SCHOOL OF POSTGRADUATE STUDIES

CONSTRAINTS OF ELECTRICITY MINI OFF-GRID SYSTEMS DIFFUSION FOR ENTREPRENEURSHIP IN RURAL AREAS OF ZAMBIA

BY

WILLIAM MTONGA

DBA19116403

SUPERVISORS:

ENG. DR. KASONGO RICHARD MWALE

PROFESSOR BIEMBA MALITI

Submitted to the School of Postgraduate Studies of the University of Lusaka in fulfilment of the requirement for the Doctor of Philosophy Degree in Entrepreneurship

2022

DECLARATION

I, **William Mtonga**, do hereby declare that this Thesis is my original work and has not been submitted for a Doctor of Philosophy (Ph.D.) degree to the University of Lusaka or any other University. All that is borrowed from other scholars has been duly acknowledged and well cited in the places where they appear.

Full Name: William Mtonga
Signature: ……...
Date: ……

SUPERVISORS' RECOMMENDATION

I have read and checked the Thesis written by Mr. William Mtonga and do hereby confirm that it meets the minimum set standards of the University of Lusaka. I, therefore, recommend for the purpose of award of Ph.D.

Full Name: Eng. Dr. Kasongo Richard Mwale
Signature: ……...
Date: ……

I have read and checked the Thesis written by Mr. William Mtonga and do hereby confirm that it meets the minimum set standards of the University of Lusaka. I, therefore, recommend for the purpose of award of Ph.D.

Full Name: Professor Biemba Maliti
Signature: …….
Date: ……

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I……..... and on behalf of the University of Lusaka do hereby confirm that I have read and examined the Thesis written by Mr. William Mtonga, co-supervised by Eng. Dr. Kasongo Richard Mwale and Professor Biemba Maliti. I, therefore, approve/not approve this research work.

Full Name: ……

Signature: ……....

Date: ……

DEDICATION

This study is dedicated to my darling wife Sandra and my children William, Jessie and Chrispin for their loving support and adoration!

ACKNOWLEDGEMENTS

The inherent richness of this study would not have been attained without the support and encouragement from my Supervisors, Family, Friends, Superiors and Colleagues from my work place, the Energy Regulation Board, Management and Staff at the University of Lusaka who in some way or another led to the successful completion of this study.

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I wish to express my profound gratitude to so many who helped me directly or indirectly on this research journey considering that the purposeful snow ball sampling technique employed for this study relied so much on primary sources and their referrals. Also, profound appreciation goes to my family members who endured my divided attention during the study period.

Above all else, I am immeasurably grateful to the Almighty God for enabling me achieve education this far according to His will.

MOTIVATION

My motivation to pursue a Doctor of Philosophy (Ph.D) degree program in entrepreneurship emanated from learning about electricity mini-grids and their efficacy to provide a least-cost solution for electrification of off-grid rural areas which are situated far away from the main grid in Zambia. It was noted with concern that there were few enterprises involved in the installation and operation of electricity mini-grids meant to provide electricity services for entrepreneurial purposes in rural areas of Zambia. Further, each of the participating enterprises had only one or two sites dotted in various parts of the country. Such a scenario piqued my attention as to why a good business opportunity with an established underlying proof of concept was under-exploited. The situation appeared exciting for me to carry out an epistemological study of entrepreneurship to not only increase my scope of knowledge, but to also gain an edge on understanding the business environment on how to initiate and operate an innovative business venture taking responsibility for the risks and rewards that comes with it.

My axiological perspective for this study was to raise awareness on constraints faced in the diffusion of the electricity mini-grids meant for entrepreneurship in rural areas of Zambia, because the electricity mini-grids can improve the quality of life for people in rural areas as they indulge in entrepreneurial activities leveraging the electricity supplied from the mini-grid to enable them meet their social-economic aspirations aimed at reducing poverty.

My aspirations were not going to be attained without understanding the ontology or reality regarding what is involved in the provision of electricity services using electricity mini-grids and the existing relationships among the associated business variables. Consequently, the motivation for this study was about pursuit of knowledge to gain a comprehensive understanding of the electricity mini-grids business to essentially contribute to the extant knowledge on entrepreneurship.

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ACRONYMS AND ABBREVATIONS

Capex	Capital expenditure
ERB	Energy Regulation Board
GWh	Giga Watt hour
Ibid	Abbreviation used to indicate that a reference is from the same source as a previous reference
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
kV	Kilo Volt
kW	Kilo Watt
kWh	Kilo Watt Hour
MW	Mega Watt
n.d.	No date
NEP	National Energy Policy
PV	Photovoltaic
REA	Rural Electrification Authority
SDGs	Sustainable Development Goals
SEforAll	Sustainable Energy for All
UK	United Kingdom
UN	United Nations
UNICEF	United Nations Children's Fund
UNSDG	United Nations Sustainable Development Goals
USA	United States of America
VAT	Value Added Tax
ZRA	Zambia Revenue Authority
^{o}C	Degrees Celsius

DEFINITION OF OPERATIONAL TERMS

For the purpose of this study, some terms used are defined as follows:

Term	Definition
Constraints	Something that limits someone's freedom of action (Collins English School Dictionary, 2018).
Critical mass of sales	A point where sales cover fixed costs for a company to operate self-sufficiently and sustainably (Johnson *et al.*, 2011).
Developers	Also referred to as Operators are the enterprises/institutions that install and operate electricity mini-off grid systems
Diffusion	Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). In this study, diffusion is the act of spreading or promulgating an innovation to cover wide spread population.
Distribution of electricity	Conveyance of electricity from the transmission system to final consumers through a transformer at a relatively low voltage ranging from 4 up to 35kV (Grigsby, 2006).
Electricity mini off-grid system or mini grids	The Energypedia defines a mini-grid also sometimes referred to as a "micro grid or isolated grid" as a set of electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a localised group of customers. The mini grid policy toolkit agrees with energypedia that mini-grids involve small-scale electricity generation (10 kW to 10MW) which serve a limited number of consumers via a distribution grid that can operate in isolation from national electricity transmission network.
Entrepreneurship	Entrepreneurship is the control and deployment of resources to create an innovative economic organisation (or network of

