funding (grants) is considered to be important from the pre-feasibility study to the viable stage. It determines whether community energy is feasible or worthwhile. Muthoora and Fischer (2019) stated that funding schemes are a useful means of adoption energy technologies for rural communities. Hargreaves, Hielscher et al. (2013)

highlighted the development process, in which the communities require professionals and expert guidance on planning permissions at different stages. The introduction of government revenue payments under the name ‘Feed-in Tariff Scheme 2010’ was the largest step forward for community energy in the UK. But there was a change of the UK scheme approach from the feed-in tariff incentives to the Market drive approach undermined the motivation of communities and local business (Walker, Hunter et al. 2007, Hargreaves, Hielscher et al. 2013, Swan, Fitton et al. 2013), reducing the participation and engagement in renewable energy projects and the adoption of energy efficiency, thus communities without renewable energy schemes may expect to experience greater barriers, particularly for successful business models as new investors might find difficult in engaging in renewable energy solutions.

Funding development programmes serve as a vehicle for community energy development. One example is the Rural Community Energy Fund (RCEF), and this funding is delivered across rural communities to inspire them to generate their own clean energy (CEE 2017, Hoicka and MacArthur 2018). The Rural Community Development Fund is a partnership programme between the Welsh government and the European agriculture fund to support community capital projects in renewable energy and energy saving. Capital investments can be made through the Seed Enterprise Investment Scheme (SEIS), Enterprise Investment Scheme (EIS), and Social Investment Tax Relief (SITR) to develop community energy. The German public development bank, Kreditanstalt fur Wiederaufbau (KfW)(CEE 2017), gives a low-interest loan for investment in renewable energy and energy efficiency (Walker, 2013).

2.2.6.1.4 Reflection factors of community energy models: The geography of community energy development

The geography of community energy is important regarding the deployment of community energy technologies, van Veelen and Haggett (2017); (CEE 2017, Muthoora and Fischer 2019) included a number of issues for encouraging community energy systems such as resource availability, access to expertise and finance, different levels of support either at state or local level, networks that could be founded in a particular location, community energy programmes, policy, support bodies, and funding stream. All of these factors played a significant role in different geographical contexts. But also, a suitable location is another factor for the successful development of community energy management (Trust 2015).

In Wales, access to hydropower and wind resources through the Ynni Leol framework supports the community. For the community energy networks, Zero West through Bristol Energy

Cooperative aims to accelerate the low carbon agenda in the west of England by networking around communities, developers, experts, local authorities, and other actors who support services such as Datblygiadau Egni Gwledig C.B.C (DEG) and the Wales Co-op.

Wind generation is employed in the UK, where this technology is more dispersed in terms of geographical locations. For example, the largest projects for community wind generation include a 6.5 WM wind farm in Wiltshire and 11.5 MW capacities at the High Winds and Moor Wind Farms in Cumbria, alongside smaller capacity projects, for instance, 250 kW turbine generators across Northern Ireland. Also, hydro projects require adequate catchment areas and steeper topography for adequate energy generation. Hydropower projects are distributed mainly in Wales and Northern England, such as the 100kW Whitby Esk Energy and Saddleworth Community Hydro, and a 300-kW hydro project called Totnes Renewable Energy Societies in Devon. Funding support plays an important role in these communities in developing their projects at an early stage. Community energy sought to be deployed the variety of technologies in Nigeria considering the potential factors for the particular location across the country.

2.2.6.1.4.1 Community energy outcomes

As part of the efforts of SDGs to address global energy issues, the previous section discussed the role of the energy community in generating cleans energy and improving energy efficiency. It stated the approaches to financing community development through the funding schemes and investment approach. This section highlights the positive outcomes of community energy such as social, economic and environmental impacts. While useful community energy factors and barriers were examined in the previous section, this sector provides some of the experienced community energy factors the practical application of community strategies in the UK.

It is considered that community energy has wider benefits not only in the form of environmental impacts where carbon emissions can be reduced, and the local environment improves by the deploying of renewable technologies such as small wind turbines and solar energy resources, which significantly contribute to social life within the area. It also has economic benefits such as the generation of incomes, reduced energy bills, and loan funding. In addition to other community energy benefits, there are social outcomes, for example, job creation, community education, and community asset purchase.

2.2.7 Theoretical Framework for Understanding the Factors of Community-Based Distributed Energy Systems

In the previous section, the literature discussed energy issues, which ranged from economic growth and energy inequality mainly through lack of energy access, to poverty and climate change; it also discussed the problems caused as a result of energy issues. The literature investigated several energy solutions, from energy efficiency to renewable energy for the different scales and models adopted in various countries. These included community distributed energy systems that can drive the energy system towards sustainability. This section aims to identify a number of theoretical approaches and concepts related to socio-technical approaches from the different perspectives of the framework. This comprises many elements for understanding the many different factors and issues of complex community energy systems. As this research wishes to answer questions involving the adoption of community-based low carbon energy systems in a specific domain for finding solutions to energy issues, theoretical approaches from the different perspectives of socio-technical systems have been adopted to develop a framework for many case studies. This theory provides a framework within which to consider community energy systems. This focus on the strands will provide the relevant pictures of the relationship and interdependences of social and technical elements and networks of actors in this research context. The basic elements of the socio-technical aspects of a community energy system can be understood by examining the nature of the socio-technical approaches.

2.2.7.1 Technological determinism

Technological determinism is a theoretical position that emphasises the view of technology as the primary causal factor in understanding socio-technical change. This position views technological innovation as a pre-determined factor, proposing that the position of technology held by its nature and the direction of innovation are unproblematic (Brown and Mercer 2009). It was outlined that technological change produces social and organisational change. Understanding the concepts of technological theory through their practical manifestation, technology is assumed to be an innovative approach that offers a sure vehicle for achieving organisational change. This change means that technology is guaranteed to develop according to inner technical logic (Smith and Marx 1994).

Many studies from social scientists have been advanced to demonstrate the patterns of technological innovation and they have sought to assess its social impacts. One example of studies on technological paradigms is that conducted by (Fleck, Webster et al. 1990) about three technologies: computer numerical control; robotics office automation; and computer-aided production management. These technologies were intentionally developed to show the significant impacts of technology and how it might replace the use of labour in the production process. There is also a technological approach in understanding how the introduction of artefacts as a by-product of their physical attributes directly influences particular social outcomes and leads to a number of knock-on effects. The approach proposes that there is a possibility of similar artefacts when they are put to different uses; they could have different effects in different social contexts provided by the pattern of social change, as a result of other technologies or economic and social factors.

Technical determinism has a range of different perspectives, the general view of the technological approaches is to insist that the technologies have necessary and determinate impacts upon the whole systems: upon work, society, and economic life (Smith and Marx 1994). The ideologies of technical imperative suggested that the linear paths of technological change were inevitably brought in to solve the problem. For instance, Sørensen (2002) indicated the importance of carbon sequestration, and solar PV or wind technology, to oppose the use of fossil fuels and outlined that the policy instrument is strictly limited an important factor for change. The broader views and perspective of innovations including the issues of community energy systems, analysing the complex factors of the systems.

2.2.7.2 Science and technology

There are many researchers talked about science and technological (ST) approaches, which consider the practical manifestation of technological innovations for solving issues. Brown and Mercer (2009) asserted that the ST approaches tend to promote technical fixes ahead of "re-shaping social practice". Carlsson and Stankiewicz (1991) considered the technological system as an integral part of socio-technical elements. The system incorporates networks of agents that interact in a particular institutional infrastructure to generate, diffuse, and utilise technology. It highlights the importance of change related to its diffusion and utilisation, although it does not conceptualise all the material aspects of the social-technical system narrowed down to networks of agents. The system is much more concerned with dynamic knowledge and competence networks to improve organisations than with ordinary goods and services.

Breschi and Malerba (1997) employed the socio-technical approach of innovation studies to analyse the innovative factors of firms, in which the complex structural industry forms in different ways through the interaction and cooperation between the physical materials of artefacts, and through the market activities for competition and selection in innovative. This perspective indicates the importance of technological innovation in building a framework that incorporates complex factors such as installing technologies (solar PV, wind and biogas digester) in the context of the community energy system. As the system of community energy is a complex network of elements that are involved in the wider social and political aspects in relation to concepts and factors of socio-technical change. This notion has raised a new range of technological paradigms, (MacKenzie and Wajcman 1985, Williams and Edge 1996), which facilitates the relationship between technology innovation and the context of social and political factors, redefining the interaction within the community energy system and how the physical artefact, social factors, and knowledge information are composed in the community energy system.

2.2.7.3 Social shaping of technology

One of the social shaping technology (SST) approaches, related to the complex aspects of socio-technical systems presented by (Hughes 1986), is a combination of innovations that incorporates many systems and sustainable networks of material and non-material elements. The SST theory is espoused by historians of science and technology (MacKenzie and Wajcman 1985, Williams and Edge 1996). It emerged in contrast to traditional approaches, technological determinism, which only addressed the impacts and outcomes of technological change in different ways for understanding innovations. Therefore, the innovations from this approach are considered socio-technical factors, which Geels (2004) defined:

“as the linkages between elements necessary to fulfil societal functions (e.g. transport, communication, nutrition). As technology is a crucial element in modern societies to fulfil those functions, it makes sense to distinguish the production, distribution and use of technologies as sub-functions (shown in Figure 2:8). To fulfil these sub-functions, the necessary elements can be characterised as resources. ST-systems thus consist of artefacts, knowledge, capital, labour, cultural meaning.”

However, the SST approach of socio-technological aspects includes large technical systems integrate heterogeneous professionals and organisations serve as interacting entities in systems or networks. Such disciplines, organisation, persons in the systems or networks operate and perform a function with one another as part of the seamless web. An example of the organisational system includes banks, firms, natural resources, research and development, policies and regulations (Hughes 1986), whereas the professionals incorporate engineers, scientists, and managers.

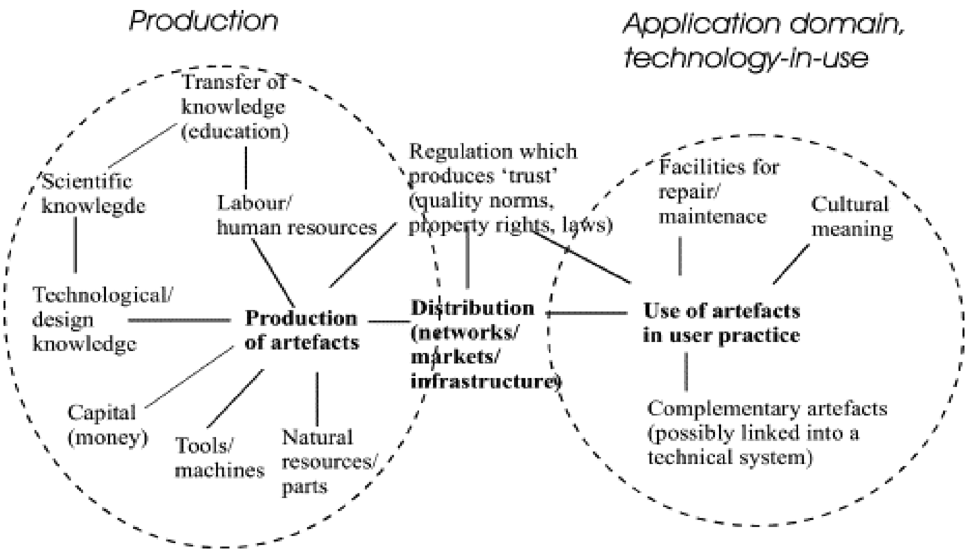

Figure 2:8 The basic elements and resources of socio-technical systems (Geels 2010).

The Figure above Figure 2:8 shows the perspectives of socio-technical approaches that propose a seamless web of interlocking institutions, organisations, and production interacts, considering the use of artefacts in user practice (Geels 2004, Ekins, Bradshaw et al. 2015). This means that the elements of a network of social actors, cultural and material artefacts, knowledge and institutions, in which the different elements interact together to fulfil societal functions from production and distribution through consumption.

2.2.7.4 Multi-level perspective

The multi-level perspective (MLP) is another theoretical position that combines the concepts of social shaping technology approaches, science and technology studies, incorporating them into the multi-dimensional factors and the complex elements of social-technical systems (Geels 2010). The multi-level perspective theory focuses on three levels of understanding the socio-technical aspects of innovation (see Figure 2:9). The macro-level forms the exogenous environment, which is considered as the socio-technical landscape. The regime level forms the meso-level range of elements, including material and non-material socio-technical elements interlinked such as the dimensions of network actors, and rules and regulations guiding the activities of actors. The last level, niches, forms a micro level, a small innovation, a locus where the novelties emerge.

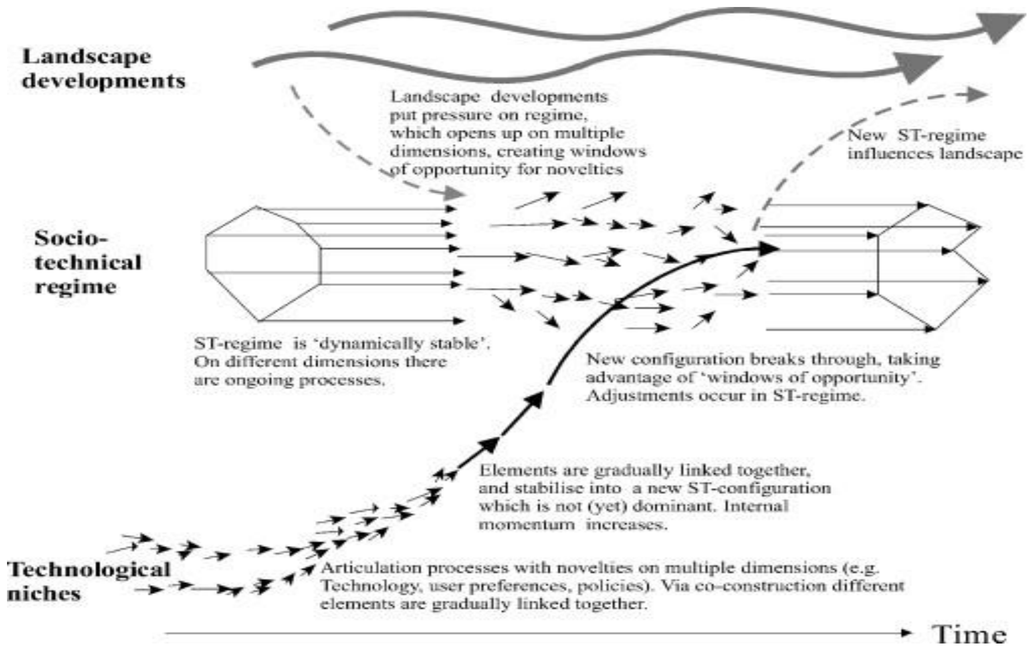

Figure 2:9 Multi-level perspective on socio-technical change (Geels 2005).

Figure 2:9 shows how the three levels of perceptive interact in the unfolding of changes dynamically; considering the landscape level, changes create pressure on the regime. At the regime level, there is destabilisation, which creates windows of change and opportunity for adopting niche-innovations, and an internal momentum is build up from niche innovations. However, the interactions of these levels can be divided into a number of phases, such as emergence, take-off, acceleration and stabilisation.

The perspective of MLP contributes to social-technical systems; as a socio-technical landscape should influence niches and regime dynamics. This perspective indicates that socio-technical systems are embedded in the regime, which represents a "semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels 2011). This analysis shows that the actual nature of socio-technical systems is established in social-technical regimes. The following section provides a wide understanding of MLP from different viewpoints and examples of literature for framing community energy systems.

2.2.7.4.1 Niche level

Niches are a crucial level for innovations in the socio-technical system because In this level the niches provide the seeds for systemic change (Geels 2004). Geels (2011) identifies three distinguished processes on niche-innovation in the niche development: firstly an articulation of expectations or visions with aims to attract the external actors attention on the issues such as funding, and provide guidance to the innovation activities Secondly the connecting and building of social networks that gather more actors to expand the more resources of niche-innovations; thirdly, learning systems and articulation processes from a number of issues that set on dimensions.

Niches are considered as "protected spaces" from the destructive and hostile actions that prevail in the regimes. The spaces are protected by subsidised demonstration projects and small market niches in which users willing to support innovations for their special demands (Kemp, Schot et al. 1998). Actors in niches such as start-ups, spinoffs or entrepreneurs deviate from existing regimes through working on radical innovations (Geels 2010). Niche-actors from this level hope to introduce the important novelties that could be used in the regime system or even replace the system. The change does not come in easy tasks that may cause from the existing of institutional, cultural, and organisational regimes (Smith, Voß et al. 2010), which stabilised through many lock-in mechanisms, while niche innovations keep difficult to stable (infrastructure, regulations, or consumer practices) with existing regime dimensions.

There is a suggestion about how niches could gain momentum when the niches' expectations become precisely accepted, the alignment of the various processes of niche become stable in their configuration, the network of actors become large and powerful enough to convey legitimacy and attract enough resources to niche innovations (Schot and Geels 2008). The niches, however, can become destabilised because of some factors from regimes.

2.2.7.4.2 Regime level

The social-technical approach of the regime originates from the concepts of evolutionary economics and the sociology of technology (Dosi and Nelson 2016). Its insights emphasise the factors of scientific knowledge, process technologies, engineering practices, and social actors intertwined together to form the systematic structure. The socio-technical regime incorporates the technological innovation but extends ideas from the sociological perspective, including the various types of institutions, rules and actors. Although the sociological perspective does not always encompass the entire elements, the socio-technical regime serves to capture the meta coordination between different sub-regimes (Geels 2011). The regime forms the complex structure that accounts for the reshaping of actors and aspects of social-technical systems.

Dosi and Nelson (2016) conceptualised technological innovation in terms of the influence of the 'outlook' defining a set of procedures involved with relevant problems and improving solutions, within each paradigm, the different definitions of progress related to specific technological innovations and economics trade-offs (Elzen, Geels et al. 2011). The concept of the technological regime, as stated by Nelson and Winter (1977). The concept of a technological regime increases many significant roles in the intertwined nature and factors of socio-technical elements.

Example of the socio-technical regime studied by Kemp (1994) about the incremental transition of socio-technical elements, which includes a changed of drivers, the key factors through the technology forced to create a market of early premises. Experiments and research Kemp, Schot et al. (1998) geared toward niche development and the creation of new alliances that are the technological relationships, bringing together the key factors of technology, market, regulation, and other many factors towards the sustainability. Schot, Hoogma et al. (1994) concluded that the changed position of regimes manages to accept sustainability.

2.2.7.4.2.1 Criticisms and strengths of sociotechnical regime

A number of criticisms have been made of this regime opposing the development of disruptive radical innovations as they encourage dependent paths and incremental innovations in the regime (Geels and Schot 2010). Therefore, the societal functions are understood to provide stability and support for the emergence of prevailing elements meaning the socio-technical systems. Kemp (1998) argued that key factors led to the destabilisation of the existing regime, therefore new regimes began to emerge.

Geel (2004) considers that the regime could be a set of rules and practices, that stabilise and organise the activities of social actors, which are reproduced as outcomes of the various elements of socio-technical systems (Kemp, Schot et al. 1998). Gidden (1984) defined the regime rules as the duality of structure: a medium action and an outcome action, in which they explained that actors of the socio-technical regime enact the rules and draw upon actions in local practice (Geels 2005). This example of regime's rules as elaborated by Swan (2013) is a regulative rule, which functions as policy instruments, standards, taxes and subsidies. Whereas, a normative rule is a range of organisational cultures includes norms and values within and between stakeholders shared in the organisation. For the cognitive rule, it is the way things are understood or wisdom that influences actions or behaviours.

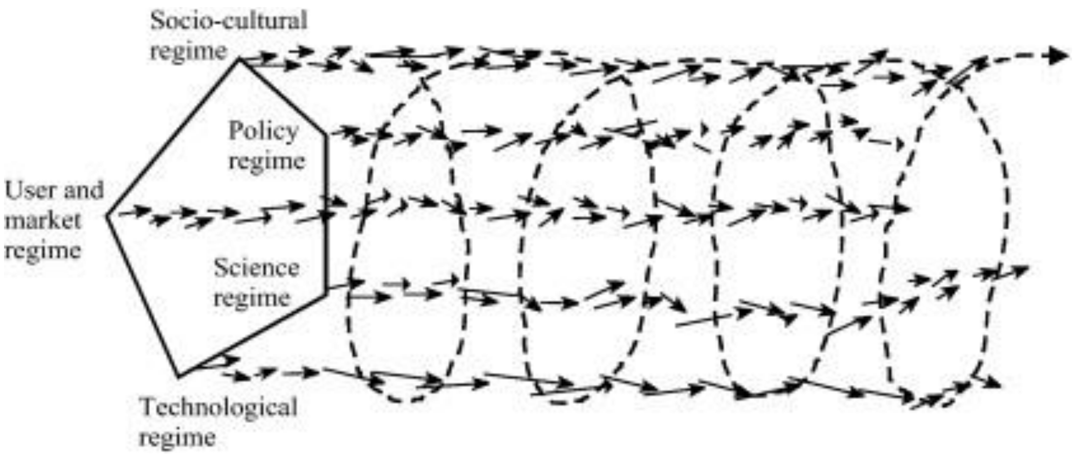

Figure 2:10 Socio-technical regime

Figure 2:10 above shows how existing regimes lock-in, innovation starts to occur incrementally. The change appears with small adjustments that accumulate into stable trajectories. It indicates the trajectories issues occur not only in the technological dimension, but in the different dimensional elements such in political, cultural, science and industry, and market. While all technology and science, market and users, politics and cultural meanings play their own roles that coordinated through different sub-regimes. The various elements interpenetrate and co-evolve with each other.

2.2.7.4.3 Landscape-level

The landscape level is a wider context of the exogenous factors, which influences regime and niche dynamics (Geels 2010). As examples of factors in the landscape level, (Raven 2004) added demographical trends, political and economic ideologies, social values and macroeconomic patterns. The landscape-level sustains social and cultural elements around the spatial arrangements of cities. The landscape influences the actors in socio-technical regimes and forms a stronger structure by setting a variety of factors (Verbong and Geels 2007). The result of this is that actors at the regime and niche level cannot change in the short run. Changes at this level occur in increments slowly. The issues in this landscape span different societal functions unfolding automatically in specific socio-technical regimes (Smith, Voß et al. 2010).

Although there are identified the various strengths of the MLP, and the approach still has been criticised for being niche-bias to create transitions systems. The approach is being restricted the importance of bottom-up dynamics in system change, as it emphasised on technological innovation by identifying the concept of transitions that only encourages the alternative pathways of technology or managing system (Walker 2008); (Smith, Voß et al. 2010). The MLP has been revealed less useful for understanding the system, as it is unclear in its application to transitions processes due to a lack of clarity, which adds confusion around abstract concepts of landscape, regime and niche. The role of places and spatial scales, which is appropriate in terms of researches, that has been an implicit issue by making a very difficult for the empirical researcher to find the specific causal factor that shapes socio-technical transitions (Geels 2011); (Shove and Walker 2007); (Smith 2007); and (Smith, Voß et al. 2010),

2.2.7.5 The implication of the multi-level perspective for community energy system

In the previous sections, the configurations of elements of the socio-technical system such as technologies, institutions and practices which are the predominant aspects of the level of the socio-technical regime were identified (Geels 2011). The implication of this approach MLP for the community energy system, it is important to consider, a framework, the energy system as a patchwork of interdependent system existed in the regime where the interactions help to reproduce and reinforce innovations to maintain the existing socio-technical system (Seyfang and Smith 2007).

Many of literature historically has been applied the usefulness of the MLP, and they are also relevant to use in this research providing insights of socio-technical issues and factors of community energy. The examples of case studies in relation to shipping, as identified by Geels (2002), and the literature about Cargo handling recognised by Van Driel and Schot (2005), hygiene and land transport by Geels (2005a) and (2005b) respectively. There are recent studies about the alternative system on a socio-technical system such as the transition of animal husbandry (Elzen, Geels et al. 2011), causing – socio-technical systems (Seyfang and Smith 2007). The most importantly relevant studies (Geels and Raven 2006); (Raven 2004); (Raven and Verbong 2009); (Verbong and Geels 2007) to this research are the system changes because they comprise the elements of socio-technical systems not only that entail new technologies, but also change for user practice, new markets orientations, changes in policy and cultural meanings (Geels 2004). However, these case studies tried to explain innovations analysing the learning networks, processes and dynamic against and deviate the problems from the dominant regimes (Lehtonen and Kern 2009).

Therefore, socio-technical factors of community energy systems must consider the three implications of the elements of MLP. First, the level of landscape issues such as access to energy, pollutions and energy availability, which is the challenge of the Nigerian energy agenda. The second level of the socio-technical regime comprises such multiple dimensions factors (shown in the figure) which including energy policy, technology and infrastructures, finance and markets, and managerial institution interact in the system. This concluded that there is no single-dimensional driver at different levels, instead, multiple factors cause link up with each other for community energy. The third perspective level from Geels (2004) tends to be interested in the elements of regime in order to integrate together successful community energy niches.

The niches include new innovations, as main elements to potentially be considered within this issue, are knowledgeable actors and stakeholders which can be involved in the community energy system, the regulations or policies which use when maintaining, replicating, or altering energy systems, and the tangle and measurable elements of physical infrastructures for the case study of community energy system, which include renewable energy elements such as technologies, and equipment and installations.

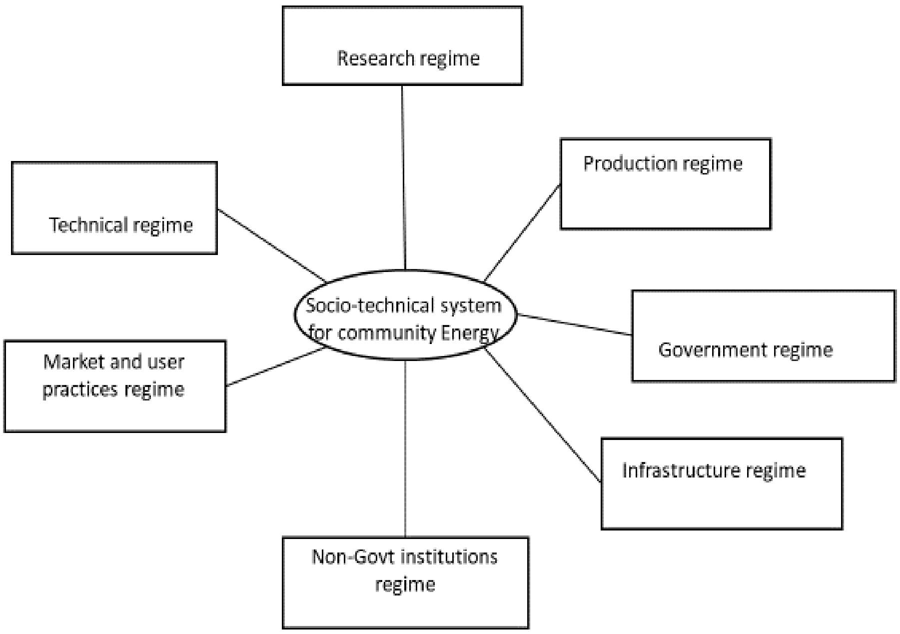

Figure 2:11 Modified socio-technical regimes for community energy systems (Will 2013).

Figure 2:11 indicates that a framework of socio-technical regimes that interrelated and interconnected with each other in the system of community energy. The framework is modified from the case study that applied in the UK for domestic energy conducted by Swan (2013). This modified framework identifies that it is useful to acknowledge the delivery and operation of community energy projects as a socio-technical complex elements problem.

The subsequent chapter will be a case study methodology this research adopted to design research for achieving the aims and objectives of this research; around investigation the complex structure of community system and the issues that lead success or barriers within the community-based energy system.

Chapter 3 : Methodology

3.1 Introduction

This research employs qualitative research to provide a detailed description of contextual features for a community-based energy system. The use of multiple methods is adopted in the data collection and analysis of a community energy system. In addition, the chapter not only refers to the methods that are adopted in this study but also encompasses the rationale and philosophical assumptions that underlie the specific research area. These subsequently influence the actual methods used by researchers to investigate a research problem as well as to collect, analyse and interpret data (Knight and Ruddock 2009).

The research applies an analytical framework of the use of comparative case studies to explore the contextual issues and factors of community energy projects in Nigeria, through a detailed description of the methods such as interviews, observations, and documentary for data collection and analysis. It also provides the rationale for selecting these methods in relation to addressing the research question. Therefore, it is important to restate the aim of this research study, which it is whether the adoption and implementation of low carbon distributed energy generation system can be established in peripheral urban communities in Nigeria.

In view of this, this research argues that by detailing and justifying the adopted methodology to examine the application of potential community energy, the research makes an important contribution to the knowledge base by providing a methodological basis for future research of community energy projects. The research methodology is structured as below in Figure 3:1.

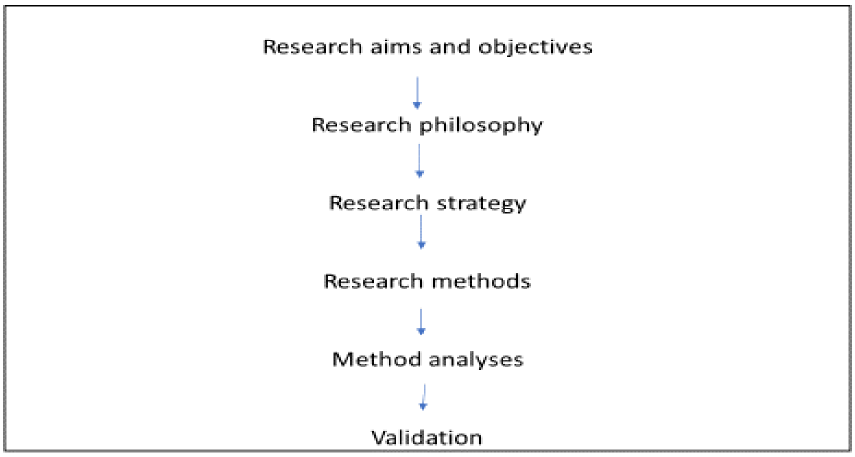

Figure 3:1: Methodological structure

Section 2 examines the philosophical paradigms of the development of knowledge, which forms the basis of this methodology. This section also introduces and justifies the choice of the pragmatic paradigm with respect to addressing the research questions. Moreover, it includes the research approach, which serves as a foundation for developing the research strategy. Section 3 also presents research strategies, which plays an important role in shaping the research. In addition, it justifies reasons for adopting a case-based strategy to address the research question. Finally, section 4 examines multiple methods of data collection and an analytical method in order to identify and analyse the complex issues of a community energy system.

3.2 Research Philosophy

As this research discusses an important methodological approach, it is necessary to consider the relationship between the research question and the research perspectives which lead to factors providing solutions to the research problem. In order to achieve the aim and objectives of this research, there is a need to understand the viewpoints and research questions raised regarding the factors motivating the adoption of community energy projects, in which these issues may be due to human development and building capacity especially for the development of sustainable livelihoods, and the economic and environmental benefits such as low carbon and reduced pollution as well as local job creation.

A designed approach is also required to understand the challenges and barriers to addressing the issue of energy access, which is one of the most prevalent issues between the rural-urban areas. This issue is viewed partly due to a centralised grid-based system using thermal power generation that was implemented in Nigeria to supply reliable electricity for the Nigerian population, but that system did not address the inequality of energy access, and poor maintenance contributed to the failure of reliable energy. Many energy access deficits coupled with inefficient energy sources in the country, led households to use low-quality biomass energy sources such as firewood. The use of fossil fuels in the country resulted in air pollution.

Some views regarding the infrastructure issues include unavailability of gas pipes, dam construction for hydropower and grid installations constraints severely limited power plant upgrade. ICREEE (2016) looked at in terms of policy constraints, although there is a framework associated with sustainable development goals for promoting the delivery of low carbon resources and energy systems, including rural electrification for rural residents to use solar PV standalone and power extension for urban areas for reliable energy use, and renewable energy use in local energy generation. However, lack of energy access is a key issue within the rural and urban areas in Nigeria. To understand the different perspectives is important, particularly regarding factors influencing the adoption of community energy. The views regarding the barriers such as financial aspects and policy and initiatives, which are issues for community distributed energy where there is need to identify the factors drive the solutions of community energy (Walker, Simcock et al. 2012). Therefore, this research explores these issues and factors through research philosophy to facilitate answering the overall research questions.

Research philosophy refers to a set of epistemological, ontological and axiological assumptions that guide the researcher to view and understand knowledge regarding the nature and conduct of research (Pathirage, Amaratunga et al. 2005). It is a philosophy adopted by the researcher and contains important assumptions about the way in which the researcher views the world.

Ontology is a branch of philosophy, which concern the study of being. The ontological assumption is mainly concerned with the nature of reality. In other words, it raises the question of what reality is. Therefore, the researcher needs to hold a position regarding his perception of how things really are and how things really operate (Perera and Sutrisna 2010). Weber (2004) classified ontological philosophy into two aspects: positivism and interpretivisms. For positivism the way of studying issues is a single reality, as the researcher has to be objective in the conducting research, whereas interpretivism rejects a single reality, taking the position that the understanding of different meanings of settings, contexts and characters gives an opportunity for understanding reality to be constructed. Epistemological assumptions concern what constitutes acceptable knowledge and how knowledge can be constructed in a real setting (Jackson 2013). Epistemology is the study of nature, and what forms knowledge. The positivist believes that understanding the reality of this epistemological point of view is achieved through the testing of the relationship between variables. Interpretivists explore the nature of reality by justifying and interpreting how the research contributes to knowledge, in particular, in a real setting (Saunders 2011).

As the aim of this research is to identify the factors to establish in peripheral urban communities in Nigeria, consideration of philosophical assumptions and their influences can have a significant impact on the methodological decision made by the researcher in the research study. This research aims to explore and identify the issues through explanation and descriptive approaches for the issues, which must be understood for a successful solution to the problem. Voordijk (2009) categorises several research paradigms, which might extend the methodological base. This research addresses social issues of the community energy systems, which are associated with the complex nature of the socio-technical problem, involving social actors who have subjective views of reality, financial issues, but also including physical artefacts. Addressing the alternative approach of more practical research is an important aspect of this research.

3.2.1 Pragmatism

The objectives of this research require the need to consider the interplay between social actors and technical aspects, thus, understanding that underlying principles will guide the construction of the conceptual framework for community-based energy systems. This research does not seek to employ a single research approach but instead focuses on the consequences and meaning of actions or events in community energy projects where the delivery of installations such as financial and procurement issues and the operation of projects can be considered in terms of practical action. Therefore, the fundamental principle of this research is based on addressing the underlying problem of the socio-technical aspects of a community project.

The research paradigm adopted in this research depends on the philosophical position of pragmatism, which is dependent upon the research question around the factors and issues pertaining to community energy projects. The paradigm provides important issues in terms of the wider demonstration in research design and its effects on the research process (Saunders 2011), which has subjective views of reality. This is highlighted based on the concept of Dewey's philosophical knowledge, which emphasises the reality practically changing with the interaction between the socio-technical systems (Morgan 2014). This position provides a contextual research process that contains an "action agenda" for reform and can improve the lives of the participants. It helps the researcher to explore the area of community-based energy systems in-depth, and the factors and issues around community energy projects in Nigeria must be identified.

3.2.2 Research Approach

As stated earlier, the objectives of this research require the need to consider the social-technical aspects, along with the need to gain insight into underlying principles that guide the formulation of the conceptual framework for the adoption of community-based energy systems. This research does seek to adopt a research approach that addresses the issue of practical action such as the issue of participant actors, rules and regulation, financial and technical aspects of a community energy system, where it focuses on how to develop for a solution or develop an answer to the research question.

As a research theory, the research approach presents a key decision which the researcher makes in developing the design of the research strategy. This approach can be either a deductive approach, inductive approach, or a combination of these approaches, as identified by Dawood and Underwood (2010). Saunders (2011), outlined that the deductive approach is linked to positivism by which the researcher develops a theory or hypothesis and designs a research strategy to test that hypothesis. In the case of the inductive approach (commonly used in Interpretivism) the researcher plans to collect data, and consequently, develops theory through their data analysis. This approach is used to interpret social reality by understanding the contexts or the set of entities. Dawood and Underwood (2010), suggested that the approach that attaches elements of both deductive and inductive approaches is the logical process of discovery in science. This process is utilised to reveal new facts that the researcher had not anticipated (Levin-Rozalis 2004). Choosing an appropriate research approach in this research depends on the philosophical position of pragmatism in which depends upon the research question, which in turn focuses on achieving the research aims and objectives regarding the sociotechnical aspects of the community energy system integrating different perspectives to help the researcher to interpret the data (Saunders 2011).

As previously discussed, the pragmatic view allows the researcher to solve problems according to the aim and objectives. Thus, this research must explore the area of community-based energy systems in-depth and needs to develop the means by which a potential community energy project can be established in Nigeria. This requires the collection of data from sociotechnical aspects across peripheral urban communities in Nigeria, in order to provide solutions regarding community-based low carbon generation systems. The data can be collected via such sources as interviews, observations, industrial reports, government policy documents, and published literature.

3.3 Research Strategy

This section introduces the research strategy, which represents the planned route to achieve the aim and objectives identified by the researcher. The aim of this research is to investigate the complexity of the elements and issues of community energy projects in Nigeria. Although research strategies may use qualitative, quantitative, or mixed methods, the most important factor in the research strategy is whether it enables the researchers to answer their particular research questions and achieve their aims and objectives (Panas and Pantouvakis 2010). Saunders (2011), recognises some prominent research strategies, such as surveys, experiments, grounded theory, action research and case studies, and highlights their benefits, as the strategies are not mutually exclusive regarding use in a single piece of research. The research question should be the tool guiding the researcher in their choice of research strategy.

The case study strategy has been adopted to design a number of community energy projects in Nigeria. Janse van Rensburg and Roodt (2009) described research design as a framework of the research process that can be planned from start to end. In the process of research design, the researcher considers the purpose of the research being undertaken, aligned with a clear research strategy, and makes choices between research techniques and procedures.

There are many research studies with the aim of discovering the truth, however, each research study has its own specific purpose (Kothari 2004). The purpose of a research study is to identify answers to questions through a systematic method and thereby increase the knowledge base (Saunders 2011). This research aligns exploratory, descriptive and explanatory study types because the purpose of the research is to develop the means by which low carbon energy generation can be established in the peripheral urban communities of developing countries. Thus, there is a need to reveal new insights through this exploratory approach for the application of the potential community-based energy project in Nigeria where the practical community energy system is limited via a subjective view of reality. In addition, there is a need to identify how people feel and what they think about working together in a community-based energy system. Therefore, the aim of the research is to develop a solution to the research problem, instead of testing a causal relationship between variables (Kothari 2004).

The following sections will start with action research, design science and ground theory as alternative research strategies, but the most important strategy for this research is the case study approach aligned with the pragmatic view, allowing the application of the triangulation approach by using multiple methods of interviews, observations and documentary analysis and focusing on in-depth studies, as found in this research question. The subsequent section justifies the decisions made regarding the multiple case study approach, which enables the investigation of community energy projects in order to develop a quality of theory replication in Nigeria.

3.3.1 Action Research Strategy

Action research is a practical research method that solves a problem in a real setting. It expands the use of scientific knowledge and develops the competencies of the social actors, as they perform together with practitioners and cooperate with the researcher in a cyclical process (Azhar, Ahmad et al. 2009). The researcher becomes an active part of social organisations so that the change process can take place together with combined efforts. According to Saunders (2011), the findings of action research are developed as a result of involvement with organisations who experience the issues concerning them. Hevner and Chatterjee (2010) proposed five steps in action research that form a cyclical process (shown in Figure 3:2) for practical research within a specific context and with a clear purpose. These steps are Diagnosing, Action Planning, Action Taking, Evaluation and Specifying Learning.

Figure 3:2 Cyclical process in action research (Azhar, Ahmad et al. 2009).

This strategy, as a practical research method, aims to transform the practitioner’s understanding through active participation, which is collaborative with the researcher. Consequently, this research needs to solve the sociotechnical complexity of the community’s real problems.