	organisations) for the purpose of gain or growth under conditions of risk and uncertainty (Dollinger, 2008, p.9).
Licensee	An enterprise duly authorised by the appropriate authority or licenced to engage in a licensed activity such as the installation and operation of the generation and distribution of electricity facility such as the main grid or mini-grid.
Off-taker	Customer that is connected to the mini-grid or main grid.
Rural Area	As define in the Rural Electrification Act no. 20 (2003) i.e., (a) Any area which is not an area declared or deemed to have been declared a city or municipality under Local Government Act; Or Cap. 81, (b) such other area as the Minister may, by statutory order and in consultation with the Minister responsible for local government, declare a rural area.
Sub-Saharan Africa	According to the United Nations, Sub-Saharan Africa is, geographically and ethno-culturally, the area of the continent of Africa that lies south of the Sahara. It consists of all African countries and territories that are fully or partially located south of the Sahara.
Supply of electricity	Delivery of electric power using distribution lines to consumers through a supplier-consumer interface point.
Transmission of electricity	Electrical power transmission involves the bulk movement of electrical energy from a generating site, such as a power station or power plant, to an electrical substation where voltage is transformed and distributed to consumers or other substations (Grigsby, 2006).

ABSTRACT

The low electrification rate of about 52% and an estimated 28% for Africa at large and Zambia in particular respectively is of concern. There is now a common consensus that renewable energy electricity mini off-grid systems (or simply mini-grids) have a great role to play to reverse the trend especially in remote rural areas that are located farthest from the national main grid in order to achieve the United Nations Sustainable Development Goal Number 7 which specifically challenges for universal access to sustainable energy by 2030. This study sought to establish the constraints of diffusion for mini-grids intended for entrepreneurial purposes in rural areas of Zambia. The pragmatism philosophy guided the study using the mixed methods methodology, particularly the embedded research design i.e., where a quantitative study was carried out and followed up by a qualitative study to obtain detailed information especially on points of inquiry where the quantitative study did not yield conclusive results. The exponential discriminative snowball sampling technique was used to collect data from a sample of 37 research subjects. Statistical methods were used to analyse quantitative data, whereas thematic analysis was used to analyse qualitative data. The study established the following constraints of diffusion of mini-grids for entrepreneurial purposes in rural areas of Zambia: high poverty levels, low population density, low profitability of the mini-grids business, substitutes provide cheap energy sources, fear of the main grid encroachment, high upfront capital expenditure required for setting up the mini-grids business, local taxes, seasonality of business, lack of access to capital finance and limited business ideas, government policy and regulations, ignorance about existence of mini-grids and their benefits, lack of incentives such as capital subsidies, business environment varies depending on specific locations and challenging physical geographical conditions. The study conclusively found that; consumer sensitisation, the marketing concept and referral marketing are the most effective strategies for promoting diffusion for mini-grids in rural areas of Zambia, supported by the declining costs for renewable energy technologies on the market. The study recommended that sensitisation should be intensified since communities respond positively whenever enlightened about the existence of mini grids and their benefits for entrepreneurial purposes. Further, the catchment area for customers deriving benefit from a particular mini-grid should be wide enough by installing mini-grids well far apart to allow for attainment of critical mass of sales in view of low population density and low profitability in rural areas of Zambia.

Key words: Constraints of mini-grids diffusion, mini-grids for entrepreneurial purposes, Renewable energy mini-grids

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 Introduction

The first chapter discusses the background, statement of the problem, research questions, objectives, rationale, and significance of the study. This chapter further provides scope of the study and the structure of this thesis and concludes with a chapter summary.

The main electricity grid transmission and distribution infrastructure in Zambia is concentrated along the line of rail and urban areas with grid extension to some peri-urban areas, but excludes most rural areas thereby leading to an existing gap in availability of electricity for the urbanised areas in comparison to rural areas. The apparent lack of electricity in rural areas, which is a source of modern energy, affects undertaking of entrepreneurial activities that could contribute to reduction of poverty. To address the electricity access gap, the government of Zambia put in place the Rural Electrification Authority (REA) through enacting the Rural Electrification Act No. 20 (2003) in order to accelerate electricity provision for rural areas. REA has the mandate to make available infrastructure for electricity for rural areas in Zambia leveraging suitable technologies in form of electricity mini off-grid systems and standalone home systems. This study investigated the constraints of electricity mini off-grid systems diffusion for entrepreneurial purposes in rural areas of Zambia.

1.2 Background of the Study

The well-being of human beings across the globe is directly affected by access to consistent safe energy supply. Availability of modern energy services in form of electricity is necessary to support the economic and social development that promotes prosperity of society and enhances its quality of life by alleviating poverty.

Satisfying the growing demand for electrical energy in a safe and environmentally responsible manner is a global pressing challenge as seen from the launch of an international organisation called Sustainable Energy for All (SEforAll) initiative in September 2011 (World Bank, 2017). The International Organisation, SEforAll works with

leaders in governments, private sector including the civil society to quicken actions aimed at achieving the United Nations Sustainable Development Goal 7 (UNSDG7), calling for universal access to sustainable energy by 2030, and the Paris Climate Agreement, promoting the reduction in greenhouse gas emissions to limit climate warming to below two degrees Celsius (Ibid, 2017).

Among the 17 Sustainable Development Goals (SDGs) adopted in September 2015 by the United Nations, Goal number 7 is on ensuring access to affordable, reliable, sustainable and modern energy for all (United Nations Sustainable Development Goals, n.d.) with the following listed targets to be achieved by 2030:

i. Universal access to affordable, reliable and modern energy services;
ii. Increase substantially the share of renewable energy in the global energy mix;
iii. Double the global rate of improvement in energy efficiency;
iv. Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology; and
v. Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, Small Island Developing States, and land-locked developing countries, in accordance with their respective programmes of support.

Despite the growing new focus on access to energy with initiation of the SEforAll, the World Bank (2017) indicates that global progress to access electricity has been slow as 1.06 billion people remain without access to electricity, and 3.04 billion people continue to depend on solid fuels and kerosene for cooking and heating. The population without electricity access is mostly found in Sub-Saharan Africa (588 million) and South Asia (337 million) including the population in rural areas generally but also those in urban areas with little income (Bhattacharyya, 2018). The foregoing affects the Sub-Saharan Africa which includes Zambia forming part of the region.

Another global progress tracking of electricity availability by the International Energy Agency (IEA) revealed that promoting access to electricity was yielding favourable results in all regions, and the rate of progress had speedup (IEA, 2017). In 2016, there was a population of less than 1.1 billion having no electricity available for the first time with an estimated 1.2 billion people accessing electricity as from 2000. Most progress was achieved in developing Asia, with a population of 870 million that gained access as from 2000, and India accounted for 500 million of that total number that gained access to electricity thereby recording one of the major electrification achievements in history. Further, a favourable trend emerged in sub-Saharan Africa, whereby levels of access to electricity exceeded population growth as from 2014, although progress was irregular with still a lot of people having no electricity then than the situation in 2000 (Ibid, 2017).

Technological improvements are availing novel breakthroughs towards achieving UNSDG7 to ensure access to electricity for all. The combined effects of falling costs for renewable energy technologies such as; Solar PV modules, increase in low-priced efficient lighting and appliances, and advancements in models of doing business that make use of digital, mobile-enabled platforms have accelerated the availing of solutions for the population without electricity currently (IEA, 2017; IRENA, 2018).

Most of the population out of the total of 1.2 billion achieved connection to electricity through the main grid starting from 2000. Over the last five years, renewable energy technologies have gained ground with mini-grid systems being installed in various places. This development is expected to accelerate if the world is going to meet UNSDG7 (Ibid, 2017).

In Zambia, the National Energy Policy (2019) has guided on addressing the barriers to achieving connection to reliable and affordable energy services sustainably. In addition, participation of players in the private sector to make available electricity for the off-grid rural settlements where 60% of the population resides was observed to be limited. Therefore, need for measures to coordinate players in rural electrification arose especially in the off-grid space (Ibid, 2019).

1.2.1 Electricity generation and conveyance

Conveyance of electricity from generation plants for supply to consumers is achieved through a network which could either be the main grid or a mini-grid. Another way for domestic or small business premises electrification is by use of the stand-alone power system (Charlie, 2019).

For the main or central grid, electricity is produced from generation plants that are fuelled by combustible energy sources such as; fossil fuels – coal and natural gas including other sources such as nuclear fuel. On another hand, non-combustible energy sources that are naturally renewed continuously such as; hydro, wind and solar are used to generate electricity. Transmission lines convey the electricity from the generating power plant to demand centres usually over long distances using high voltage transmission lines that carry more power. As the power reaches consumer centres, the voltage is reduced by a step-down transformer in order to convey electrical energy using distribution lines to deliver to final consumers (Kaplan, 2009; Grigsby, 2006). The electricity from generation stations is conveyed to consumers via an interconnected network known as the electrical main grid or central grid. The interconnected network consists of; electricity generation stations, electrical substations for stepping electrical voltage up for transmission, or down for distribution, transmission lines that convey high voltage power from far away points of generation to consumption centres, and distribution lines that deliver power to individual customers (Ibid, 2009; Melhem, 2013). The main grid typically provides a certain level of redundancy to allow for flexibility and expansion in operations (Pittet, n.d.). Therefore, the main or central grid involves electrification over a wide area network and is characterised by conveying huge quantity of electrical energy.

The term grid is used to describe a wide variety of networks ranging from elementary to very complex ones. However, a basic installation with a single generating station and associated distribution lines leading to customers as applied in decentralised renewable energy projects is called a mini-grid or a “generating and distribution network” which involves small-scale electricity generation from 10kW to 10MW serving a limited number of consumers through a distribution grid that can operate in isolation from the main national

electricity transmission network (Renewables in Africa, 2018; Energypedia, 2019). An electricity mini-grid system that is connected or feeds into the main or central grid is referred to as on-grid or grid connected, whereas one that operates isolated from the central grid is known as mini off-grid system. Further, electricity mini-grids fuelled from energy sources that are continuously naturally renewed such as solar, wind and hydro are referred to as green mini-grids (Ibid, 2018). Electricity mini off-grids have come out as a least-cost solution for electrification of off-grid areas such as rural areas whereby modern energy services are made available for lighting and other commercial services in a timely manner that is sustainable and environmentally friendly.

A simple network for a stand-alone home system generates power to cater for the basic electricity needs of a single home or small business premise (Electrical4U, 2020). It is ideal for use as power back up system in urban areas as a stopgap measure whenever a power outage occurs from the main grid, but also as a primary power supply in off-grid areas.

1.2.2 Electricity generation in Zambia

The NEP (2019:7) has highlighted that; hydro, wind, biomass, solar, coal, uranium, geo-thermal, petroleum and waste (i.e., inclusive of municipal solid and agricultural waste) are Zambia's main sources of energy. Hydro power generation of electricity remains Zambia's predominant source of power generation. For instance, table 1.1 presents Zambia's electricity generation mix for the years; 2017, 2018 and 2019. The table shows a sharp rise in electricity generation by solar from 0.04% in 2018 to 2.99% in 2019 following the commissioning of the on-grid solar PV power generation plants; Bangweulu with a generation capacity of 54.3 MW and Ngonye with a generation capacity of 34 MW. The two (2) on-grid solar plants are situated in Lusaka District.

Table 1.1: Zambia's electricity generation mix 2017 to 2019

Generation Source	2017 (%)	2018 (%)	2019 (%)
Hydro	83.00	82.76	80.45
Coal	10.00	10.35	10.06
HFO	4.00	3.80	3.69
Diesel	3.00	3.06	2.80
Solar	< 0.10	0.04	2.99

Sources: Energy Sector Reports; 2017, 2018 and 2019

The demand for renewable energy such as solar has recorded a notable increase, while the search for alternative sources of energy on the market is going on. Renewable energy appears like a feasible alternative source of energy. Alternative sources of energy refer to energy sources other than fossil fuels and generally includes energy sources from natural processes that are continuously replenished and have low environmental impact such as energy that is generated from sunlight (solar), geothermal heat, wind, tides, water (hydro), and biomass (Ciolkosz, 2009). Electricity generation using renewable energy appears to be on the increase in Zambia with several small hydro and solar electricity mini off-grid systems dotted across the country that are installed for own use.