Despite the action research outcome resulting due to involvement with organisations who experience the particular issues of delivering operation and management community energy projects, action research would have been inappropriate because it is highly time-consuming, and also restricts the ability of the researcher to obtain rich, multi-faceted knowledge about the research project. This research needs to explore the number of issues, within the scope of community energy project, which includes the wider understanding of networks of community actors, their motives, where action research limits the views of these actors, focuses only on social learning, particularly within adaptive management(Mackenzie, Tan et al. 2012).

3.3.2 Design Science Research

Design science holds a great prominence particularly regarding the relevance of academic research for practical problems whereby the researcher works collaboratively to create a solution with participants. It serves as an appropriate research method, which improves the applicability of the research. According to Van Aken (2005) design science is a solution-oriented research strategy that focuses on developing knowledge, and the researchers can use it in a real setting. It is suggested by Van Aken (2005) that design science does not relate to the descriptive strategy, which more concerns explaining the phenomenon context. Instead, it focuses on improving the aspects of organisations. A research solution assisting in the field problem takes the form of what is called is an artefact in design science research (Johannesson and Perjons 2012), which is defined as an artificial object created by people who look to solve practical problems. Johannesson and Perjons (2012) stated that an artefact is not only a physical entity, such as a hammer, car, and hip-replacement, but can be a set of guidelines, blueprints, models or an IT solution (Peffers, Tuunanen et al. 2007).

Bearing in mind this principle, the research involves the development of a model, which can serve as a structured community-based energy system so this could be categorised as an artefact in design science principle. By designing this principle into the research, however, the researcher would not create a full community energy interface. Instead, the researcher follows a scientific means of design science, planning procedure so that part of the system can be worked on in the future. This perception is considered in the research where the application of a potential community energy project is proposed by the researcher, which it is possible to implement in the future.

Regarding the impact of the research output in design science, the artefact is the research output, but it is important to understand that it is not merely a physical object, such as a hammer or blueprint. As discussed before it is the artefact research output that has an effect on the environment as a result of being introduced to it (Peffers, Tuunanen et al. 2007). This means that in design science the methodology allows the presentation of the artefact in the fieldwork or its introduction to potential users (Van Aken 2005).

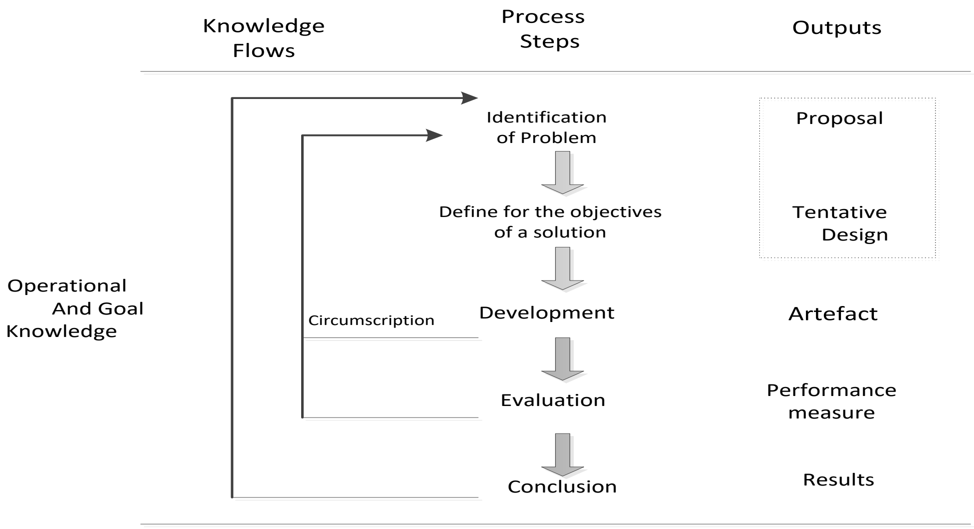

Figure 3:3: Rationale in the design science cycle (Hevner and Chatterjee 2010).

A cyclical development process for conducting research based on design science is well defined and articulated by the researcher through developing a solution. There are several process steps adopted by many scholars for the development and evaluation of the process in design science. These process steps are articulated with similar frameworks (shown in Figure 3:3) using different terminology (Peffers, Tuunanen et al. 2007). Here five common stages of these strategies are outlined as follows.

3.3.2.1 Identification of the Problem

The initial point for researchers in developing design science research is the identification of an issue surrounding the world, which must be an important factor (Johannesson and Perjons 2012). In addition, at this initial stage, the specific research problem is defined by diagnosing the primary research problem and justifying the value of the solution (Holmström, Ketokivi et al. 2009). Identification of the research problem could involve self-interpretation through an initial literature review, this could involve reviewing the existing literature in the field (e.g. academic papers, industrial reports and practice publications), with the problem being diagnosed. Otherwise, the problem could possibly be identified as published or reported with the solution yet to be addressed (Azhar, Ahmad et al. 2009). Thus, the purpose of this research is to develop a community-based energy project for replacing the current systems of centralised energy generation practice, which is identified as the problem and could be addressed by a community based distributed energy systems.

3.3.2.2 Define the objectives of a solution

This second stage is to define the objectives of a solution that will address the practical problem. It concerns defining a specific objective that can be a solution to the problem definition and supposes that the gaining of knowledge is feasible (Peffers, Tuunanen et al. 2007) because the objectives should suggest and describe how new knowledge is anticipated to deliver a solution to the current problem. Some of the necessary requirements to be developed in this stage include the knowledge of the state of the problem and current solutions (Azhar, Ahmad et al. 2009). In the research which proposes a potential community energy project, where the community organisations structure the energy management systems the researcher needs to develop the final solution for a community-based energy system. Thus, the researcher is not only concerned about the developed artefact but also how this artefact was developed.

3.3.2.3 Design and development artefact

Activity at this stage involving designing and developing the artefact as a model or method that potentially addresses the practical problem. Von Alan, March et al. (2004), described that designing and developing this artefact is the process of creating a solution concept for the identified problem. Creating new knowledge in design science requires the demonstration that the process is effectively applied as a solution (Peffers, Tuunanen et al. 2007). Therefore, the process to develop the artefact should be transparent in order for the solution to be applicable this is an academic perspective. It mainly requires a full explanation of the development process as well as the decisions that were made as the solution evolved (Von Alan, March et al. 2004).

This research involves developing a community based distributed energy system that can solve the issues of technical elements. The researcher would need to work closely with some community members those who provide the subjective system of knowledge, and consequently; deliver the necessary insight to understand the abnormalities being studied. This can be performed through a cyclical process of action research.

3.3.2.4 Implementation and evaluation

This stage concerns an effective demonstration of how the use of the artefact could solve the problem in the case study area (Holmström, Ketokivi et al. 2009). Furthermore, at this stage, it is determined what must be accomplished by the change as well as the mechanism for the evaluation proposed (Glanz 2005). The characteristics of quality and efficiency of an artefact must be thoroughly demonstrated, and its utility should be proven through well-executed evaluation methods(Azhar, Ahmad et al. 2009). This evaluation requires methods, which determine how successful the proposed change is in the area of study. Azhar, Ahmad et al. (2009), recognised that a researcher should use methods and techniques which are related to the research, as the researchers can decide whether the method is feasible or not.

However, this research needs to identify an approach that entails a detailed and intensive analysis in constructing a real representation of socio-technical aspects of community energy project, in which understanding the practical action of community energy is important (Pries-Heje, Baskerville et al. 2008), but design science strategy assumes that the construction of an artefact is a solution to the problem, considering the use of evaluation process as an empirical methods for research is the key method (Petty, Thomson et al. 2012). Therefore, the design science is limited typically in studying the complex issues of the community energy system and causes the restriction of detail description of the method this research needs to provide. It limits also exploratory research issues especially for an empirical research design that addresses the use of multiple research projects this research requires to be adopted in order to draw the general conclusion of research findings.

The ground theory is important to approach as the research practice describes in research processes, where the theoretical assumption is grounded in data (Suddaby 2006) and observation. A systematic process of data collection and analysis in this approach is emphasised, informing the development and redevelopment of theory. In the research process, the approach encourages researchers to use the existing theory (Douglas 2002), ensuring to identify the issues relating solutions to the research problems before collecting and analysing data. Although the approach could provide insight into the issues related community energy systems, maybe in terms of understating (Smyth 2004) the analytical frameworks of socio-technical aspects, building on the existing theory to design research for data collection. However, considering theory before the exploratory study could cause overlook important factors in the way the research illuminating some elements, while ignoring other factors (Maxwell 2012). Alternative methods such as case study approach used to investigate the wider issues of a real-life context in this research. Case study method can examine the complex and contemporary phenomenon of the community energy system(Yin 2013), which is suitable to adopt in this research.

3.3.3 Adopted Approach: Case-Based Strategy

The adopted case study approach will address the question around the issues of producing rich, in-depth description. It provides insights into the natural settings of community energy projects. It also facilitates to design research across different locations in Nigeria, so that the research uses to approaching for the data to be collected in order to answer the question of the research problem, as factors and barriers for community energy projects. As Philliber, Schwab et al. (1980) described research designs, as the blueprints that address research issues ranging from research questions, relevant data types to be collected, and how the data can be analysed for conclusions.

The exploratory of main case study approach attempts to understand the questions of how and why community energy projects are implemented. The approach could assist in exploring the elements of community energy and the wider understanding of issues such as political actions, social interactions, economic incentives, and cultural factors in relation to the phenomenon. These factors and issues explored through the interaction between participants and researchers may be unknown in advance. The quantitative approaches, such as surveys and experiment studies would be appropriate in this research and they may be limitations for the information the research needed to acquire for analysing data (Petty, Thomson et al. 2012).

The survey practice, the questionnaire approach as an example, can lead to unsatisfactory information, can only be used to determine whether the theory of propositions is correct and tested. This study considers the experiences of community energy systems through observations held in a community setting the perspectives of actors participating in the community energy project (Yin 2013). This outlines the survey method limitations of collecting data for this study, which particularly focuses on exploring the community energy project. For this reason, the research focuses on a particular research question as the intention is to identify the socio-technical aspects of community energy projects, which involve the practice of operations, norms, values and policies for responsibly developing low carbon energy technologies (Geels 2010). The aspects of energy communities include rules, regulations and individuals who have an important role in the project. The networks of social actors also affect the integration and stability of the projects (Bollinger, van Blijswijk et al. 2016).

The case study approach is selected as a strategy to deal with an intensive, complex social phenomenon of community energy projects in a given context and the location (Yin 2013). The approach provides the opportunity for a possible direction to choose a broad range of data sources. However, interviews together with document reports would be harmonised to develop the conceptual framework of the sociotechnical system; the mixed observational method, in particular, could enable insight to emerge through the interplay between the researcher and the researched (Saunders 2011). This allows the study of a community energy project in a holistic way, with the intention to identify the issues in terms of the delivery of projects, processes, and management within the individual cases study and its relationships and environment. The case approach also provides an opportunity for the use of multiple methods of data analysis which draw a conclusion based on the research questions (Baxter and Jack 2008). Therefore, a case study method employed to investigate the contemporary phenomenon of a community energy project given a specific context and will assist in acquiring the detailed contextual analysis of a number of events (Yin 2013).

The case study focuses on contemporary community energy projects and allows the identification of a better representation of the contextual characteristics around the relationships and different objects involved in each different community energy project in the country. This also leads to identifying the capacities of the project, institutional governance, and funding sources involved in socio-technical complexity (Bollinger, van Blijswijk et al. 2016). As a socio-technical project, the case study focuses on depth to obtain as much information as possible around the multi- dynamics, interconnected and structural relationships. The researcher intends to explore the contextual features related to the community energy project that involve physical artefacts and social actors. One of the strengths of this approach is the employment of a variety of data collection methods. With the aim of adopting and implementing factors may emerge as a socio-technical aspect of carbon energy generation, which is established in the peripheral urban communities of developing countries, the research investigates the relationships between social actors, technicalities and the wider socio-technical system in order to appreciate the effect of the relationships on the community-based energy system. Thus, this research employs a range of methods, defined by Clark and Creswell (2008) as research in which researchers use multiple sources and methods for a single study, not only to collect and analyse data but also to integrate findings and draw inferences. These methods enable the researcher to draw on insights into the existing energy generation system, community-based energy system and sociotechnical systems.

Considering that the researcher requires an understanding of the interplay between social networks within the sociotechnical systems, it would be appropriate to develop and explore their relationship in order to provide the necessary insight to generate tentative theory (Ihuah and Eaton 2013). The researcher employs a flexible method as the means of generating theory relating to the interplay of a community energy project with regard to sociotechnical systems. External validity allows the researcher to study the holistic and meaningful nature of a community energy system. For this research, which explores the issues and factors around socio-technical aspects of community low carbon distributed energy, a typical single research design can be employed to investigate outcomes of a community energy project and capture the circumstances and conditions of a real-life community energy project.

The above discussion highlights what a case-based approach provides in terms of encouraging the investigation of new phenomena and uncovered aspects, in the case of individual community energy projects such as Usuma project, the Gnami project, and Green off-grid project identifies the typical circumstances of the case, which are yet to be studied. It also makes a significant contribution to theory and knowledge building. Identification of this kind of socio-technical issue is critically important to ascertain features and operational measures, including the success of, and barriers to, the community energy system. The approach, furthermore, represents the typical pictures or context of the case that the researcher intends to study, allowing the research to capture the circumstances and conditions of the case study setting. Using at least the two to three case studies can produce a strong effect in investigating the phenomenon contexts in the form of generating conclusions. Yin (2013) recommended that multiple cases such as community energy entities can be designed to represent strong findings towards the theoretical replication.

3.3.3.1 Comparative case design

The multiple case study is designed to analyse differences within and between the contextual entity and conditions of community energy projects situated in Nigeria. With the nature and complexity of the processes and factors concerning technical factors, cultural factors, funding sources and motivations in engaging this community energy project (Goodrick 2014), the multiple case approach is employed to play a central role in concept-formation and analysing the similarities and differences among community energy projects in order to develop results and conclusions.

The approach addresses alternate explanations and helps to identify different findings from selected community energy projects. Yin (2003) states a replication design to facilitate rigorous results with the use of comparative cases for developing replication, through which case can predict similar or contrasting results based on theory building. This means that the approach design replicates the quality and effective findings within community energy projects (Bryman 2015).

3.3.3.2 The definition, characteristics and units of analysis of case studies

This section will explain how this research selected cases for the purpose of creating a solid foundation, which leads to addressing the research question. The research aim is to investigate both the varying effects and factors within the contextual conditions of individual community energy projects and the relevant information about socio-technical aspects of the community project, which should be accumulated. This section further enumerates the criteria used for choosing each case study, not only high-quality outcomes but also the criteria used for interpreting the research results. Selecting several community energy projects can yield a variety of outcomes for comparing different contexts.

Four individual community energy project cases were selected for this research: the Usuma solar renewable energy project, Gnami community energy system, the Danjawa community energy project and the Guzape Off-Grid energy system selected for this research, the results of these case studies are considered more robust and compelling. The following case study parameters are to be considered:

- Each case study should select the community energy organisation, which applied for the use of renewable energy sources in Nigeria. Such technologies include hydropower, wind, biomass, and solar. It is important to note that communities play a significant role in terms of facilitating the low carbon energy technologies model. Yamamoto (2016) identified the implications of the use of renewable energy technologies in communities, which is a significant factor influencing the success or failure of the community energy system.
- Energy projects should take into account as a case study whether the project is informal or formal energy entity but also include some elements of management and networking,

social system context, technical, governance, and a financial factor. These issues are the key units of analysis.

- The case involves the complexity of the various actors engaging in energy issues. This principle measures whether the community-based energy system can be used to justify the adoption and relationships between the community management and the use of technologies in the local energy system explores the practical realities of community energy organisations. This element is strategically selected to provide a more valid result when the research intends to draw a conclusion and recommendation for enhancing the sustainable community energy system in Nigeria.
- The case should provide certain benefits in the local context particularly for the communities, such as community governance, and engagement and ownership structures in controlling and operating the renewable energy technologies.
- The project is concerned for energy supply and efficiency systems mainly in terms of community scale. The principle of this is to identify the capacity and installation of resident energy end-users.
- Each case is chosen due to its availability and access for data collection. This criterion was considered during the research design to prevent data collection issues regarding absent or scarce data, which lead to threats to internal case validity and prevent the use of desired analytical techniques for drawing overall research conclusions.

Therefore, based on the above community energy features, the researcher is enabled to collect information relating to the typical elements of a community energy system and describe and analyse the individual issues of social and physical artefacts of the community energy system. These issues help in understanding the contextual differences and similarities when analysing the process, dynamic pattern, and socio-technical aspects of the community energy system. A pilot case study will be used to test the overall case study design.

3.3.4 Pilot Case Study

The Plateau State Hydropower Project (PSHPP) was selected for a pilot case study to develop the relevant propositions and questions adopted by this research. The project involves a large-scale energy generation in Jos state, which is slightly beyond the framework of the community energy system adopted by this research. The project figures the important aspects associated with a community, which the researcher considered in its selection in terms of renewable energy technology being used, free energy use for the communities live to close the project site and the issues of partnership between the state government and stakeholders for the extension of the use of electricity for community energy benefits. The project extended its energy services to the communities that live within the Jos state. The project partnered with Jos state government on a contractual basis in order to deliver the community electricity. The most important criterion enabling the researcher to conduct this study was access to the PSHPP. The project manager received and confirmed the research application, allowing the researcher to hold some conversations with the project workers. Seven individuals, including the manager, were interviewed in this case. The company officials planned a trip to the site to observe the project's operation and management. This presented the opportunity for the researcher to observe the type of technology and capacity of the project; it was also an important opportunity for the researcher meet with the engineers and project operators, allowing discussion of important issues related to the project. However, the issue of obtaining data through historical records was experienced in this case, as the company was restricted in the information it could reveal, but the opportunity to take the pictures was allowed. The following Table 3:1 summarises the data collected in the PSHPP case study.

Table 3:1: Data collected in the pilot case study

Interviews	**Documents**	**Observations**
Chief Engineer -11/06/2017	Financial report	12/06/2017
Project Manager 13/06/2017		13/07/2017
Site Engineer 12/06/2017		
Maintenance staff 12/06/2017		
Energy user 12/06/2017		
Financial manager 14/06/2017		
Customer 14/06/2017		
Staff 11/06/2017		

The pilot case study approach used in this research to clarify a real case study design. The purpose was to ensure that the main cases studies research functioned effectively (Yin 2013). It is important to note that the pilot results were not included in the real cases conclusions research, rather they were used to inform alterations of the main case study design (Yin, 2013).

This issue is about straightening the problems of research processes this concerned about methods of data collection and analysis, as a result of issues encountered during collection in the data case by the researcher. In this pilot study, the interview questions used were refined particularly because the questions did not work for a community energy system. Therefore, the changes were made to assist in theory building. The new additional questions also designed for suitability and the opportunity for the researcher to investigate the big picture and meaning of community energy.

3.3.4.1 Issues occurring during the case studies

The issues the researcher had experienced during the empirical research; for example, in the process of selection case study candidates.

The researcher contacted the Rural Electrification Agency (REA) to request lists of local renewable energy projects and their contacts in Nigeria. In addition to contact with the REA, the researcher conducted an internet search using the terms “community energy in Nigeria” and “identified community energy projects”. Eight case study candidates were selected for identification of community-based energy projects in Nigeria in order to gather data. The criteria considered to choose the case study matched with the definition of community energy considered in this research (sees in section 1.3.)

The community energy project that was selected in Logas was merely a project framework, which was impractical to implement. The researcher flew to the location and found that the project could not be accessed but had the opportunity to interview with some of the project management. Therefore, this project was not included in the research. The same issues were found in the similar community energy project located in Sokoto State under Kachou local government, after a 500-km car journey, but the project did not exist. However, before the researcher returned to his local area, he contacted the Energy Commission of Nigeria to ascertain whether they were aware of any community energy project in Sokoto State. That was the reason the Danjawa community case study was selected. The project manager could be easily contacted by the managers. Guzape Off-grid system was also found, as a community energy project for ten apartments but it was difficult to conduct proper interviews with project management. Various schedules were planned to meet, but interviewees did not present for conversations until night schedules when the manager and other staff were less busy. In terms of the Usuma project, a colleague working in Abuja Distribution Electricity Company introduced the researcher to the manager. The project was found to be practically implemented, using solar power technology for water board and local communities. The staff were always ready for interviews and escorted the researcher to the site. Access to the installed equipment rooms was provided. In the Usuma project, the project manager recommended that the researcher should enquire about the Gnami community project. The Gnami project case was subsequently selected as the final case. Considering the time and resource constraints of this research, four different types of cross-sectional community energy projects would be chosen for in-depth analysis.

3.3.5 Data Collection and Analysis Methods

The empirical study of this research concerns data collection and analysis methods used to capture the distinctive perspectives of the participants in each community energy project. In terms of the data collection methods, many methodological options can be used to collect data from the stakeholders related to the study of the conduct of community energy projects. It is important to note that this research collected information about the key actors, social networks and influential individuals involved in the community energy system in order to answer the research question devised to achieving the aim and objectives, with a complex number of factors, processes and issues involved in each community case. This means the objective of the research is to collect data on the processes, issues, and factors of the community energy project. Methods of data collection used included instrumental tools, qualitative mixed methods, which include semi-structured interviews and observational methods designed to allow participants to explain their own situations regarding why they are engaged in community energy. These methods also give the researcher the opportunity to observe and describe the complex phenomenon of a community energy system within a real setting (Ritz, Noltemeyer et al. 2014).

3.3.6 Principles Used for Case Study Data Collection and Case Study Quality

This research incorporated three principles mentioned by Yin (2013) regarding quality research techniques: multiple data sources, a reliable database for the case study, and the chain of the data source. This section will start with a full account of data collection used in this research in order to facilitate answering the research question and the methods used are justified over alternative methods that could possibly have been applied in the research. It also mentions the data sources used in this research for each case study. Finally, it depicts the logical description used to achieve the research conclusion.

3.3.6.1 Multiple data sources

Multiple data sources were employed in this research to build the development of converging lines of inquiry (Yin 2013), shaping the outcomes by interpretation from a broad range of data. This notion directed the researcher to methodological triangulation and corroboration for the purpose of confirming findings from case studies, resulting from their different sources and methods (Yeung 1997). The data sources adopted represent different outcomes particularly from subjective realities as well as physical artefacts of the community energy system, thus using multiple sources would help to strengthen the construct validity of the research findings. The research will become more compatible after corroborating for the findings from community energy projects. Data sources used by this research in terms of triangulation data included interviews, documents, and observations. These sources are commonly found in each community energy project. They are inputs, the contextual conditions of the community energy system. This describes how the factors and actors within the community energy, contributing as niches, which influence the success of or identify as barriers to the community's energy system.

3.3.6.1.1 Interview data

Semi-structured interviews were designed for this research to explore the views of the participants who engage in community energy activities or the community members who benefit from the energy project. The main intention of conducting these interviews was to understand the issues regarding the delivery of community energy projects and to identify the factors of financial and operational substantiality and the problems associated with processes of delivering the project through actors involved in the project. The most important issues explored concerned drivers such as financial issues, motives, benefits of the community energy project and the people who made significant contributions to the development of the projects. Concepts and theories can emerge out of such conversations, which contribute to answering the questions of why and how factors and processes of delivering community energy projects are developed. The answers from these questions provide a full picture of the community energy system, formed from the views of social actors related to the projects. The actors have interviewed either direct actors involved in community energy project development (community energy practitioners) or actors who have an interest in community energy projects, and others who have a found somewhere, but significant effects on community energy projects such as government policymakers, research organisations, energy agencies, and non-governmental organisations.

The interviews were conducted in-depth and open-ended questions provided the essential information to explain the key issues related to the community energy system and capturing a range of similar and different perceptions due to various social interests, unlike approaches that tend to be structured to investigate a specific perception for interesting to answer. The interviews provided the opportunity to the researcher to learn new matters of interest when the answers were given by interviewees, which justified the questions being asked. The open-ended technique made the interviewees relaxed and willing to discuss sensitive information related to the case study. It gave the researcher opportunities to extend the conversations in different interview settings. Additionally, it consumed time and resources.

3.3.6.1.1.1 Format of interviews

Before the interviews were conducted, the researcher made a topic guide, a written document that includes details of the key topics of interview questions. Topic guides are designed in order to help with the direction of research, facilitating the systematic collection of data and ensuring consistency between different interviews. The researcher would design a different topic guide for each type of interview. For instance, the topic guide for community energy users was different from those for experts or intermediary organisations. The researcher designed interview questions for each topic in order to collect right information for achieving the aim and objectives of the research.

- How did you join the project?
- How was the energy project started?
- What do the participants think about the community project?
- What are the drivers of the energy project?
- What motivated the community energy project?
- What are the project's aims and what does the project want to achieve?
- What were the funding sources and how much was provided how easy was it obtained?
- What are the benefits for you for this energy project?
- Who are the beneficiaries of the energy project?
- How the benefits are shared and managed?
- What are the barriers to the project?
- What sort of support do you require to overcome these issues?

3.3.6.1.1.2 Access to interviews

For initial contact with potential interviewees of these cases studies the researcher used phone or email to explain the aims and objectives of the research. The interviews were used to identify key issues relating to community energy projects in Nigeria. By interviewing the experts, it helps to establish the niche activities of aggregation.

3.3.6.1.2 Participant observation

Choosing the participant observation method concerns aiming to generate practical and theoretical truths, formulated around interpretative theories, interviews and other relevant sources from the adopted case study. The observational method is used to gather the actual information about socio-technical systems about behaviours and environmental conditions of physical elements and the action of actors participating in the community energy project being investigated. In other words, it provides the opportunity to observe who is involved in the project, what types of renewable energy are used and the location in which they operate and why the project must be maintained What are the skills people acquire in engaging with the technical process of the project? What are the issues and measures that have been discussed by the social actors in a particular situation?

3.3.6.1.3 Documentary analysis

Documentary analysis, such as written reports, and articles in newspaper and websites were the most important source in this research, used to corroborate and augment evidence from other sources, which were the part interests of community energy projects. The documents helped to identify the social networks of participants in a community energy project. They were helpful in constructing the full meaning of a community energy project. This method also enabled the research to be triangulated from the other data.

3.3.6.2 Case data sources

Each case study of this research used the following data sources:

- Documentary analysis - relevant documents from each case, such as progress reports, written reports, and websites of the community organisation. Other articles were provided by newspapers and other websites.
- Participant observation of site visit activities and organisational meeting organised by the community energy project.
- Photos - for understanding the actual characteristic features of low carbon technology at community energy project site.

- Interview data - one to one unstructured interviews conducted with a range of participants involved in community energy projects.

The tables below present and organise the data collected for each case study. Each table represents each case involved interviewing a small number of individuals (ranging 7-8 participants) about the community energy project. The participants interviewed either directly engaged the project such as community members, energy users or were actors who had an influence on the project either during the developmental process or after the project was implemented such as government policymakers and energy agencies. Most interviews for these cases took approximately 45 minutes to 1 hour, although in some cases the researcher had an opportunity to hold further conversations with the interviewee on the site.

Table 3:2: Data collected for the Usuma energy project

Interviews	**Project documentary**	**Observations**
Chief engineer 10/08/2017	JICA website: www.jica.go.jp	Sites observations 08/08/2017
Project manager 11/08/2017	Preparatory Survey Report, March 2014	Photos 09/08/2017
Consultant 08/08/2017	JICA annual report 2014	Workshop training
Ministry of Power Assistant Director 09/08/2017	U: Vision, mission strategy and challenges. Workshop paper, June 2015	
UWB Revenues Manager		
UWB staff member		

In the Usuma project, many interviews were conducted, and rich writing materials and report supplements were provided for the research. A phone number was also provided for the research for follow up purposes. On the project site, the management was always prepared to allow observations.

Table 3:3: Data collected in Gnami case study

Interviews	Documents	Observations
Community leader 11/08/2017	Huawei Off-grid Solar Power Project Report (2014)	Site visit 12/08/2017
Resident 1 12/8/2017		
Resident 2 12/08/2017	Website: www.huawei.com	
Resident 2 12/08/2017	Video record:	
FM RE Director 11/8/2017		
HTC Engineer 17/08/2017		
HTC Manager 17/08/2017		
MP staff 14/08/2017		

However, in the Gnami community case study, the researcher had limited access in conducting observations, particularly when the researcher wanted to observe the project equipment installed in the control room. The site at which the solar panels are installed the researcher had an opportunity to take pictures from short distances. Observing the capacity of the solar PV installation, the researcher used documents that were provided, and interviews were conducted.

Table 3:4: Data collected for the Guzape Off-grid Energy System

Interviews	Documents	Observations
Installer - 07/07/2017	The African Power Elite; projects and people	Site visit 07/07/2017
Assistant manager 07/07/2017		
Project Manager 09/07/2017	Blue Camel profile	Monthly Meeting 09/07/2017
Project Maintenance 11/07/2017	Living off the grid in Nigeria: videotape	
Resident Apartment 14/07/2017	Blue camel brochure	
Head of Corporate 09/07/2017		
Accountant 11/07/2017		

In the green off-grid, more than six people interviewed each interview lasting less than an hour. Due to the limited time available, the interviews were conducted on different days depending on the availability of the interviewee. The researcher contacted the project manager with a view to conducting an interview. The project observations data was not a problem. Photos were allowed to be taken. Documents were also provided.

Table 3:5: Data collected for the Danjawa Community Energy Project

Interviews	**Documents**	**Observations**
UDU H.O.D 1/08/2017	Situation Report 2013	Site visit 04/08/2017
Project Director 3/08/2017	Danjawa project reports	The project pictures
Project coordinator 03/08/2017	Project brochure	
Project Manager 03/08/2017	Invitation report for bids for the procurement project	
Community leader 04/08/2017	The financial agreement between FRN a and IDS	
Community resident 1 19/09/2017		
Community Resident 2 19/09/2017		
Community resident 3 20/09/2017		

The Danjawa project had the highest number of people who agreed to participate in the research, so several reports were collected in this case, and the opportunity was given to the researcher to look around the project installation.

3.3.7 Data analysis

In analysing the above data, the research adopted thematic analysis (Braun and Clarke 2014) for in-depth analysis of the qualitative data, which provides the basic idea for a theoretical understanding of the key issues, such as, governance and maintenance of community energy. This approach helps to develop a framework with sets of themes and subthemes identified from the empirical study, focusing on real meaning identified across data (Braun and Clarke 2014). This means that, with ideas and concept, interpretations can be made for a variety of data. This approach also allows the researcher to develop a set of processes for identifying and organising unstructured data into a standardised format in order to make inferences about the characteristics and meaning of written or recorded materials. A number of community energy projects methods were designed for empirical inquiry so that the researcher can engage with case study projects to collect rich data that allows the research to generate theory from the findings. The data is analysed to frame answers from the research questions why and how the socio-technical aspects of various systems and institutions were established to deliver low carbon technologies for communities (Baxter and Jack 2008). This helps to represent the internal validity in addressing alternative explanations (Bryman 2015).

In conclusion, the research adopted a comparative case approach to identify the key success factors and barriers of community energy systems in Nigeria. Multiple data were collected to analyse the issues in relation to the real context of case studies. Therefore, the thematic approach will be applied in the following chapter to identify and analyse the important issues, using the key themes formulated for each individual community energy, the selected system case studies.

Chapter 4 : Case study analysis

4.1 Introduction

The Chapter 2 discussed the sociotechnical aspects of complex issues such as climate change, energy inequality, and energy fuel pollution in the context of community energy systems. The methodology chapter proposed comparative case studies to empirically draw data from multiple sources in each particular case study.This chapter will use an analysis of the qualitative data (semi-structured interview, observations and material documents in relation to a specific case study) in order to draw a conclusion. It will use case study propositions and a thematic analysis approach as an analytical method to explain and describe the concepts and ideas in the case studies. The analysis reflects the research question of this study, (Table 4:1) which states that what are the successes and challenges experienced in terms of the processes, deployed technologies, financial issues and people involved in four case studies identified in Nigeria.

Table 4:1 the overall feature of individual case studies

Features	Criteria	Pilot case	Case 2	Case 3	Case 4	Case 5
Drivers	Motivations	Profit motives	Carbon & cost reduction	Economic motives	Market opportunity andsocial responsibility	Researcg and development
Institution and governance	People constitute and contribute to the project	Limited liabilities	Multiple partinership	Cooperative entity and relationship	Public-private partnership	Public irganisation
Finance sources	The original funds used of foundation of community energy	Banks	Bilateral finance institution(JICA)	Borrowing and shares	Independent developers	World Bank grant
Location	Factors influence community energy systems in specific areas	Natural and artificial rivers	Soalr radiation, national government support	Solar radiation and wind	Solar radiation, national support	Solar, wind and biomass resources
Technology type	Used for the local for energy activites	Hydropower	Ground-mounded solar PV	Rooftop mounted solar PVwind turbines	Granded-mounted solarPV and Streetlights	Dome biomass, ground-mounted solar and wind
Generation capacity	Measured by the quanlities of energy generation	40MW	1.2MW	40kWh	150kWh	14kWh
The operation and matnance	The committee of people who ensure the constant and efficient usage of electicity	Optimal	Neutral	Slightly optimal performance	Underperforming	Underperforming
Energy users	Benefits of providing the electricity	Reliable energy	Cost saving and free energy	Profits and income generation	Improved wellbeing for the community	Improved wellbeing for the community

4.2 Pilot case study: Plateau State Hydropower Project (PSHPP)

4.2.1 Case Study Introduction

This case study is a hydropower system, which is constructed in Plateau State by UK private investors and supplies electricity to 6000 customers, including commercial businesses, industrial businesses, and government distribution companies. The project is located in a remote area, which about 300km to the city (shown in Figure 4:1), a road constructed as a result of the project to access the project site.

Figure 4:1 Aerial View of the case study Power Plant

The PSHPP has a 40MW generation capacity, upgraded from the 19000KW that was used by the mining companies before turned into a new business model. The hydropower was used for mining activities in 1929 pumping water from the rivers to wash the mined tin and to smelt tin irons so that companies could transport products across to Europe. It was redeveloped as a result of an assessment in the location. The site was assessed for construction given that the location has a potential water head for large-scale commercial electricity generation.

The electricity is distributed through the distributed energy network comprising seven power substations and transmission lines to deliver electricity across and outside Plateau State. However, the Ministry of Water Resources engaged in the project due to the need to improve local electricity distribution and increase the revenue collection in Jos. The Jos State Government encountered the challenges of network expansion into rural communities, supply availability and high tariffs. It formed a partnership with project owners to provide electricity services to the community within Jos.

The PSHPP was developed by a private investor organisation, which borrowed money from UK financial institutions. The company's capital was valued at around £2.5m for the construction and installation development in the first phase of the project. Two management departments oversee the installation services: an administration unit and an electrical unit.

Table 4:2 Summary of the Case Study Parameters

The time period of operation	1929 to date
Location	The project is located in Jos State where electricity is generated. It is distributed within and outside of the area. The location has potential energy for electricity generation.
The project installation	Seven hydro turbines generators are installed with a central water management system. The installation includes a high voltage grid transmission, primary grid substations, a high voltage and a lower distribution line. The installation can generate 40MW capacity.
Stakeholders	The federal government, Plateau state government, and private investors are the key actors involved in the project.
Project management, and ownership	NESCO is the project owner, a profit organisation. It provides training workshops and manages the financial activities for maintenance and operations.
Project Capital	£2.5m was borrowed from a financial institution. Initially, the interest rate was 7-8% but it is now settled free and the capital estimated around £24.8m (N 11.7 billion Naira). The Government charges taxes for water use and other levies.
Energy Users	The company delivers energy to around 6000 including residential users, industrial and commercial industries and bulk energy supplies such as the government PHCN.

Outcome and issues for the project	The company has been operating for over 80 years, and it successfully making a profit. It provides skills, trained engineers and jobs. However, thefts and vandalism are the key difficulties for the company as it delivers energy.

A main objective of the project is to increase the amount of electricity produced for the retail market for communities and to share the profits among Jo's state stakeholders. In addition, it aims to continuously provide electricity for reliable services using a standard business approach. The main challenge faced by the company was regulatory uncertainty and changes in government administration which put the project at risk. The company aims to sustain the Nigerian energy system for future business targets.

Several parameters of the project shown in table 4:1 and will be discussed. First, is about the stakeholders who are involved in the plant. They will be discussed in order to understand the benefit they expect to receive from the company. The project's customers are also mentioned; they are in both private business and communities' sectors. The plant location will be described, along with the dam construction, the electrical power installations and how the plant has survived for so long. Maintenance and operation will be explained. Finally, the outcomes and issues will be identified for this case study. Therefore, this case study will start with the project background in order to give the reader an idea of the plant's development.

4.2.2 PSHPP Background

The case study, a hydropower system, was initially constructed to deliver power to the tin mining companies from 1929 to the 1970s. During these years the PSHPP provided an opportunity for growth in the tin mines around the Kura area. A specific objective was to work the tin mines, the product ores, for easy transportation into the UK. In 1938, eighty mining companies were amalgamated as an exporter of tin products. They exported 10,486 tons, which was valued at £1,435,157. People from Zaria, Kaduna, and Bauchi state moved into the Kura area, the town where the plant situated to work in the company. Following the 1962 decline of the tin mining industry to keep the plant viable, the company owners changed the use of the PSHPP from delivering electricity for mining activities to focusing on the town and local communities and towns delivery of the power. Thus, the investors expanded the installation to seven turbines generators with central water management to produce and commercialise electricity in Jos Plateau State.

4.2.2.1 Location

The project is located in the Kuru district, which falls under the Jos South local government area. Kuru, where the project was built, is one of the areas with a lower temperature in Nigeria due to the altitude and longitude of the area. This area is about 1,200m elevation above sea level, and the coordinates are 9. 32446^0 N and 9.3673^0 to E. The average temperature is 18 ^{0}C between November and February. During the rainy season, the rainfall persists for up to six months from April to September. The average rainfall is about 1,460mm per annum. The project relies on natural rivers that form from annual rainfall. Kura experiences soil erosion because of the rainfall. The dam was created for the hydropower plant. The flowing water from the Delimi river is stored in a reservoir and held there by the dam. This stored water is used throughout the year to generate electricity by reusing the water from the reservoir. The project developer was confident about the location of the river and its capacities was a predetermined factor for generating electricity on an economic scale as stated by the NESCO manager: "You have to have suitable rivers and suitable location and consumers.

The hydropower plant exploits the sufficient energy source of the head of water created by the dam built on the plateau. The water from two rivers, the Kaduna and Bauchi channels, is stored in the dam. The dam controls the rivers to increase or decrease the volume of the water head to generate electricity through the power plants. The project has 84% efficiency. The dam has a constant head of 750 feet (**Figure 4:2**), but the water volume is increased during the rainy season. During this period, the plant has sufficient energy and the communities surrounding the plant site use the dam for irrigation and fishing.

Figure 4:2 Water Head of the Project

A high volume of the controlled water is released, when there is a need for energy generation, through 200 interconnected pipes. These allow the water to flow up and down from the dam to the turbines and generators. The generators are attached to the same turbines shaft, which rotates to create electricity. The generated electricity is distributed through transmission and distribution lines to the customers. The areas that were targeted include Du, Gyel, Kuru, and Vwang district with a total population of over 306,700. The population in these areas engage in poultry and cattle rearing, the cultivation of potatoes, maize, millets and aches. There are also a large of businesses in these districts such as NASCO Foods Limited Nigeria, Joaquin Bakery, and Dan Investment Argo Products. The total areas of the districts are about 1,037km^2, and they are around 20km away from the plant.

4.2.3 Technology Installations

The PSHPP installed an electrical power system with old technology, but it upgraded the control systems to monitor energy production and consumption. The power system is not a small-scale installation, that generating energy closer to users either for a few community groups or small businesses. The PSHPP is used to generate and supply consumers electricity using the grid distribution networks. This means many of the installations used in the project required high capital investment while there were costs of operation and maintenance. The PSHPP is delivered through the structural processes that provide technical material and financial sources for installing and increasing the power system.