Although the NEP (2019) recognises uranium as a primary source of energy in Zambia, there is currently no electricity generation using the uranium resource due to inadequate policy, legal and institutional frameworks governing the electricity sub-sector to implement the nuclear power programme (Ibid, p. 9). The Zambia Atomic Energy Agency is spearheading the progressive programme on exploitation of uranium as an energy resource and the works are in the early development stage. Further, waste to energy currently remains an identified potential of primary energy source with several private developers having expressed interest to undertake feasibility studies for waste-to-energy projects in Zambia (Ibid, p. 9).

1.2.3 Electrification of rural areas

Electrification of rural areas is achieved through the following three ways; grid extension, stand-alone home systems and mini-grids (Charlie, 2019).

1.2.3.1 Grid extension

Grid extension is a cost-effective way of extending the existing grid to meet electricity requirements for communities that are densely populated and live in near proximity to the main grid, so that the population avails a market that can economically support the cost of the grid extension (Ibid, 2019).

1.2.3.2 Stand-alone home systems

For sparsely populated communities dwelling in the remote rural areas; stand-alone home system usually fuelled from solar or wind sources operate on off-grid basis to provide the electricity to meet elementary needs like lighting, operating a radio for entertainment and phone charging among others (Ibid, 2019; Electrical4U, 2020).

Deployment of stand-alone home systems in off-grid areas of Zambia has augmented efforts to achieve electrification of rural areas (REA, n.d). The solar stand-alone home systems have been implemented through a phased programme known as Sustainable Solar Market Packages (SSMP). Scope of Phase I of the programme on SSMP served to electrify public institutions and included; the procurement of Solar Home Systems (SHS) with subsequent installation and commissioning services. Phase I further provided for maintenance services to be provided for a period of five years after commissioning the project. Three districts namely; Kalomo, Isoka and Lukulu benefited from the SSMP for a total cost of US$ 2.6 million for 707 Installations. The follow up phase II of SSMP programme was carried out at a cost of USD$665,100 in Lundazi, Chama and Mwinilunga (Ikelengi) with the expectation for the project to benefit rural health centres, Chiefs' palaces, schools, local courts and staff houses once completed (REA, n.d).

1.2.3.3 Mini-grids

The installation and diffusion of electricity mini-grids technologies has been understood to be an effective means to achieve rural off-grid electrification to meet requirements for sparsely populated rural areas that cannot economically support grid extension. Mini-grids provide electricity solution with a high poverty reduction potential for productive use of electricity as they can power machinery with bigger

electricity loads such as those used for agricultural activities and other commercial uses (Ibid, 2019; Blum *et al.*, 2015).

Electricity mini-grids serve a variety of customers who include; private households for own use to small and large commercial customers for entrepreneurial purposes. They are installed in urban areas usually for backup power supply, while they are installed in rural off-grid areas as the main or primary source of power supply.

Electricity mini-grids or simply mini-grids have been defined in various literatures. Electricity mini-grid also referred to as a "micro grid or isolated grid" comprises small-scale generators of electricity from 10kW to 10MW usually coming with an energy storage system and is interconnected to a distribution network that can operate in isolation from national electricity transmission network supplying electricity to a limited group of customers (Energypedia, n.d). In the same vein, the Nigerian Electricity Regulatory Commission (n.d.) describe mini-grids as electricity supply systems with own power generation capacity between 0 kW and 1 MW size supplying power to more than one customer. The mini-grids can be either isolated (standalone) or interconnected to the main network. Further, Bhattacharyya (2018) has shared a broad definition for mini-grids citing Yan *et al.*, which states, “Electrical infrastructures that serve diverse users from a single building up to an island and can interconnect and interact with the main utility grid or operate independently based on distributed energy generation.”

Bhattacharyya (2018) indicates that other terms used in reference to mini-grids include; micro-grid, pico-grid and nano-grid even though consensus in terms of size to distinguish the terms used has not been established. To aid understanding, Table 1.2 presents a compilation of the comparison of different size generation ranges with reference to International Renewable Energy Agency (IRENA) proposed categorisation for different mini-grid systems.

Table 1.2: Size generation range for mini-grid systems

Local Grid System	Commonly Used Size Definitions	IRENA Proposed Categorisation
Pico – grid	0 – 0.5kW	0 – 1 kW
Nano – grid	0.5 – 1 kW	1 – 5 kW
Micro – grid	1 – 10 kW	5 – 100 kW
Mini - grid	10kW to few MW	100 kW – 100MW

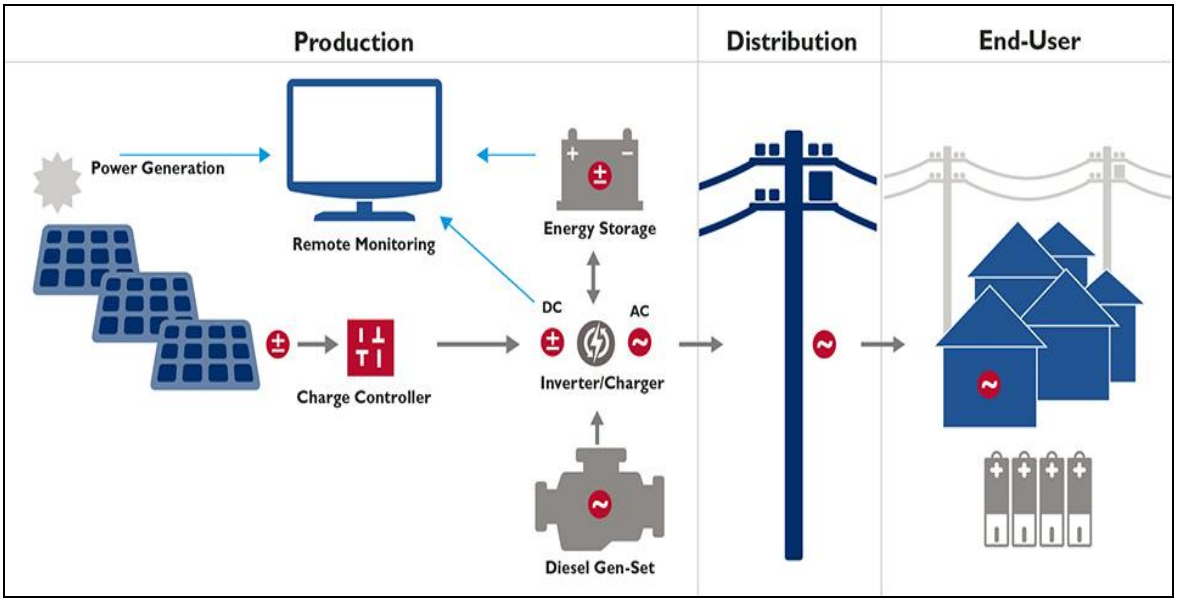
Source: Adopted from Bhattacharyya, 2018

Electricity mini off-grid systems are known to provide least-cost and timely solution for meeting the electricity requirements to off-grid communities. For this study, electricity mini off-grid system implies a generation unit with a local distribution network used to supply electricity to consumers of a localised area (territory) regardless of generation capacity or size range and operating isolated from the main or central grid.

There has been significant growth for the electricity mini off-grid business globally as mini-grids are differently configured with sizes tailored to meet customer requirements (Bhattacharyya, 2018). The focus of this study is on mini off-grid systems i.e., mini-grids that generate, distribute and supply electricity to a localised small off-grid area or territory and not those mini-grids that generate electricity and feed into the main grid (On-grid).

The technical components of an electricity mini-grid are specified into three parts that is; generation or production, distribution and supply to end users or consumers as illustrated in figure 1.1. Consumers access electricity units through a smart metering facility and pay for the services using various mobile-enabled payment systems such as pay-as-you-go and mobile money among others (Beyond the Grid Fund for Africa, 2021).

Figure 1.1: Illustration of electricity mini-grid components



Source: Renewables in Africa, 2018

Installation of stand-alone and mini off-grid systems has become prevalent due to falling technology costs, innovativeness in technology deployment, and advanced models of financing, coupled with a set of diversified stakeholders, which includes locally based entrepreneurs, the international private sector plus financing institutions. Mini off-grid solutions contribute to improving the standard of living by powering productive end-uses not only for domestic purposes, but also for commercial and industrial needs such as providing electricity to support operations aimed at making public services available in areas of; education, health-care, pumping water from underground and agricultural activities among others (IRENA, 2018).

The regular sources of fuel for electricity mini-grids include wind, solar PV, hydro and biomass. Electricity generators using fossil fuels such as Diesel and Petrol, and Hybrid systems which are a combination of either of the aforementioned sources are also available (Ciolkosz, 2009). Nevertheless, clean energy technologies that use renewable energy are preferred for achieving the UNSDG 7 and the Paris Climate Agreement on reduction of greenhouse gas emissions.

1.2.3.3.1 Electricity mini-grids in Zambia

Electricity mini-grid systems have been installed by both state and private institutions in Zambia with Solar PV and Hydro based electricity mini-grid systems being common (Payen *et al.*, 2016). Most of the diesel-powered electricity mini off-grids (in North Western and Eastern Provinces) were phased out through the grid extension programme implemented by REA. Some of the installed off-grid systems in Zambia are hereby discussed.

The well-known pioneer installation for Solar PV mini off-grid is the installation at Mpanta in Samfya District in the Luapula Province of Zambia by the government agency, Rural Electrification Authority (REA). Private entities have also established Solar fuelled mini off-grid systems to serve localised customers namely; Standard Micro-grid Initiatives Limited has installed sites in Chirundu District of Lusaka Province and Sioma District in Western Province, Muhanya Solar Limited has installed a site in Sinda District of Eastern province and Solera Power Vending Machine Limited has sites in Luangwa District of Lusaka province and at Kacholola in Eastern Province. Engie Power Corner Zambia Limited has a site installed at Chitandika Village in Chipangali Constituency of Eastern Province.

The hydro mini-grids are installed in the following places; on the Zambezi River in Ikelenge District of North Western Province of Zambia by Zengamina Power Company, in Shiwang'ndu District of Muchinga Province operated by Zesco Limited (grid connected and therefore not subject for this study) and the recently installed site at Kasanjiku river in Western Province by Rural Electrification Authority (REA).

The aforementioned hydro and solar mini-grid installed in Shiwang'ndu District and Mpanta in Samfya District respectively were projects funded by the United Nations Environment Programme. A review conducted by Grøn and Chisonga, (2015) intended to figure out challenges encountered in the application of renewable energy based mini-grids for electrifying off-grid rural areas in Zambia found that delivery against the project objectives to overcome political, financial, legal and technical

barriers affecting promotion of diffusion for renewable energy mini-grids by private enterprises was low despite the stakeholders considering the project successful.

1.3 Statement of the problem

As aforementioned, the UNSDG7 has challenged for universal access to sustainable energy by 2030 ensuring access to affordable, reliable, sustainable and modern energy for all. Africa has the lowest electrification rate at 52%, with the Sub-Saharan Africa at 46.7% in 2019 and Zambia in particular at 31.4% in 2019 for which there is a common consensus now that mini-grids systems have a great role to play to reverse the trend (Renewables in Africa, 2018; World Bank, 2021; National Energy Policy, 2019). With the foregoing, REA has set a goal to increase the access to electricity in rural areas of Zambia from the current 3% to 51% by the year 2030 (REA, n.d).

For the period 2013 to 2019, it was observed that Operators took long to replicate the installation of similar mini off-grid systems elsewhere whenever a pilot electricity mini off-grid system was installed at one location, thereby slowing the much-desired diffusion of mini off-grid systems. For example, the number of electricity mini-grid installations for each Operator from 2013 to 2019 remained unchanged as follows: one for Rural Electrification Authority, two for Standard Micro-grid Initiatives Limited, one for Muhanya Solar Limited, three for Solera Power Vending Machine Limited, one for Engie Power Corner Zambia Limited and one for Zengamina Power Company Limited. This fact was pro-argued by Payen *et al.* (2016) that mini-grids have fought hard to breakthrough beyond pilot projects phase for them to contribute meaningfully to making electricity available.

Hence, this study was undertaken to identify constraints causing slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia and is premised on the fact that mini-grids are a proven least-cost technology for accelerating electrification of rural areas in an effort to attain the UNSDG7. Therefore, the statement of the problem was that, although electricity mini-grids are known to be a feasible option for electrifying off-grid rural areas, there appear to be significant constraints to installation and diffusion of electricity mini-grids especially for entrepreneurial purposes in rural areas of Zambia.

1.4 Research questions

Research questions help to state the problem of the study to concisely bring it into perspective.