However, the project was controlled by the government in 1978, as National Electric Power Authority (NEPA) introduced the policy regarding the total control of energy generation capacity and distribution so that the state-owned agency built its own power stations in an effort to take control of the economy. After 2000, the Federal government of Nigeria privatised the energy sector and allowed the PSHPP to operate as a business entity to continue producing and supplying electricity.

4.2.3.1 Electrical power system

With regard to the high voltage transmission grid and distribution system (shown in Figure 4:3) during the site visit, the project engineer explained that the generators were connected to the high voltage transmission network of around 274km. The generators can produce a total power of 40M.V. A. The voltages are transferred to seven substation transformers that can store loads of 57.5MVA. This load is transported about 370km to 55 substations with a load capacity of

70.0MVA. Using lower voltage for customers services, the PSHPP is installed with the secondary distribution system 220km long to reach the customer points. It is not only risky management in terms of operating the generators, but the electrical power is also required highly-skilled engineers in a site inspecting the system.

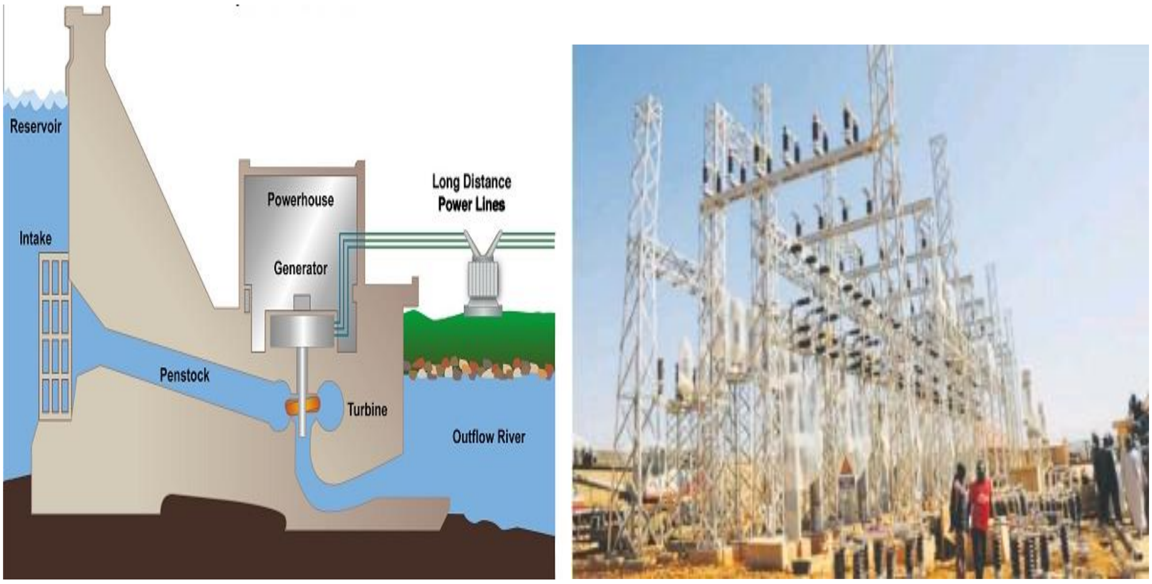

Figure 4:3 PSHPP installations

4.2.3.2 Components of the system

For the electrical power system, the installation included the following three components: Pelton and Francis turbines generators, a high voltage and transmission grid, and distribution systems. The Pelton turbine is a machine recommended by the manufacturers for this project, it is used to move a water head greater than 25 metres. It performs day-in and day-out and works reliably. This machine was installed at the site imposing the water, which headed at 228.6m. on the other hand, the Francis type was the first installed at the site when it changed its function to take the water stored in the dam. The equipment suits the plant’s system and they provide high quality and performance with a proven track record. The project chief engineer stated that the equipment life would be “indefinite if maintained according to manufacturer’s specification.” When the plant was constructed, the turbines generators had concrete structures provide durability. Even the dam was constructed with a concrete structure to ensure its water tightness it. This approach was selected by the project designers to prevent damages due to water percolation.

The PSHPP used technological equipment for economic consideration and to improve working performance. the use of the dam and the turbine generators from the control room is carried out by the engineers, operating the system when the electricity is demand. The dam is monitored to ensure that the regular energy demand is met. The use of the sensor is important as they provide frequent data on the turbine generators' speed, they monitor the degree of imbalance in the power production so that solutions can be undertaken, and they monitor the energy distribution to customers. This electrical power system was the first hydropower system constructed in Nigeria; therefore, its design, procurement and fabricated installation parts were imported from the UK and then assembled in Nigeria. This assembling meant that it was necessary to have an engineering workshop to ensure that the project worked effectively. This workshop developed its human capacity with well-trained engineers, and it provides employment opportunities, skills, and technological transfer.

4.2.4 Generation Capacity

The PSHPP manages to produce 16MW per day for its customers, even though the power system is described as having a generation capacity of 40MW. During its development, the project was subject to different policies in different governments, reducing the investors' confidence in producing and distributing energy.

The PSHPP started with a production of 2MW capacity, supplying power only for only mining activities in 1928. An extension of the project including generators, substations and cables, was performed in 1970. At that time the project was the sole electricity supplier in the Kura location, delivering energy now of more than 26 MW to 27 towns. The plant operation became an issue because "forty per cent of the energy supply was restricted by the government in 1978," a company manager stated. At the same time, the government proposed a policy whereby the Nigerian Electric Power Authority aimed to take effective control of the Nigerian energy system. In 2000, energy policy was reformed to encourage privatisation and the National Electricity Power Authority (NEPA) cooperated with NESCO to obtain 10MW extra, and a twenty-five-year licence was granted for the company project to generate and distribute electricity in Nigeria. However, the company was engaged only in some parts of Kaduna, Jos, and Nasarawa states for energy services and it did not exceed generation of 16-18 MW a day.

The firm was concerned due to the government's uncertainties about energy projects in Nigeria. The project is one of the largest energy providers in Nigeria, but the mechanism of the government reforms has not encouraged its operation and it has risked the company's capital. A sustained strategy is needed to build up investor's confidence in the Nigerian energy sector.

4.2.5 The delivery of PSHPP

4.2.5.1 Organisation and governance

A number of participants were involved in the PSHPP such as investors, management, governments and energy users. These stakeholders are highlighted in the following (Figure 4:4). PSHPP is a private project established by investors for the production and distribution to its customers of electricity generated from hydropower. Although it experienced the control of energy production by the government, the PSHPP has existed for eight decades. Its commitment to the plant to providing quality management and a good relationship with other stakeholders has enabled the project to thrive until the present day. The investors-built power plants and used to upgrade the power systems regularly. They imported fabrication materials from the UK and the local people had an opportunity to assemble the equipment.

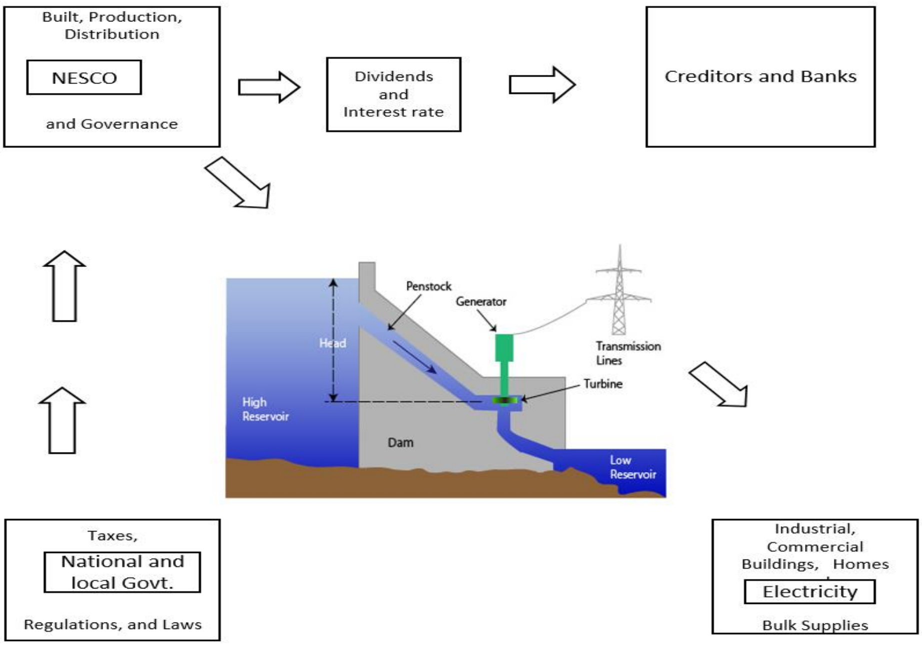

Figure 4:4 Project stakeholders

From the inception of the project, the stakeholders established the plant with loans banks and financial intuitions. The creditors charged an interest rate ranging between 7% and 8% for the loan, but the company now does not pay any fees. The investors use 65-70% of their annual earnings to reinvest in the project as a company book rule. It started the installation of the power plant with 19000KW energy production, but this was extended to seven power stations and improved to 40MW with the central water management system.

PSHPP built a long-term relationship with the federal government and the Jos State Government in the project. The federal government consumes the bulk of the energy from the project as NESCO's largest energy customer buying the electricity through its energy distribution agencies. The government also communicates with the company concerning the environment and commercial issues, the project is charged with a fee annually. The government collects the fee, which functions as a company tax, and other levies for water uses. The company manager said "We pay the Nigerian government charges of 24% taxes"

The Ministry of Water Resource and Energy of Jos obtains the generated energy from the company to retail and distributes the electricity to some rural communities. It issues the community energy bills and later returns the payment to NESCO. The federal government participates in the project not only in partnership for the supply of electricity through the government distribution companies but also in imposing tax charges on the project due to the use of rivers.

4.2.5.2 Maintenance and operation

To manage PSHPP's facility, two management units were established: maintenance and an administration unit. They are key to the management of the plant and they ensure that the PSHPP runs effectively. The site workers are engineers who trained to undertake the repairs and maintenances of machines. The engineers make new parts to replace parts in the project's turbine generators when they are needed. There were engineers working on operating and monitoring the power plant system every day and rotated in seven hours shifts ensuring that the electricity generated constantly. The administrative workers are the management function as customer care services. They interact with customers in terms of new customers registration and the charge of connection fees. The connection charges included the cost of cables, a meter and other installations. This charge is depended on proximity that the customer has to the power plant. The management has maintained the facility for over eight decades. There were cables installed at the initial construction that still operate efficiently supported by the site engineers.

*"NESCO employees have a strong sense of ownership and job satisfaction. The company also has a very low staff turnover with some employees working for the company for as long as 50 years" (*The Project Consultant).

There is evidence that PSHPP has operated for over eighty-five years: generating and distributing the customer's electricity by the efforts made from the company's stakeholders. As the project manager recalled the project duration, as the project was the first hydropower built in Nigeria in 1928, the project's objectives influenced by the management strategy, making an effort to run the administration structure and energy activities. Therefore, the maintenance department works on the installation standards and ensures that its activities are in accordance with the manufacturers' specifications. In daily activities, the workshop work is carried out by trained engineers, who repair and maintain the turbine generators machines. The administration subdivisions interact with the customers about financial issues and register new customer, who pay a fee for the installation materials.

4.2.5.2.1 Technical management

The management used a monthly post-paid billing approach for the delivering electricity to six thousand customers connected for the project to use the energy services, these customers comprise Plateau State Ministry of Water Resources and Energy Jos, industrial and commercial businesses, bulk suppliers, and PHCN. The Ministry of Water Resources and Energy and the PHCN consumed over 10 MW from the project and their energy charge was lower than the residents. The electricity the NESCO charged for the customer's bill was depending on the tariff of the federal government categories. The customers could register as an industry, small scale businesses or residential use.

"We charged whatever we charge as far what you consume monthly. What we do is every month we go around to read the meters and convert the meters, whatever the read rates there, we choose that bill to know how many units. From there base on the NERC tariff, we produce what is needed to pay. Each household has the standard, the individual house can be more, and the government regulated what we charge" (The Company Finance Manager*).*

PSHPP uses accumulation meters to access bills. It may not read them regularly and occasionally there are errors. There is also a similar approach to developed countries where bills are not paid, individual households or business may be disconnected. There was a view that a smart approach, which allows for remote control and readings, might make this process more efficient.

The Ministry of Water Resources is a large electricity buyer and supplied electricity to Bukuru, Unguwar Roga and Pam communities when the electricity was provided from the UNESCO's distribution networks. The Ministry of Water Resources installed its own energy distribution lines and manages the community's bills, and then pays to the PSHPP. There have been some issues where the network has been tampered with. In 2017, the Ministry of Water Resources reported two persons to the police after they sabotaged the distribution networks by using bypassing meters.

4.2.5.3 Financial approach

The management and the financial institutions involved identified as having different objectives. Finance partners required the project to procure annual return and to grow the company as a profit-oriented entity. The project infrastructure installed with government consent, providing taxes for state and local government revenues. Although the project delivered energy free for the community that lives nearly to an area, the project was financially supported by the group of entrepreneurs through financial sources. With the improvement of the plant, the capital was estimated at £24.8m, due to an increase in the number of turbine generators, redevelopment of the dam, and other transmission equipment. The project manager also stated in the following quote that the hydropower has installed to operate at full capacity, and it running as a profit-making enterprise to bring additional income to the company

"To get sufficient profits in order to justify the borrowing money, shareholders put money in the business to make a profit. the project pays 7- 8% interest" (The Project Manager).

From the inception of the project, the project owners raised the funding by taking a loan from banks in Europe. The cost of the project was estimated at £2.5m for the construction of the dams, generators and substations in the first phase of the operation. The company's installation is now valued at £24.8m (N 11.7 billion Naira) due to the redeveloped installations. The equity and retained earnings funded the operations for the second phase as the company's stakeholders planned to retain 65-70% of annual earnings to reinvest in the plant.

A main objective of the project was to grow electricity services for the retails markets and to share the profits among the shareholders involved. Additionally, the project was to continue to provide electricity for reliable services using the business standard approach which organisation formulated for the operation of the power system.

4.2.6 Summary

The case study is succeeding, as a result, the factors, which summarise as effective management for the project maintenance, access fund to build the power system, incentives given to the project staff encouraging the workers to engage during the project operation.

4.2.6.1 Institution and governance

This case study built a relationship with financial institutions and other stakeholders as the project maintained the environmental ethics this enabled the project to operate since its inception. The management achieved the criteria given by financial institutions for the interest rate charges during the lending periods on the project, the management delivered the borrowing agreement. The success of the PSHPP depends on the investors' transparent and effective management culture. Therefore, stakeholders enabled to deliver the PSHPP as a result of the development process through the interaction of other networks.

4.2.6.2 Financial drivers and incentive approach

Access to the debt, which the PSHPP stakeholders obtained financing all the development of the system, was an important factor. The key issues of what stakeholders had used the capital sources when they secured building capital infrastructures such as the constructions of dams, roads, and installed generators and transmission lines to the energy users. A sharing of benefits from the capital revenues through incentives approach was another approach the stakeholders used to sustain the system. This case study improved the energy services through the project staff by providing incentives for a performance-driven outcome. The PSHPP operators also allocated seven hours duty, providing an hour time for relaxing, an estate was built nearby the project site ensuring the employees reached work on time. There were employees identified they were working in the project for the 50 years. A minimum of hours was considered important during the project operation work. The employees received a high payment, compared with available jobs in the area. The financial ability the PSHPP's stakeholders used as raise equity was the key driver to the delivering of infrastructures, facilitated throughout the project development, and operations where the project workers to be active participants.

4.2.6.3 Developing and deploying technology

The case study was first hydropower technology built in Nigeria over the decades and it contributed a lot of benefits, such as changing the use of energy fuel to hydropower system a sustainable energy source . It was also identified that the human capacity, skills to workers. Although it was not free, energy services to end-users were served by such hydropower. The main installations were important elements imported from the UK, the employees were trained to operate and maintain the equipment. This outlines that the project provided human capacities and employment opportunities as well as operational sustainability for the plant. The project is a part of students, engineers and consultants used to visit the project site understanding the dynamic nature of the hydro technology. This PSHPP has been in operation for over 90 years. Nigeria has replicated the project in other places. The project serves many energy users in the country, including national and state government, who now have contacts with the project to deliver generated electricity to their people, particularly to the rural areas. Developing this hydropower system was the economic cornerstone in Nigeria, where the deployment of the system seemed to be a transfer of technology

4.2.6.4 Geography factors and challenges of energy project

This case study identified is suitable in the area where the hydropower installed due to the availability of rivers, however, the issues of limited energy supplying, it seemed a barrier to the progress of the project generation capacity within the geography area. As the PSHPP can generate more energy capacity than the generated energy delivered to the users. The energy services the project provided for end-users particularly, the local residents could not afford based on market prices, although the projected electricity was provided free to the community living close to the project site.

The case study sustained the uncertainties and changes in the government administrations, although there was no further confidence in reinvesting the capital. The tariff regulation from the government agency is more concerned for the project stakeholders to create an ecosystem, which enables to deploy economic scale capacity. The government occasionally proposed the policy changes that were affected by the development of the power system.

Technical issues in this case study, such as grid disturbance and a loss of overloads, distribution networks, were found as major challenges to the project. The example of bypassing the electricity meters as thefts used to steal electricity during the distribution of energy.

4.2.6.5 Operation and maintenance

Most importantly, the PSHPP adopts effective management systems such as workshops and monitoring a central water management system. Maintenance is an important factor in this case study. An engineering department provided services to ensure the project maintenance and repairs and to operate on a standard of the hydropower system. The engineers were well trained in fabricating the equipment and spare parts in the site. The engineers were enabled to manage the project machines for the project operating at optimal capacity. The dam water system was constructed storing the annual rainfall to meet the daily energy generation. The management controlled the dam from the powerhouse, where they determined and monitored the flowing water for the generators to produce the electricity that would be demanded.

In terms of community engagement, however, renewable energy projects promote networks such as the involvement of communities, developers, investors to facilitate in building capacities and educating skills for behaviour change through operation and maintenance of the renewable energy projects. In this case, there was a lack of community participation. Despite the project composed of actors including Plateau State Government, shred partnership with intentions local communities would benefit from the project, but the project did not create a platform that assists communities for building knowledge and exchanging expertise.

4.2.7 Conclusion

This case study indicated that economic outcome is the main motivation for the installation of the hydropower system. The PSHPP primarily provides the benefits to the shareholders, where the investors make capital dividends. A percentage of the equity and earnings from the project investment were recycled into the business to ensure its long-term sustainability. The government collects an annual tax for using the rivers. The project is extended seven power generators to increase the capacity for profit generation as the initial single generator installed was generated only around 2MW generation capacity. It identified that there is four hydro projects contract under construction using the designing and modelling from such as hydropower system. The PSHPP system had sustainable management. However, the PSHPP needs to improve the method customers use to pay for their electricity.

The use of metering systems to replace traditional analogue technologies has identified that is a complicated issue to manage customers energy costs as well as recording the information. There was a lack of confidence for the project stakeholders in this project due to the frenquent changes of national energy policty in the Nigerian energy sector. The project investors need to be optimistic in order to expand their capitals resources in the project for delivering the customer's energy services. There is a need to develop effective policies from the government, which ensure and allow the stakeholders to invest more in the project for the extending delivery of low energy projects. Most importantly the creation of a dedicate action and programmes engage for communities to be actively in operation and maintenance, which did not exist in the development of PSHPP.

4.3 Case study 2 - Usuma Solar Project (USP)

4.3.1 Case Study Introduction

The USP is a Clean Development Mechanism (CDM) project for the introduction of clean energy using a solar photovoltaic system at lower Usuma Water Board (UWB) treatment plant (Figure 4:5), located in the isolated small community around FCT Abuja. The USP area is suitable for the project. The temperature of the area is identified as 33 ^{0}C on average during the dry season, from November to April, and then it changes to 30 ^{0}C during the rainy season from May to October. However, in August the lowest temperature in the area is around 26 ^{0}C. During this time, the project faces frequent challenges from the amount of sunlight reaching the solar panels.

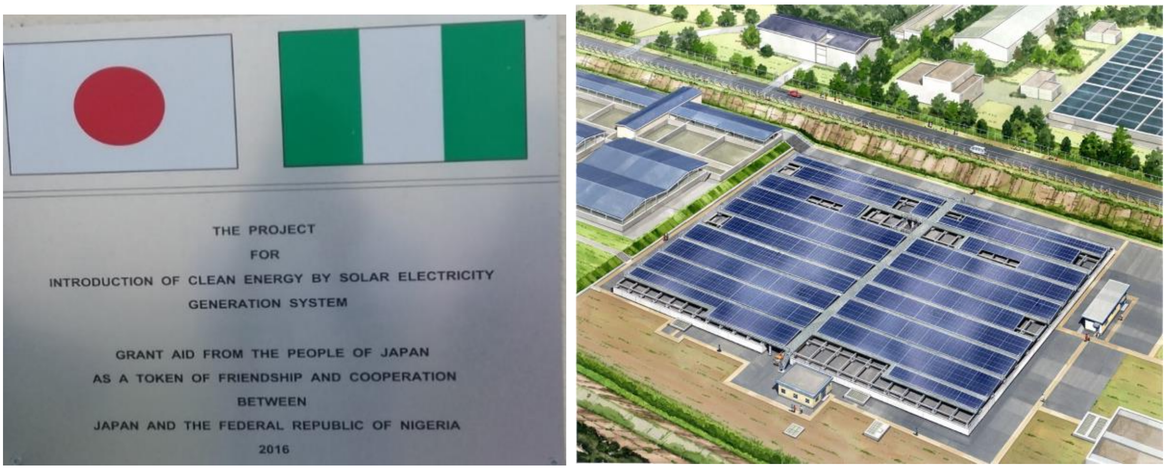

Figure 4:5 USP public partnership project

The project is a grid-connected PV system with the main components being interconnected to provide electricity to the end-user. The components of the project system comprise PV arrays, junction box, collecting box, power conditioners, AC distribution panel, interconnection transformer and interconnection equipment. Solar panels are installed on the top slabs of existent water tanks and in the open spaces they are ground-mounted between the big two water tanks at the water treatment plant (with a total area of 8,800m^2).

Multiple stakeholders from Japan and Nigeria were involved in the delivery of the USP. The project was commenced in 2016 after several meetings held between the stakeholders Ministry of Power (MOP), the National Planning Commission (NPC), the Energy Commission of Nigeria (ECN), the UWB and the FCT administration from Nigeria and Japanese International Cooperation Agency (JICA), the procurement agent, who represents the Government of Japan was implemented under the grant aid scheme. It was undertaken by the UWB and only five persons, the chief engineer and the trainee staffs controlled and monitored the project. The other staffs working with him had skills in operating solar energy technology.

The project is funded by the Government of Japan through the Cool Earth Partnership schemes, which help the country to mitigate the effects of climate change and improve access to clean energy for sustainable development. The principle of the schemes helped Japan to disseminate technological advancements in developing countries. The country is highly developed in terms of solar panels, batteries and generators etc, and they have a competitive advantage in an international cooperation project.

The financial support of the project to the point of operation is not clear in terms of value numbers; it was kept confidential by the Japanese government. However, it estimated that the total cost was around JPY980m (GBP 68m), which was announced during the implementation period. There were also some additional costs in terms of the bank's commission fee, which was charged at 0.1% of the total grant. The duration of the implementation period was approximately 19.5 months. The grant remained as a surplus in the account after the calculated capacity was reached, which led to the second project phase. The initial project plan was to install 975kw capacity, but the capacity increased to 1.2 MW due to the costs of technology. The project was in operation seven days a week. The mechanical and electrical engineers who were managing the project at the UWB had been selected for their experience in operating diesel generators. However, the personnel in charge of operation and maintenance lacked some basic necessary techniques and knowledge of solar PV.

The goal of the project is to help some parts of the country generate a reliable electricity supply (shown in Table 4:3), which will be used by consumers and used for water treatment. The project was implemented to achieve sustainable development and prevent the impacts of climate change. The issue that the project sought to solve was decreased in the power generated by the hydropower plant due to a drought affecting water flows from the Niger River. The project had brought social, economic and environmental impacts not only for the Usuma community but for the whole Abuja state. The USP is expected to contribute approximately 2% to a total of 5% of renewable energy installed capacity in Nigeria.

There were grid connection and distribution issues identified in the project since the solar model was brought in from Japan. Although the project qualified for permits for implementation and environmental impact assessment, the project faced challenges in gaining access to the grid and entering the energy market. The model had issues of reserve power flow for some days. The frequency reference values and the installation capacity of the grid-connected solar PV system need to be studied for power quality. The legal issues connected to generation systems and grid connection are understood to have been the key challenges for the project.

Table 4:3 Summary of Features of Usuma Project

Features	**Usuma renewable energy project**
Location	Usuma FCT
Type of technology	Ground Mounted Solar PV
Capacity generation	First phase:975kW & second phase: 220kW
Funding	The Government of Japan
Total capital cost	980 million yen
Ownership	Public
Benefits	Electricity for water treatment and consumption by residents in Usuma community and CDM project for Japan government

4.3.2 USP Background

Renewable energy projects require environmental and social considerations in Nigeria. The surveying approach for energy generation and distribution system is considered an important tool in any energy project, whether it is private or public. This leads to an environmental impact assessment for Usuma solar PV installations, which is implemented by the Federal Ministry of Environment Agency (FMEA) based on Act No 86 (Decree No. 86), enacted in 1992. The initial project proposal was for Umar Musa Yar'adua University (UMYU), Northern Nigeria because the survey finding was that this site was suitable for the deployment of a solar project. However, the location of the UMYU was finally changed to the Usuma Water Board (UWB) site in Abuja due to the recent crisis of Boko Haram in the area. It was identified that the assessment of the Usuma project had been waived. Although the assessment is compulsory under the master plan survey for solar energy utilisation, because there were no batteries in the system, it decided that the PV power generation would create no major environmental impacts and the FMEA disregarded the process.

However, the observation was made during the site visit that some concrete and metal waste had been left after the building of the solar PV system. This might cause safety issues as well as stopping the panels from absorbing radiation. The safety management was minimal on the solar site; the board did not complete the building of the steps would take the project inspectors to the higher panels. The board also needed technical personnel for the solar system, but there were pressures on the engineer who inspects the technical aspects of the solar project.

4.3.2.1 USP location

The USP is a designed grid-tied Solar PV, located about 30km away from Abuja city. It was introduced as a pilot solar electricity generation. Although the USP was introduced to demonstrate solar technology and provide electricity for both the water plant and households, many of the residents lost their homeland and farmlands to the government. The government moved the communities from the Usama location to increase the plant's power capacity for public benefits. This was an opportunity for the first time for the development of the USP, as it was successfully driven by the effect which associated community farmlands access in order to integrate the solar PV panels and its other components of infrastructures that were considered as larger-scale installations. The following quote from one of the respondents illustrates the changes the community experienced as a result of the project, such as jobs, land compensation, and losing their farmlands.

"*All the communities living here are called Usuma communities but some of the people who lived in the project area were relocated to Bwari Road community to live, and they benefited from an improved electricity in the day time. During the construction, people were recruited to work but once the construction was over, we established an organisation" (UWB Staff).*

The project installation site is an extension of the water treatment plant, which is built on land secured from the communities, who agreed to move 2km away from the water board's premises. But indigenous members remained in the UWB area (Figure 4:6).

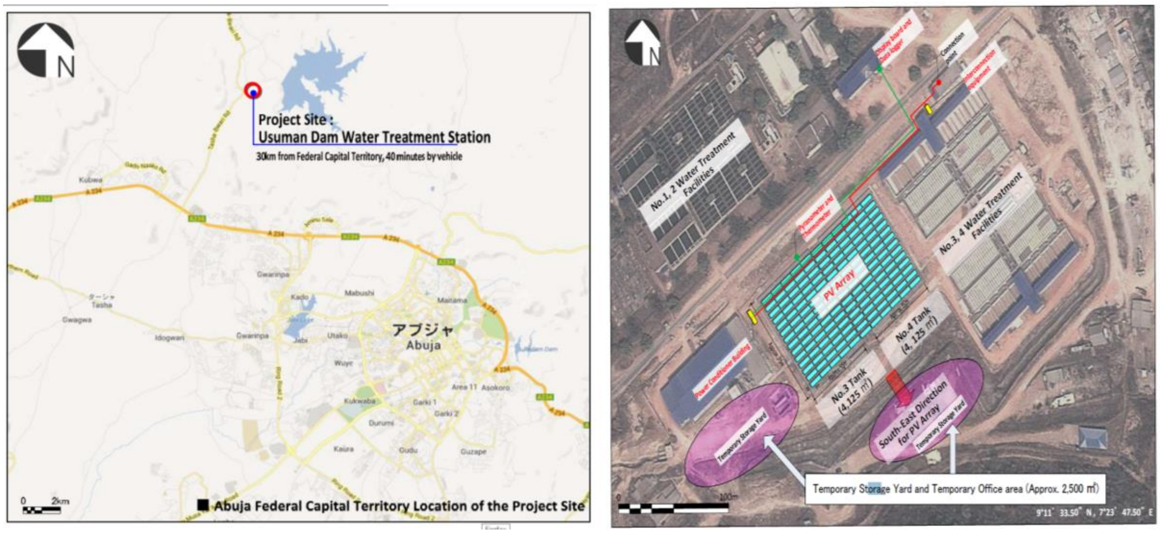

Figure 4:6 USP location

For the building of a community energy system, there is a need to build a legal, administrative and management structure that this project should be included in the local government system. However, the project co-ordinators temporarily recruited local people to work on operation and installation before the water board organisation created their own management for the project. Lack of connection and relationships from the local government in order to provide support was identified, in that it made it difficult for the community to engage in the project. However, the process through planning processes delivered by the FMEA for the solar installation inspection identifies as one of the key factors, succeeding the development of the USP.

4.3.3 Technology Installations

The project was named "Project for the introduction of clean energy by solar electricity generation system" and upon completion, it was handed over to the UWB treatment plant. The USP was carried out by Japan and Nigeria, who joined a partnership to share the project's benefits. The Japanese government approved the project to help Nigeria with issues connected to climate change and economic development. The project was funded through the Japanese Cool Earth Partnership Scheme, which mainly supports developing countries to achieve sustainable development.

"Japan Cooperation Agency (JICA) was the one that proposed this project for the Nigerian government. So, they were the one who conceived it, designated it and brought it to us" (**Project Manager**)

The UWB ran its activities for water treatment during the daytime, and electricity is only delivered to the water plant when solar radiation is available to the solar PV system. Other activities carried out on-site include blending chemical materials and monitoring services. These are normally operated between 8: 00 am and 5:00 pm. However, the water board uses a diesel generator to run the services when the solar panels cannot provide energy or during the night, instead of adding batteries to the PV system. When a participant was asked about the solar system and how it delivered electricity to the water facilities, they responded: -

"It is grid-tied it does not have battery banks to the grid. So, now we are generating". (The operation manager)

The solar PV system does not utilise battery storage to keep electricity for whenever it is needed. However, it is understood in the part of project grant agreement the project should not include with batteries storages due to high cost of replacement. The solar PV system is a direct energy generation system unlike the solar system, which can generate and store the rest of the generated electricity. The UWB managing the project understood the vital role of batteries in terms of energy capacity. But their concerns over battery technology were since in the planned model of the solar system. The model structure of solar technologies is complex, constituting a number of technologies configured for successful energy generation. The project consultants considered environmental issues during the development of the project processes.

It was noted that there were different kinds of technological models, installations and factors that were taken into consideration before the technologies were put into place. The USP technology model is based on the existing solar system that has been tested in Japan, and which has been proven to provide high performance, reliability and durability. The model was also selected because it considered the local footprint and natural environment.

4.3.3.1 Solar PV and components of the system

The identified components of the project include the PV system (Figure 4:7), data management system, cables and fitting materials they were procured from Japan and installed following JIS and IEC standards and specifications.

Figure 4:7 Grid-tied solar system connected with the Transformer

Each of the PV modules can produce an output of 250 W at an average temperature of 25^0C of solar radiation (1000 M/m2) at an efficiency of 14.5 per cent. Junction boxes are an important installation for the project in linking electrical connections with other technologies.

It was noted that the solar PV arrays were connected to the junction boxes, which had input circuits with a number of sub-array unit parallel lines for the maximum power voltage of a string or more. There are problems in the UWB area due to the weather changes that may bring some issues, which limited the progress of the project. Many actions were taken to safeguarding the people working and the equipment installed in the UWB solar generation site. The equipment was selected for its suitability for the environment, in order to protect each piece of equipment and the installations. Utilising the land for the solar panels is an important issue identified at the project site.

The project plant site did not have enough space to install the system. The panels for the first phase of the project were successfully installed, using approximately $77.5m^2$ of land for the PV arrays. However, when the project secured the opportunity to increase the capacity and add extra panels for the second phase, the space for the installation was not enough to accommodate the 3,696 solar panels required. There was an understanding that the surplus of the grant would be taken back by the project representative sponsors as a result of the land issues. The Water Board, with the local government's approval, was provided with another site. The top of the mountain space in the water plant was used to install the additional solar panels. This brought in the second phase of the project, which reached a total capacity of 1.2MW PV through a PV power plant connected to the grid.

On-site, the junction boxes and collection boxes were noted, and they were installed outdoors in the water treatment plant. They were protected with IP45, which might be due to the uncertainty of the weather in Abuja; for example, the rainy season brings frequent violent squalls, while during the dry season, sand storms blow off from the Sahara Desert into the site. The power conditioner was also noted; it was rated at 50 Hz frequency with power conversion 93%. It was used to operate automatic start, stop and adjustment. This technology was installed in an indoor building, considering that it is the heart of the grid PV system. It was protected with an IP20, due to its main function in the delivery of electrical outputs from the PV system. The transformer installed outdoors close to the building of the power conditioner room was used to step up the AC power that the power conditioner had converted, according to the voltages of the distribution grid.

The transformer had a capacity of about 1,250 kvA, but the management was able to adjust the energy output from the power conditioner. The solar system was an underground connection model using cables and electrical materials such as a load break switch in the delivery of the electricity. The components of the management system, including data logger, display system and weather monitoring instrument, were installed on-site to facilitate standard designs of the project model. The solar system used the solar arrays that were installed approximately 200 m from the gate, and which covered a space of around 8,800 m2. Each array generated DC from solar radiation collected through the junction and collection boxes for the power conditioner to convert. Data from a pyrometer and thermometers were used in the central monitoring system. The USP is the biggest project of its kind in Nigeria and itis the first-time grid connection has been achieved. The solar system contributes electricity through grid, operation and maintenance, ensuring that the project contributes to the future dissemination of grid-connected PV systems in the country.

4.3.4 Generation Capacity

The project comprised two phases for its operational period. The main activities carried out from the inception of the project include an exchange of notes, a grant agreement, agent agreement, consultant contract, contact for supply and installation of plant equipment and capacity expansion. The Nigerian government representative engaged with the Japanese authority providing a source of knowledge and expertise in the project contexts. The exchange of notes is a written agreement regarding the project contexts and brief information. The grant agreement is the total cost that Japan promised to provide for the project development. The Nigerian government and the government of Japan agreed to sign the exchange of notes and the grant agreement after a number of meetings were held between 15 May and 25 September

2012. A consultant contract is a contract applied to the Nigerian Government by the Japanese Government in July 2014, while the Ministry of Power was responsible for ensuring that the contract was appropriately completed. In the contract for the supply and installation of plant and equipment, Toyota and Tsusho Cor were appointed in April 2015. The first phase of the project was successfully completed in August 2016 with a maximum capacity of 975KW generated to the grid. As one of the participants said, the project secured the opportunities of an extension of the solar panels as additional capacity.

"The reason why we are still doing this project is that the panel's money was left, and the grant given to Nigeria… (total cost of the capital) so the balance of the money was used to procure 207kw". **Project Assistant Manager**

It is worth noting that the capacity of 207KW was added because over the development of the project the price of solar equipment drastically reduced. This led to the second phase of the project, which commenced in June 2017.

4.3.5 The Delivery of USP

4.3.5.1 Organisation and governance

The USP is a public partnership between the Nigerian government and the Government of Japan. It also involved several multinational companies, ranging from small to large-scale production corporations, all with a wide variety of skills in terms of solar equipment and building materials. The Ministry of Power was one of the contractors of the project under the supervision of the Japanese JICA through the procurement agent. The local contractors were employed as labourers to work at project sites on tasks such as plating, steel processing and, assembling, and the calibration and testing of the machinery and tools.

The Ministry of Power was in charge of selecting and contracting the works. For example, the consultants and suppliers were selected through its Electrical Inspectorate Service Department and then connected to the Japanese Procurement Agency. The Japanese Government suggested that the Procurement Agency came to Nigeria for the implementation and execution, and general supervision of the project, and to ensure that the components of the project were appropriately implemented. The Nigerian Water Board was the owner of the project and it has been responsible for operating the solar project since it was completed in 2016. However, the capital territory administration promised to secure the necessary budget for maintenance and operation activities.

The UWB exists as a structural management body before the independent solar power generation, treating the water supply for communities, private houses and small businesses. It is a water supply cooperative registered as a public entity and has management structures such as the distribution department, which consisted of the finance, mechanical and electricity section to support the project. Normally they used diesel generators to run the water systems, which to lead to high daily expenses.

A series of meetings were held during and after the development process in order to identify the objectives that should be delivered for the project. The meetings included international developers, contractors, and the water board itself. However, the emphasis of the meeting was to deliver better technologies with more efficient specifications. A number of contractors were asked to be involved in the project. The decision made in the agent agreement was that the contractor consultant should be an experienced company that had knowledge of solar systems. The technical materials were prioritised in terms of quality and durability as explained by one of the project consultants:

"*Abuja has not only local construction companies but also a number of foreign construction companies with a wide variety of work performances. For this reason, in carrying out the foundation and installation work for the photovoltaic system in the project, consideration should be given to allow for the reliable transfer of equipment management and technology related to quality and processes"* (Project Consultant).

Japan's relationship with Nigeria is not new for social projects, but in the case of a solar project, this is the first such initiative: "The solar plant built in partnership with the Japanese government is the first solar plant tied to the national electricity grid" General Manager. Japan had been a partner with Nigeria over the years, helping with basic infrastructural development such as building schools and hospitals and supplying potable water. Even most of the companies that won the bidding for the Usuma project had already established their activities in Nigeria. These companies included Toyota and Tsusho, who sought competitive market advantages around the electronics, as they partnered with the government in various activities such as building roads, schools and houses. Therefore, they engaged in supplying materials as a contractor during the delivery processes.

However, the project actors controlled within the project included government representatives from Japan and Nigeria. They played an important role, making sure that the project was delivered. They had responsibilities of consultation and monitoring. This issue is outlined in the exchange of notes between the two countries. The main actors identified in the project understood that it was made up of not only the government representatives, but also organisations that designed and modelled its components and delivered the solar system, and the people who continued to manage the project.

*"The renewable energy project made up of local and international energy stakeholders, development partners, as well as Ministry and Agency officials, dedicated to the Usuma Dam Water Treatment Plant, was a ground-breaking achievement because water meant life, good health and enormous opportunities for the people" (*General Manager).

The modelling of the project was considered an important aspect at the beginning of the development. Japanese companies were successful in their bids to construct and install the components of the solar system. The experts from the company managed to achieve the time given in the project plan: 2 April 2015 to December 2015.

Hitachi Construction Limited, situated in Japan, delivered the solar PV products. The company partnered with Toyota and Tsusho and provided the PV modules, power conditioner, grid connection transformer display unit and wiring materials. This is because they are specialists in the field of electric power products and industrial plants worldwide. Experienced organisations, such as government agencies, and industries stakeholders gathered together to run the activities of the USP, but the priority was given to Japanese companies to supply the products required because of their quality and standard. There was an important contribution identified from Nigerian industries who facilitated in delivering the project materials. For example, the IP group, local contractors, were successful in their bid, supplying the materials used during the construction of the solar system, which was mainly cement, concrete and reinforcing bars. There was an understanding that local workers would be recruited temporarily to work on steel processing, plating and assembly, while the Japanese engineers supervised the activities at the site. Most of the workers live, close USP, and are the members of Usuma community. The USP remained only ownership to the UWB, although the community members enabled to use electricity. The USP should be a space, that should target both UWB staff and community members set up for training courses and educational programme.

4.3.5.2 Operation and maintenance

UWB did the maintenance in terms of cleaning the solar panels, cutting the hedges and regularly checking and making sure that the USP was working to achieve good results from the solar system. The USP system-generated electricity is sufficient during the day with no technical issues. This was explained by the project engineer, appreciating the energy capacity in terms of energy generation from the USP panels so far. As the USP was not an off-grid system that delivered direct electricity to the water loads, it is a grid-tied system generating electricity only from the sunlight through its interconnected equipment. The UWB worked with the network and local distribution company (DISCO) as a temporary arrangement to manage the distribution network and effectively deliver electricity to the UWB facilities and the other users. There was an understanding that there was no metering used to quantify the units of generated electricity coming from the solar panels, and the solar system added voltage directly to the company's distribution grid.

"So, there is no process yet because we pump the excess we generate to the grid, we know from our initial calculation and all that". **Project Manager**

For the 975kwp, the project was tested for two weeks to see how it worked with the grid connection. This was necessary because this was the first time that a solar PV grid system has been used in Nigeria. The operation was not stable due to the reverse power flow issues. On days when the water board operated No 3 and No 4 water treatment facilities, with a total capacity of 20,000m3/hr, at the same time as No 1 and No 2 facilities with a total capacity of 10,000m3 /hr, plus loads of residents and offices, reverse power flow was not expected. The management, however, used to control the demand for water service when the PV system was online. Usuma adjusted its operations from the plant facilities after all the tanks were full the plant's peak load time matched the time slot in which the PV system reached its peak power.

"*We cannot pump more than 50% of what we generated into the grid. So really you have to involve the local power generator who has the impact"* (Operations Manager**).**

The water board management was conscious of their electricity consumption because they had an idea of the capacity used every day. This was estimated since the first phase of the project confirmed that 975KW would be enough for running the water activities and could even result in in a surplus, despite the demand for electricity from the connected community.

After the second phase, the Usuma solar system had a capacity of 1.2MW, which surpassed all of the load in the water treatment facilities and delivered electricity to the staff's offices, workshop halls and residents close to the plant. This gave the Usuma management opportunities to engage in commercial energy as the supplier sold every single unit generated by the solar PV system for additional profit, rather than bargaining with DISCO. However, they needed to fulfil the existing rules enforced in the context of energy generation in Nigeria.

Therefore, the water board negotiated its surplus with DISCO based on the local arrangement in order to balance the excess is generated. This is clearly stated in the following statements from one of the respondents:

"*For the excess, we sent it to the grid just to try to balance. In the future, we intend to procure a meter. What we think and what we give we will be measured and at the end of the day we sit down and reconcile. We will be able to trade with the local power utility i.e. Abuja local power distribution Power Company as to trade power we have to go through the bureaucracy of licences and all that*" (Project Manager).

The Usuma water board's commitment and engagement in the project were restricted to the generation of electricity and its target was to sell its excess electricity to the grid. Because the Usuma project was extended to 1.5MW capacity. Usuma had to measure the actual electricity generated to sell based on the Nigerian energy policy.

"*We need to have licences from the national regulators because our capacity is more than 1MW, meaning that we have to go through the licences*". Project Manager

However, the lack of legal requirements for power generation and grid connection is a barrier in the Usuma solar system. UWB engaged with the DISCO without obtained licensing and permitting requirements for supplying energy into the markets. Supply business licenses need to be addressed regarding the generation plan details, minimum loads, and reactive power and voltage that may allow them to participate in the generation system. The electricity generated by Usuma did not conform to Nigerian regulations. Although there are no clear regulations or distribution code regarding the generation of solar PV, the owner of rotating generators, such as hydropower and thermal power, with more than, 50kW, should obtain a distribution code. This project produced an output of more than 1000kW and is therefore subject to the regulation authorised by regulation R-0108 if the solar generation power included among the rotational generators. Therefore, the UWB sold its electricity units to DISCO at cheaper rates. It just used the estimations to its energy units.

4.3.5.2.1 Technical management

The project shaped a number of actors in adapting to use the technical aspects of the solar system. The UWB was responsible for its daily operation and maintenance, and they were also introduced to the distributing company DISCO and the Ministry of Power members, who officially participated and promoted the development of the grid-connected PV system. DISCO is a distributing energy company that is responsible for maintaining all of the distribution grid networks and supporting equipment within the location of the project. The water board used the DISCO distribution lines to supply electricity to its water treatment facilities, and the electricity was supplied via the DISCO 11kV lines and stepped down to the water board's switching equipment. DISCO connected their overhead dual lines across 33kV to the electrical room on the premises of the water board.

There was one identified issue with the distribution grid reverse power flow. This usually happened during the day time, and it occurred when the sun was at its strongest. The solar cells generated an amount of energy that exceeded the load of the water board and the residents. In this situation, the Usuma management could not keep the voltage within acceptable limits, because they did not have a battery system. Instead, there was a flow of generated energy back towards the DISCO networking equipment. This issue was solved by adopting an informal arrangement with DISCO to manage the excess electricity generated during the day time.

4.3.5.3 Financial Approach

The Japanese grant scheme is flexible funding that enables developing countries to secure sustainable projects. The Japanese government created this funding scheme due to issues related to poor education, health, energy poverty and climate change. In response to the interview below, it is stated that Japan helped Nigeria through the funding programme, considering the capital barriers that the country experienced in deploying basic infrastructural development. The USP is not funded from local or national network scheme rather it was internationally financially supported throughout the project development.

*"It is a grant aid project as you know we have a lot of development partners in the country or in the world. We have UND, USA, DP and JIZ. The JICA is the more responsive to the need of developing countries basically to provide basic needs" (*Project Assistant**)**.

The Usuma solar project was funded through Japan's grant aid scheme called the Cool Earth Partnership Programme. It is linked to developing regions, which can use the funding to improve issues related to the adoption of clean energy, including in areas that provide job and income opportunities. Nigeria is one of the partnership programme countries listed for the grant. This grant was successfully secured as the result of the Federal Ministry of Power's application. FMP engaged in the various procedures of the Japanese grant aid policy in order to collect and prepare the development of the solar system. The funding, which came through JICA, was estimated to be approximately £5.92m. JICA partnered with the FMP to secure main project materials and installation in Japan.

"The project is being executed with grant assistance worth nine hundred and eighty million Japanese yen through JICA" (JICA representative).

The total cost of the project was an important aspect of all the project stages, although the UWB through the local government promised to take on the expenses of the project. The capital costs were divided into two accounts to procure the materials for the project. This separation of costs was based on the responsibilities of both countries. Nigeria received JPY 7.82 JPY, equivalent to £61,554.82, to provide local materials that were needed during the construction and to cover other costs, including payment of commission to the bank and worker's salaries. There were also some additional costs in terms of the bank's commission fee, which was charged at 0.1% of the total grant. The total capital cost of the project to the point of operation is not clear; it was kept confidential by the Japanese government. However, it estimated that the total cost was around JPY980m (GBP 68m), which was announced during the implementation period. The duration of the implementation period was approximately 19.5 months.

There were clearly a number of costs incurred by the Japanese representatives to pressure the PV modules, transformer, power conditioner and generator equipment. The cost on the Japanese representative's side remained in their account because they had provided all the necessary equipment based on the contractual agreements. It was decided to use the surplus capital for the second phase of the project. The USP sought to establish a financial source, to keep which keeps the solar energy sustainable in terms of operation and maintenance. There were no financial issues with the development of the Usuma project an increase in the capacity of the installed solar panels which were added to the initial target. This is the result of the grants provided by the Japanese government.

4.3.5.4 Energy end-users

The USP was developed to provide a power supply to the water board and electricity that is used by approximately 40,000 residents of the UWB community. There were more than 50, 000 households in the area. These included 120 Water Board staff homes and three different communities: school buildings and farmland. These should people would benefit from free electricity after the completion of the project.

The UWB owned the project as it was dedicated to them after the project successfully started to operate being used to generate electricity for water treatment. The UWB generated their revenues by supplying potable water to the houses and industries, but the local government-controlled the UWB's spending executing the costs required for the project activities, the main responsibility of the UWB was to operate and maintain the solar system. In this regard, it was found that there were challenges of the capacity building particularly the knowledge of the operation and maintenance of the PV system for UWB personnel; the USP was considered as a new system for UWB staff. The UWB should be a central pillar of sustaining all issues related to the USP, but there was an arrangement programme organised by the governments for UWB members, in order to provide them with practical training on the technical equipment such as PV arrays and transformers and on measuring with other instruments and tools installed in the project. The training is one of the benefits that the USP would bring in terms of the "transfer of knowledge and technology." This were soft issues that encourage learning of the basic principles of PV systems, as well as their operation, maintenance and monitoring. Consultants from the JICA were employed to take the workshops, ensuring that the operators understood the soft components of the project.

As the USP involved a number of stakeholders and organisational agencies each of which wished to achieve different goals. For example, the FMP, who was responsible for executing and promoting the installation of renewable energy in Nigeria, considered that the project had wider implications than the importance of solar projects compared to the conventional fossil fuel. They thought that the project would bring political and economic stability, considering the difficulties the country faced in securing a constant power supply by using the energy policy.

"*This is an elaborate project that will contribute power to the national grid to improve supply within the nation's capital*" (General Manager).

There were many reasons at the initial of the installation of USP, but the most important one for UWB was the cost of fuel used to generate electricity during the water treatment activities. The UWB was charged high bills of electricity by the utility company, and there were also costs of filling the generators with diesel fuel, when the electricity went off. As a staff member said "Sometimes the Usuma treatment service (UWB) stopped in the middle of the day," and the UWB workers had to wait for electricity to come back if there was insufficient money to fill the generator. The project contributed to the stable power supply to the UWB, in turn, achieving stable water supply.

One of the future visions of this organisation centred on the use of technology, which could fix the issues of reverse power flow. The water board was provided with the project, not only to reduce the cost of electricity bills and improve their supply of water to residents but to engage the residents in training for the operation and maintenance of the technical elements of the solar PV system. This achieved the goals of technology transfer.

*"For us is to reduce our energy bills and build the capacity in the field of renewable energy, we have the people who train on planning and developing for the future project. So, the capacity building is part of it and improving the water supply to the residents of Abuja, it will also reduce the rate at which we consume diesel to pump water and reduce the cost of generating electricity" (*Chief Engineer).

There are many projects in Nigeria funded by Japan. Most of these are bilateral initiatives built for commercial purposes. However, the Usuma solar PV system was funded by the Japanese to help relieve global issues and reduce the impact of climate change. Japan is one of the developed countries that signed the Kyoto protocol treaty, committing to working together to save the planet. Within Kyoto, less developed countries have less responsibility for tackling emissions. When asked about Japan's motivation for engaging in the Usuma project, the project director answered with:

"If you are reducing the amount of carbon being released into the atmosphere, you mitigate carbon emissions. You will abide by a carbon mechanism you will also do a clean energy project that will reduce the amount of carbon going into the atmosphere. This is part of their (Japan's) own clean energy mitigation scheme as this responsible country has to do the project through renewable energy to reduce carbon that is the real motivation" (Project Director).

The Japanese Government delivered the project as a Clean Development Mechanism project. It could trade certified emission reduction units through the clean energy project. This targeted mainly Cool Earth Partnership countries by creating newer "knowledge" by international joint research between Japan and developing countries, as well as solving global-scale issues by giving research outcomes back to the real world.

The USP provided many benefits not only for the UWB as shown in Table 4:4. There were positive economic, social and environmental outcomes identified by the project. The lives of 40, 000 households around the Usuma community were improved with access to free clean electricity, but only during the daytime. UWB saved N17, 700 (£38) its energy bills. It also secured stable and reliable electricity for full-time work services without any interruption from the utility company.

Table 4:4 Summary of the Usuma project benefits

Benefits	Capacity
Provided the energy capacity for the water board and residents	1.2MW
Expected to contribute to annual energy generation	Approximately 1,496MWH
Reduce the water treatment electricity bill	N31.5M (£)/ year
Fossil fuel reduction	334,613Nm3/year
CO2 emission reduction	741.9 tones/year

The UWB had no longer to pay electricity bills, instead, it became a commercial energy supplier. When asked about the benefits, one of the respondents stated that:

*"Normally in every month the energy units we consume up to 420 - 430kWh. Power is measured in kW so, 1kw for the industrial price is N41.20.k (£0.09), and if you imagine the amount of money we spend, but the solar system reduced consumption by 200- 220 kWh every month. So, if you multiply by 41.20k it tells you how much in Naira it saves us as an organisation" (*Water Board staff)

The capacity of the first phase of the USP, 975 kWh, is the constant capacity demand of the UWB load, although there was the additional capacity that caused the reverse power flow - from the solar generation plant - to the national grid. The electricity tariff applied for the water board for the project is understood to be about 21.03/kW at a meter rate. This rate has not changed since the first installation. However, the electricity bill is approximately N30 million lower by adopting the solar system. As noted, the cost of the solar power generation estimated to be approximately N3 millions. This is a great contribution in terms of sustainability.

"If covered by dust, its output will be reduced by more than 15% which is equivalent to millions of Naira in a year." JICA Representative

The mathematical assumption of environmental effects could benefit both Japan and Nigeria as a result of the Usuma project. The equation below shows that the reduction in greenhouses gases caused by the PV generation system is calculated

as (t):

= the amount of generating electricity by using the thermal generation (GJ a year) × [tC/GJ] × 44/12

$= 114{,}195.7 \times 0.0139 \times 44/12$

$= 723.5$t.

4.3.6 Summary

The USP project is installed for UWB services but the general public by achieving lower air pollutions and financial benefits.

4.3.6.1 Adequate initial finance and capital project

The grant finance from the Japanese scheme contributed significantly to the development of the project, particularly for the delivery of solar and other components in the UWB facilities. All the UWB activities such as treatment water used through re-evaluate the cost of expenditure for diesel fuel facilitated due to the grant opportunity, which was found part of the Japanese scheme supported to set climate change objectives for environmental sustainability. With this support, the capital sources, the USP enabled to be extended from 97kWh initial capacity installations to the implementation of 1.2MW capacity of solar energy solutions, in which beyond the UWB and community users' needs, as a result of the financing of the system.

Ensuring access to capital sources for long term project sustainable is important particularly for the quality of operation and delivering the energy service.to energy users. In this case, there was a local revenue institution enabled to contribute little financial services. But a part of the initial investment grants, the project was not designed to generate revenue for improvements

4.3.6.2 Effective governance

There is a number of the stakeholders formed for the USP and these comprised professionals and skills from the government and industries participated in the delivery of USP. Ministry of Power dedicated much in terms of project inspections and coordination during the project projects. Therefore, effective governance through collective and individual responsibilities was found important aspects in order to implement the project on the time. JICA who represented the Japanese government in Nigeria leading the affairs of the project. Various meetings were held between the Japanese representative government, the Ministry of Power and the UWB making decisions on the project, such as the increase of generation energy capacity when the grant remained in surplus.

4.3.6.3 Technical

Developing technologies and the need to integrate innovative battery storage

Local communities have opportunities to integrate distributed energy resources solutions such as solar PV, metering systems and batterie storages. But there was clear evidence of lack of installed battery and metering systems in this case study. Reverse power flow occurred in the solar power system due to the additional capacity of the solar panels (second phase) when the UWB facilities were not in service and the panels produce a lot of electricity from the sun during the day. The surplus generated power can be important economically to the UWB, instead delivered to the DISCO equipment free.

The USP needs to install batteries on the system because of the power supply interruptions from DISCO may cause power outages. The power is supplied from the DISCO distribution equipment lines to the plant and users. It may be disrupted by natural or technical factors. The USP services can be stopped as a result of this power distribution failure. The issues of reverse power flow need to be addressed by using a metering system, measuring the electricity generated from the USP.

4.3.6.4 Adjusting regulation

Issues regarding the licence requirements

There are issues related to regulations and legal systems that concern the USP in terms of power generation and connection to the national grid. The UWB needs to acquire a licence for power generation in order to create market access the surplus electricity legitimately to the commercial market.

4.3.6.5 Proper operation and maintenance

Maintenance and operation provide efficiently particularly in the cleaning of solar panels and controlling project equipment. There were examples of dedicated services found in this case study, but also there were financial gaps for effective and proper operation and maintenance.

The chief engineer operated the system as he instructed to do through the project hand manual. It was noted that there was money from the UWB revenues to fix small broken cables or costs of lubricating oils. It was found the financial issues in the USP including the addition of technology used to restore electricity, the UWB still sought to obtain capital source to deploy battery storages, which can use if the USP has the problem.

4.3.7 Conclusion

It is evident from the case study that there is a number of issues enabled to explore due to the adoption of USP; such as the residents and the UWB homes in the Usuma area benefited from free of charge electricity while the residents used to pay for the water services they consumed. The UWB used the savings from the costs of diesel fuels to maintain the solar system. In addition, Japan enabled the design of USP to address one of the climate issues by promoting the low-carbon energy project through the Clean Development Mechanism (CDM) scheme. It was identified that the CDM scheme brought opportunities to address the technical issues of solar technology in Nigeria through the transfer of knowledge as a soft power component.

This case study was identified with a financial challenge where the need of capital flow or more financial support to sustain the project, as the USP needed to deploy capacity technologies, that contribute the sustainable impacts to the energy user. One of the important benefits, which the Usuma communities need to progress from the project is the practical engagement, they should be engaged and adopted in the USP activities in terms of operation and maintenance phase of the system, although the communities were recruited during the development of the project. Including the community activities in the management of the systems may implement some of the principles of the community energy system.

4.4 Case Study 3 - Guzape Solar-Wind Hybrid Project (GSWHP)

4.4.1 Case Study Introduction

The GSWHP is a community energy project designed for one apartment building in the Guzape District of northern Abuja (Figure 4:8). The project is located around 10km away from Abuja central, where it was assumed that most homes had reliable energy sources as they were connected to the national grid. Guzape District (GD) is a newly developed area in the city, connecting to the national grid for the residents living in and close to the district is a challenge in the area, where the residents need to request an extension for the installation of poles and transformers from the government.

Figure 4:8 GSWHP Building

In May 2015 the GSWHP was set up to run a combined distributed energy system using solar and wind for ten apartments. The project was developed to deliver a self-sufficient energy supply for the forty residents but delivered through private developers. There is a installation of 30kW capacity from the solar system, and 15kW is from the wind turbine; both of the installations are mounted on the rooftop of the building. The GSWHP also installed solar water heating and a water tank system, supplying 57,000 litres of water. The solar generation capacity was extended with an installation that served as a carport around the building. For energy generation and the distribution network, the project used an inverter, which connected with other electrical equipment (Figure 4:9)such as an inverter power cable for alternative energy use, and individual batteries, which stored reliable energy use and supported the solar and wind generators to shift loads for the residents, providing 4kw for each apartment for use at night.

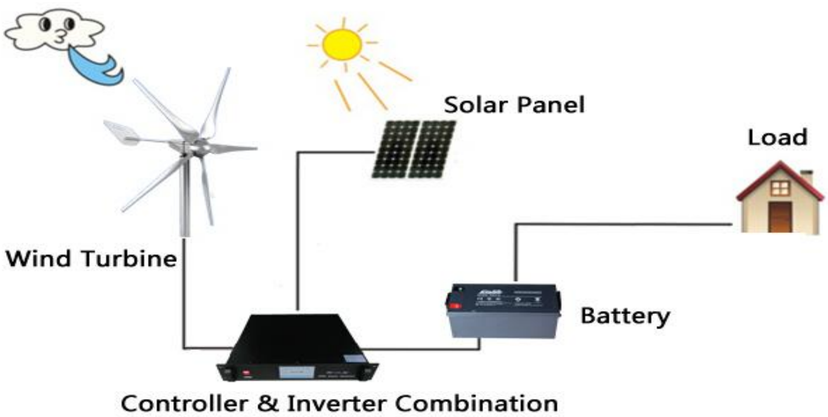

Figure 4:9 Components of technical materials installed

The GSWHP was sponsored by Blue Camel Organisation (BCO), who oversees the operation. Financial support is provided by the Bank of Industry, which helps the development of small-scale projects. BCO engaged with the residents about undertaking and maintaining the project to provide a reliable energy supply. The appliances used most in the apartments were LED bulbs, fans, TVs, Fridges, Freezers, air conditioners (AC) and PCs. The Off-Grid system has been in operation for 24 hours a day throughout its life so far.

The BCO is responsible for carrying out key activities such as the installation of technologies. They are a shareholding organisation who look to generate a dividend from financing the project. They also provide energy audit and consultancy services to the energy users to help them save energy. The GSWHP has financial assistance from the Bank of Industry. The total capital cost of the project is about £115,447. This includes the cost of installing the equipment such as solar panels, wind turbines, inverters and batteries; the cost of battery replacement and project maintenance are excluded. There are a number of issues that hindered the development of GSWHP including import taxes which were levied by the government on batteries and solar panels, access to financial support and guidance on how to develop viable business models. Table 4:5 shows the summary parameters of the project

Table 4:5 The GSWHP parameters

Feature	Guzape Off-grid Project (GSWHP) commissioned in 2015 to provide a reliable energy supply.
Location of the project	The project is in the northern part of Abuja city, where the average temperature is 25 0C. it is located 590 metres above sea level.
Type of technology deployed	148 solar PV (200 watts) on the rooftop of the building, combined with 10 wind turbine units mounted on the same rooftop. There are solar water heaters installed on a rooftop and the water tank system is run by solar power.
Generation capacity of the project	45kW for the entire building. 15kW from the wind turbines and 30kw from solar PV.
Funding sources -	The project secured its capital cost by raising finance from the company's shareholders.
	Estimated an N30m (Nigerian currency). This is equivalent to £115447 and does

Total capital cost	not include the costs of maintenance and battery replacement.
Beneficiaries and the Developer of the project	10 households living in the building and Blue Camel Company
Benefits	The project will provide low-cost energy at £3.7p per day for the next 10 years post-commissioning. It has provided reliable electricity for over two years for residential apartments. It is clean and there is less noise for the homes. Dividends expected. It provided job opportunities.

4.4.2 The GSWHP Background

The main developer of the GSWHP was BCO. This developer is a private organisation that provides energy services. This organisation includes many investors some of which are the residents living in the building. It was identified that the project manager, managing director and installer live in the building. The organisation started over 10 years ago by supplying energy equipment. The organisation is focused on the distribution of batteries and renewable electricity, which is mainly used as a standalone. It provides the battery capacity that its clients request at indicated points and it carries out regular maintenance on the system. It failed to progress further due to financial issues that made it difficult to develop the delivery of the batteries. In the subsequent years, its shareholders made the decision to raise investment into community energy generation for the residents living in the GSWHP area. The renewable energy technologies (solar and wind generators) were chosen for the ten apartments (Figure 4:10) to generate electricity. The GSWHP was one of the projects run and managed by this organisation. The organisation commissioned the project in 2015 and it located its office in the building for easy monitoring of the energy system.

"Basically, going into the history of how we started as Blue Camel Energy in 2007. We registered a company called Blue Camel Energy for the purpose of transportation. We created a vital group in 3 years then; we learned in 2010 about potential business opportunities in renewable energy and we diverted our activities from transportation to inverter solutions specifically as power storage solution" (**Managing Director)**

4.4.2.1 Location

The GSWHP is an energy generation system situated about 590 metres above sea level. The topography of the area is higher than other districts in Abuja by approximately 100 meters. The sunlight and the wind levels around the district are suitable for the project. The average temperature in the area is 26 ^{0}C, and the maximum temperature is above 30 ^{0}C in March. As a project installer stated that there is a strong wind, which normally starts from April to October, challenging the installed wind technologies. Solar and wind technologies are installed on the rooftop. The roofing is made of concrete slabs to support the installations. A rooftop installer remarked that a number of factors had been taken into consideration when deciding where to mount the solar and wind technologies, including minimising heat penetration into the building, having sufficient space for PV panels, and the potential location of the project. Although the building is above the equator, which is a determining factor; it was noted that the building apartments lack a suitable surface for the installation of technologies.

The building is positioned in a geographical area where the environmental factors affect the technologies and output of solar and wind technologies. This is a certain number of elements require to be considered for the solar PV installation. The sunlight, orientation and inclination were also important issues during the surveying and modelling of the GSWHS, as the project installers and managers had to avoid any obstruction of the system's technological performance.

Figure 4:10 Ten apartments each with four rooms.

4.4.3 Technology Installation

The GSWHP has installed wind and solar power generation system. The mounted wind turbines and solar panels have a small energy generation capacity and are set up to provide electricity, hot water, and water borehole pumps for the people living in the building. The solar panels are only operated during the day when there is sunlight, but the wind turbines are able to generate electricity even at night, providing some of the additional power to the batteries. The GSWHP is an off-grid power generation and delivery energy system even when the solar and wind installations are not generating electricity. Batteries are used to keep the power constant for the residents' use.

4.4.3.1 Combined solar and wind system and components of the system

The system uses a circuit breaker that is connected to installations on the rooftop, protecting the voltage feeding the energy users. Apart from the offices, which use the direct energy solar PV energy, there are two types of apartment in the building that have different loads for their appliances. The two-bedroom apartment has as a 4kW inverter, while the four-bedroom apartments use a maximum capacity of 8kW. Therefore, this system of wind turbines and solar PV technologies helps the residents to have access to reliable energy all the time.

In GSWHP, the capacity of solar technology is approximately 148pcs monocrystalline cells. Each panel could produce 200W and they are resistant to the cloud last over 20 years, and they have an energy efficiency of 15-20%, as confirmed by the installer during the site visits.

Figure 4:11 Carport installation.

Additional solar panels were added to a carport (Figure 4:11) that is located close to the fence of the building. Each panel generates approximately 200W. These panels have a limited high-performance capacity and cannot generate more than 300W as current standard technology does. Wind turbines support the solar system in a different way, they are suitable for the area's weather, and they are useful for backing up the electricity generation for residents. Ten fairly small individual wind turbines have been installed on the rooftop, and they generate electricity 24 hours a day due to the windy conditions in the area. Each wind generator generates 1,500W and their total capacity is 15kW. They were imported from China. Both the solar PV and the wind technologies connect directly to batteries and their generated electricity is stored in the batteries for use the when demanded by apartments.

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Figure 4:12 Broken solar panels and wind towers.

Figure 4:12 shows some of the issues associated with wind and solar technologies. There are broken panels noted during the site visits. For the wind turbines, a similar issue was identified; some of the wind generators are broken, and their towers need to be fixed to enable them to maintain a stable supply of electricity and achieve the function of the GSWHP. In addition to the aforementioned solar PV modules and wind turbines, the project also uses a number of electrical components, including an off-grid inverter and stranded cables that interconnect together to connect the solar-wind system to the controller system. The GSWHP was installed with a charge controller that limits or adds the electrical current coming the from solar PV and being delivering to the batteries. The charger stores the data coming from the solar PV, and statistical information about the current amp level of the batteries, which determines how much energy is stored for the residents.

Figure 4:13 Project's inverter

The project has installed an inverter with an average capacity of 4.0kW –102kW XANTREX (Figure 4:13), which converts the electrical outputs from the solar PV and sends it to the batteries where it can be used by the residents. As stated by the project manager, the GSWHP is comprised of multiple components that deliver electricity to the users. It is a kind of distributed technology system that does not send its excess electricity to the grid. Instead, the system stores energy for the building's own use, and for the use of flats, offices, and streetlights around the building.

"Project lines were in very specific terms, it is the household solar power generation and storage. Storage means it may not be solar, but we have inverters and batteries that store power. Secondly, we also went into a solar power borehole system for community water supply solution" **Manager Director**.

Figure 4:14 Type of the installed GSWHP battery storage

The GSWHP battery bank has different capacities of 180 amp and 200amp. They are used to store the electricity generated by the solar-wind system. The batteries were sited close to the carport and were connected to charge controllers. The most common battery storage used for the residents was the 12V 200AH Camel Battery (Figure 4:14) made in China. However, it was identified that some of the batteries in the system were of better-quality regarding efficiency delivery and performance for long discharges and operating services. Each household in the building uses the batteries for electricity, except the offices, which use direct solar PV. The GSWHP was delivered by the organisation that provides ancillary services such as supplying reliable energy, frequency-voltage stability and the increased penetration of renewable energy technologies.

4.4.4 Generation Capacity

The main rationale of the use of rooftop solar technology was a spacing factor where the ground floor apartment limited to contain the total installations of solar panels. This was the main issue during the delivery and installation processes, however, the project' owner suggested the carport installation approach as a solution, completing the generation capacity of the GSWHP.

"Our entire roofing space is limited besides being slightly below the space we need to generate power for the houses... The reason why we introduced the solar carport is that it generates the additional 6 kW (GSWHP engineer).

The amount of energy generated was not enough for the building when the GSWHP was commissioned. Each apartment in the building has varying average loads due to the use of air conditioners and fridges.

The use of fridges and freezers identified was a significant issue for the residents. The residents need to use electricity 24 hours a day for these appliances because they wished to preserve their cooking materials and stop them from being spoiled. The residents could increase the energy capacity energy by using either new renewable technology options such as biogas or an extension of the existing installed technologies. The management made the final decision to extend the solar system, as it was considered that the solar PV generated most of the energy. Indeed, the situation of the building, the average sunlight and temperature of around 25 0C facilitated the generation of electricity from the solar PV for the GSWHP.

"In terms of solar generation capacity, we generate about 1MW in each month if you divided 1 MW over each month, we have an average we generate per month" (GSWHP Installer).

The residents opted to extend the generation capacity of solar technology as the building location benefit from significant levels of solar radiations. However, the great concern was how

148 panels were going to fit on the rooftop of the building. It was identified that the panels already installed on the rooftop took up most of the space and the small amount of space left over was used for maintaining the installed equipment. Thus, the GSWHP designed a solar carport as an extension approach to increase energy generation. A charge controller was integrated into the system to prevent overvoltage and overcharging the battery storage.

4.4.5 The Delivery of GSWHP

4.4.5.1 Organisation and governance

The BCO was founded as a structured organisation. It designed a business model for its limited shareholders. The company was responsible for all the procurement and delivery of the materials required for the construction processes and installation of the green energy system. the BCO links with various networks of organisations of seeking assistance, funding and expertise to improve its projects. The organisation completed the project under the supervision of engineers and architectures who watched and supervised the integration and adaptation of materials installed on the building in order to obtain the best performance from the system. They established a governing body that managed the GSWHP, but it was run by several departments addressing technical issues, the operation and maintenance of electricity generation and the distribution of energy to the residents.

“We don’t have proper closeness in the community you can see two and three people using some, so we don’t have coordinating community that is running on solar solution except here where we have a community of ten families. Project Manager

A number of people were involved in the project management including investors and shareholders, and the experts and casual members delivering either administrative or technical services. “Not in shareholding only, (but also) in terms of expertise and remuneration in terms of salaries and allowances,” said the Assistant Manager

However, at a high level within the organisation, there was a governance board engaged in the project’s development. They were also the shareholders who make decisions and influenced the project. This was noted at a meeting during the owner's visit, which took place only for shareholders. It was confirmed by the assistant manager who when asked in a casual discussion, stated that it was the board directors meeting, which consisted of the higher shareholder of 75% of the project.

"Corporate governance is our structure of the board and ownership. Before establishing a board of directors, it was a two-man business between the two directors. It was just two directors" (**Assistant Manager)**.

4.4.5.2 Operation and maintenance

The managing director played multiple roles and had several responsibilities in terms of monitoring and overseeing the other subdivisions, playing a vital role in attending renewable events. Collecting reports between the interrelated organisations involved in the project is important for BCO. Sharing information with the residents who use the electricity is a key task for a specific unit allocated in the organisation. When asked about the people, who take decisions related to the GSWHP activities, a staff member explained hierarchical structure as

"*We have only a structure that in reporting standards the managing director oversees the activities of the various departments and then they still report directly to the managing director for proper correlation. "By way of operation, we have a management board which comprises about six different departments: we have the head of the corporation service we have a managing director we have a general manager we have the head of logistics and we have also ahead of engineering*" GSWHP staff).

However, there were voluntary workers in the GSWHP who gained expertise skills and technical capacity as a result of working with professional staff. The GSWHP administrative structure is found as a vital underpinning the quality of project system, although the project manager stated that the organisation experienced difficulty in raising funding from financial sources to develop the project. when the GSWHP secured available capital the energy activities could be improved in terms of heating generation, energy storage and energy efficiency for resident's appliance the project owners looked to find financial support from the government.

4.4.5.2.1 Technical management

There were a number of specialists involved in managing the efficiency of the technologies and running the energy project, for example monitoring the generated energy, data storage, and timing the technical equipment. Trainees also operated and maintained the project, carrying out activities such as blowing and cleaning the solar panels, batteries, inverters, and cables to avoid failures or operational problems. However, some of the units were inter-related with each other to work together for maximum efficiency.   Also, the entire divisional structures that ran the GSWHP could be interchanged to facilitate and manage the activities of the organisation.

4.4.5.3 Financial approach

The GSWHP was the first project of its kind developed in the area. It raised £10,500 from companies, and some of the investors were residents in the apartments. In the interview with one staff of Blue Camel's staff, it was stated the project was able to deploy the various components of solar and wind technologies, to extend the capacity of the energy power system, and maintain the existing solar panels.

*"Five million Naira (N5m) (£10,500) is the initial capital that Blue Camel started with and in less than one year we made a turnover of around one hundred million, basically a higher turnover but not profit margin because we mostly distributed equipment and the profit margin of such equipment is not necessarily very high. However, we were able to run low through that and we were encouraged to further restructure the business and expand our activities into solar and water supply systems such as solar power boreholes and roof home solar systems" (*GSWHP Manager).

Therefore, for the above reason, BCO became the developer of the GSWHP and it was responsible for the delivery process. The idea of the project emerged as a result of funding raised by its stakeholders. There was also financial assistance for the project, provided by the Bank of Industry, which helps to diversify the economy through small-scale technologies for development. Much of the project's financing flowed from the stakeholders who used their transferable shares in reinvest into the GSWHP. The funding raised by the offers reached £11, 5447.20 (€132,000) in the subsequent years, which was the project's capital, and this was managed in order to develop the solar water heaters, solar PV and wind turbine technologies. This outlined some of the achievement in running portfolio projects, encouraged the shareholders to create a process of organisational self- policy, in which part of the share units was developed to form the green energy project. As stated by a staff member

"Up to now the dividend still totally requested back to grow the company and whatever rate the company is growing 15% equity still remains, so we have not started enjoying dividends, yet we are reinvesting all the profit back into operations to grow the company". Staff Member

The project was required to provide significant investments to install several renewable energy technologies such as solar PV for electricity generation, solar water thermal for heat generation for the building capacity so that the residents secured the convenience of the energy system. It was identified it was not possible for the stakeholders to raise the investment. While a number of external financing sources are required for the organisation to secure the project development, BCO experienced challenges from the government and financial institutions due to low awareness of renewable energy technologies. Programmes for financial support are one of the driving factors encouraging local energy people to adopt business models in renewable energy. For example, in the UK the Feed-in Tariff scheme is a key force committing and emerging community energy initiatives to ensure a minimum purchasing price from renewable energy. But the challenging financial sources, in this case, led to less opportunity to deploy the various technologies that delivered low energy services as the manager mentioned below:

"Using tariffs means that you have money to invest and deploy equipment and then use a tariff to collect money little by little over time, but we don't have the financial comfort to enable us to deploy equipment for N20 N30 installation". Pr**oject manager**

BCO highlighted the issues of securing capital investments from banks where there is needs to fulfil certain requirements. This issue led the organisation to focus on other capital sources. BCO has successfully raised capital through the individual's shares but their concern is that they should wait for a long time to gain the profit. One of the project respondents expressed his concern as this investment is a relatively low impact in the business model due to expecting higher risk and return on investment is less.

"The cost of duties is transferred by the importer to the dealers also transferred by the dealers to the end-users but that additional marginal cost is discouraging the adoption of solar technology in Nigerian space" (Head of Blue Camel).

The project used the total capital raised of £11, 5447 for designing the project. The expense of the use of imported panels, battery connections, and other installation materials was a big risk for the organisation because there was an economic policy introduced by the government that meant the investors had to pay 25% import duty on the batteries. This levy discouraged shareholders from supporting the project. However, their investment raised the costs of development of the project. The stakeholders sought to improve the power system by providing smart technologies but the issue of import duties on electrical equipment the stakeholders considered it does not respond in the project.

There were government policies regarding the importing batteries solar products, tax duties levied on technologies that could have been a constraint on the project. As stated by the manager, the battery was a major component of the project, forming more than 50% of its cost.

The government prioritises grid extension (the current energy generation system that uses oil and gas) over solar and wind energy technologies. This discouraged the project and its extension to a higher capacity. There were issues related to the technical standards of the project. Some equipment was such as broken solar panels, which could have functioned for up to three years. The energy storage system (batteries) also needed to be repaired in order to recover its discharging capacity.

4.4.5.4 Energy end-users

The building had been well-arranged to deliver energy efficiency. The 4kW capacity set-up for a two-bedroom apartment and 2kW for one resident all designed to provide lights every day. The 18W LED consumed less than 1000Watt of energy for the whole building, which meant it was no problem if the residents all put their lights on at the same time. All of the apartments equipped with 120Watt, LCD TVs and 1.5-Watt air conditioners, which were solar DC products. The residents used their refrigerators and freezers by connecting directly to the solar DC, and the equipment separated this from the generated 4KW solar going to the batteries to be saved.

Therefore, the refrigerators were programmed to work for a certain number of hours; they were connected to a timer to minimise energy use and normally they ran for an average of 10 hours a day. There were units that used AC in the building, where each house had three AC units that were instructed to operate at the same time. The AC was run for no more than 8 hours per day. Also, garden and security lights were installed around the external perimeter of the building and they had their own independent energy supply away from the residents' connection.

The maintenance of the GSWHP is not complex, according to the resident participant, who stated that the system required no rigorous maintenance, particularly for the cables which were tied to uphold transmission losses during the installation of the solar and wind technologies. The blower was an electric device that the management used to clean the charge controller and other equipment that had dust deposits on them. The residents were conscious about their power consumption and they were always encouraged to switch off appliances when not in use.

Table 4:6 Energy uses for the households

Equipment	Description	Range of quantity	Working hours
LED bulb	18W LED bulbs	10-30	8

Fan	70w Ceiling fan	3-10	8
TV	120W LCD/LED TV	3-10	6
Fridge	120W Home fridge	1-10	12
Freezer	220W Deep freezer	1-10	12
AC	1.5 Air conditioner	1-5	8

The average energy used per apartment in the building is approximately 4kW. Much of the energy consumption occurs either early in the morning (5 am to 9 am) or in the evening (5 pm-9 pm) after the residents return work. None of the householders was around during the daytime, only the project management remained in the offices of the building providing services, and they used solar DC to run their appliances. Table 4:6summarises the loads and the specific equipment used for the apartment.

4.4.6 Outcomes

This case study showed that the project provides economic benefits through the motivation to deliver financial benefits to the shareholders for a certain period of time.

The project has achieved its entire development process by raising capital to finance the project. This capital makes it possible to cover the technical procurement aspects and the project management costs the stakeholder delivered. As the total cost of £115447, it estimated that each apartment will use £3.70 of electricity per day in the next ten years, considering battery replacement and maintenance costs.

"If you want a solution like that… (You) … can go straight to the numbers and see what it cost you to deploy a solution like this or that" **Project Manager**

Thus, the project provided a clear financial costs analysis that investors and financiers can use for similar projects if the risk needs to be managed. The project has encouraged more stakeholders to invest in renewable energy. The project provides job opportunities for installers, management, and voluntary workers. But also, the project needs to get financial supports for building capacity and expertise. There were also challenges associated with the shading of the solar panels when there was cloud and, but the wind turbines sometimes did not supply enough to fulfil demand. The strong winds that occur at the beginning of the year mean that the project struggles to stabilise the technology.

4.4.7 Summary

4.4.7.1 Governance

Introducing a business ambition by the governance

The decision to install solar and wind business in small communities or local areas is an important factor for the development of the areas. The setting of better decisions and strong jointed partner members fulfils economic and social goals. In this case study, stakeholders, the BC organisation was responsible for the all installation of generation energy and battery storage systems. The BC shareholders embraced and engaged in the energy activities sought that the investment in distributed renewable energy systems is profitability business designed for the delivery of energy services while servicing solutions for residents.