1.4.1 Research questions

The following questions aided attainment of the study comprehensively:

i. Why is the diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia slow?
ii. Why are mini-grid developers not initiating additional projects after completion and operationalisation of the initial project?
iii. Do developers' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages?
iv. What are the feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion as an innovation for entrepreneurship in rural areas of Zambia?

1.5 Objectives of the study

The main objective highlights the core idea and what the study intends to achieve, while the specific objectives detail relevant processes for the comprehensive study.

1.5.1 Main Objective

The main objective of this study was to establish the main constraints of diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia.

1.5.2 Specific objectives

The specific objectives of this study were to:

i. Determine the cause of slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia;

ii. Establish why mini-grid developers are not initiating additional projects after completion and operationalisation of the initial project;
iii. Examine whether developers' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages; and
iv. Propose feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion as an innovation for entrepreneurship in rural areas of Zambia.

1.6 Rationale of the study

There is a gap in making electricity available for urban and rural areas citing high costs of electricity supply and a general lacking among consumers in rural areas to afford electricity supplied using the main or central grid. Now that electricity mini off-grid systems technology is available and known to be of least cost to provide timely solution for meeting the electricity demand for off-grid rural areas in Zambia, it is of concern that diffusion (wide spreading) of electricity mini off-grid systems is slow yet off-grid rural communities continue to have no access to electricity supply. In this regard, meeting the UNSDG 7 at a global level and the Rural Electrification Authority of Zambia's goal to increase the access to electricity in rural areas from the current 3% to 51% by the year 2030 may not be achieved if the slow diffusion of electricity mini off-grid systems continues.

Making electricity available for the communities in rural areas has the benefit of promoting their socio-economic development and well-being as they engage in income generating activities leveraging the available and emerging opportunities such as; agriculture, merchandising, fintech, recreation, mining and other viable areas. The increased active productive utilisation of the electricity supplied from the electricity mini-grid contributes to improving the local economy of the community as jobs are created and the local spending pattern changes as people earn from various economic engagements. As the community economy improves, it feeds into the regional and eventually national tiers of the economy to bring about wide spread development.

In view of such envisaged socio-economic benefits, it was necessary to conduct the study to establish why diffusion of the electricity mini off-grid systems was slow and find out what could be done to improve the situation.

1.7 Significance of the study

The study revealed constraints of electricity mini off-grid systems diffusion for entrepreneurial purposes in rural areas of Zambia. Further, feasible measures to mitigate the identified constraints were recommended for use by developers of electricity mini off-grid systems in their projects, and policy makers including regulators as they seek to provide an enabling business environment. Further, the study unveiled areas for undertaking related research in future.

1.8 Scope and delimitation of the study

This study considered players that are presently participating in the installation and operation of electricity mini off-grid systems for entrepreneurial purposes in Zambia. At the time of undertaking this study, the players taking part in establishing electricity mini-grids included Rural Electrification Authority (REA) the government agency, and private entities namely Standard Micro-grid Initiatives Limited, Muhanya Solar Limited, Solera Power Vending Machine Limited, Zengamina Power Company and Engie Power Corner Zambia Limited.

The study covered electricity mini off-grid systems that are fuelled by energy sources that are naturally continually renewed like; Solar PV and Hydro among others so as to align with the focus on clean energy technologies targeted by the UNSDG 7. The study excluded traditional fuel generators that use fossil fuels such as diesel because such installations contribute to the greenhouse gas emissions such as carbon dioxide.

Mini-grids are defined in various literatures and the knowledge is used to contrast the main or central grid. The term electricity mini off-grid system was used to describe facilities for the electricity generation and local distribution through a network to consumers in a localised area (exclusive territory) regardless of generation capacity or size range and not connected to the main or central grid.

1.9 Structure of the thesis

The thesis comprises seven comprehensive chapters detailing the study undertaken.
Chapter one informs about the background, states the problem followed by research questions, objectives, rationale, significance, scope and delimitation of the study. The first chapter also provides the structure of the thesis prior to concluding with a chapter summary.

Chapter two discusses a review of appropriate published literature about electricity mini-grid systems technology in order to lay foundation for the study. The chapter further presents history of electricity mini-grid systems followed by a thematic literature review covering; setting up mini-grids, models of business for mini-grids, strategies for sustainability of mini-grid business, government support systems including policies and regulations and constraints of diffusion of mini-grid systems. The chapter further presents literature review for electricity mini-grids in Zambia, emerging learning points from the reviewed literature, establishes the knowledge gap and concludes with a chapter summary.

Chapter three presents the theoretical and conceptual framework. It outlines theories used for the study, followed by critical reviewing of the selected theories. The theory of knowledge (epistemology) is systematically provided through a conceptual framework to specify how variables relate in order to predict and explain the phenomena of diffusion of innovations regarding entrepreneurship. The third chapter further operationalise the variables in the conceptual framework and presents hypotheses for the study prior to concluding with a chapter summary.

Chapter four provides the framework for the research design and methodology used for the study. Beginning with elaborating the philosophical assumptions of the study the chapter proceeds to discuss the research design, target population, sampling procedures and the nature of the sample. Further, the chapter describes the research instruments concerned with procedures for collecting data, the analysis techniques and presentation. The undertaken pilot study is presented and then discussion of the validity, reliability and ethical considerations for the study prior to conclusion.

Chapter five involves data presentation, analysis and provides results of the study in order to establish the constraints of electricity mini-grids diffusion for entrepreneurial purposes in rural areas of Zambia. The presented data, its analysis and subsequent results are based on the responses obtained from quantitative and qualitative surveys, augmented with information obtained from focus groups and document review prior to conclusion.

Chapter six discusses the study results obtained in previous chapter in order to interpret the relevance of the findings with respect to existing knowledge regarding the research problem and to explain emerging revelations or insights emanating from investigating the problem. The chapter concludes with a chapter summary and precedes the final chapter of this thesis - chapter seven.

Chapter seven is the concluding chapter and outlines the study conclusion. Further, the chapter presents the recommendations resulting from interpretation of the study findings. The limitations of the study are discussed including opportunities for research areas which could be explored to build upon this study in future.