4.4.7.2 Finance

Accessing commercial debt and raising capital flows to fund installations

Capital sources are key factors for the installation of infrastructures especially when the project is to be developed. The most important driver, the funding source in this case study, is the financing of solar and wind system, made possible through commercial equity. The stakeholders developed GSWHP due to access to the debt funding and they agreed to pay an interest rate. There were also residents who live in the GSWHP building put their capital into the business investing for profit. The GSWHP sought to deploy more battery storage systems for the delivery of electricity to customers, but it was understood there were difficulties in raising more capitals and the financial support financing the batteries storage systems.

4.4.7.3 Technical

Designing and installing technologies on the rooftop

In terms of installing technologies, this case study delivered wind, solar PV and battery systems independently for ten apartments. The building design sustained technology model as the building facilitated the installation of much of the equipment on the rooftop; the flat roof accommodated some of the 148 solar PV panels and 10 wind turbines, which saved the costs of distribution and transmission from the grid. The design of the system and technical model developed in the building the BC realised as a successful system foundation.

4.4.7.4 Capacity

Designing an effective capacity market

For the development of the energy system in GSWHP case study, the use of market design for different installed energy capacity connected for the different energy users in the GSWHP building. Pay as you go, a model is applied, as residents use the energy services through meter net billings. With installed 45 kW from the installation on the rooftop, constant 4kW and 3 kW are allocated to residents in the building. Electricity from the batteries storage systems delivered for residents normally during night time. There are a 57500 litres water tank system and water pumping system run by the solar power. By design, the residents are able to put loads on the system and benefit from reliable power. In this case, although the project sought to repair broken wind towers and solar cells may be due to the lack of proper maintenance, it also identified the residents satisfied their energy demand by covering the loads use in their apartments and enabled to engage with the project manager responsibility for the delivering energy services, controlling loads, and billing energy services.

4.4.8 Conclusion

This case study summarises the main issues and factors concerning the delivering of distributed renewable energy generators and managing for energy demand. The commitment to the desire to generate energy through control and ownership of energy assets for economic benefits helped the shareholders to balance and supply on the daily basis of residents' needs. In the case study. financing the project through different stages such as planning, design, and installation was a development effort for the project's organisation. The solar-wind hybrid power generation system was also successfully installed to provide approximately 45kW for 40 houses. The GSWHP used batteries to store the generated electricity for use when required by the residents. However, there were issues of financial application, such as a high interest rate for loans, in the project that thought it is limiting the stability of energy system. The installed battery storage technologies used to supply electricity for the resident's communities at night did not have standard qualities, and the import duties on the batteries were also another key issue need to be measured for the GSWHP to foster the robustness of energy services to energy users. In the case study, the project developed to deliver the energy services only to the ten apartments but limited to other residents of GD involvement. There is a need to build adequate community-based energy capacity within the public by raising awareness and supposing financial services.

4.5 Case study 4 - Gnami Off-grid Solar Power Project (GOSPP)

4.5.1 Case Study Introduction

The GOSPP is a partnership between Huawei Technologies Company (HTC) shown in Figure 4:15, the project contractors and the Ministry of Power (MOP), who served as the government's representative. The installation is a pilot off-grid solar PV, aiming to provide access to clean energy for people living in the community. The GOSPP entailed the installation of solar arrays with about one hundred and sixty panels mounted on the ground, and the provision of batteries which were used as a standby to maintain the supply of electricity.

Figure 4:15 - GOSPP pilot partnership project

The GOSPP is the result of a visit to China by the MOP. When the Ministry of Power visited Huawei Headquarters in Shenzhen, both the MOP representatives met with Huawei officials and they spent two weeks proposing a solar project. The project would be built as a pilot in some selected communities in Nigeria. The initial activity arranged by Huawei and the Ministry of Power was to build the Gnami community project as a pilot, hoping it would be a successful start to the relationship. The Gnami community was selected because it was one of the areas of Nigeria that lacked access to energy. HTC was the project developer and it provided infrastructural materials and procurement in order to develop the community energy project.

Huawei spent 38 days on the project including conducting a survey, assessing the site and installing the equipment.

HTC provided the project workers, engineers and installers, during the project development process. When the installation started operating, Huawei used the meters to control the resident's energy from the central unit, and energy services would be delivered for free to the Gnami houses, but this arrangement was temporary. Thereafter, the GOSPP was funded using card meters with charges to cover the capital investment. Thus, the project is funded by HTC. It was also designed under the Huawei company model. Huawei and the Ministry proposed the GOSPP solution, which was one of the objectives of the partnership. The GOSPP would be rolled out throughout Nigeria through a scheme organised by the Ministry of Power as a model. The MOP and Huawei's officials held a ground-breaking ceremony in Gnami community to introduce the project.

The community way of planning means that their cultures and house settings are dispersed within the community area. The community residents are located in Kaduna State in Northern Nigeria Under Kagarko local government (Figure 4:16). The community leader is called the Chief (Sarki) in the community and he is responsible for making community decisions on the day to day activities, including the issue related to the GOSPP. Other community members assist him with assigned duties. These committees are instituted to ensure that the project works for selected houses. Because a hundred houses within the community were selected to have electricity provided by the GOSPP. This issue caused some protests within the community.

The community members have diverse backgrounds that include multiple languages, tribes, religions and occupations. The community population was approximately nine hundred in 2006. This figure has increased recently. It identified that the number of houses built in the community is two hundred and fifty and the houses are semi-detached in design. Some of the people live in either extended or polygamous families. Some houses have 4 or more bedrooms. The majority of the people are farmers accounting for approximately 65 per cent. The farmers grow their plants once a year during the rainy season they needed to apply modern farming systems through government subsidy schemes. There are also public servants in the community working outside to Abuja city to earn the money, travel 170km. These workers are considered as low-income earners because their minimum wage rate per month is low.

Figure 4:16 Gnami community

There are other issues identified in this case after the project starts operation, including management and technical resources such as onsite delivery expertise, and available leadership for monitoring the project. Although there are facilities for controlling and monitoring in the central unit, it understood that there was a failure of the maintenance and operation system, resulting in low performances from the solar panels and the batteries. This outlines that the community needs training and educational programmes, which help them to take self-action as the approach of the management system in a way that achieves project performance.

The households needed to have community energy scale capacity than the capacity they have been installed in the GOSPP solution. The applicability of community energy scale capacity customises and promotes social and economic standards of the community, while it leads to the issue of the shutting system down the GOSPP. By identifying the GOSPP capacity, one of the challenges for the GOSPP is supplying sufficient energy to the community. The solar system was installed with the 150KWh capacity to supply electricity to one hundred households. The generation capacity was not enough for the households as the plant actually delivered less than 1.5 KWh. This was the average energy that households were permitted to use. But there was an issue in the connection plant system when any household tries to use more than 1.5 KWh capacity, the entire project system shuts down. Table 4:7 summerised the feature of the project

Table 4:7 Features of the case study.

Feature	40KW Off-grid PV plant commissioned in 2014 to test the system.
Location of the project	The project is a pilot off-grid system built in the Gnami community located in Kaduna, Northern Nigeria.
Financing the project	Huawei Co Ltd supplied the installed materials based on contracts.
Generation Capacity a day	150kWh
Technologies deployed consist	The solar PV: 160 panels, each cell produces 250Wp. The storage: 240 batteries, rating 490Ah and 480v capacity. The distribution network: 220v 12 street lights installed: each consumes 80W.
Beneficiaries	The metering system was installed: for use and protection. Huawei used to top up the credits for community use. 100 houses in the community use electricity.
Energy consumption for houses	Average energy consumption for each house is less than 1.5kwh. There is a plan to use meters to charge energy at N21.3 (0.4p) per KWh.
Outcomes and issues	The project highlighted concerns about high energy demand, lack of proper maintenances schedules and monitoring by the governance body. The contractor lost the capital costs. However, it provides security lights and energy consumption for 100 houses.

4.5.2 GOSPP Background

The GOSPP started with a visit to Huawei Headquarters to discuss how about off-grid solar projects if they can be delivered in rural communities in Nigeria. On 29th August 2014, the Nigerian government was invited to Huawei Company in Shenzhen, China, in order to plan energy solutions for the Nigerian energy system. Huawei's global VP and Nigerian representatives had a successful meeting about a contract, which involved the development of solar energy projects in Nigeria. The solar project would be built the same way as the

Huawei's model that the Ministry visited, but with a smaller capacity. The proposal was based on mini-off grid energy systems.

The Ministry of Power selected Gnami community for the installation of a pilot project. The Ministry of Power formally relaunched the renewable energy scheme in late 2014 in order to encourage the contractors. Huawei was a specialist in the manufacturing technology of items such as inverters and PV arrays and it was prepared to operate the solar project with effective control under the Ministry of Power scheme. The Ministry of Power identified that there were large communities that lacked access to energy. It wanted this energy issue to be solved with solar technologies. This goal was the reason for the relationship between the Ministry of Power and Huawei as stated by a member of the staff at the ministry.

"*The Minister visited Huawei headquarters they show him more of technologies they are willing to do with hope government patronised that. That is the relationship*".

4.5.2.1 Location

The communities were requested to provide a project location where Huawei could install the system (Figure 4:17). Immediately after returning to Nigeria, the government representatives and Huawei members consulted GC to introduce the solar pilot project. The main goal of the project was to build a 40KW off-grid PV plant for lighting and electricity. Huawei would provide all the infrastructure required but they needed support from the Ministry of Power. The GC leader was also asked to select one hundred houses out of two hundred and fifty houses in the community, in order to deal with the 40kW capacity. This selection caused protest within the GC.

Some community members, particularly those who were not included the project, raised groups to protest hoping that the project would be cancelled for the whole community. After that, the issue was resolved by the community leader, by promising additional power capacity. A location was selected around GC farmlands for solar generation. The GC residents expressed their desire for their environment to be electrified. Some of the community members were prepared to engage in the project after it was implemented.

The GC location has a rainy season, which can last for up to six months a year. During the rainy season, the panels are incapable of producing the expected installed capacity. This issue was normally found when cloud forms shading the panels. This might cause the challenge for the generation capacity. The winds are also strong during the rainy season, meaning that particles are carried in the wind and deposited on the solar panels. However, in the sunny season, the solar arrays generate energy at a high level of performance.

Figure 4:17 The GOSPP location.

It was noted at the project site that the solar panel cells could be adjusted manually for seasonal changes from the beginning of April until October when the average temperature is 10 ^{0}C. During this period, the households have to reduce the amount of time they use electricity, otherwise, the system shuts down. The project operator may not always be present and by that time the system has shut down automatically.

4.5.3 Technology Installation

The solar PV arrays and the indoor room for equipment such as batteries, inverters and the monitoring system are enclosed with square top fence panels. This was needed for the project to be a secure and safe site. The location was one of the determining factors for the project to be developed. There was adequate space for 160 panels and room was used to manage the entire system.

The GC did not have a single rooftop suited to solar panels. Their houses are scattered around each other. Thus, the project opted to adopt ground-mounted solar panels. This grounded installation enabled the project managers to better operate the energy system for the community residents. This is one of the interviewee's responses when asked about the GOSPP installations:

"This one is an off-grid distributed system where you centralised the power plant, so it is more a centralised power plant when you have land that it uses. We have the land because we are able to run a distribution network from there (from the system) you able also to tell them (community) this is a certain limit" (The company installer).

The system used distribution networks to transport the energy to the households because the installation was located about one kilometre away from the GC homes. The transmission equipment such as the poles and cable infrastructures were installed at various points before the energy reached the houses. The transmission lines were complicated and a danger to the people because wires were hung close to the residents living and business area. A number of obstructions were noted which could block the transmission of energy. The poles were not properly installed deep in the ground so the strong wind could possibly cause issues for the system, and the plastic bags could be seen hanging on the cables.

4.5.3.1 Electrical energy system

Huawei designed the distributed generation system based on its company model. The model was an integrated solar system, which adopts a 3-in-1 design comprising the solar cabinet, the off-grid inverter cabinet, and the AC distribution cabinet supporting integrated control of AC and DC electricity. The model adopted high-power appliances that deliver an efficiency of up to 96%, the front-runner in the company. When asked about technological materials used for the off-grid project, one of Huawei's managers mentioned:

*"ITC company we actually manufacture the inverters the key component of power plans we produce the inverters" (*HTC manager).

The project installed a bi-directional inverters system to convert the direct energy (DC) generated by the PV arrays into AC electricity, then AC energy is transmitted to the AC power bus (**Figure 4:18**). Thus, the inverters were connected to the batteries and to the AC bus. At a time when the solar energy is sufficient, the amount of electricity generated exceeds the household demand for energy, the surplus is stored in the batteries through the two-directional inverters, and it is used during the night or when there is a cloud.

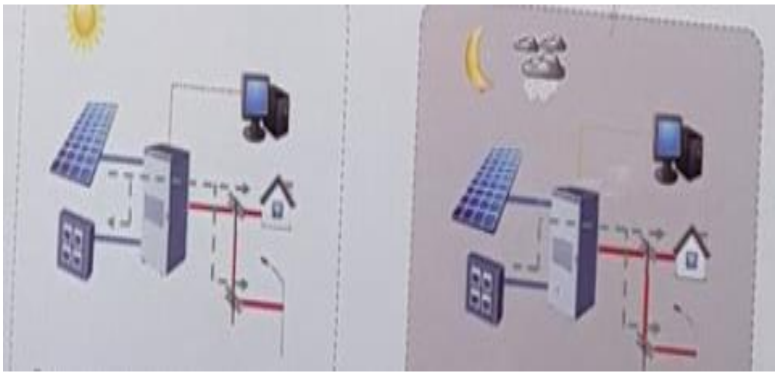

Figure 4:18 The solar system working principle

4.5.3.2 The components of Solar PV

It was recommended that the project developers used a piece of land in the GC area to install all components of the pilot solar PV system. PV modules form the power generation system which is integrated with the controller and inverter unit to control and convert the energy system. The company installed 160 solar panels on 10, 000 square metres surface area. Each solar cell generates 250Wp from sunlight.

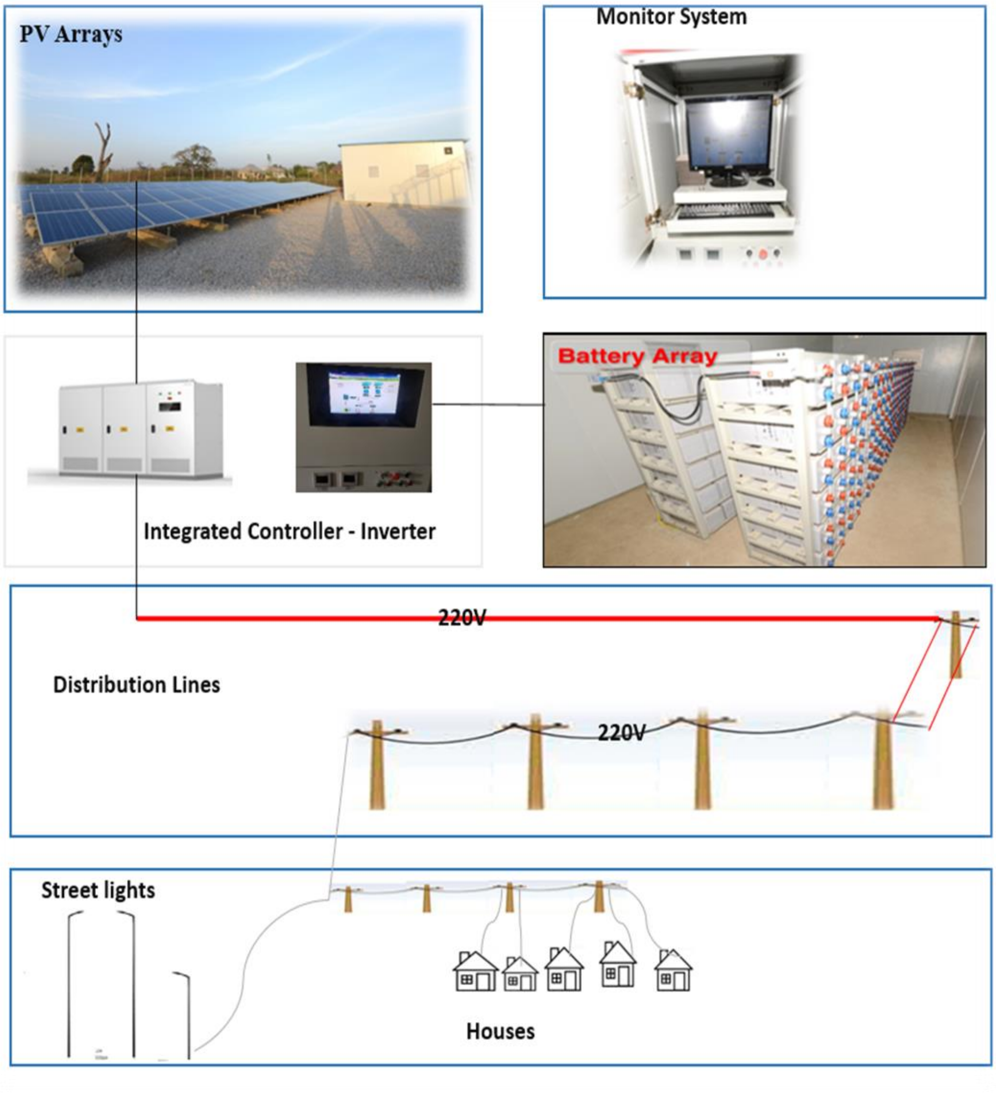

Figure 4:19 GOSPP energy system

For the inverter, the Gnami project utilises two inverters attached to the controller system and connected to the battery system. Each inverter converts 20 kW and then transmits it to the AC control unit that is set up in the same operating system room, controlling the energy system (shown in Figure 4:19). Both inverters deliver alternative current either to an external load or to deep cycle batteries for the community loads. The capacity of the project and the quantity of technical equipment installed means that it is an independent power system.

"The GC project is the off-grid, 40 kW system. It has the configuration of 160 panels which each of them 265Watts there are two stream inverters and those inverters are rated 20kw each so feeding in to control cabinet and bus 238 volts" Chief engineer

A group of batteries are connected to the solar panels to store electricity. 240 units were arranged but their capacity was dissimilar. It was noted that 490Ah and 480V connected with the monitoring system discharging the life cycle.

Twelve street lights were installed from the GC 'entrance to the residential centre helping to address security challenges around the area. The street lights are set up on an automatic switch that operates from 6:00 pm to 6:00 am. Their bulbs consume about 80 watts when the house appliances have lower loads during the night. The 80 watts bulbs cost N73, 612.8 (£159.94) to run a year if they are in use for 12 hours every day. The street lights have been free of charge so far and in the future, they will be counted on the beneficiaries 'meters.

4.5.4 Generation Capacity

The installation has a 40KW capacity, and it generates 150 kWh every day to benefit one hundred households. This means that each household is supplied with less than 2 kWh, which equate to the use of four light bulbs, a TV set, a ceiling fan, one electric socket, but no air conditioner or iron. The households use 1.5 kWh, which is the maximum capacity the house is allowed to use if the street light is turned off. The average electricity consumption per year for the Gnami households is around 540KWh. This is substantially less than energy consumption per household in the US and Europe. In the UK, a typical household uses around 4600 kWh per year. This is similar to a household in France, which consumes around 6400 kWh. In the U.S on the other hand, households consume around 11700 kWh yearly on average. This shows that the average energy consumption of Gnami household is around twenty-one times less than that of households in the US and around nine times less than a household in the UK.

Despite this Gnami residents often encounter difficulties with the solar system because the energy supply cannot keep up with their energy consumption. The residents struggle to connect and use all of their electrical appliances.

"*The connection was not transferable because the contractors wired all the houses to use only approved appliances. It was not possible to add extra bulbs or use more sockets adding that should any resident want to move to another house, the electrical installations are moveable". Community member*

The households complained not only that the rest of the rooms were restricted in term of appliances but also that the small-scale businesses established in the community were not included in the project. If any furniture makers in the community needed to use large machines, they had to use a gas or petrol generator. However, some households found that plugging in refrigerators and irons resulted in problems in the system such as sapping the batteries and shutting off the entire system.

4.5.5 The Delivery of GOSPP

4.5.5.1 Organisational and governance

The GOSPP was delivered through relationships between two organisations. The HTC and Nigerian government energy agency were involved in providing social responsibility and benefits for the GC (Figure 4:20). HTC funded the project and the Ministry of Power participated in the project to fulfil its responsibility as part of the SDG, which addresses the challenges of achieving a clean, secure, and reliable energy supply. The Ministry of Power also advised on the issues related to the project.

HTC involved in the GOSPP with the aim of growing a market. Thus, the Ministry of Power and HTC were the key actors and engaged in interactions with different purposes and responsibilities for the project as

"It is a corporate social responsibility. It is their own company they wanted to come to Nigeria as the electricity industry and provide mini grid-like solar systems in the environment. So, they do it all over the world from there they might be able to come to contract and so on" (An engineer from the Ministry of Power)

HTC initially contacted the Department of Renewable Energy, which is under the Ministry of Power in its research and development institute based in Nigeria. It requested that it be allowed to develop renewable energy projects for customer-partner platforms in Nigeria. HTC was given approval for the development of the project, beginning with the process of supplying materials, and it was also responsible for managing energy services. HTC guaranteed that the project would deliver a high-level performance it had all project materials at its disposal. Huawei specialises in enhancing energy products and solutions particularly for smart city projects, which could promote the application of finance and technologies.

On the other hand, the Ministry of Power, which represents the Nigerian government, agreed to support Huawei with a strategy and commitments concerning the environmental, cultural and social markets surrounding energy users. It was prepared to be Huawei's partner in building the Gnami project. It also organised activities and events to make sure that the project was completed. It selected the location and sponsored the project for the period of its construction from 23/10/2014 to 20/11/2014 until the project was ready to start generating electricity. It also structured the procedures determining how power was purchased from the company by the community energy users. The Ministry of Power created a scheme for community projects in Nigeria. This scheme comprised not only environmental issues, but also financial and technical support acknowledged through the renewable energy technology agenda.

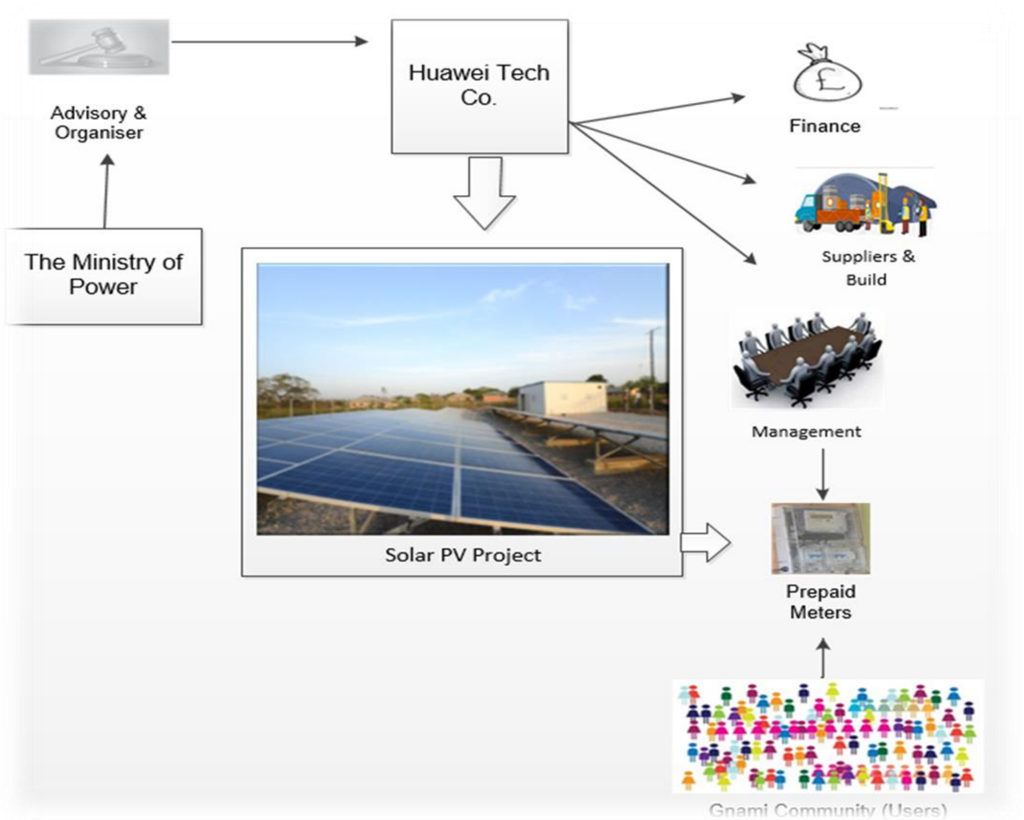

Figure 4:20 - The GOSPP stakeholders

4.5.5.2 Operation and maintenance

The community supplied with electricity from the GOGSPP, under the managing and operating the system by the HTC staff free of charges. Energy charges were not applied to the residents for three years, due to a decision from the Ministry of Power over the use of card meters. When asked about the incomes to sustain the project, one of the interviewers stated that the cost of electricity charges residential homes is controlled by the National Electricity Regulatory Commission, which is an agency under the Ministry of Power.

"*For the commercial value like paying by the smart card no (it is not used). That one is free. The NERC makes available the normal tariff after the concession".* Huawei staff

The GOSPP provided the electricity for the community free, but the HTC would apply charges when they are approved by the government. Huawei installed smart meters in each community house. In the future, each resident will be asked to use a prepaid card, with meters installed meters of their houses. In this way, not only will the system's performances be protected but households can be refunded any overpayment.

Huawei planned to manage the GOSPP through the network of the GC. This is a time when HTC included the community leader in the project decision. From the total of 250 houses in Gnami community, only one hundred houses were selected, and their energy use would be monitored from the central monitor unit placed on the project site. Since the GOSPP was a mini solar system, Huawei arranged to provide a reliable energy service for the selected houses so that it committed to delivering a quality system with expecting this to contribute to its business success. The residents also agreed to contribute N300 every month, which was used to pay the solar panel cleaners and the security guards employed for the project. The panels are cleaned twice a week. The community houses configured their appliances with limited energy supply as explained by one interviewee:

"There is one technology we have now added (central control unit) if they extended to more than one hundred and fifty kilowatts, the meter goes off. So, you need to reduce whatever you do if you do not take it you would not have lights" (GOSPP operator from HTC)

The operative technology, which was set up to control overloads from any resident, this is an important factor for the GOSPP particularly for the residents use allocated capacity to the installed 150 kWh. The households often tried to use irons, the use of which is not permitted in the system. However, there have been identified a number of incidences since the project implemented due to the issues of residents, who did not adopt the project instructions, causing the system shut down, but a resident action is yet to be taken to ensure that the system runs efficiently. When discussed with the community leader, and he explained that a committee was formed by the community stakeholders to enforce compliance with the project conditions. For any household that contravenes the directive, the committee members disconnect their electricity for one month or permanently if they are identified as an offender more than three times. But within the community, one of the residents showed concerns about the use of electricity either the resident uses the allocated small capacity or to move to another community.

4.5.5.2.1 Technical management

The GOSPP required the use of meters within a year, which both project stakeholders agreed to. Each Gnami house was required to open an account in order to possess an IC card used to pay for the credit. However, over a year, HTC was concerned because the metering system was not applied. The Ministry of Power was also reluctant to organise a successful power purchase procedure that the households would use to cooperate with the project, leaving Huawei and its engineers to manage the project. Thereafter, Huawei decided to give up the maintenance of the installation to the Ministry of Power. Huawei's partnership with the Ministry of Power failed, understanding the Ministry of Power was not very committed to the renewable energy programme. HTC needs to apply a proper management system that makes profits:

"*HTC has a social responsibility; our target is to make more (revenue) to be frank. We are a profitable company we want to make a profit*". (HTC manager)

HTC initially intended to build more projects in many areas in Nigeria as it had done in Cameroon, but it achieved projects in only two communities i.e. the GOSPP and the Pakau project. Even though it succeeded in completing the Gnami project, Huawei obtained no further projects approvals from the Ministry of Power to replicate the scheme nationwide. Although it was interested in supplying the inverters and the electrical panels, Huawei's investment was a huge risk because it could not perform the financial management alone without the Ministry of Power.

4.5.5.3 Financial and support of the Project

HTC sponsored all the infrastructural materials used in the project. With the intention of extending beyond the 40 kilowatts capacity, Huawei invested in the project. The plan was to increase the generation capacity to include the whole GC. An arrangement was made between the government and Huawei over the project. Project capital would be secured if the project was successfully operated and the project would be expanded to other communities in Nigeria.

Solar components such as inverters, solar panels, and monitors were delivered by Huawei. HTC paid the installers and the builders during the project construction, and it introduced engineers to the project for maintaining the performance of the system after it was implemented.

Questions were asked about the GOSPP cost in relation to the scale, and the expected payback period, but the contractors did not clearly disclose the financial details. The capital costs of the project were classed as confidential by the company management. The project manager had knowledge of all the expenses for transportation, the installed equipment, and the labour costs, but did not like to talk about the project value. The project installers and electrical engineers worked for Huawei, and they were paid a monthly salary. So, the capital investment of the project was not clear. However, a Chief Engineer for the project, who had experience of a mini project with 60,000watts capacity built-in Qinghai, China estimated the cost of the Gnami project.

"I don't have the full cost for the Gnami project, but you can only estimate that for the off-grid it is about $300,000 for 60 kilowatts, so if you multiply by the number of kilowatts you can actually have an idea of how much this system could have cost"(HTC Project Chief Engineer).

The Gnami project was a valuable project. The estimated capital investment is around $200,000 for the entire project. Huawei took only thirty-eight days to develop the project. The construction period helped Huawei to minimise its expenditure. The project was built as a short-term project in order to determine if it was a viable market. Households in the community pay an average tariff of N21.3 (0.04p) per kWh of electricity, and this is regulated by the government (NERC)

The GC assumed to consume a total of 54000 kWh a year, which is valued at $3188.53 (£2506.19). With capital costs of $200,000 (£157250.01) invested in the project and the electricity charges per year being $ 3,188.53 (£2506.19), the project expected a return on capital after 63 years. Therefore, the investment would be at risk because of the low charges and the long period of time required to recover the capital. A government representative commented:

"The idea was to cover the cost of investment and the government has to replicate into some other areas. It is supposed to be a pilot project from there we are given some option that we cover the cost of investment."

HTC as the contractor took the risk of building the project. It expected that it would have a chance in the future to make a profit by supplying technologies. This idea had been applied by Huawei in Cameroon and China where it had invested in renewable energy projects. For example, Huawei built a 35MW off-grid solution in Cameroon for more than 1,000 communities. Similarly, in Qinghai province in China Huawei installed 10MW off-grid solutions with 4,200 meters installed in houses. However, the company started with a small capacity, the Gnami power plant system, which was an unsuccessful project in Nigeria.

4.5.6 Case study Outcomes

The driving factor as the Ministry of Power also identified the Gnami location as suitable for the off-grid solar PV plant. The GOSPP is now delivering electricity to 100 houses. It provides security street lights daily for 12 hours from 6 pm - 6 am, helping communities to feel secure from a number of criminal activities that happens during the night.

"Communities are enjoying power now as communities increase because of the power supply" (HTC Manager).

Before the project was applied the people living in Gnami area were using small diesel generators and kerosene for their cooking and lighting. At the present time, the residents are allocated some energy use for at least watching TV and charging phones, but they still need to use other appliances such as irons and heaters.

GOSPP, however, is identified with the issue of additional energy capacity from the residents in this case study, it was identified that the use of new solar panels and components installed in the project. This means the situation of GOSPP is in full operation if the setting that is programmed to deliver the energy is not interrupted. The households considered that the capacity allocated to them was too small. The average energy that each house is permitted to use is less than 1.5 kWh but some of the households use more than this leading to the shutdown of the system. a lot of repetition of the same issues.

A committee was set up by the District Head to inspect and monitor the project. The committee includes the disciplinary unit, which deals with the households that contravene the directives regarding the restricted use of refrigerators, irons, or two or more TV sets. When the committee identifies an offender, they disconnect their services. For example, one was removed for a month and another one permanently after refusing to comply more than three times. If the household uses an extra or heavy appliance such as a pressing iron, then the system shuts down.

The system can only be restarted when the household has disconnected the appliance. This happens in the community as a result of activities undertaken by energy users. The households still do not listen, putting the other users at risk.

"We do not expect benefits from the project because we are losing money that is why we leave it free" (Company Manager)

HTC and the government agreed that the GOSPP was developed as a pilot project. Thereafter, the government would implement new community projects in other areas in Nigeria, and Huawei would supply the project materials. However, after the new administration came into the power the solar programme became less of a priority for the current government. The project contractors were unsatisfied with the way in which the government supported the scheme.

The management system of the project remains unreliable, particularly when they were needed to be looking after the project. There was no structural management system to control the community energy services. The project lacked appropriate management and skills to operate properly. The households use the energy any way they like because they know they are not being charged. Smart meters were installed in each house for economic and protection reasons, but they are still not in use.

The community cannot pay for energy services. It is difficult for households to pay one-third of their salary on energy bills. Huawei used to maintain the project after it was built but the project is now seeking financial support to the government to perform the maintenance.

4.5.7 Summary

4.5.7.1 Governance

Deciding on testing of pilot solar renewable power to electricity through the project institution is a complex issue

A visit to China to meet with Huawei officials proposing a pilot test resulted in the installation of a solar project for energy generation in the Gnami community. The important aspect in this case study is the project development, where the stakeholders contributed commitments in making the decisions processes, in which Ministry of Power selected the GC for pilot project. It is particularly important in community energy projects, where the community should be involved in decisions, building the terms, which also includes investors, government and community representatives, who are responsible for an arrangement and agreement in the installation technologies. But in the GOSP, the community was not included in the arrangement of use meter systems, which led an issue in the future. This case study indicated that there was a lack of understanding between the project stakeholders. It was not specified where the project governance was, as many times the system was identified to have a shutdown. This issue is a barrier to project progress.

4.5.7.2 Technical

Developing distributed energy resources

The renewable energy technologies such as solar PV and battery storage system are the key drivers in this case study, promoting the development of the area particularly for the rural communities because they have limited energy access. The solar PV is installed as a centralised system in the community, provided the opportunity to residents, by installing at small scale, which changed the mode of producing energy from fuel energy to solar supply system with better managing without high costs and expense during the maintenance. But it identified the lack of proper operation in the case study could lead the batteries and solar panels to start weakening.

4.5.7.3 Supply Capacity

Providing the electrification of a limited supply capacity for community

Energy capacity is provided in the GOSPP and the system is installed as a community ownership model. As a community energy scale, the model should have been enabled to provide energy services to a whole community. The people in the community can benefit with renewable mini energy grids, by providing energy as services, in the sense that the residents use the electricity for cooking, cooling and lighting and they enable to manage the power system efficiently. In DC, resident loads resulted from power failure due to additional power capacity needs. The entire DC have no opportunity to connect to the grid. The people who were connected to the grid strained the system when they need to put more loads to the grid. GOSPP needs to reinforce the infrastructure in the future.

4.5.7.4 Finance

Developing and committed partnerships for financing a pilot installation

There are many actors in this case such as governments, industries, individuals, communities could participate in markets and the investment partnership for financing renewable energy in order to evaluate the cash flow of expenditures used through the investment of renewable energy technologies. In the GOGSP case study, HTC committed investment through a partnership with the Ministry of Power for the development of a pilot project in Gnami community. There was the intention of the project where the project capacity is to redesign the market model. It noted that a lack of commitment in redesigning the project capacity considering as barriers that may be contributing to the limited issue of development and improvement community are due less likely commitment to renewable energy.

4.5.8 Conclusion

The case study is a pilot renewable energy project developed by Huawei Technologies Co in relationship with the Nigerian government. Some of the important factors were explored in this case study The GOGSP developed with 40 kW solar PV mini-grid, which installed at GC for energy demand. It found that the GOGSP delivered with the project goal was to supply electricity free as the project trial, but there was need GC to pay energy services after a few years. The project was found with the limitation of progressing especially for energy reliability due to the lack of public finance contributions for energy services.

The GC would use prepaid cards to pay their bills during the payback period. But a financial challenge was found in the case study community, where the residents could not enable to afford electricity services. The capital cost of the project through electricity revenues is difficult to payback in the estimated years. The GC found in terms of energy demand they need to procure supply energy capacity in bulk to recover their resident loads and small business. The energy generation capacity delivered by the stakeholders for GC was lower than their loads.

Therefore, the GC need support for the design of programmes, in which the provision of finance is important, and the building skills for communities to manage, operate, and maintain energy systems should also be key priorities

4.6 Case Study 5 – Danjawa Integrated Renewable Energy Project (DIREP)

4.6.1 Case Study Introduction

The Danjawa Integrated Community Energy Project is concerned with renewable technologies installed in the Danjawa community (DC) which have a significant impact on the people living in the area. DC is a rural community located in Wamako local government in Sokoto state, which is part of Northern Nigeria. The DC is based on the state periphery, 5km from Usman Danfodiyo University (UDU). The DIREP 's primary objective is to generate electricity by installing a hybrid system based on solar and wind energy on an off-grid distribution network. The DIREP is also composed of three main technologies: solar street lights, a biogas digester system for gas cooking and a solar water heating system. The design takes an innovative approach to the generation and distribution of energy within the DC.

The DIREP involved a wide number of stakeholders who participated directly and were also involved indirectly in facilitating the delivery of the project. The DIREP committee was constituted and organised by the Nigerian federal government. This committee comprised the Ministry of Finance (MOF), Ministry of Education (MOE), Ministry of Science and Technology (MOSAT), and the Energy Commission of Nigeria (ECN. They provided project strategy guidance, coordination and management. Following implementation, the Energy Commission approved SERC's annual funding for maintenance. The Sokoto Energy Research Centre (SERC) manages the project, in particular by supporting engaged residents. The project was funded using World Bank credit, which was given as a grant to members of the International Monetary Fund (IMF) countries members. The SERC worked with the Nigerian government agencies to establish the project, but the directors of the SERC took responsibility for its maintenance and day to day operation by engaging the community. SERC engaged with DC households through the community leader concerning the issues of energy distribution and how it would be delivered to the community. Some of the residents were selected to use woodstoves for cooking, while others were chosen to use electricity.

The DIREP is a pilot project sponsored by the World Bank. It is delivered by the SERC which was created by the UDU. The planning aspect of the technological installations took several years, and its delayed implementation. It was commissioned in 2012, although the installation phase began in 2006. However, the project participants benefited from a lengthy and inclusive participatory process. The project development was supported through a process of engagement activities which included workshops, and formal and informal discussions between the project stakeholders and the project funding sources.

A strategic plan at the planning stage was developed, but the stakeholders were committed to having an important role such as organising, coordinating and implementing the strategic plan. One of the key issues is that a grid extension was needed in DC to supply electricity. Rural citizens lack communication tools, thus they needed to be educated on the practical aspects of renewable energy such as new forms of cooking, and lighting. In 2006, the project proposal was submitted to the World Bank and it was approved in 2011. Most of DC are farmers. They grow crops such as maize, millet and sorghum during the rainy seasons between June and October. They are largely subsistence farmers, they usually export a few crops to the local market and use the remainder for food to sustain themselves. Many live-in large families as many as five to ten people.

Figure 4:21 Map of Danjawa community

The DIREP area was identified as a suitable site for the project with particular potential regarding solar and wind energy installations. The climate is dry with little rainfall in the season from May to October. The surface soil (shown in Figure 4:21) is characteristically sandy, loamy and clay and it produces crops, grasses, and trees such as Acacia Nilotica and Tamarindus Indica. Thus, the project sought to blend with and adapt to the topographical and geographical features of the Danjawa area and principally to the prevailing condition of high temperatures.

There were some issues with regard to the handling and management in the project, which has complicated the development of some installations. The Danjawa project identified that there were issues regarding accountability and transparency, which project management needed to deal with. The project funding is complicated because no comprehensive record of spending has been maintained. It is therefore difficult to link grant expenditure to the project. Against the project code, which is the identification number 4304 assigned by the World Bank. The use of substandard materials in this project has been an issue. For example, the solar panels used to generate electricity provide low capacity given the potential solar radiation in the area. Similarly, the wind generator performs with the same low capacity for exploiting wind energy. In the community, it was found that training and advice were important for community households in the early of the project implementation so that they could understand how to use the wood stoves. The woodstoves, which allocated to DC members, did not last more than two years due to little understanding of how to use woodstoves properly. Table 4:8 shown key case study parameters

Table 4:8 The key case study parameters

The project model and location	The integrated renewable energy system built-in Wamakko local government for the Danjawa community and commissioned in 2012
Technology Installations	Comprises 60 panels, a single wind turbine generator, and 16 200A deep cycle batteries. A dome-type biogas digester was constructed, a heating system was designed, and there are five solar street lights.
Generation capacity	A hybrid system of 2000W wind turbine and 10KWh solar PV for electricity. Water heating system: 250 litres of hot water. Biomass: 20m3 capacity
Stakeholders and institution	The project involves several stakeholders from international agencies, Nigerian government Agencies, the university and the community participants
Funding	The funding is from the World Bank through the Ministry of Finance
Management and operation	SERC takes on the project tasks
Beneficiaries	World Bank, the Nigerian government, SERC, and Danjawa community
Outcomes	The project was developed for the community. This was the first time in the community’s story that it had electricity and other energy needs.

4.6.2 The Background of DIREP

There is a wide disparity in income between the city area and the DC area. The community's living standard is low because subsistence farming generates little income. DC requires better infrastructure quality such as electricity and storage facilities to allow them to preserve their products. Instead, they use open places to dry their agricultural products and they depend solely on firewood for their domestic energy needs.

4.6.2.1 Danjawa community and location

The DC is a village in Wamakko that local government needed to have electricity to preserve the seasonal agricultural crops, and they needed to reduce the use of charcoal and lantern oil for cooking and lighting. DC is located in a peripheral area that lacks basic social amenities such as potable water, roads, and electricity. The DC needs, at least, a diesel-powered pumping system used to lift water from boreholes. Electricity can be used to transform the local economy, raise productivity, and improve livelihoods. Renewable community energy activities are seen as important aspects of DC.

The geography and the available resources in the DC area are among the factors assessed by the SERC when installing the solar PV and wind generator, but the roads that link into the area were unsuitable for access. The SERC was able to organise the members from its units to examine the potential energy production. The SERC carried out research activities on weather events to understand the use of wind, solar and biomass. The annual temperature was found to be approximately 29 ^{0}C on average but they noted that sometimes the temperature was as high as 47 ^{0}C usually from February to May. The average solar radiation was estimated to be approximately 7.0KWh/m2/day, but the variable of seasonal changes influenced the solar energy in the location. The area is bounded on latitude 13.0670 N and 5.2490 E longitude, and the elevation is around 351m. This parameter shows the potential for a wind generator. The communities used to generate a large amount of waste such as dung for the growth of crops as the community relies on the farming system.

DC have interesting cultural and historical human activities with a different heritage to the other communities in the Wamakko local government in terms of buildings and occupation. There are approximately 1,000 people in the DC population in an area of five km^2 (833 hectares). This population rate is high when compared to the total number of people living in the Wamakko local government area which has an area of 697 km2 and a population of 179,619 people.

The characteristic features of the DC include the buildings such as homes, mosque halls for community prayers, and grains stores made from clay and wood. There is also a lot of farmland for DC farming. Farming is the main occupational activity; 85% of the people of the community are subsistence farmers growing food crops such as millet and maize. Planting the Acacia Nilotic trees serves multiple uses nationally and locally they are a source of timber, fodder, tannin and gum. DC needs to improve the modern farming system, introducing electric equipment. Through the production of dyes and timber, the farming system helps to sustain a traditional culture.

Farmers monthly income is less what their demand. It seemed that they could not afford some essential services. The typical DC family is a patriarchal family with the father at the head and one or more wives each with a number of children. Approximately 70% of DC has a large extended family size of 6-15 members. This shows that the residents live with a low income underserving their needs. There is a need to address the DC issues that replacing inefficient fuels and increasing capacity to meet demand while improving the environment and improving health issues. It was found that SERC engaged with DC residents and fragmented them into two sections in order for each resident benefit with the project; some homes were provided with electricity whereas others were given woodstoves.

4.6.3 Technology Installation

The various installations consist of a new wind turbine, biogas digestive technologies, and redeveloped Solar PV. In DC, the project developed a system for pumping water, a water heating system, solar street lights, and PV for electricity all using solar power (Figure 4:22). One of the project participants stated

"In this project, we brought wind the integrated hybrid actually plus biogas the digester that supplies the gas. Electricity comes from wind and solar for the lighting. So, it is a hybrid power when you generate electricity from two sources wind and solar. The power station is there. It is distributed off-grid. A borehole is there and a solar thermal. There are individual street lights" (SERC Project Manager).

The solar energy system has various installations for different purposes. This issue understood that the model of the DIREP delivered by the installations of solar distributed energy systems depends on materials the developers used during the development.

4.6.3.1 The water heating system

The local economy and climate issues are among the factors that motivate the installation of solar thermal technology. The DIREP engineer identified the use of local materials for the construction and installation of the solar heating system. The main installations consisted of three absorber plates, glazing glasses, a collector case, insulation pipes, a hot water tank, a cold-water tank, and stands to secure the collector and other storage facilities. When selecting these components, the constructors are responsible for securing the best value equipment at market prices. The aluminium and steel were found to be cheaper in the market than copper materials. The absorber plates, two collectors used in the DIREP, acting as energy generators for the system, were 1m2 thick, and they were made with a mix of copper, aluminium and steels. Their surfaces were covered with single glazing of transparent glass, painted black with an emissivity of 0.95 to improve the absorption capacity. For the casing of collector, mild steel and Afara wood were purchased because they were the only materials available in the market. Galvanized steel pipes were used to connect the system storage tank to the collector. The cold-water tank used to store water was a temporary choice and it supplies 250 litres. The hot water tank is made from iron and it is lagged with sheet iron material to reduce heat loss. The stands for the two collectors and the cold water and hot water tanks are made from mild steel. The solar water heating system was installed at the DC clinic health centre using the average temperature of 25^{0}C to heat water to a minimum of 70 ^{0}C for the clinic use.

4.6.3.2 Solar PV and solar street light

There are five solar street lights in the community, in chosen places as the DC does not have urban planning. Individual solar street lights have a panel of 125W capacity with a 36W LED bulb, and the pole is attached to a 100Ah deep cycle battery. There is a charge controller which fixed on top of the pole.

The solar PV system is installed close to the wind turbine near the DC homes and it is mounted on the ground. The space required for the installation of 60 panels is 900 - 1,056 m2. Space was cleared, by cutting down trees and grass, before the installation to avoid any overshadowing, but it was noted that the wind installed around the panels is likely to shadow some panels. Each panel is able to produce 160Wp energy output. Therefore, the solar system has the capacity of 10KWh for sixty solar PV arrays. Given the solar radiation of 7.0KWh/m2/day that the Danjawa location receives from daily sunlight, the solar system produces about 2,100 kWh in an average month and 25,550KWh in a year. The DIREP uses sixteen batteries in a closed building, storing the excess energy that is generated by the solar panels and the wind turbine. The battery specification is rated as 200A deep circle.

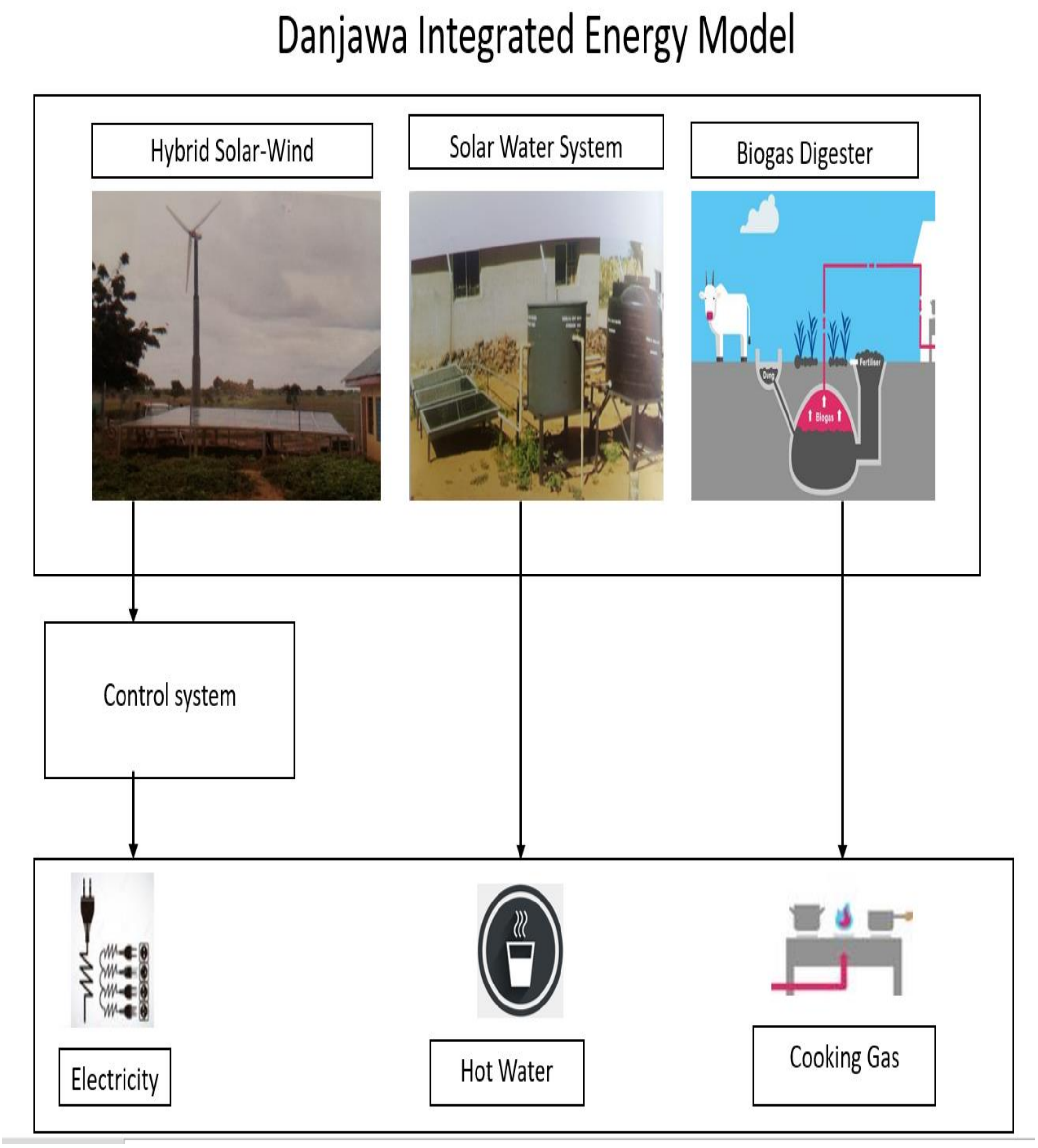

Figure 4:22 Installed technical materials

4.6.3.3 Wind energy

The wind turbine generator installed for the project is a permanent magnet generator; it is mounted on the top of a tower and it is designed with three blades. It is made from glass-fibre reinforced polymer (GFRP). Each blade is approximately 3.2 m long and their rotation per minute is around 400rpm. This turbine was expected to produce 2KWh according to its manufacturer, situated in China in the Guangmang province.

Although the wind speed at the location is higher from December to February due to the Harmattan period, the amount of power output depends on the installed capacity of the wind turbine, which influences the energy generation. The wind speed for the location is highest at 7.89m/s in February, and lowest at 4.40m/s in September. The average, annual wind speed is 6.22m/s at a height of 18m above the ground. The Guangmang model's 2.0kw has an average power of 7.65W/m2. The wind technology generates high outputs in October, but it delivers unexpectedly low outputs in September. This highlights that in order to be competitive, the technology must operate at a higher performance level.

4.6.3.4 Biogas digester

The construction of a biogas digester for gas production reduces the use of wood as a fuel for cooking. The biogas digester is a 20m3 fixed dome construction adjacent to the community homes. It uses pipes to supply the generated cooking gas. Dung from the DC cows provides the main energy source for the digester. The digester is made of concrete and it is not a complex design. It consists of an airtight container constructed with stone and cement. From the top to down, the digester has a curved design and several layers of mortar are used to seal the building. The digester is important as the wastes generated by the digester after gas collection is used as agricultural manure. The gas is collected from the digester is allocated to about 200 families out of the 1,000 community residents.

4.6.3.5 Improved woodstoves

The DC later introduced an improved version of the woodstoves which reduced the fuelwood consumption of wood by a significant amount. The improved woodstove is a three-hole stove with the middle hole providing the main burning chamber. Modernising the stoves improves cooling efficiency. It is a time saver because it cooks the household's foods 45% faster. Although the stoves have been improved, the households encounter problems when cooking; excess smoke causes watery eyes and coughing. In some homes, the stoves are too small to support the pots in use. Families are unable to meet their cooking needs.

4.6.4 Generation Capacity

The generation capacity of 12 kWh for the hybrid system could not even light a 30W bulb for a community member. The many households that were not connected to the hybrid system use lanterns to light their homes. The DC is divided over the extent of the project's benefit; some families were given woodstoves, while other families were provided with electricity, but the community leader benefited from both the cooking stove and electricity. He expressed his opinion about the project:

"We benefited so much from the project. For cooking foods, they brought us woodstoves and electricity at that time, which was distributed to our residents, but later it was turned off for a long period of time"

The DIREP should be installed with a capacity for the electricity requirements of the DC when it was commissioned in 2012. Both the wind turbine and the solar PV have the 14-kWh capacity for home lighting, televisions and radio. The solar system generates a capacity of 10 kWh whereas the wind turbine generates less. As the project director mentioned, "4 kW was integrated with 10 kWh PV plant." However, the wind generator's specification 2000W rated power. This issue might be related to the weather or the project's location, as the wind turbine generates energy based on the wind speed.

4.6.5 The Delivery of DIREP

4.6.5.1 Organisation and Governance

DIREP leads the opportunity of delivery the finance used to install distributed energy resources, but the relationship is initiated when the need for solar and wind installations to integrate into the community. The SERC is the key organiser, making ensure that the relationship becomes effective as stated

"We are the institution that if we want to embark on the project, have to shoulder all the responsibilities. We do designs. We also cover the finance one hundred per cent. We prepare the community for running and maintaining the system" (SERC Director).

The DIREP has found a complex issue in terms of the stakeholders' involvement in the project development. The stakeholders comprise the following five organisations (Table 4:9): The International Development Association (IDA); Nigerian Government Agencies; Sokoto local government; SERC; and the DC, the energy users. These stakeholders provide significant inputs, particularly SERC which participated in all of the project stages.

Table 4:9 Governance and organisations involved in DIREP

Institutions	Organisations	Roles

The World Bank	International Dev. association	Creditor
Federal Government of Nig	Ministry of Education	Advisory and director
Federal Government of Nig	Ministry of Finance	Grant debtor
Federal Government of Nig	Ministry of Science Technology	Coordinator and facilitator
Federal Government of Nig	Energy Commission of Nigeria	Controller of financing
Sokoto State Government	Sokoto water resource	Site consultant
Wamakko Local Government	-	-
Sokoto University	SERC	Developer, management and owner
Local Community	Danjawa Community	Energy users

The IDA founded the project in order to improve the lives of the rural community. The government representatives engaged with SERC to meet the Nigerian energy targets on the access to energy in the peripheral community. The SERC is also more concerned with the research and development of renewable energy technologies. The Table 4:9 above summarises the roles and the stakeholders who contributed to the project.

4.6.5.1.1 World Bank

As a sponsor of the project, the World Bank-funded loans to the Ministry of Finance as a credit to deliver the infrastructural materials. The World Bank used the IDA to arrange the credits. The IDA assessed and then issued the loans based on per capita income. The Ministry of Finance received credit from the World Bank for national empowerment and development projects. Thus, the government's representative agencies monitored the development project as stated in the following quote.

"This project was sponsored by the governments, especially the Energy Commission of Nigeria. These stakeholders provided the finance for the project. We carried out the project activities. We have an academic university community, the Energy Commission of Nigeria and the Rural Electrification Agency. All these are stakeholders and collaborators and they collaborated in many areas." Energy Centre Director

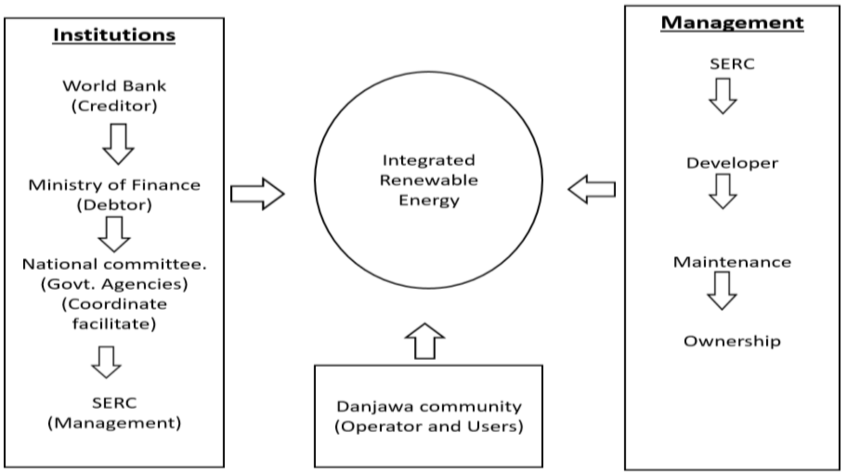

Figure 4:23 The DIREP stakeholders

4.6.5.1.2 Government agencies

Various government agencies from the national and local level (Figure 4:23) represent the government in social responsibility projects. The Ministry of Finance served as a grant recipient during the financing agreement. In association with the Ministry of Education, the Ministry of Finance was charged with monitoring and evaluating the progress of the project. The Ministry of Education contributed in an advisory capacity and also directed some project activities. The Ministry of Science and Technology (MST) agency coordinated the project activities such as meetings and testing the pilot machines created through the research. The project approval was confirmed through the MST. Within this agency, the ECN takes control of the finance based on monitoring and evaluation reports. The ECN was used to approve the money requested for the project procurements and installations. So, a number of the network's stakeholders between the funding source and the government covered the project management.

The Sokoto government includes the Sokoto state government and a representative from the Wamakko local government. The Sokoto state government, SSG, (Sokoto Ministry of Water Resources) contributed to the land inspections that needed to be conducted within the community. Grid extensions have been made to the DC, but the Sokoto state seems to be limited in its provision of social services especially in the design of the DC homes, road access and other networks that provide access to the DC. How to set up the commercial infrastructure, such as poles, wires and the metering system in the case of grid extensions, to provide cost-effective, clean and reliable energy is one of the main challenges of community energy. The development of a local community programme is important, but the SSG overlooked this kind of scheme.

The Wamakko local government did not contribute funding to the project. This issue started from the beginning of the project as one of the participants indicated that “in the ideal situation, the local government is supposed to be engaged from the initial stage of the project. Unfortunately, we tried to get some contacts with local government, but we did not get responses.” When assessing the level of local and federal government responsibilities, the Nigerian constitution mandates that local government has responsibility for social projects.

The SERC served as a developer who built the project. It was used to receive the annual budget from the ECN. Its project managers maintained the system while it engaged with two community residents for seven hours a day operating and monitoring the system. It planned to upgrade the community’s solar and wind system using metering systems. However, the Sokoto state government provided grid extensions within the community, at a time when the solar and wind turbine systems stopped supplying electricity to the community. Electricity is delivered free to Danjawa residents.

During the development process, the DIREP has found a complex issue in terms of the stakeholders' involvement in the project development. SERC, the developers were required to submit several proposals, at the national and local government level, outlining the project objectives. The SERC first corresponded with the Ministry of Education, and the Ministry of Finance, Science and Technology. The documents contained detailed designs and models of the project; they explained the surveying of the location, the designing of the installations and the maintenance issues. This proposal is subject to World Bank evaluation. The Ministry of Science and Technology engaged in financial issues until the project was implemented. It received hundreds of proposals from various institutions in Nigeria including the SERC, all requesting to secure funding as institutions for research and development. The programme focused on sustainable development use to promote local communities.

“There are so many processes in the project you have to develop proposals and send them to the relevant departments. The relevant department generate… the project…” (SERC Director)

Therefore, the SERC was responsible for surveying a location and designing the project installation in order to fulfil its role as the energy research centre. The DC complied with the grant requirements by identifying suitable project areas. The proposal required government officials to affirm that the project would meet local community needs. The SSG made formal applications through the Wamako local government verifying the suitability of the land in the Wamako zone to be used. Before the installation of the project’s materials, the land surveyors from the water resources inspected the DC area, making sure that the project could be installed in accordance with the modelling.

The DIREP was commissioned in November 2012 but its delivery (preparation for acquiring grants, surveying the land site and acquiring permission for its use) delayed the project for up to six years. The Ministry of Finance adopted a bureaucratic approach, establishing committees (such as a national project steering committee, a technical review committee, a national project secretariat, and an international advisory board) who functioned as planners in order to implement the project effectively. DC consultation took several months resolving community land issues. The communities were consulted because of the importance of the use of land in the community in terms of farming. The local government engaged with communities to prevent residents subsequently claiming land ownership. There was an understanding that this issue had occurred in another community energy project, Sayya Gidan Gada where the community claimed that "the community sold out the land to the centre," as stated by one respondent.

As an important factor to the DIREP, its site is secured free from community ownership. The SERC assessed the most suitable location for installing a solar array and wind turbine. The project site was designed as community-owned property and it was registered by the Ministry of Water Resources according to the Land Use Act.

4.6.5.2 Operation and maintenance

The initiative started with a distribution of woodstoves and the solar PV, which was relocated from Sayyad Gidan Gada community to DC. The Sayyad community solar installation comprised solar panels and batteries for fifty households and it was shifted to DC to meet the needs of 1000 people. The DC distributed 200 woodstoves, installed in an open space in homes to test as a technology model. However, the model did not last for a year because of a failure to repair and reinforce the wires and plastic materials that strengthened the woodstoves. The engineer noted that "when the residents cook Tuwon Shinkafa – a thick pudding type of foods – they put pressure on the woodstoves". These cooking techniques weaken the stoves and an innovative approach is therefore required to maintain them, such as the application of special clays to protect the stove and prevent cracks. Acquiring the funds to improve the stoves and purchase the essential materials were challenges for the centre. The centre used UDU funding as it had a limited budget. Thus, the centre has had to look for other financial support in order to improve the project installations.

4.6.5.2.1 Technical management

There are many factors caused the barriers to the development of the DIREP, which resulting in the solar and the wind technologies generating a low capacity. DC engagement is important in order to learn how the operations and maintenance of technologies. The SERC recommended certain approaches, which included a modern innovative approach, a training skills scheme for the community-owned energy system. The residents were encouraged to use the recommended number of bulbs in their homes. There are stabilised energy issues, for example by controlling and managing the use of electricity, particularly, focusing on who is not connected. The approach recommended for the DIREP through the use of combined solar-wind generation electricity can provide multiple benefits such as jobs, income and local economic development as briefly stated by the project manager: -

"Gradually we do meter and charge through token when they have accepted the scheme and find the project internally beneficial. We do meter to every individual you have the meter and you pay according to your consumption, again that village was connected to the national grid. So, our system is not in use" (Project Manager**)**

The combined system for the DIREP did not last three years since transformers were extended in the Danjawa community, and they were separated for use in a different community in the Sokoto state. In 2016, the wind turbine was moved from DC to the Kaura Bello community. The installed solar system is there around the community supplies energy to the security guards but not to the people because they have access to the national grid. One of the community members stated that

"For the NEPA, it is used for many things. As you know some of the people have a fridge and a freezer and irons but that one does not do these things"

Unfortunately, the SERC could not deliver the second plan for the metering system to the residents. The residents had an opportunity to be given a transformer, which extended to the national grid. The DC were taken off the use of solar and wind energy because they seemed to be the grid extension from the state government. The DC acquired this in 2015, the Sokoto state government campaigned on DC's improved uses of energy.

4.6.5.3 Financial approach

The SDR is an amount of credit allocated to a Nigerian International reserve by the IMF. The figure of 120m SDR, equivalent to 166,140m USD (£133m) was agreed to supplement the Nigerian account to run the project. In the process of receiving this grant three conditions were attached to the project: on goods and works, on a specific method for procurement and charges for repaying the grant after the SDR had withdrawn.

"There are some conditions for any international projects. They are supposed to quantify funding during the application procedure. Some of these quantify, the institutional provide the main items and the bidding personnel and they paid the salaries of the personnel because they are part of the project" (SERC Director).

The goods and works are the renewable energy installations itemised in the project proposal. Therefore, the proceeds of the grant should use to procure the goods, works and services for the project, and is also required to finance the consultants' services. Several companies were invited to run workshops for the project materials and then supplied some parts of the project installations. These companies were promoted by providing their services and project consultation.

A specific method – the National competitive bidding method – is required for the procurement of goods and services and it is mentioned in the financial agreement. One of the project's objectives is to use high-quality materials. But the National Competitive Bidding was specified by the World Bank as a method for the procurement and delivery of materials to be used by the Nigerian contractors. Local contractors were required to provide previous evidence of previous experiences related to similar works and they were required to register for National Competitive Bidding by paying upfront and non-refundable fees of ten thousand Naira (£20). In the event, despite these safeguards, SERC's Head of Department acknowledged that the locally sourced materials were substandard and blamed this on "a lack of credible research and development infrastructures." Some international companies such as the Gunggung company based in China and the J.V.G Thoma Gmbh situated in Germany delivered many of the project materials. The international companies noted that they provided wind turbines, solar panels and batteries. They were asked to provide these because the Nigerian industries did not manufacture wind generators or some solar equipment.

The IDA allocated the goods and works and their amount in SDR for the Ministry of Finance to disburse during the course of the project. Change to the expenditure can be requested between the IDA and the Ministry of Finance. The process of repaying the credit is shown in Table 4. There was a commitment to a charge rate specified by the Ministry of Finance to be paid if the withdrawal or unwithdrawn credit balance. The unwithdrawal rate is charged at ½ of 1% per annum (one half of the one per cent of the principal), but the withdrawal rate is charged at a higher rate of ¾ of 1% per annum, while USD is required to measure the SDR credit.

The DIREP committee, which includes the Ministry of Finance and the Energy Commission awarded USD $4.2 million to SERC for the project activities. Breaking down the project costs, the centre was given less than USD $2.5 million for the installation of the infrastructural materials and USD $2.6 m was allocated for training and development. It is a complicated issue because in the reference credit number 4304 of the project the World Bank supplements the total cost of 120m, SDR (166,140m USD), stating that the project's expenditure is based on the category shown in Table 3 above.

The centre carried out the main activities for delivering the project's installation with the minimum amount of grant that the committee awarded. However, to cover the costs of maintaining and operating the project, the centre applied for the fund and then the Energy Commission approved them through the annual budget. It noted that the project installations developed in the community, which comprise multiple technologies from the solar photovoltaic, the biomass and even the wind energy even though it is not available so far.

4.6.5.4 Energy end-users

Traditional wood stoves and lanterns were replaced in households by improved wood stoves and electricity. The biogas system, the water heating, the improved wood stoves, and the street lights of the project are the main infrastructural benefits for the community. These have improved the quality of rural life. As one community member said:

"Of course, we enjoyed this thing for the first time it was brought here. We used it for the television to watch the area that we cannot see only listening to the radio. Therefore, we could turn on to watch what we want." Community Member 1

4.6.6 Outcomes

Participation in the project through the development processes, training workshops, and consultation has provided some social and economic benefits such as partnership approaches for delivering innovative technologies in Danjawa community.

In spite of the successes found in the case study, there are a number of issues as the government delayed the bidding and granting processes of planning permission, this, not the fractional issues in the DC energy's development but also the issues of budgets transparency. It was found that there was no audit trail to track the allocation of grants to fund construction and installation work. It is a little indistinct because the Government of Nigeria received credit from the IDA to go towards the cost of the Science and Technology Education Post-Basic (STEP-B) Project. However, the proceeds of the credit to pay the contract for the procurement and installation of renewable energy equipment were found in the case study. It was understood that the costs of maintenance were paid by the Energy Commission, with financing through the SERC, but the funding was stopped three years after it was first commissioned.

The project identified substandard solar arrays, which could not meet the potential solar radiation in the chosen location, and the wind generator was not designed to utilise the maximum wind speed at the location. Also, the lack of a coordinated approach between the SERC, the Sokoto state government, and the community, that led to the solar panels and wind turbine being abandoned. Moreover, the installations needed to be upgraded, but due to a shortage of funding the water heating system and the woodstoves were remained rudimentary.

4.6.7 A brief of the DIREP

The Key findings include; The success of access to funding to deliver the various technologies and installations This was the breaking ground to develop the project in Danjawa. There is complexity during the planning and development process. Rigid requirements established in the case study to fund the project. There is a lack of delivery transparency, expertise, and management. The use of substandard materials was an issue. A poorly planned community programme made sustaining the project more difficult. There was a structure for the community-based energy system, where only the SERC deals with the project. Therefore, community engagement is not in the community.

4.6.7.1 Governance

Organising effective management for the project delivery but limited and poor responsibilities

An effective engagement of governance structures, making decisions about the development processes such as coordinating, financing and organising infrastructures for the community system, led to the effective development of installing distributed energy resources. In this case study, DIREP involved a wide number of stakeholders from NGOs National Government and Educational Institutions who contributed successfully with capital and material provision disposal. There were important issues, by contributing the commitments through Nigerian government agencies, incentives provided from the World Bank, while SERC engaged with skilled personnel. These stakeholders helped with delivering renewable energy systems. This has enhanced the life of the community who live in the areas where the grid does not reach. But it was identified that the roles and contributions among these stakeholders were temporary, limited for the period of development and implementation. The DIREP was identified with a lack of institutional framework, who would take responsibility for monitoring and financing the system.

4.6.7.2 Finance

Promoting and supporting sustainable renewable development through the international scheme.

The World Bank supports innovative solutions through the provision of capital resources, building of capacity and deploying sustainable technologies. For this case study, DIREP, the financial support and capital loans were given by the World Bank, driven as the factor in the Danjawa area where the welfare of community improved by providing free electricity and the installation of solar street lights for security. However, there were issues of transparency in the process of handling and installing distributed energy systems in the community area. It was identified that lack of a clearly established fact was an issue including reporting finance expenditures and the process of bidding and implementing project practices, these may have caused there to be less installed supply capacity in the DIREP.

4.6.7.3 Technical

Emerging distributed energy resources to electrify for community

A number of distributed energy resources were constituted in DC, which are the key foundation of the energy system in the community area where the impact of air pollution reduces. A micro wind-solar PV, solar thermal, batteries storage and cookstoves were important installations in this case. The provision of these technologies helps to install different technology models in the community, such as a local innovative thermal system in the clinic, imported solar PV centralised in the community for residents and street lights.

4.6.7.4 Supply Capacity

Improving community life by introducing mini installation capacity

Implementation of 15kW in this case study helped residents to start use electricity in the community. The energy service that the community consumed as wider benefits is the delivery of electricity used for only for street lighting. There are other energy services such as the provision of heat at the community clinic and distributing cookstoves for the cooking. All these services were the first energy development in DC and the opportunity to change the use of the energy system in the area. However, the distributed systems and capacity given the community literally are small in terms of community energy scale capacity. For example, solar panels capacity installed in the DC is 10 kWh, the wind generator has 4kWh, and the energy capacities are not enough for the whole community

4.6.8 Conclusions

The case identifies various factors influences the DIREW development. This case study is the first energy initiative in DC, as it commenced with the basic idea of using woodstoves as a pilot project. The SERC raised the project funding from the UDU. The project was redeveloped by improving the woodstove performance and introducing new installations of solar PV, solar water heating, a wind turbine and biogas digester, due to access to financial services from the IDA. The World Bank imposed certain conditions such as the use of standard materials, National bidding approach and the withdrawal of charges on the grant. Submissions were evaluated, and verification reports arranged during the review period. The main goal was the provision of access to modern energy to a community previously reliant on lanterns and fuelwoods for energy. The community's main energy needs included hot water in the clinic, electricity in their homes, and functional wood stoves for cooking. The SERC oversaw the project and controlled the installations. But there were some issues challenging the project in the case study, the solar PV and the wind turbine presently did not supply the electricity for the whole community homes due lack of proper plan for the project developers in terms of engagement with local government to set up the community scale infrastructure for community energy demand. Other installations such as the solar street lights, solar water heating system, woodstoves and biogas digester were needed to be operated with considerable maintenance by the DC. The most important aspect is community engagement. The DC was ready to participate but lack of facilitation tools, such as financial support and human capacity schemes, discouraged the DC in the project.

Chapter 5 : Discussion

5.1 Introduction

This chapter discusses the cross-case analysis of individual case studies. It addresses the common and divergent issues that emerged from the main case studies: 2, the Usuma Solar project (USP); 3, the Guzape Solar-Wind Hybrid Project (GSWHP); 4, the Gnami Off-Grid Solar Power Project (GOSPP); 5, the Danjawa Integrated Renewable Energy Project (DIREP). It is important to note that the discussion will use some of the pilot case (PSHPP) characteristic issues and compare them with the selected main case studies.

In the previous chapter, the findings of the research study were for each case study with explanations and descriptions of community energy phenomena obtained from documents, site visits, and interview data gathered from different community entities in Nigeria. However, addressing the cases individually limits the strength of the findings that this research purpose intended to produce that is to understand more generalisable findings. The discussion of the differences and similarities of issues and factors across the case studies will draw conclusions about the practical concept of community-based energy systems. The cases describe the important results such as successes and difficulties technical and financial factors associated with the development of community energy systems. These outputs from the cases will facilitate the development of community energy in Nigeria.

The table below shows the thematic factors and issues developed from individual case studies. This will lead to a discussion of common and divergent issues across case studies in order to build a synthesised result for the genuine development of community-based low carbon energy systems. Firstly, the discussion will cover the different and similar drivers of community energy systems. Secondly, it will discuss sociotechnical factors such as financing, technologies and the management of community energy systems in order to identify the enablers of and barriers to community energy development. Thirdly, there will be a discussion of whether community energy delivers benefits to energy users.

Table 5:1: Cross Case Study Analysis

Features	Criteria	Preposition	Pilot case	Case 2 - USP	Case3- GGOG	Case4 - GOSPP	Case 5 - DIREW
Drivers	Based on motivations	Different stakeholders build renewable energy for different purposes	Profit motives	Carbon and cost reduction	Economic motivations	Competitive market advantage and social responsibility	Research, development and social responsibility
Institutions and Governance	People constitute and contribute to the project	The organisation forms the project and makes important decisions for the development of the system	Limited liabilities	Partnership Multiple stakeholders	Cooperative entity and relationships	Public-private partnership	Public organisation multiple stakeholders
Financial sources	The original funds used of foundation community energy	Financial sources for the development process sustain the energy activities within the local community	Commercial Financial institutions such as banks	Bilateral finance institution (JICA)	Independent developer- borrowing and shares	Independent developers- procurement installation materials	UN agency – World Bank
Location	Factors influence community energy systems in specific areas	Available resources encourage the implementation of renewable energy	Natural and artificial rivers	Solar radiation, national government support	Solar radiation and wind	Solar radiation and national support	Solar radiation, wind and biomass resources
Technology type	Used for the local energy activities	Many small-scale renewable technologies can be	Hydropower	Ground-mounted solar PV	Rooftop mounted solar	Ground-mounted solar PV and street lights	Dome biomass and ground-mounted solar

		installed by community actors			PV and wind turbines		and wind installation
Generation capacity	Measured by the quantities of energy generation	Generation capacity that enabled of powering communities leads the energy system resilient and reliable	40MW	1.2MW	40kWh	150kWh	14kWh
The structure for the system energy - operation and maintenance	Considered the committee of people ensuring the constant and efficient usage of the energy system	The proper and structured committee provides the optimal and long-lasting energy system	Optimal	Neutral	Slightly optimal performance	Underperforming	Underperforming
Energy users	Benefits of the generation system	Community renewable energy provide impacts	Reliable energy	Costs savings and free energy	Profits and income generation	Improved wellbeing for the community	Improved wellbeing for the community

Table 5:1 shows a set of defined criteria that were selected from each case in order to discuss the findings. It highlights a number of hypotheses formulated in order to build some similarity and differences from the cases, which lead the general conclusions to the adoption of practical community energy in Nigeria. The following section will start with community energy drivers before discussing the factors and process issues of community energy development.

5.2 Drivers for community energy

The issue of energy access corresponding with the issue of climate change is the key drivers for the delivery of community energy systems in developing countries.

Underling the issues of energy access in developing countries where the use of fossil fuels, due to the growth of economic prosperity and the increase of population, results in the growing impact of climate change. Climate change is a global issue due to the consequences of climate change. These are the drivers, which may influence the development of community energy. This means the community energy is the response to the issues of energy access. However, some community-based energy drivers found around the motivations and priorities are associated with community energy project interests. Energy security concerns such as fuel scarcity, or rising fuel prices are types of motivations that drive many stakeholders to become involved in community energy systems. Even though the general thoughts about community renewable generation is that the motivations behind it are not limited to environmental, economic and local ownership energy issues (Seyfang, Park et al. 2013), the four selected case studies have addressed the motives in starting community energy projects and some of them share the common motivations in terms of the project energy initiative. it is possible to find the number of alternative motivations that led the project implementation within the case studies.

For Case 2 (USP), the reduction of carbon emissions was the most important driver of solar energy development: the stakeholders assumed that the generation of energy through solar renewable technologies would prevent the consequences of fossil fuels. The stakeholders who funded the project had a specific reason for its implementation. The USP was sponsored by the Japanese government in order to address global environmental issues. The funding was approved through Japan's grant aid scheme, which aimed to improve energy issues through the adoption of clean energy. This scheme was created as a Clean Development Mechanism (CDM), measuring and mitigating climate change and helping a solution to the global problems of drought and water and air pollution in developing countries. This effort is highlighted by

(Chatterjee 2011), as the implementation and transfer of more sustainable technologies in developing countries for emissions reduction through the CDM's contribution. Therefore, the principle of environmental values and objectives was clearly the factor behind this case study development, where the relationship between Japanese government and Nigerian government enabled to develop solar low carbon technologies, the adoption of solar solution constituted safe, reliable, and affordable energy use, and the energy-related carbon emissions required to be reduced based climate goals. But also it brought a range of socio-economic factors such as better access to energy services and energy security, which Carraro and Massetti (2012) point as benefits - less vulnerability and sustainable of the vital energy system.

There was also another motive that needs to be considered in this case; where the Water Board, who owned the solar system participated in the project to benefit from a reduction in daily expenses on gas fuel, as well as reducing energy use. This interest is related to the issues of greater control over energy bills and the ability to save energy charges from energy supply distribution companies. The electricity that the Water Board consumed through the supply companies for the water treatment activities was unstable due to the limitation of reliable energy. This issue led the Board to appreciate the opportunities of solar energy installations.

The USP saved a significant amount of money the Water Board spent, by changes the way electricity delivers in the water treatment premises to the production of sustainable energy. This outlines that the economic impacts influenced Water Board engaging in the use of solar generation, but also they sought to generate revenue from the solar system to wide and address some organisation development needs. Schreuer and Weismeier-Sammer (2010) described the economic motive, as the rationale attached to community energy, which is a vehicle towards developing renewable energy business to its present state market maturity where the local natural resources could be harnessed to build social capital.