1.10 Chapter summary

This chapter discussed the background, statement of the problem, research questions, objectives, rationale, significance, scope and delimitation of the study. The chapter has also presented the structure of this thesis. The next chapter is on literature review.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The appropriate published literature about electricity mini-grid systems technology was reviewed in order to lay foundation of this study. Further, literature on philosophy, history of mini-grids and related empirical studies was reviewed to establish the philosophical underpinning for the study as well as to garner awareness of the existing knowledge from other researchers on the subject and hence establish the knowledge gap that this research shall attempt to fill as its new insight contribution to the body of knowledge.

2.2 Research Paradigms

It is necessary for a researcher to establish the philosophy right when commencing the study in order to firm up the philosophical underpinning for one's study regarding the paradigm to guide the study and the underlying assumptions on ontology, epistemology, methodology, and methods (Singh, 2019). A paradigm constitutes the abstract beliefs and principles that shape how a researcher sees the world, and how s/he interprets and acts within that world. It is the conceptual lens through which the researcher examines the methodological aspects of their research project to determine the research methods that will be used and how the data will be analysed (Kivunja and Kuyini, 2017). A paradigm is also defined as a pattern of considering the world and comprises philosophical assumptions that control and direct thinking and action (Mertens, 2010:7). Similarly, Saunders *et al.* (2009) describe a paradigm as a way of probing social phenomena from which particular understandings of these phenomena can be gained and explanations attempted.

Mackenzie and Knipe (2006) provide guidance that if a paradigm is not chosen at the commencement of the study, there would be no basis later for selecting options regarding methodology, methods, literature and indeed research design. The author perceived the paradigm as a tool that provide the general direction for the study in order to select the appropriate research methodology for studying the phenomena, which in this case was the

constraints of diffusion of electricity mini-grids for entrepreneurship in rural areas of Zambia.

The four key philosophical views or world views or paradigms reviewed for this study were: Postpositivism, Constructivism/interpretivism, Transformative and Pragmatism (Creswell, 2009; Mertens, 2010; Mackenzie and Knipe, 2006). The paradigms are briefly discussed in the following subsections:

a) Postpositivism

Postpositivism paradigm is also referred to as the scientific method or doing a scientific study and the applicable assumptions remain true more for quantitative methods of data collection and analysis than qualitative research (Creswell, 2009; Mackenzie and Knipe, 2006);

b) Constructivism/interpretivism

Constructivism/interpretivism is the understanding of assumptions that individuals seek comprehension of the world where they live and work and it is naturally seen as an approach to qualitative research (Ibid, 2009). The constructivism paradigm relies mostly on qualitative data collection methods and analysis and also on a combination of both qualitative and quantitative methods i.e., mixed methods (Mackenzie and Knipe, 2006).

c) Transformative

The transformative paradigm also known as Advocacy or Participatory Worldview is the understanding that inquiry into the study needs to be intertwined with politics and a political agenda. Thus, the research contains a work plan for reform that may change the lifestyle of the participants, the institutions in which individuals work or live, and the researcher's life. This worldview characteristically applies to qualitative research, but it can be a foundation for quantitative research too (Ibid, 2009); and

d) Pragmatism

Pragmatism as a worldview emanates from actions, situations, and consequences rather than antecedent conditions as in postpositivism (Creswell, 2009). Pragmatism is not committed to any one system of philosophy or reality and is applicable to mixed methods research where inquirers draw liberally from both quantitative and qualitative assumptions as they are involved in their research focusing attention on the research problem and employ various approaches to comprehend the problem (Ibid).

2.2.1 Building blocks of the research process

The research process begins with ontology after which epistemology, methodology, and methods follow (Tuli, 2010; Singh, 2019).

2.2.1.1 Ontology

Ontology is concerned with the issue of what exists or the core nature of reality (Neuman, 2014; Saunders *et al.*, 2009). It is a system of one's belief that reveals an interpretation of an individuals' perception about what constitutes reality of something. The two types of ontology are realism or objectivism and relativism or subjectivism (Singh, 2019; Saunders *et al.*, 2009).

a) Realism

According to Singh (2019) citing Realism (n.d.), realism also referred to as naïve realism is a philosophical view that whatever we perceive is real and truly out there. It holds the view that whatever science informs us about the world is correct and the object of research like organisations, culture, ethics etc. exists independent of the knowledge of the realist researcher. Similarly, Saunders *et al.* (2009) say that objectivism depicts the position that social entities exist in reality external to social actors concerned with their existence.

b) Relativism

Singh (2019) cite Scotland (2012) that, Relativism holds the view that reality is subjective and it varies from person to person so there is as many realities as

are people. In the same way, Saunders *et al.* (2009) inform that subjectivism provides that social phenomenon are created from the perceptions and consequent actions of those social actors concerned with their existence.

2.2.1.2 Epistemology

Epistemology is an important aspect of philosophy that deals with the theory of knowledge and is concerned with how we know what we do, what justifies us in believing what we do, and what standards of evidence we should use in seeking truths about the world and human experience (Audi, 2003). Epistemology concerns what constitutes acceptable knowledge and is concerned with possibilities, nature, sources and limitations of knowledge in a field of study (Saunders *et al*., 2009; Dudovskiy, 2018).

2.2.1.3 Methodology

Crotty (1998) describes methodology as the strategy or plan of action which decides the kinds of methods to be used. Methodology of a study links philosophical assumptions and methods opted for use. Further, the methodology selected for use in a study in informed by the type of paradigm chosen.

2.2.1.4 Methods

Methods are constituted by the techniques and procedures utilised for collection and analysis of data (Crotty, 1998). Therefore, once the methodology is chosen as guided by the paradigm, methods inform about the instruments to use for the collection and analysis of data (Mackenzie and Knipe, 2006).