Case 3 (GSWHP) was identified as a financially-motivated investment. This case study is the economic outcome project, is partly similarity with the USP but in terms of generation of income rather than the energy saving. In the initial development of the GSWHP at points of feasibility and development stages, the project developers held the rationales of coming together to raise the capital for revenue earning around the sale of electricity. The decision made in this case study was related to resources assessment and financial modelling for electricity generation for the residents used the energy, where solar and wind generators were the options chosen by the stakeholders for the ten apartments to generate electricity. The motivation for stakeholders was to generate revenue, and this encouraged them to invest in renewable energy in order to keep generating profits through the payment from the energy users. The GSWHP lacked any incentives backup from the government schemes, which driven the installations, where these schemes are the mean of opportunities, creating the right environment for growing community energy (Haites and Mwape 2013), but GSWHP was a success in the interests of the shareholders and it was the small-scale energy system developed progressively by raising share offers from the public limited liability with the intention of capital paybacks and maximising profits. It was chosen as a small-scale renewable energy business enterprise model rather than helping the maintenance of energy security and tackle climate change to meet low carbon and environmental objectives, which were the important factors in the USP, introduced as an integrated approach to address the issues of carbon and energy savings.

Case 4 (GOSPP) was a pilot project built by Huawei, as the social enterprise model, to support the Gnami community. Some of the model's key objectives included environmental and social motivations, where regenerating a green community and creating employment opportunities were important considerations for the area. However, the case study was typically delivered with the aim of gaining an international competitive advantage. The diver of this case study was profit, that is economic issues shared aims as in the GSWHP. The project developer stated the economic interests for the project when was asked. This means that the economic advantage was the key priority, which can be gained by public supports and acceptance for renewable technologies. This objective led Huawei to build an off-grid solar system in Gnami, where all the infrastructural materials used in the project were sponsored through bonds and ethical investment from the Huawei Technology Company.

Although Huawei requested that it be allowed to develop renewable energy projects for customer-partner platforms in Nigeria, it specialises in enhancing energy products and solutions, particularly for smart city projects, which could promote the application of finance and technologies. There were also issues found in GOSPP, which were the shared partnership commitments between Huawei and the national government in terms of creating training for community members, efficient energy supply and sustainable social enterprises. GOSPP was indirectly used for income generation, but it was developed to promote the manufacturing of solar energy technologies. It was meant to show that the national government had linked with the Huawei company for domestic energy security, supporting the fundamental issue of sustainable energy access, as balancing energy supply and demand in the community area.

Case 5 (DIREP) made distinctive commitments, which involved complex stakeholders' participation in delivering an integrated approach to renewable energy technologies in the Danjawa community. SERC was a key driver in terms of the process and delivery of the DIREW aimed to educate the public about renewable energy. More broadly as fundamental issue noted in this case study relates to research and development, as the SERC selected community energy projects and prioritised knowledge in terms of developing and enhancing renewable energy technologies. SERC considered that rural citizens lacked communication tools, therefore they needed to be helped and educated on the practical aspects of renewable energy such as new forms of cooking, and lighting. There was also an issue of increases the production of clean sustainable energy in the case study where this motivation was mainly on an off-grid extension, as the communities needed to generate their own electricity locally without connecting to the national grid. This issue motivated the World Bank to lend money for DIREW development. The DIREP was established to find whether the Danjawa communities could take control of energy management.

The discussion of the case analysis shows that there was broad evidence of social, economic and environmental values driving the development of community energy systems due to the growing interest in the delivery of sustainable energy in energy systems. Community-based low carbon energy found instrumental factors and essential elements (Parag, Hamilton et al. 2013) in triggering the low carbon energy transition that issues were taken place in the case studies. These factors can be seen to be global energy issues such as energy security concerns, environmental protection and inequality in energy use. In the literature, a number of studies recognise various factors as key drivers to community low carbon energy, competitiveness (Council 2004), new business opportunity (Becker, Kunze et al. 2017); health impact through quality and noise; and ecosystem impacts(Peterson, Stephens et al. 2015).

USP was driven by the Japanese environmental funding scheme, used for projects related to climate change issues. This case pledged to engage and committing action on climate change measures by improving air quality and promoting resources efficiency. PHP, the pilot case study, was a private profit-oriented company delivering electricity services for the retail market in order to share profits among the shareholders. The stakeholders confirmed that the money used for the development of PSHP was borrowed from the banks, likewise, the GSWHP was done in the shareholders' interests, as the stakeholders were interested only in making for profits. The investment made in solar and wind through shares and borrowing money was the concept of GSWHP. GOSPP was also built to promote the Huawei company's economic advantages over the international market by using renewable energy technologies. In contrast, DIREP was not implemented for economic reasons, but it was built for research and development activities and social responsibility. The SERC identified the Danjawa community for creating and evolving renewable energy technologies. Also, the motivation for developing community-based energy systems is another important issue. The cultural power of community energy activities encompasses not only the drivers of ecological protection and social benefits (Seyfang, Park et al. 2012) but also community control and energy ownership. This issue was limited in the findings from the case study analysis.

A large share of community energy development is found in developed countries, where the most important drivers tend to be decentralised governance energy systems and local economic structure. An increase in community energy systems has been witnessed in the UK, driven by the localism agenda 2010-2015, which provides opportunities for local communities to make energy decisions (Allen, Sheate et al. 2012). The concept of people interested in community energy developing community energy initiatives was identified through the rise of social and environmental movements such as transition towns and the Scottish community land movement. Bauwens, Gotchev et al. (2016) highlight the prevalence of both cooperative and community ideals drives the growth of community energy in Denmark. It is also the strength of anti-fossil fuel movement played an important factor in Germany, where the municipalities development banks are developed as actors to drive for the development of community energy. Across the case analyses, local schemes were not found to be a key factor for the development of community energy, which was also among the most cost-effective (Nakhooda 2013).

5.3 Governance and Institution for Energy System

The institutions and processes of governance for community energy systems mobilise both formal and informal structures to manage a community energy system.

Governance or stakeholder structure, in which several social actors come together for the deciding, managing, and implementing community energy measures, that are related to the social, economic and environmental benefits for sustainable energy uses are defined as energy governance. The social actors establish the institution for rules and norms, constraining and shaping human interactions using direct control, through incentives or through the processes of socialisation. However, the institution can be formal or informal taking the form of organisations such as regulatory agencies, community bodies, and private firms. This structure is an important establishment and it can be designed from the complex stakeholder system within and outside the local area for the need to access stands of supports (Wood, Handley et al. 1999) to maximise the potential community energy.

The institution's structure may facilitate the important aspects of the legal, specialist technical and financial impacts. These impacts are driven by factors led by the social actors who are involved in setting up the community energy project. In the case studies, there were different and similar results of governance such as shared interest firms, partnerships energy project, community ownership, contractor stakeholders, while there were different ways of developing and engaging with communities for energy projects. This form of comparison similarity in the cases discussion helps to identify the implications of governance where it can be promoted for the positive impact of stakeholders form in the delivery of community energy. Schmidt and Radaelli (2004) point that the governance energy system is the stakeholder’s structure that brings the outcome in which dominant models and measures such as ideas, instruments, and policy goals can be favoured or imitated energy actions from consideration.

USP formed through two governmental institutions, who committed for the development process by providing financial support and coordination and the decisions about the implementing of the system. This case study built a partnership between the Nigerian government and the government of Japan for the delivery of solar renewable energy. The partnership brought interventions driven by multiple stakeholders from these countries. Many engineers, consultants, suppliers, and contractors supplied by the Nigerian government during the project development, managing and monitoring the progress of the project. From the beginning, the governments held different kinds of formal responsibilities and roles in order to achieve the implementation of USP. The Ministry of Power was responsible for the contractors of the project under the supervision of the Japanese international cooperation agency (JICA) through the procurement agent. The local contractors were employed as labourers to work on the project sites on tasks such as plating, steel processing and, assembling, and the calibration and testing of the machinery and tools. The government of Japan was responsible for providing financial support. The Japanese government also played a significant role as the procurement agency from Japan visited Nigeria for the implementation, execution, and general supervision of the project. The visit helped to ensure that the components of the project were appropriately implemented.

This case highlighted that the form of partnership between both governments appeared to offer a significant contribution to the delivery of solar power. Involvements and networking promoted and provided knowledge sharing and collaborative for working in the development of USP. However, the organisation that owned the solar is not operated under a specific legal ownership model. Where the model needs to be legal regulatory frameworks formed to promote community ownership and management for the energy generation company. When the USP structure was founded there were issues with the energy generation policy as the energy regulation in Nigeria does not allow grid supply if the project capacity is more than 1 MW.

GSWHP had a private organisation that served as the main developer for the delivery of solar and wind energy services. It was clearly observed that this form of institutional arrangements was a business model designed for limited shareholders, who make decisions about energy investments. The GSWHP is contrasting with USP institution in terms of the governments led the relationship between institutions of the community energy system, although there was evidence of financial services and technical skills from both external and internal resources the stakeholders undertook day-to-day administration and other services for the development. The key members providing these services within the organisation in the GSWHP included the investors and shareholders and experts delivering administrative and technical aspects of the project. The private organisation led wide ranges of efforts and activities regarding the energy generation and scale. Regulatory issues are the key challenge to the organisation's progress. The formal governmental efforts were not favourable for the private organisation's approaches, particularly in generation scale and emphasis. (Aoki 2010) highlighted the importance of efforts where the regulation, policies, strategies and coordination mechanisms are designed to address and support the energy issues through local planning. The kind of materials used in this case study such as solar panels and batteries were imported. Tax relief was needed to encourage local investors. The tax relief was critical for supporting GSWHP's economies of scale as the organisation assumed that the imported materials were better produced and of a higher quality.

However, GSWHP's institutional structure has multiple stakeholders engaged in project development. These stakeholders were responsible for all the procurement and delivery of the materials required for the construction processes and installation of the energy system, through various networks of organisations that provided the funding and expertise to improve energy activities. The organisation was able to hire the engineers and architect to supervise the integration and adaptation of materials installed on the building in order to obtain the best performance from the system. The organisations experienced a lack of access to the government distributional equity for economic effectiveness at each level to help to sustain their energy systems.

GOSPP was identified as a formal public-private partnership between Huawei and the Nigerian government with the aim of delivering a community energy project. The network of stakeholders was important in this case study. The federal government and Huawei coordinated efforts to deliver the community energy project. This institutional network was built to shape the political interests in the issues of energy access, which were an important aspect for government by empowering communities. It was also set up for business decisions making. In the initial project development, the organisations between Huawei technology company and the Ministry of Power proposed a structure used to deliver community renewable energy projects for the community. The Ministry of Power organised activities and events to make sure that the solar system was completed. It selected the location and sponsored the project for the period of its construction until the project was ready to start generating electricity. On the other hand, Huawei supplied solar installations based on procedures that ensured its adherence to legal ethics and standards for solar PV materials. The solar system was developed in a short period for the community's daily energy services.

The main barrier that limited GOSPP progress was the lack of the institutional structure that led and maintained existing energy installations. This might due to the poor efforts, the weaker relationship between Huawei and the Ministry of Power, which was loosely coordinated to the institutional arrangements. Thus, the poor governance of the energy system was found in this case study where there was a mismatch between organisational arrangements and socio-ecological context. This means the formal rules or informal norms on technical knowledge, contacts and labour time to help improve the solar energy operation were limited. The capacity of specialist skills and volunteers who manage the solar system within the community was also the key issue found in the GOSPP.

DIREP was built by complex institutions and the various processes of governance structures making decisions about Danjawa community for a low carbon economy. DIREP like other cases, the UPS and the GOSPP, involved a wide number of stakeholders from NGOs, National Government and Educational Institutions. It understood that the organisations formed formal rules and norms that set the social and economic incentives structure for the development of the project. A number of departments from Usman Danfodiyo University were set up to construct renewable energy technologies. The SERC was responsible for surveying a location and designing the project installation. With regard to the networks, the World Bank gave a loan to the Ministry of Finance to deliver the infrastructural materials. The Ministry of Science and Technology controlled financial issues and participated in facilitating the delivery of the project. The SERC managed the DIREP by supporting residents engaged with the operation and maintenance of the system. It was noted that the communities were not able to participate in decision making and had to rely on SERC interventions. The decision made by these organisations was a key factor in the delivery of the community energy systems due to the fact the individual residents had limited expertise within the community to deliver the energy system.

The comparative case analysis shows that there were differences and similarities in the forms of governance energy structure. From this case study discussion, the research can compare with the pilot case, which was a private governance system where the commitment to provide quality management and a relationship with other stakeholders enabled the stakeholders to manage the facility for a number of decades. This relationship was built with financial institutions, using the legal forms under federal government and state for hydropower.

Each case study from the main cases formed partnership organisation for the development of energy initiatives, but it was not always under a specific framework, which would regulate and facilitate local involvement in the production and ownership of energy. USP, GSWHP and DIREP case studies were built through a top-down system the decisions from the national government about energy issues, while the communities and local government were passive, had little knowledge of energy systems and were reliant on inter-governmental partnerships. In the case of USP, the Water Board, the dedicated solar system was stable and partly active in the decision making about the system. The national government used certain decisions such as legal ownership model that influenced the Water Board's activities. GOSPP shared similarities with USP, in that it formed a government sector relationship for energy development. It was built through a top-down partnership for community energy. It was found that coordinating governments through a variety of local government and state levels was not involved in the GOSPP, as Huawei was one of the influential actors in the project, although local energy planning and other energy frameworks are important issues. The communities were also weak in decision making and had limited technical knowledge as well as limited support for their solar power.

In the DIRE, the communities had the similar issues of framing and governing the foundations where the communities had limited statutes, which mandates at least partial community ownership; thus, decisions made in this case study, such as management of operation and financial issues, were influenced by the SERC and the Energy Commission of Nigeria. GSWHP used a similar form of governance structure as found in the pilot case to deliver the energy system. It was a private organisation and its decision came completely from the shareholders' committee, which sponsored the system. GSWHP was strongly formed for body making and executing decisions. But it was not entered into formal partnerships with the various level of governments like in the pilot case study. The organisation sought to have helped from local governments for realising the project installations, maximising efficient use of local resources, and promoting the business model of the community energy system.

The case studies analysis there was no evidence of legal frameworks model for community-based energy system and the institutional barriers to form a local entity where it is possible for local government and communities to work together as governance system to promote sustainable community energy. Cooperatives (2009) report identified the importance of legal community energy power in terms of the ability to own and manage installations and recognitions from national and local governments. This framework helps implement the vital instruments, promoting energy measures by effective dialogue and involvement with communities through their participation and ownership where the communities can be the institutions that address the issues of energy poverty, energy security and employment.

There is a strong commitment between national and local government to engage in community energy in the UK. This is an important factor driving and offering scope for real long-term sustainable community energy solutions. However, Nigeria is a federal government and it has introduced a variety of policies encouraging the use of renewable energy generation and they have allowed states and local governments to participate in energy activities by adopting renewable energy technologies. The sequence of policies includes rural electrification strategies that could provide opportunities for community energy. The responsibility for energy strategy become a barrier towards shared competence and governance of energy. Thomas (2010) highlights the issues of practical community energy that driving the various aspects of policies, where local governments hold some important roles for ensuring local strategies for realistic community energy. Eyre (2012) stated that effective governance of community energy could not deliver through a system that relies on top-down governance energy. However, the dynamic system through competitive markets and active community ownerships potentially has a strategic role for government bringing the local sustainable energy (Parag, Hamilton et al. 2013).

5.4 Financial Approach

Financing community installations and infrastructure materials are important for the evolution of community energy.

The finance approaches to community renewable energy refer to the provision of capital mechanisms to provide the initial financial support required for the construction and installation of the community energy system. This approach fits the definition where they define the capital in terms of investment on community low carbon energy, but it is also important to note that the investment includes relevant financial flows, both capital and operation costs, such as financial resources or funds. There are a number of financial streams capital managers use to invest in community energy. Single or multiple sources mobilise the required capital and finance it for the development of a community low carbon energy system. Green (2016) and Jung, Lee et al. (2018) described the potential financial sources, such as governments, householders, and corporations who can be the owners or sponsors of the project. This outlines that the funders can implement a project using their own capital or other capital sources.

Such projects obtaining capital project driver from financial sources could be used as instruments examples of raising equity as a financial agreement between the sponsor and a source of capital, and the financial driver through crowdfunding, which facilitates access to capital for off-grid renewable energy projects. This factor could encourage opportunities for community energy development. It could also be challenges and barriers to community energy development, resulting in the use of several sources of financial support for the energy activities and development of low carbon energy technologies within the local community. Therefore, the following case studies show different financial flows to funding community energy projects such as mobilise international backing in developing countries, where these countries provided funding specifically dedicated to financing rural energy projects. There are also climate change scheme funding and donor money comes through Multilateral banks.

USP used climate finance that came from the Japanese national government through the Cool Earth Scheme. The funding was an important factor in this case study, as the Water Board relied on the grant for the deployment of the solar system. It was identified that the contribution funding given to the developers was a substantial amount of capital for a large-scale renewable energy project. In the first stage of the project, the USP's developers used capital delivered the energy activities and technologies that had been designed for the Water Board. It was noted that the solar energy capacity was extended due to the extra capital that remained in the reserves. Addressing the issues of operation costs for the project, the stakeholders intended to obtain another financial source or engage in the local business of energy generation, in order to maintain reliable energy use by installing energy storage on the Water Board premises. They likely generated the capital to finance the batteries and meter technologies used to progress the solar system. Given the difficulties of alternative capital access, the Water Board decided to sell electricity in order to promote the system.

GSWHP funded installations and other infrastructural materials by commercial financial institutions (that institution is the commonality of capital sources identified in the pilot case study) such as banks to invest in energy generation in residential buildings, but the bank loans may have been received for the detailed planning, technical aspects construction and development of the energy system. The banks made decisions about equity and debt that both of them come at a certain cost, which was critically sensitive to risk.

However, there was also capital raised in this case study. The role of the rise of capital shares is an important factor as some of the residents raised the capital among themselves to start the application, plan survey and design the project process. So, the capital sources enabled the stakeholders to carry out tasks such as feasibility studies, development, and to pay for legal and consultancy services. In this case, there was an investment risk, which related to the political and transfer risks facing the specific technologies installed in the GSWHP. It was found the capital challenge in this case study where the manager stated that basically there was a higher turnover of electricity but there was no profit margin due to the level of investment and infrastructures installed GSWHP system needed to take more times before the capital return. GSWHP's stakeholders tried to obtain business rate relief from the government to help reduce the costs of the procurement and delivery of materials. The shareholders assumed that tax relief provided the motivation for community renewable energy investments and that the capital risks could be reduced in the GSWHP.

GGOSPP was funded by an international electrical company as a result of a relationship between the national government and the company's management. The case study was designed if it could commission and operate business model in renewable energy. This project was developed through Huawei’s solar installations and procurement to promote renewable technologies in a community. The solar panels used for the energy generation, the batteries used for storage and the solar street lights were delivered directly from the Huawei company. The Ministry of Power created a temporary committee to handle the energy infrastructures and it was responsible for paying for the consultation and surveying conducted in the community. Huawei supported all of the infrastructure used in GOSPP. It was noted that the operation costs had significant effects in the case study, as the limited capital for the works and monitoring of solar installations caused energy generation issues in the community, as the performance of installations was reduced.

DIREP obtained the procurement and installation materials through a World Bank low-interest grant. This grant was one of the factors that helped the development of science and technology education in post-basic projects in developing countries. The DIREP was developed and designed by the SERC under a science and technology education scheme who was established in Nigeria responsible for higher institutions, and the World Bank approved all of the capital used in the provision of goods and works. The capital was directed towards the expenses of consultant services, workshops and training for community development.

Therefore, the limited funding was identified as the most important barrier to completing the grid connection for the other community houses. The delivery of community energy capacity was the key challenge as some of the residents were not offered energy services. It was found in this case that the developers tried to reprocess the funding through a partnership with the Sokoto state government to further fund the project’s capacity.

The DIREP had some of the issues of project finance, like in the GOSPP, where both the financing approaches used for the project development were not worth for more capital that provided for the community energy capacity. Although there was also a transparency issue, which assumed limited the progress in this case study due to the lack of institutional capabilities at financial intermediary and regulatory level.

The cross-case analysis indicates that capital sources were key driving factors for the emergence of community energy in the case studies. It also outlined that most of the cases obtained their capital development project through bilateral, multilateral finance institution such as UN agencies, that meant they have heavily relied on international intervention. The USP as an example indicates the importance of the financial scheme, which drove the success of the project development. But the funding was available for the public good to address global efforts on climate change when the scheme requirements are satisfied. This financial scheme was not seen as beneficial to the specific country objective of access to energy and used for quality installations instead only for the provision of the project support. Certain conditions stated by the Japanese government facilitated quality procurements with the project grants. This led to the project being completed with higher standard equipment. DIREP shows the vital role of the World Bank in providing capital support for community development but there was a lack of transparency during the development and procurement of materials. This was found to be the key barrier to implementing the required quality and quantity of installations for the community residents.

GOGSPP shows that there is a need to provide financial support to extend the onsite generation for energy capacity. Even though Huawei provided the support materials to build the solar energy capacity in the community, the project needed more financial resources for widening the installations and operation management. GSWHP shows that more is required than finance obtained from the project developers as part of the money was raised from the stakeholders, helping to develop the system.

In the cross-case analysis, it was identified that the projects frequently used grants and financial assistance provided by NGOs, national and international governments. From the four main case studies, three received international interventions to finance the initial project processes and development until its implementation, but the pilot study case and GSWHP borrowed the money through loans from financial institutions to develop the project.

This insight from the case studies shows that there is a relative lack of funding strategies for the community energy systems as three of the cases were critically dependent organisations, although the other was local private-sector enterprises. Many important concepts were constructed as the financial models used to develop the community energy projects were either equity or debt for the entire project development for equipment installation in the community energy initiatives. It was indicated that private organisations were able to finance the community energy projects, but financing community energy through a loan is sometimes a critical issue considering that the community energy projects are less attractive initiatives due to their higher risk and returns on investment.

For these case studies to deliver the energy services they had to have articulated programmes such as a feed-in tariff scheme used for renewable energy technologies. The programme is designed to encourage uptake of a range of low carbon distributed technologies. Under this scheme the case studies are poor. They used the limited resources and they had to install the community energy capacity. Borrowing money from a bank to finance the project is another challenge for communities. The cases, for example, GSWHP has not generated its income through the energy tariff set by the government instead it offers based on a market agreement with the clients.

The case studies sought long-term financial support from the local government. Romero-Rubio and de Andrés Díaz (2015) highlight financial models as niches that can be achieved by the creation of ethical finance companies and schemes offering loans to fund community energy systems, particularly those that are relatively underserved or that lack capital access. Important policies on financial programme support may lead to substantial and accessible funding for the development of community energy.

Many examples in developed nations have been found for funding programmes that drive the success of community energy systems. Such as the programmes are initiated through various financial bodies such as international, regional bodies, but also national, and state, local and private organisations are the important capital sources to deliver capital sources for technical and advisory issues. Funding such as the Feed-in-Tariff Scheme, the Rural community energy fund, the Urban community fund, the Renewable Energy Heat Incentive, and the Local Energy Assessment Fund for community energy activities(Walker and Simcock 2012, Romero-Rubio and de Andrés Díaz 2015, Swan, Fitton et al. 2017) are all included as supporting programmes for community renewable and energy efficiency. These sources provide capital used for low carbon technologies as well as energy capacity for communities and determine the effectiveness and efficiency base on the programmes' objectives.

5.5 Project Location

The geography area makes a difference to the success of community energy

In terms of area-based, issues of community energy, many factors were found to be key drivers for community energy systems. The factors that impacted the area's context were resource availability, local support and access to finance, describing the influence of environment and economic elements on the evolution of community energy. With regard to location, renewable technologies can be useful when the technologies have a suitable location for installation. For renewable technologies, this would mean that the spaces and territories are endowed with a specific natural environment for the technologies; this has a big impact on the delivery of high outcomes. For instance, a wind turbine needs strong wind, solar PV requires solar radiation, and hydropower must be installed in a location with flowing water and head if electricity is to be generated. The factors surrounding community areas and territories can be discussed in the case study analysis in terms of opportunities for the evolution of community energy. These opportunities were found to vary in the case studies.

USP is located in the central part of Nigeria and the area was an important factor for the solar energy generation due to opportunities, which include viability and ability to install a large generation capacity. The nature of Usama's area was the basis of the decision for the location of the installation of the solar system. In the process of developing this case, the developers considered the territories for energy issues. The initial project site was somewhere in Katina due to security reasons; this led to looking for an alternative location for the project installation. The installations were moved to Usuma after the environmental impact assessment, which was not simply conducted to determine the installations site, but also to assess the available energy resources. The temperature of the area is 25 ^{0}C on average and sometimes it reaches around 40 ^{0}C.

GSWHP found a similar geographical advantage in USP. The site of the technologies has a great impact, particularly for solar generation systems. Solar and wind installations were the types of technologies used in this case and they were installed on the building rooftop. There were slight wind turbine issues in the area, where there is a strong wind normally from April to October, which is challenging for wind technologies. However, the area is suitable for both technologies and it is located in northern Abuja in centre of the country where the average temperature is 26 0C, and the maximum temperature is above 30 ^{0}C in March.

GOSPP is located in Kaduna in the northern part of Nigeria and the temperature of this area was identified as a disproportionate disadvantage, unlike the other cases that used solar technologies. The installed solar system did not suit the weather due to the high number of rainy months in a year. Wind technologies might be suitable for the area because of the high winds during the rainy seasons. The average temperature in the area is below 20 ^{0}C from the beginning of April until October. During this period, the energy users had to reduce the amount of time they used electricity, otherwise, they caused the system to shut down. DIREP is situated in the northwest of Nigeria where energy resources are available. The solar source, wind source and biomass materials are the key factors that the developers considered when the technologies were brought into the community. Therefore, the solar panel generated electricity a day from this area was an average of 7.0 kWh/m2/day. The DIREW had available produce such as crops, grasses, and trees such as Acacia Nilotica and Tamarindus Indica and it generated a large number of wastes such as dung for the growth of crops, as the community relies on the farming system.

The cross-case analysis indicates a high level of use of solar technologies. Each case used solar technologies because of the suitable weather with high levels of sunlight, except case study four, which had the issues of the frequent and long-time rainy season. However, most of the areas had an optimum temperature over (25 ^{0}C). Case three and case five installed more than just solar technologies; they also used wind and biomass, which were suitable opportunities for the area.

Another factor that needs to be considered in the cases discussion is that access to the project sites could be a challenge for the development of community renewable energy. Some cases used rooftop-mounted technologies, which presented challenges and resulted in the limited take up of the technological installations. In the urban areas, such GSWHP had limited spaces to mount the aggregated solar panels and wind turbines were therefore installed on the domestic building, although a carport was created to extend the installed solar panels. In other case studies (USP, GOSPP and DIREP) found in the peripheral urban area, there were opportunities in the site used for the installation of the technologies. This issue may be due to a relatively low distribution of the population. Therefore, the available spaces in the area are important when the solar panels are mounted on the ground.

5.6 Technological Installations

Renewable energy technologies are more effective in the evolution of community energy

Under this proposition, the discussion will focus on the use of community technologies, and renewable energy such as low carbon distributed energy installations. These technologies are considered to be the key energy activities that communities engage in for the generation of energy from renewable sources; they use small scale installations such as wind turbines, hydropower and solar PV systems. It was identified that community energy organisations could integrate many types of technologies for the growths of community electricity generation. It is important to note that certain factors could influence the implementation of renewable technologies, such as community energy development where the technologies are developed to become more productive and cheaper. In the following case studies undergoing discussion, it scrutinises renewable energy as an innovative technologies issue. This could have an impact on community energy scales.

USP used a solar PV installation, which was designed to be ground-mounted in the local community. Most of the components had a quality design, based on JEC and IEC's standards and specifications. The solar arrays were able to produce optimal outcomes of electricity more than 250W/1 using solar radiation. The components of solar technologies were developed through experienced Japanese manufacturing companies who were engaged to promote the sustainable use of technologies. The solar system was a small-scale generation project, but it was able to connect to the national grid distribution infrastructure networks, due to the number of component technologies. The solar panels used for the installation were found low costs than the time the project capital approved. This issue led to a high level of generation capacity. The USP's panels were efficient generators that delivered electricity at full capacity and they installed all over the Water Board's properties. Therefore, the technologies in this case study were found to be productive for efficient energy generation. This outlines the importance of the use of low carbon energy technology, the photovoltaic grid-connected system was used to generate electricity on a small scale within the local area. However, it was noted that specific technologies such as smart meters and electricity storage were used to control and keep the project within standard operation so that the entire solar system could be stabilised over the period. The case study needed to use battery installations due to natural and technical issues such as the cloud and strong wind that related to the area. This case study had the opportunity to install the wind generators used in GSWHP because of the strong winds.

GSWHP deployed three types of technologies, which were observed on the rooftop installation on the apartment building for electricity generation. These technologies provided impact in terms of small-scale energy and a business model for local generation, as a combination of wind generators and solar PV generators of energy. The solar thermal system was used to deliver hot water for the residents' apartments. The residents internally deployed not only a number of efficient technologies such as eco-friendly air conditioners, television sets, freezer and fridge, but also timers connected to save energy. Many of the technologies in this case study were found to be productive and low cost. But they were all manufactured outside of Nigeria. For example, the solar PV, the solar thermal and the wind for the generating electricity and hot water were made in China; the solar street lights imported from the US, and the batteries used for energy storage made in India. In this case, there were quality issues with the technologies. The bottleneck in supplying small technologies led the GSWHP to use.

Less-experienced manufacturers of renewable energy technologies and standards, as these technologies were available in the local market at a low cost. The solar thermal was a passive installation for the provision of hot water for the residents. They were a substitute for both kerosene fuel and stove technologies in the apartments. The manager expressed the economic concerns of solar thermal for hot water and the other technologies that they used gas fuel for operation. Thus, the use of a water tank supplying hot water remained one of the most important options within the residential building. This case study sought to install biomass technologies, which can be an alternative for both the water tank and thermal gas technologies.

GOSPP used a solar technology option made in China, and the technology was developed as a pilot for a new model trading platform in rural communities. The off-grid solar technology was identified and built by Huawei to replace the use of fuel generators in the community. The technology deployed for energy generation in this case study is similar to that employed the other four case studies but to the USP case study. The technology was a completely off-grid energy system that comprised of solar PVs. This had a significant impact on the local generation system. There was also a battery system that benefited the houses. There were individual solar streetlights identified in this case study, using 80W compared to a normal bulb of 800W. The use of 80W bulb streetlights provided significant energy savings. The passive installed prepayment meters were a key technical issue, as the technology control brought into the solar system shut down the entire power system when the solar system was overloaded. A meter was installed in the home of each resident who was entitled to use the power system, yet they waited to start using them. IRENA, (2019) identifies that there are sustainable technology challenges and a need to focus on more active and flexible management technologies. This case study could deploy several low carbon distributed energy technologies in the community such as wind turbines and biomass, as small-scale energy generation systems for use day and night. The installation of solar PV capacity needed to be increased to meet the need of residents loads. Connecting more loads cause the power system to be weak in operation. This issue was not related to the quality of the technical installation because the main components of solar technology used in this case study were developed through Huawei's standards and specifications. The technologies such as meter installation are important aspects to help in managing and delivering sustainable energy.

DIREP used a range of renewable energy technologies such as a biogas digester, wind turbine, solar PV and solar thermal for the different energy activities within the community. Some of the technologies presented localised difficulties for DIREP, due to poor manufacturing and inexperienced developers. The quality and efficiency of the materials used to develop these technologies were the key issues. The biogas digester, woodstoves and solar thermal were manufactured by new local developers. It was noted that these developers used low-quality materials. It was also found that some installations were brought from the university, where the students engaged in creating new innovations. The bottlenecks seemed to be the main issue due to the limited procurement and delivering processes and the use of substandard materials for the developing technologies.

Of the 200 woodstoves that had been delivered to community homes to test research innovations, the majority were broken. The model sought to improve the residents' use of energy in their cooking. The biogas digester was a $20m^3$ fixed dome installation developed for cooking gas, but it had limited performance capacity compared to a modern anaerobic digestion plant. Its installation was a typical traditional design, developed by using concrete, pipes and airtight containers constructed from mixed stones and cement. The issue identified from this technology was that the gas fuels generated from the collection system leaked. Furthermore, solar PV and wind systems were made outside Nigeria. The solar components including PV cells, an inverter and charge controller were made in Germany and the wind technology originally came from China. The solar panels did not perform well, and the wind turbine was not able to produce the actual outcome specified by the developers. There were issues of weather-related to the area where the wind blowing in the area constant strong, but also technical standards in regulating to import renewable technologies in the county consider as another issue.

These technologies were a small scale of distributed energy generation systems, they have more adventages for rural and urban communities compare to grid-tied power plant systems, which would be used to deliver electricity through transmission and distribution lines to the resident's homes. The systems could possibly develop some delivery issues due to the lack of experienced management such as installers and energy planners, the technologies ended up being delivered incapable of operation. It was noted that all of the case studies preferred to use solar installations, although some of the cases installed wind generators instead of hydro, biomass, and geothermal technologies, which were less used in the communities. Each of the four case studies used solar PV, but case three and five integrated multiple technologies. Case five installed solar, biomass and wind technologies, while case three used solar and wind technologies. It was noted that all the case studies deployed renewable energy technologies for energy generation, but the quality of their performance varied in the production of energy due to the different capacities and quality of components installed for the power energy systems.

5.7 Capacity Generation

Community energy scale needs to be provided in order to improve the quality of life of community residents.

Generation capacity that enables and is capable of powering community residents drives energy systems' performance. This assumption covers issues related to the generation capacity provided to the energy users, where the residents provide an energy capacity to meet their energy demand so that the energy system remains resilient and reliable. The selected four cases in this research had different generation capacities to deliver energy to the energy users. This compares with the other case studies as their generation capacities seemed a barrier to the project progress. The limited size of the installations might hinder the performance of the energy system.

USP provided sufficient energy capacity to deliver electricity for the Water Board's activities and the residents around the power plant. The power system had enough installation capacity and provided a reliable energy supply for the users' demand. This case study had a high electricity generation capacity. The generated capacity was found to be much higher than the energy users' demands because more than 3,695 solar panels were used to generate over 1.2 MW a day. The Water Board and the energy beneficiaries used about 900kWh. In this case study, an excess of generated electricity seemed to bring economic opportunities. However, localised difficulties to sell electricity through the grid connection gave the Water Board an issue in the energy market.

GSWHP used micro renewable technologies mainly from the solar and wind installations generate energy. The generation capacity was found to be fairly allocated to the residents. GSWHP was able to deliver the total capacity from both installations. It is found about 148 solar panels were used to deliver 40 kWh, along with ten small individual wind turbines with a capacity of 15kW. The developers estimated how many units of energy the residents could possibly consume in the building. The flats in the building were designed to use an average of 4kWh a day. The generated electricity given to the residents was managed through timer devices reducing energy consumption. Many of the appliances in the houses consumed a low amount of energy. This helped maintain the small capacity energy GSWHP generated. The residents used electricity for a few hours a day between 6 pm and 11 pm, which is an important issue that enables reliable energy for the residents.

GOSPP used the installation of 160 solar panels to generate 150kWh for the community. The actual energy that should be delivered to the community was found to be a vital issue that needed to be overcome in this case study. It was noted that the entire community did not have the opportunity to connect to the electricity only hundred residents in the community were selected to use the energy system as a pilot off-grid solar project to be tested in the community. A little less than 50 households were selected for sustainable energy use because the energy capacity scale given for the selected community members undermined the power system. The solar system encountered difficulties at a different time as the capacity of the community' appliances was not accommodated in the generated power supply. It was estimated that the residents used less than 2kWh for their appliances.

DIREP identified the same issues with generation and distribution capacity as found in the GOSPP case study. The energy generation capacity was unsuccessfully designed according to all of the community members. The residents thought that they would use electricity to light homes and local economic activities such as drying agricultural crops. But the installed energy capacity did not provide enough energy to use in their homes due to the small scale of the installations. The DIREP used 60 solar panels that generated 10 kWh and a single wind turbine generating 4kWh. The total generation capacity provided in this case was 14 kWh. This was significantly lower than the community energy demand, which meant that the delivery of energy was limited to all residents.

The differences in generation capacity were identified in the four cases, but in some case studies, the size and scale of the generation capacity was the key challenge as this was below the actual capacity that the community residents needed to consume. Case two used the generation scale where the Water Board sold the excess generated electricity to the market. The installed capacity in this case study was not an issue as in the pilot case study as several hydropower turbines were installed and the generation capacity that the management delivered to its customers was surplus. However, in case three, the residents only used the electricity for home activities, not for the business thus the residents did not need as much installed capacity as in cases four and five required. Cases four and five both had communities with more than 1,000 inhabitants, the electricity given to the communities to improve wellbeing is a key challenge. It was found that the communities ran their businesses by using fuel generators or other means of resources rather than the renewable energy installed for use in the communities, as the installed capacity was not having capable of powering their businesses.

5.8 Operation and Maintenance

The operation and maintenance of community systems require the key issues of resources and capacity building, including schemes and financial support, training skills and community engagement.

For the tasks related to the operation and maintenance of energy systems, the management energy group played an important role in ensuring the systems' ongoing operations and maintenance based on the standard level of system performance. Maintenance management refers to the people who are responsible for ensuring ongoing community energy. Chua, Zubbir et al. (2018) mentioned maintenance tasks and activities such as repair and replacement, plan and budget, system performance and monitoring systems for highly sustainable installations. In the case studies such as pilot case, the tasks were identified that delivered long-lasting energy systems (Wong and Baldwin 2016). The pilot case study (PSHPP), which had departments for ensuring project maintenance and operation at the same standard as hydropower system their tasks are classified as an optimal activity, so the maintenance and operation tasks in this case study can be compared with the other case studies.

USP used a formal structure for operational and maintenance as in the pilot case study where full robust quality assurance in the operating system was identified with high level of competency, technical and operational capabilities are found available. But also, in this case, study, management and operation was a shared structure. The management of maintenance was created prior to USP implementation. The Water Board had organisation structures that maintained technical and administrative responsibilities on the water treatment premises. When USP was dedicated to the organisation, the Water Board management provided solar panel cleaners and people to cut the hedges around the power system. The Water Board interacted with DISCO in terms of maintaining all the distribution grid networks and supporting equipment technically within the project premises. DISCO was officially introduced to the project to participate and promote the development of the grid-connected PV system. DISCO was in charge of distribution energy when generated electricity reached to the grid. The local government through the local revenue office also controlled the Water Board's spending executing the costs required for the project activities. The USP operation system required high-quality competency supported by the relevant organisations, which facilitated distribution performance to sustain operations and compliance with the delivery of the generated energy. It was identified that the issues of measuring and tracking energy from the distribution grid reverse power flow were still difficult. However, the USP was neutrally operated based on practical training received by the personnel and secured by using the verification certificate as the Japanese government commissioned the project to operate according to the standards for project survival.

GSWHP established internal and external organisations for project operation and maintenance. There was evidence in this case study that the GSWHP's components were delivered from the external organisation and had warranties to ensure safety and reduce risks. There were a number of internal management personnel involved in the GSWHP including investors and shareholders, and casual members monitoring the system and the budgeting expenses. They also delivered important tasks such as accounting and billing for energy using a metering system. The management was able to communicate with energy users through weekly reports. This case study had a robust quality operation and maintenance as a result of the management divisions for the system, but it was not optimal as in the PSHPP and pilot case study due to the technical issues of efficiency and energy delivery from the solar and wind generation technologies. GSWHP needed to address the technical issues to comply with solar installation codes and standards. Some of the project equipment such as solar panels and the wind turbine tower, which could function for up to three years was broken. The energy storage system (batteries) was also seen to be repaired in order to recover its discharging capacity.

GOSPP was underperforming because the community that could be operated and maintained the solar system was weak. GOSPP was built with no specific management maintenance as it founded in the pilot case study, that ensures the system ongoing operation at a high-level performance. The project did not have a structure for supporting or generating revenue Huawei was in control of the general aspects of the project and owned technicians and engineers helping the system. The experiences people and skills work within the community for the solar power noted in this case study were unavailable. GOSPP relied on the people and technical engineers from the Huawei company to take the tasks of monitoring the performance of the solar system. The community energy users were founded that they used fewer hours for energy consumption due to deficiency in the delivery of energy. GOSPP was designed with a metering system to reduce the cost of management and safety of the system, however, the meters installed were founded not operated. GOSPP required to improve for increase the lifetime and efficient energy delivery.

DIREP showed that operation and maintenance were underperforming. Some parts of the project such as wind generator had stopped working due to limited capacity and support for the generation systems. The solar PV installation was found to be neglected, although it worked. The management for the system was mainly preventive operation and maintenance due to the lack of capital expenditure by DIREP. The communication gap between the community energy users and the administration that monitored the installations was significant barriers to the progress of the project. Due to this problem of lacking structural development in this case, maintenance and operation were not adopted and shared responsibilities were not provided for the community energy services. The coordinated approach used between the SERC, the Sokoto state government, and the energy users was insufficient for the maintenance of the system standard as it found that the solar panels and wind turbine being abandoned. The support obtained from the Energy Commission was suspended, when the issue of operation cost was originated. The main selected cases show that operation and management were less optimal with pilot case management.

The case studies discuss the importance of technical designs and maintenance such as quality and competency was found in the pilot. The robustness of configuration and maintenance was noted in the USP, but the Water Board was dependent on the DISCO organisation, which failed to provide measurements for distributing energy capacity. For GSWHP delivered the management skills needed in operation and maintaining a solar system but were unsuccessful in delivering the regular basis of solar PV inspections, that might lead the underperforming of the system as a result of the failure compliance with solar standards.

Financial barriers were found in the GOSPP as the same issues in the DIREP, both managements had limited support to manage the installations, the community engagement for operation and maintenance activities were not structured, and these cases needed to build technical capacity as well as training local technicians to ensure effective management. This important issue is elaborated by (Sullivan, Pugh et al. , Olanrewaju, Khamidi et al. 2010) as they highlighted the key factors that include technical and administrative actions that ensuring the elements and items in the energy system are able to function and perform in a satisfactory and acceptable standard. Nilsson (2009) identified two approaches to resolve difficulties of the energy system in terms of maintenance management, keeping a system sustainable; firstly, qualitative approach focusing on reliability issue as structuring and planning maintenance and the second a qualitative approach that indicates in relation to preventive maintenance through total maintenance, operation cost and system reliability. These approaches could be the importance of structured maintenance ensuring reliable community energy system.

Therefore, in the cross-case analysis, there is a need for management structures to support ongoing operations for the performance of the energy generation system. The structure can be a governance system of coordination and shared maintenance responsibilities, providing technical and non-technical support during operation and management.

5.9 Energy Users

Sustainable energy improves the wellbeing of energy users.

Community energy provides significant socio-economic as well as environmental impacts.

USP showed a number of benefits for energy users when the project started operation. USP provided multiple effects as a result of sustainable solar generation. It was found that the users, Water Board at Water facility, suffered substantial air pollution from fuel gas generators, before the Usuma solar installation. The project manager stated that reducing the amount of carbon being released into the atmosphere provided environmental benefits for the FCT population. There were positive impacts identified by the project such as energy bill savings and free electricity for the nearby residents. The project's owners appreciated the project performance. This case study project is built based on the purpose of quantitative effects for the realisation contribution of energy acces in Nigeria.The development plan and energy policy in relation to access to energy in Nigeria is understood the general population are the need for Japan's development assistance. The decisions were made from the stakeholders both the government of Japan and Nigerian government, who plans to achieve the goal of installed capcity of clean energy power generation. Therefore, the electricity from the solar power generation systems will expect to contribute energy supply to approximately the lives of 40, 000 households because the quantitative outputs of solar PV expect from the project around 1.459 MWh. There are also alternative lifestyle for community members around Usuma Water Board, the beneficiary of this project to one side of Usuma Water Board treated services for potable water by the solar PV supplying to the entire Federal capital territory Abuja, the people live close to the project benefit by supplying the reliable electicity. The electricity will socially help the community people to study at homes or schools. The Usuma Water Board saved on energy bills that used to come to nearly N17,700. It also secured stable and reliable electricity for full-time work services without any interruption from the utility company. The Water Board no longer had to pay electricity charges during the daytime. They sought to find a means of generating electricity during the night time.

GSWHP provided evidence of benefits. The project seemed to be an initiative with future consumer investment. This means that the users were expected to benefit from massively reduced energy charges in the future. The maintenance of the GSWHP is not complex compared to generator machines, according to the resident participants. The system required no rigorous maintenance and it had low maintenance costs. The manager identified that these were the most important aspects that encouraged such installations. They supposed that the installation of the solar and wind technologies was tied to upholding the system as the users were not experiencing any transmission losses. The project provided social investments in renewable energy technologies such as solar PV for electricity generation and solar water thermal installed for heat generation for the community building. It was identified that the project was sustainable for the residents and the residents confirmed the convenience of the energy system. With access to clean energy and reliable power, the apartment residents were able to benefit from a better life.

GOSPP also showed the existence of community energy benefits. The communities in this case study had been without energy access for a long time but due to the project installation, the project was the first off-grid connection in the community. Almost 100 people were connected with the project, and they were provided with free electricity for their appliances. Communities benefited from security streetlights daily for 12 hours from 6 pm to 6 am, helping them to feel secure from several criminal activities that happened during the night. The community changed its mode of energy consumption of using kerosene and candle lights when the small-scale solar PV system was installed. This improved the health of the people living in the community. This outlines that the impacts of relationships between HTC and Ministry of Power contributed to the factors of financing the solar system.

In the DIREP there was free electricity for the communities, provided through renewable solar PV and wind technologies. These technologies may provide better air quality compared to gas generators. This case shows that there were multiple community benefits. In the initial project implementation, the traditional wood stoves and lanterns were replaced in households with improved wood stoves and electricity. The biogas system, the water heating, the improved wood stoves are the key part of infrastructural benefits for the community. But also, the streetlights installed in the community are expected to provide lights and security at night. However, many community households were not connected to the hybrid system and they have to use lanterns to light their homes. There was division in the community over the extent of the project's benefit; some families were given woodstoves, while other families were provided with electricity, but one of the community leaders benefited from both the cooking stove and electricity.

The case studies show that community energy brings benefits, particularly when the community energy project focuses on supporting or implementing renewable energy initiatives linked to sustainable energy consumption. Each case was identified as the use of solar power in terms of the concept of renewable technology initiatives. Solar generation was provided without the issues of noises and air pollution so the energy users could benefit from improved wellbeing. Case two was a practical community power project with public ownership and participation in the generation of renewable energy in the interest in climate change. Case three was related to community social enterprise where the goal was to make a profit. Case four was formed for special supportive treatment of self-energy sufficiency. It is important to note that in each case there was an indication of a lack of community energy power where the communities owned and participated in the production of sustainable energy such as community engagement and empowerment.

5.10 Summary

The cross-case analysis identified several thematic factors and issues as important aspects of the development of community energy. These themes are summarized as governance energy, technology and infrastructures, finance and energy user's management.

Governance energy - community energy project is developed through a partnership that determines how decisions are made. Most of the case studies the formal structures are established through top-level governance of energy (Federal government agencies, e.g. energy policymakers, financial institutions) to develop the processes and technical issues of the projects. it found that there is a lack of information between the top-level governance the energy developers and energy users. However, the network structural approach on local and community governance of energy can be contributed more to the development of community energy. This approach can be accommodated as a meso-level perspective, that sighted (Seyfang and Haxeltine 2012), indicating the presentation and relationship between the various level of state actors and non-state actors in the system.

Financial models – there are multiple capital sources used to support the development of community projects, particularly, for the initial and development phases. Such a source is needed in terms of financial support and incentives to sustain the operation and maintenance of the systems.

Technologies and infrastructures – there is evidence of renewable technologies in the delivery of sustainable energy in the cases, but the capability and capacity installation are the key issues. The community energy organisations can enable the installation of technologies innovations such as smart meters, electricity storage, and small-scale energy generation systems that make the local generation and business models.

Engagement - the cases need to address the issues of public participation and engagement where the communities can take part and influences the energy processes.

5.11 Conclusions

This chapter concludes the issues related to the research goal that is to explore the factors of sociotechnical elements drive as the key factor for the adoption and implementation of community energy projects in Nigeria. The socio-technical aspects of community energy are complex issues, especially by studying the factors, including not only financial issues, operational systems, innovative technologies, but also composed issues of relationships that constitute community energy projects. There are a number of issues this research needs to explore in addressing the delivery of community energy, management and systems operation. What this chapter enabled to identify is the number of challenges and barriers regarding lack of incentives and funding programmes particularly from local government to promote the uptake of low carbon distributed energy systems. There was a lack of skills and limited capacity personnel concerning the communities actively engage in the maintenance phase of energy systems.

Chapter 6 : Conclusion

6.1 Introduction

6.1.1 Summary of the Thesis and Restate of Research Questions

This chapter summarises the empirical contributions that this thesis has made by drawing on the research questions around the drivers of motivations, technical solutions, responsibilities, transparency roles and expectations from the energy management and users, and the issues of financial sustainability, which are summarily as the factors of delivery and operation of the energy systems that are needed to address the development of community energy projects in Nigeria. It also reflects the key theoretical aspects by understanding the nature and problems of community energy through the broader literature, as used to address the complex systems of community energy. The systems that comprised the interconnections and multiple aspects are structured around several actors and physical elements that interact together in different ways in the development and application of energy systems, which focused on the implementation of community energy systems. Therefore, the research questions were formulated fundamentally to achieve the research aim and objectives. The aim of the research was to develop a means by which socio-technical factors of low carbon energy generation can be established in peripheral urban communities in developing countries.

The thesis was developed through an investigative study and it has established the factors that drive the emergence of community energy particularly for the specific issues such as skills and knowledge used in developing solutions to the delivery of community energy needs. It also addressed the question of barriers in terms of technical and social aspects including the monitoring and controlling issues limiting the potential of the development of sustainable community energy in Nigeria. The thesis has also addressed the importance of community energy systems and its benefits in Nigeria particularly for sustainable energy systems. The research identified the key drivers amidst energy poverty and climate change, which are important issues in Nigeria due to the fact that the system the Nigerian energy sector is very reliant on fossil fuels. This has caused high air pollution and contributed to green gas emissions.

The thesis also explored the issues of the reliability and availability of energy services in peripheral urban communities; these problems have arisen due to structural governance issues of the energy system. It is also important to address the complexities and constraints due to the high cost of the infrastructure and the fact that the traditional electricity grid is challenging to design, manage and operate for millions of Nigerians. The research identified successive efforts by the government to install large innovative technologies such as thermal gas plants and large hydro powers to increase supply in the national grid. This study indicated that the governance energy position, a central management approach, was controlled by political interests and the government strategies used for the management and distribution of the energy system remained relatively poor for peripheral urban areas. It was difficult for them to benefit from the available energy services due to lower national priorities. The research acknowledged the socio-technical elements of low-carbon systems managed by communities, the extent of community-based energy models and the emergence of local energy companies in Nigeria in both rural and urban areas. These models are used to provide sustainable electricity generation and to promote and provide access to reliable and affordable energy.

The thesis outlines that multiple stakeholders and capital sources were key factors in the delivery of community low-carbon energy. The research indicated how the wider aspects of socio-technical approaches need to be applied in Nigeria. The multi-level perspective identifies the implications of processes, finance, community engagement, and the technical solutions employed interacted with important factors such as actors, communication issues between the different levels, policies and regulatory issues for community-based energy systems in Nigeria. The combined elements provide a better energy system for the community energy model, which facilitates sustainable and local economic development.

The thesis evaluated models for community-based energy systems in Nigeria. These were developed through investigative research for comparative cases study, which identified the factors that were drivers for the emergence of energy projects and a number of factors that could be limiting the progress of sustainable energy. The main aim of this thesis was to answer questions about the drivers of and barriers to sustainable community energy systems in Nigeria.

The findings from the case studies indicate that the initial capital for the development of the project is an important factor. There was evidence of financial sources used for project procurements, processes and installations in the case studies, such as in the USP case study, where the project installed 1.2 MW of solar energy capacity to reduce the impact of climate change. This was driven by the Japan International Cooperation Agency, as a result of climate fund schemes. This case study also identified that funding for the operation and maintenance the installed energy system was one of the key barriers to the progress and development of some of the projects. The Gnami Off-grid Solar Power Project was developed by independent developers, the Huawei Electrical Company, to introduce a new solar off-grid model in the community in order to maximise the efficient use of local resources and to promote community-based energy systems. However, the project could not generate revenue to finance the operation and maintenance works. It was noted that the project sought to obtain other capital sources to cover operation costs.

The results from most of the case studies indicate that there were efforts made by governments and institutions in the development of projects. An example of this is the institutional capacity requirements for direct access to funding, as in the Danjawa Integrated Renewable Energy Project case study, where the multiple efforts and decisions were important. This was driven by the coordination of national efforts by the relevant government agencies in Nigeria to address energy issues such as climate change and also to increase the deployment of new innovations and technologies such as small-scale distributed energy systems and energy storages. This was done by introducing new actors and players into the sector. The efforts from the institutions involved many decisions from the Energy Commission, the Ministry of Power, and the Ministry of the Environment often coordinated by the Ministry of Planning.

The decisions in this case study involved a wide number of stakeholders who participated directly and were also involved indirectly in facilitating the delivery of the project. The institution was constituted and organised by the Nigerian federal government. It comprised the Ministry of Finance, Ministry of Education, Ministry of Science and Technology, and the Energy Commission Nigeria. They provided project strategy guidance, coordination and management. Their involvement became stronger due to engagement with the World Bank in negotiations and the promises of credit to fund the project. The capital was given as a grant to members of the International Monetary Fund (IMF).

The cross-case analysis highlighted one of the barriers to the sustainable incorporation of community energy structure: a lack of detailed understanding of effective local energy governance. The research found that the structure of governance, both formal and informal at the local level did not help to provide better decisions for the supply of technical aspects. In some of the projects sustained operation and maintenance were undermined as the projects were left to the community members who did not have adequate technical knowledge and training to manage the system. The Gnami project was not able to deliver a quality installed capacity for the community, due to a lack of management and communication over controlling the technical aspects of the installed solar energy, resulting in the frequent failures of grid operation.

Important issues were identified with the use of renewable energy technologies, such as hydropower, solar PV cells and wind turbines, and which was the most useful across the case discussion, as in PHPS pilot case used hydropower to generate electricity for the customers, wind generators were found in both the GSWHP and DIREP case studies, while solar PV technologies were used in all the main case studies. The research explored the use of smart meters in the cases. The use of smart meters enables the development of active and flexible management and they to make local generation and supply business models viable. The roles of meter technologies in the selected cases studies were not developed in terms of revenues flows and scale in the energy system.

The resident participants could show a strong team commitment and dedication to community energy projects. They also provided incomes for the participants and developed their skills and knowledge based on the operation and practical management of the sustainable energy system. The awareness of the impacts of community energy initiatives was considered in the case studies. Relationships, communication and connections between communities and energy developers often failed and this affected the adoption of stable and sustainable operation of projects such as in GOGSPP and DIREP.

6.2 Implications of the Thesis Drawn from Practical Actions of Community Energy Systems

6.2.1 Implications for Practice

Through the case studies, the issues and factors that affect the real practice of community energy systems in Nigeria were identified. Portraying the responsibilities of stakeholders and governance at various levels of government is an important factor for the development of community energy projects. The research recognised that sustainable and effective supports for a community-based energy system can be realised through local, state and national commitment with the purpose of formulating policy tools and soft commitments. This attracts and provides signals to community energy actors regarding the detail of legal and technical requirements for establishing regulatory certainty.

In the case studies, however, the thesis identified a top-down process approach as stakeholders and actors such as the Ministry of Power, Ministry of Finance and Ministry of Environment were engaged in activities for the development of community energy. This technique was a key factor in terms of the delivery process, particularly at the initial and development project phases. The participant actors and agencies coordinated a number of events and visits proposing the implementation of renewable energy in Nigeria. They formulated the vital intergovernmental relationships to support certain aspects of the community energy projects such as funding resources and installation materials.

The research acknowledged that the decision made to engage the actors in community energy projects was formed out of political interest, as opposed to national and sustainable energy goals. The framework of national renewable energy and the energy efficiency policy of Nigeria have been influenced since 2012 by the climate change policy and strategy to achieve basic universal access to energy, in line with the International Energy Agency policy. The decisions over energy issues remained a matter at the national level while local governments were identified as passive in their roles and responsibilities especially in preliminary investigations and work in relation to community energy projects.

The important roles and responsibilities of the local government were identified for shaping various aspects of energy demand and generation, using energy programmes, renewable technologies, policies and practices. They could engage in the energy issues in the way they developed low-carbon energy systems and used regulation to influence energy production and efficient use of energy in the community homes. This enabled the implementation of the technologies that stored electricity for the community.

There are many measures and incentives used to develop local energy systems, including community energy projects, through small scale renewable adaptation scheme and energy efficiency programme for the development of sustainable energy. The research demonstrated a lack of specific local government focus and responsibilities for energy programmes. This was found to be a barrier in the contexts of the cases studies, as the opportunity for the residents to benefits from energy strategies were limited.

Adopting intelligent management for sustainable community energy systems is an important issue that the research considered as part of the wider sustainable energy systems. The use of smart meters combined with renewable energy technologies in community energy projects provided the multiple benefits for both contractors and energy users: generating revenue flows, reducing energy consumption, saving energy bills and improving quality of energy distribution while the sustainable energy system is developed. However, the research explored many issues associated with the use of smart technology in the case projects where the lack of a proper technology hindered the impacts of the sustainable energy system. In the pilot case study, producer-customer conflict was found where the customer refused to accept the total energy bills because of miscalculations due to the use of traditional analogue meters to provide detailed of information and energy data to the customers. The issues of quality operation of the system, consistent and reliable energy and revenue generation for the delivery of energy services to the community were not found in the case of GOSPP.

6.2.2 Implications of the Research

What are the best processes and impacts of community-based energy projects in the delivery of low-carbon distributed energy in Nigeria? This question could be answered through the following recommendations, but also by overcoming the community energy barriers, which prevented progress and limited the development of the community energy projects (case studies) discussed in Chapters 4 and 5.

- From the case studies analysis, it identified that the structure of developing community energy projects in Nigeria was not systematically established to keep projects stable. In the case study 4 and case 5 there were no legal frameworks for community-based energy system and the institutional stucture to form a local entity where it is possible for local government and communities to work together as governance system to promote sustainable community energy was not adequate. Community energy projects should be built through effective ownership models. This would enable local community members to participate in low-carbon energy systems and secure the range of benefits including but energy generation, community self-sufficiency, providing local capacity and creating social capital. It is also important for these communities to utilise a different model of ownership, which comprises a mix of community and public ownership or a commercial business entity. Certain schemes need to be provided in order to promote effective information, the exchange of ideas, involvement, and responsibilities for residents in ensuring technical and financial measures for the community. A partnership between community energy organisations should be facilitated in order to allow community energy systems to progress. The relationship should provide the procurement and processes necessary to deliver community energy.

- Community energy systems should be developed through the integration of a local planning system where local plans can support the system, thus mapping and creating opportunities for community energy deployment. This will provide a roll-out of local energy activities. The project approved by local planning would be more accepted and have a few issues in terms of obtaining land ownership compared to informal community energy projects. This support can help local members to develop the sustainable community energy projects in Nigeria. The research identified that each case study established, through the participation of external organisations such as NGO, government agencies, for the development of renewable energy projects. The case study results indicated there were no evidences of local government involvement participate under a specific framework, which would regulate and facilitate the production and maintenance of the projects. USP, GSWHP and DIREP case studies, as examples, were built through federal govement agencies the decisions from these government agencies were final, while the communities and local government were passive, had little knowledge of energy systems and were reliant on inter-governmental partnerships. A down-top policy should be introduced at local government level for a change to programmes and policy, in which the framework should be developed to mandate community participation in decision-making, focusing on the key issues of environmental impact assessment, empowering capacity building and promoting economic development. This could provide a community with specific consideration for tackling the challenges of energy issues more effectively than government alone. This is, in turn, involves communities in the issues of national politics as the funding of community energy project can be more readily approved.
- Encouraging renewable energy for communities provide small and inter-mediate businesses with the rate of tax relief in order to invest in community energy. The national government of Nigeria should modify and extend energy policies to comprise local investments in community renewable energy where the policies and rules put on businesses for low-interest rate relief. The community energy businesses must be provided with a mandate for the rate relief to match investments over a long period of time. The issue of energy access still is still concerned in Nigeria where the use of traditional biomass, gas and oil was found as an evidence across the case studies, due

to the increase of population, results in the growing impact of climate change. Community energy projects are the response to the issues of energy access and climate change by the adoption of renewable energy. In case studies such as the research found there were need for financial motivations and energy infrastructure for the project to be the consistent and sustainable energy operation.

- Effective local energy governance should be developed in the community by establishing the relationships and networks of communication and interactions between the residents and other actors. This facilitates important issues, for the community energy system, such as the transfer of information and technical and financial support. There was complexity issue in Danjawa community energy project during the development process. Federal government and World Bank established rigid requirements to fund the project, that made the project developers to deliver the generation capacity the community needed. The research found that there was a lack of delivery transparency, expertise, and management. A poorly planned community programme made sustaining the project more difficult across the case studies. There was no a structure for the community-based energy system, that deals with the project. Therefore, community engagement is not in the community. There should be an institution in the federal government that uses a strategy for identifying local structures, informal institutions and peripheral actors for various local energy initiatives in a particular place. This approach would allow multiple capital sources, local government, research and a knowledge hub used in the UK, as well as allowing intermediary organisations to come together to recognise important opportunities for supporting the social infrastructure of community energy. The community energy model should be created financial sustainability by introducing a recyclable loan fund to encourage investment in community renewable energy. Support has to be demonstrated for energy projects through relationships between local people, and social investors and community energy.
- Residents and community members should be provided with effective training and workshops by the developers who introduce innovations such as smart meters for trials. This involvement and engagement between the communities and the developers provide the means of learning about practising new technologies. In the case of the Gnami community energy project and Danjawa community energy project, case 4 and

5 respectively, they were all developed as community energy projects without effective management, with inadequate community energy training of how to use technologies, and the communities needed the skills that helped them to operate and maintain the projects. It is important to implement community energy projects through incentives with high-quality materials and skills. This could be a challenge for the delivery process and for the installation materials used for community energy projects. The developers and installers should design and deliver high-quality technologies and services, that can sustain the use of the system by community users for long-lasting operation.

Therefore, this study enabled to address solutions of community energy problems for improving the energy access, but due to the related factors of complexity sociotechnical issues, which can be explored the research needs to cover. The study can further investigation using approaches that actively engage communities in practical energy action for the development of community low carbon distributed energy systems.

6.3 Original Contribution to Knowledge

The research has two areas of contribution: contribution to knowledge as the application of potential community-based energy systems makes an important contribution in developing countries. It also contributes to the literature by providing a methodological basis, that has unique contexts and settings for the research. It also contributes to future research on community energy.

The thesis has employed a specific approach to community-based energy systems, which focuses on socio-technical factors and issues affecting community energy systems, that need to be implemented in Nigeria. The approach investigated the various elements of the socio-technical system from stakeholder, financial sources, and governance to energy management for the delivery and operation of sustainable community low-carbon distributed systems. Much research into community-based energy systems has been conducted for developed countries to tackle the issue of climate change (Hain, Ault et al. 2005, Maruyama, Nishikido et al. 2007, Seyfang, Park et al. 2012, Anda and Temmen 2014, Wirth 2014, Bollinger, van Blijswijk et al. 2016). Some studies have contributed to the use of renewable energy technologies (Wilkins 2010, Uyar and Beşikci 2017), and many of these have focused on a small scale and decentralised renewable energy to address traditional energy systems. Systems have been changed to employ the community energy approaches at the local level, but little research has been carried out to investigate community-based low carbon distributed energy systems in developing countries. There is no evidence of research undertaken for community-based energy system in Nigeria with a specific focus on the use of low carbon distributed energy systems to address the issue of energy access. Therefore, this research contributed to community-based low carbon energy distributed systems in Nigeria.

The research contributes with a conceptual framework built from different works of literature (Geels and Raven 2006); (Raven 2004); (Raven and Verbong 2009); (Verbong and Geels 2007) for understanding the key factors related to community energy systems in Nigeria. It adopted the framework and employed a combination of theoretical issues that comprised the elements of socio-technical systems not only those entailing new technologies but also changes to user practices, new market orientations, changes in policy and cultural meanings (Geels 2004). In addition, the framework was applied specifically in the community energy context in Nigeria so that this approach could determine the particular practices employed and provide a full representation of community-based energy systems.

The research identified that the approach is useful for understanding the delivery and operation of community energy projects as a socio-technical complex elements problem. Community participation in the Gnami Off-grid Solar Power Project, although it was minimal, capital grants and loans in the Usuma Solar Project and the Guzape Solar-Wind Hybrid Project, delivery of the installation materials in the Danjawa Integrated Renewable Energy Project, and operation and maintenance of the energy system in the pilot case study.

The research used ideas and applied these to physical energy electricity systems, dealing with regulatory issues within a community energy system that was interrelated and interconnected for the implementation of community energy problems. This develops the concepts that can be used for evaluating the complexity of the socio-technical system of community energy needed to apply in the case studies for opportunities to better understand practical systems for community energy in terms of the delivery process, technologies and management system.

6.4 Research Limitations

This research has its unique limitations, which comprise the complex nature of the socio-technical elements of community energy systems, and the challenges associated with data collection from individual cases for interpretation. The research process was systematic. The researcher established the relevant literature, which was reviewed in terms of energy issues, such as an increase in population; energy consumption; fuel poverty; developing a sustainable community and the key theories and concepts used for frameworks of community energy. These were discussed by presenting the research questions, which were formulated to answer the research aim and objectives. The selected case studies and methods of data collection and analysis were explained and justified to enhance the findings of the research. However, the research data is limited to providing the actual issues and factors related to community energy in Nigeria due to the modest resources and data available at the time of data collection for this research. It is possible important issues, were not identified, such as drivers and barriers to the evolution of community energy in Nigeria.

The research adopted a case study approach that used the complex elements of a socio-technical system for understanding community energy systems. These elements were adopted by using the different concepts of technical, financing and organisational stakeholder strategies, facilitating the delivery of community energy. Thus, the research is limited to examining detailed information on these complex interrelated elements and issues in the case studies.

There was a need to access adequate data on each case study and its contextual issues within the boundary of the research; it was, therefore, difficult to demonstrate realistic pictures of complexity. In the USP case study, for example, the solar project had been completed when the research was carried out during data collection; this limited access to some stakeholders, particularly Japanese government representatives, and was an obstacle to identifying the full range of benefits of the creation of social capital and the financial benefits of community energy. Although documentation was provided, in the Gnami case study, site visits were not allowed by Huawei. The project developers refused to answer a large number of relevant and appropriate questions on the key mechanisms that were identified by analysis of the qualitative data obtained from the community stakeholder interviews and documentary analysis. However, the research findings were presented and discussed using themetic analysis to draw conclusions regarding community energy systems, through different contexts of community energy.

The research also encountered the issues of scope and boundary but due to the limited number of uniformities of operation and practical community energy projects, the study selected some of the urban community energy projects. Data was collected from the Blue Camel, which is a type of urban community, whose contexts and setting contradicted with cases four and five. Finding suitable existing and operating projects was a challenge. For example, community projects were found through the Rural Electrification Agency, which was established the complex issues of community energy, but when the site visit was planned to have a practical demonstration and understand how social interests are presented in the community areas, the cases were identified as impractical for data collection. This issue forced a change and new cases studies had to found that fitted the methodological principles and the investigation of the research results.

6.5 Reflection on the Research Process

Although the research started with a design science strategy, changes were made to the realistic approach through the academic research process due to the nature of the research problems. The approach that the research adopted used a decision that encompassed the philosophical assumptions and the rationales positioning this research. Thus, the research employed a case study strategy to study community-based low-carbon energy system. This is useful for a systematic research process that has the purpose of understanding, investigating and exploring the complex socio-technical issues and elements of community energy, i.e. a range of relationships and issues between energy drivers such as climate change, energy access and the delivery and operation of sustainable community low-carbon technology solutions. However, the design science may have limited the relationships and complexity issues of community energy and develop only a picture of community energy solutions.

The research identified a number of issues in the literature describing relationships, governance energy systems, technologies, markets, policies and regulations to address the energy issues of sustainable energy. In terms of community distributed energy systems, themes and concepts are used to highlight important points relating to solar and wind renewable energy technologies and intelligent management. This is particularly important in the housing sectors, where the community energy scale could be adopted to measure the usage of heating, lighting and cooling, which are the dominant activities for the development of local areas. It was found that sustainable objectives could not only address the issues of energy inequality and environmental effects but also promote community energy self-sufficiency. The research explored the important factors related to the motivation of local people to form a governance energy system to generate and use their own energy. It outlined that community energy is achieved through various relationships, that could be formed at intergovernmental and organisations levels for the implementation of community renewable energy.

As stated earlier, the research was developed through an investigation case-based approach and it provided the results using interviews, documents and observational data against the key propositions: around the governance of community energy problems, financial measures and the issues of technological and cultural use of energy. This approach was used to answer the question of what the drivers and barriers to successful community energy system are.

The thesis used a comparative case study design for four community energy projects selected in different regions of Nigeria in order to develop common issues specifically from the findings obtained in the case studies as the general conclusion needed to be drawn for the success factors of community energy. It considered the institutional factors around the delivery of community energy projects. It found different relationships between international bodies and actors, which were key to the decision to deliver the projects: the Japanese and Nigerian government solar renewable energy partnership project, which happened due to the commitment, connections and financial support for the installation technologies; and the Huawei Electrical Company and the Federal Ministry of Power partnership for the off-grid solar system.

The research found some failures in implementation and management that prevented consistent operation and maintenance of energy systems. It identified also the use of programmes such as subsidies and business loans for adopting low-carbon energy systems, training schemes and encouraging community engagement for the benefit of community energy users.

6.6 Further Work

6.6.1 Recommendations for Future Research

Focusing on the study of energy issues such as energy access, climate change, and energy poverty by solving the complex issues of community energy system, the case study approach could also be used to further the specific study of a local issues such as water, community waste management or drainage systems, by introducing the ideas of socio-technical elements in communities. Several methods and strategies are also recommended for further research; these could employ qualitative and quantitative methodological approaches with the aim of implementing a practical solution.

The research could use an exploratory approach to address socio-technical elements and the financial flows in the operation of business community energy models, where an action research approach could be adopted and uses as a practical method to solve a problem in a real setting. This approach expands the use of scientific knowledge and develops the competencies of social actors. It is an important issue supported by Creswell (2013), as a participatory researcher holds the position in which the research contains an action agenda for reform that can improve the lives of the participants. There are also methodological approaches such as the design science strategy, which could be used to study the complex nature of community energy in relation to its interconnected organisations, funding structures, management and resources.

The research could use this strategy as it has a great prominence, particularly relevant to academic research on practical problem whereby the researcher works collaboratively with community energy users to create a solution that has an effect on the environment. This means that It serves as an appropriate research method, which improves the applicability of the research as it focuses on improving the wellbeing and aspects of community-based energy systems. This approach may be applied to the design and development of a model of multiple variables for utility service companies in small energy generation, local heating and water systems. It potentially addresses practical problems and seeks to fulfil multiple community needs in a sustainable manner.

The research could be further extended through a network approach to study the local governance of energy. Pluralistic methods using a network survey and interviews could be potentially based on gathering data for mapping the relations in terms of information and communications, capital sources, as well as specific structures, own for the local energy governance. The approach could be applied to study the different institutions of actors and policymakers for a better understanding of their functions and supports.

On the other hand, research may be employed with a quantitative technique to study the financial issues related to monetary issues and quantities of resources in the context of community energy systems. The community business model, such as consumer energy behaviour assessment and the financial value approach, is important for analysing the quantitative aspects of financial markets, and the socio-economic impacts of community energy. This analysis could be facilitated to propose an accurate model where community energy can be operationally viable. It can also be used to assess the environmental impact and determine the level of GHG emissions. This solves an important issue by drawing more accurate conclusions for policymakers and markets for sustainable energy.

Appendices

Appendix 1: Participants Information Sheet

Title of the Research: AN INVESTIGATION OF MODELS OF COMMUNITY-BASED LOW-BORBAON DISTRIBUTED ENERGY SYSTEMS IN NIGERIA

This research is focused on the applicability of community-based energy projects in Nigeria. The aim of this research is to identify the processes and benefits of community-based energy projects, which deliver the low carbon distributed energy to the Nigerian energy system.

You are invited to take part in this research that I am undertaking as part of the award of a Doctoral Degree. This information sheet is designed to provide you with the necessary information concerning the research and your participation. The information will guide you to make the right decision concerning your participation in the research. There will be no material or financial reward for participating in this research because it is a voluntary exercise and the research will be conducted in English.

Do I have to participate?

Participation in this research is not necessary, it's up to you to decide to take part of the research. You can also withdraw from the research at any time you wish without being questioned by the researcher. If you require more information about the research for you to participate, will be provided to you. However, if you agree to take part of the research, there is a consent form which will be given to you, for you to sign.

If I agree to take part, what is the next step?

If you decide to take part in the research, you will be given a copy of the interview guide which will explain to you, the extent of your involvement in the research and the kind of questions the researcher intends to ask you. If you have any questions about the research, the researcher will be happy to answer you your questions. After all, the guidelines will be made in a convenient date, location and the time for the interview also will be arranged between you and the researcher.

What is expected of me if I take part in the research?

- Interviews - If you agreed to take part in the research, you and the researcher will agree on the date and time that is convenient for you to conduct interviews. The interview will be unstructured conducted in an open discussion and it is to express your knowledge of community renewable energy projects. It will not take more than 60 minutes and if necessary, the researcher may record the discussion if you agree. The purpose of conducting interviews is to tell a story about how the renewable energy projects come about and what are the processes of identifying a problem. Does this project networking with other intermediaries e.g policymakers, engineers, installers and shared with community energy projects and What are the personal motivates that led the stakeholders to come together to establish a project for community-owned energy

- Participant observations – the researcher will be participating in your organisational meetings, workshops and the project sites. In the case of your organisational activities the researcher takes the pictures at a project site or in the meeting and will ask permission to do so. The researcher also brings consent forms into the meeting to get a signature from any member that attends meeting agreeing that all responses are given in the meeting will be treated utmost confidentiality and will be available only to the researcher and supervisor of this research.
- Organisational documents - the researcher may request documents from your organisation in order to get a fuller picture of your project. This may include websites, policy documents, project reports, meeting minutes, for example.

Will my involvement in this research be strictly confidential?

The researcher will make sure that the personal information about the participants is securely kept for the researcher to adhered to the data protection guidelines. The primary data that will be collected electronically using your case study such as interview, documents etc., will be stored and kept on a secure password protected a computer that only the researcher and the supervisor can access for review. In case such need arises such names or personal details will be handled with utmost care and confidentiality. The participants will be handled with strict confidentiality during analysis, publications and write-up of the thesis.

The primary data gathered from this research will be stored and kept for 5 years after the completion of the PhD at the University of Salford.

What are the benefits of taking part in this research?

Your knowledge, experiences and perspectives, which you share with the researcher will play a crucial role towards developing strategies by which the low carbon distributed energy systems can be established in local community areas. Such contributions not only in Nigeria will help a those who live in the peripherical urban community in developing countries.

What is going to happen with the findings from the research?

The findings or results from the research that analysed and compiled is to develop strategies implementation for community-owned distributed energy systems in Nigeria. The findings will also be presented to the Nigeria government for implementation, will also be published in form of academic journals, paper presentations during seminars and conferences etc. for whatever the findings are used, the anonymity of the information will still be maintained.

Is there any reward for the participant?

Participation in this research is voluntary, therefore, there is no material or financial reward attached.

Additional Information

The researcher is a PhD student from the School of Built Environment, University of Salford. If you need more information or you have any question concerning this research or about your participation, please feel free to contact the researcher below:

Contact Details

Researcher contact

Mobile N: +44(0)7442772748

Email: I.A.Sadiq@edu.salford.ac.uk

Supervisor contact

Tel: +44(0) 161295258

Email: w.c.swan@salford.ac.uk

Hope you will take part in this research; your participation will be highly appreciated

Thank you for your time and cooperation.

Appendix 2: Invitation

University of Salford MANCHESTER
The Crescent,
Salford, M5 4WT,
United Kingdom
0161 295 5000
www.salford.ac.uk

Dear Sir/ Madam,

My name is Ibrahim Abubakar Sadiq a PhD Student from the School of Built Environment, University of Salford Manchester, United Kingdom. I am conducting a research on sustainable development focusing on the processes and benefits of community-based low carbon distributed energy systems in Nigeria.

The aim of this study is to investigate community delivery of low carbon energy generation in urban communities in Nigeria. The research is being supervised by Professor Will Swan and Dr Yingchun Ji.

I understand that you have an experience of *renewable energy projects,* therefore; your input will be of a great importance. In addition, I believe that your participation will add value to this research due to your knowledge, experience in this area. The Rural Electrification Agency has provided your details as a potential participant in the study and I would like to invite you to take part in this research. For more information please see the attached participant information sheet.

If you have any queries please contact me at the contact details below.

Yours sincerely,

Appendix 3: **Consent Form for PhD Research**

Please tick the appropriate boxes	**Yes**	**No**
Taking Part		
I have read and understood the information sheet dated ……/…../……...	☐	☐
I have been given the opportunity to ask questions about the research.	☐	☐
I agree to take part in this research. Taking part in the research will include being observations, interviewed, photos and recorded (audio).	☐	☐
I understand that my taking part is voluntary; I can withdraw from the study at any time and I do not have to give any reasons for why I no longer want to take part.	☐	☐
Use of the information I provide for this research only		
I understand my personal details such as phone number and address will not be revealed to people outside the research.	☐	☐
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.	☐	☐
Please choose **one** *of the following two options:*		
I would like my real name used in the above	☐	
I would **not** like my real name to be used in the above.	☐	
Use of the information I provide beyond this project		
I agree with the data I provide to be archived at the UK Data Archive.	☐	☐
I understand that other authenticated researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	☐	☐

I understand that other authenticated researchers may use my words in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. ☐ ☐

So, we can use the information you provide legally

I agree to assign the copyright I hold in any materials related to this research ☐

____________________	____________________	________
Name of participant	Signature	Date
____________________	____________________	________
Researcher	Signature	Date

Research contact details for further information

Researcher contact

Phone: +44(0) 07442772748

Email: I.A.Sadiq@edu.salford.ac.uk

Supervisor contact

Tel: +44(0) 161295258

Email: w.c.swan@salford.ac.uk

Appendix 4: **Unstructured Interview Guideline**

The proposed research aim is to develop a strategy for community-based low carbon distributed energy systems in order to increase energy availability and reliability to Nigerian energy systems. Nigerian government considers the increases of energy generation through low carbon energy are priorities in the days to come. The data collected from the interviews will help the researcher understands the current issues within the Nigerian energy system, critical success factors, and key issues and challenges. Furthermore, acquired data will help to develop the tool to improve energy generation and management. Accordingly, there are no right or wrong answers to the upcoming questions rather it is a matter of reflecting the interviewee's experience with the phenomena as they were conceived by him/her.

Your rights

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn or destroyed. You have the right to omit or refuse to answer or respond to any question that is asked of you. You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you may query the researcher at any time. The interview is semi-structured so questions may be related to your comments. However, the main themes that will be explored are as follows.

- How you come to be involved in the project?
- How did the energy project start?
- What do the other participants think of community project?
- What are the drivers of the energy project?
- What drove the community energy project?
- What are the project's aims and what does the project want to achieve?
- How does the project networks with other energy projects?
- What are the funding sources and where are they from?
- What are the benefits of energy project?
- Who are the beneficiaries of the energy project?
- How are the benefits shared and managed?
- What are the barriers to the project?
- What sort of support do you think to overcome these issues?

Appendix 4: Approval of Ethics application

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

13 December 2017

Sadiq Ibrahim

Dear Sadiq,

RE: ETHICS APPLICATION STR1617-93: CREATING A STRATEGY FOR COMMUNITY-BASED LOW CARBON DISTRIBUTED ENERGY SYSTEMS: A STUDY OF GWAMMAJA DISTRICT IN NIGERIA

Based on the information you provided, I am pleased to inform you that your application STR1617-93 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

APHigham.

Dr Anthony Higham
Chair of the Science & Technology Research Ethics Panel

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