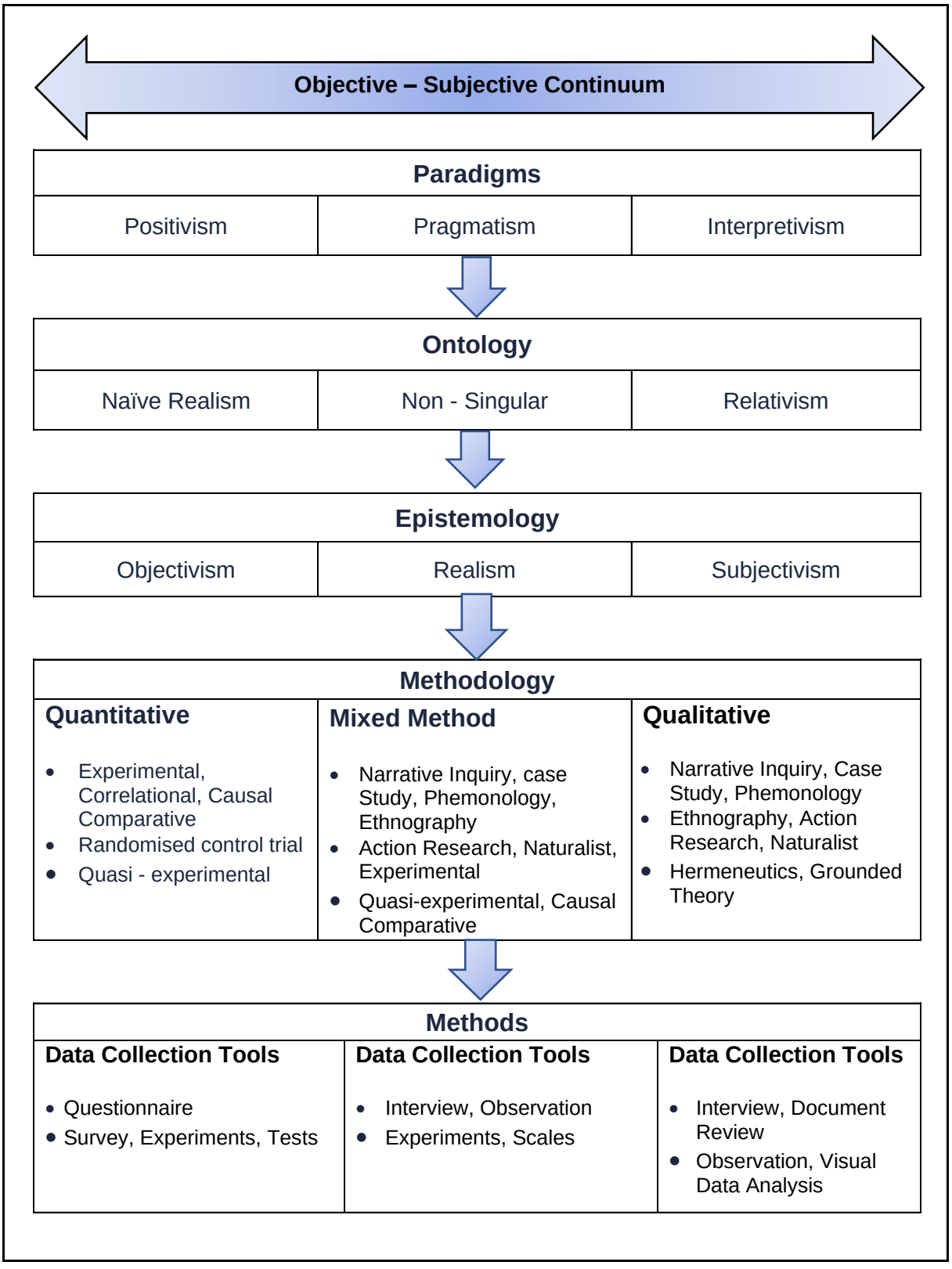
In order to establish the philosophical underpinning for the study based on the various research paradigms discussed in the preceding sections, an objective - subjective continuum summary of the paradigms with their underlying assumptions is presented in figure 2.1 to provide a bird's eye view for understanding the research process. The objective - subjective continuum summary adopted from Singh (2019) shows a positivist paradigm (objectivist view) on the left-hand side and the interpretivism paradigm

(subjectivist view) on the right side, while the pragmatism paradigm is on the center. Kivunja and Kuyini (2017) cite Gage (1989) that pragmatism paradigm was developed with a view to end “paradigm wars” between the two diametrically opposed viewpoints of the positivist on one end and the interpretivists on the other. The transformative paradigm although discuss earlier was not part of the latter discussion because it was not part of the objective - subjective continuum summary adopted from Singh (2019) for consideration.

Based on the bird's eye view for understanding the research process in figure 2.1, pragmatism paradigm was chosen as the philosophy to underpin this study because it is applicable for mixed methods methodology as opposed to the other paradigms that are either suitable for use with quantitative or qualitative design.

Further benefits of applying the pragmatism paradigm are that: there are no limitations of committing to any one system of philosophy and reality; the researcher liberally chooses the methods that meet their needs and purposes for conducting the study to best solve the problem at hand; pragmatist believes that the research environment is not independent of social, political, historical and other contexts; pragmatist researchers seek what and how to research based on the desired results (Creswell, 2009; Singh,2019; Kivunja and Kuyini, 2017).

Figure 2.1: Philosophical underpinnings of various paradigms



Source: Singh, 2019

2.3 History of electricity mini-grids

A historical review by Korkovelos *et al.* (2020) has revealed that the development of electricity mini-grid systems dates back to the second half of the 19th century. Further, the review revealed that large scale electrification networks enjoyed today evolved in loosely four distinct phases based on the cases studied. The first Phase mostly involved innovative pilot projects that were small but promised a possibility of gainful ventures. Such pilot projects occurred in different places such as; Chicago in 1878, New York in 1879, Godalming in the UK in 1881, Härnösand in Sweden in 1885 and Zhang Garden of Shanghai, China in 1890s. The pilot projects that were innovative got supported by new models of business and unveiled new possible technologies. Second phase was characterised by diffusion of the technology to anchor customers that were able to pay a premium to access certain electricity services thereby providing the proof of concept that the technology was economically viable for a variety of electric power productive uses. Many inventions and innovative ideas prompted an explosive increase of electricity related technologies during that period. The third phase was the economic boom for electricity mini-grids to form wide interconnected networks that exploited economies of scale to reach areas of economic opportunity to further stimulate development. The final social scale-up forth phase involved an increased public sector participation in establishing power systems through parastatal utilities and policies including regulations for the private sector (Ibid, 2020). The evolution is what has brought up the socio-economic scale-up of power systems seen today, where public actors conduct regulation to supplement the market in order to accomplish further electrification.

In Southern Africa for which Zambia is part of, electricity mini off-grid systems have been available for decades and have been used to electrify off-grid areas such as; military facilities, villages, islands, economically important industrial sites and telecommunication towers among other places (Payen *et al.*, 2016). Therefore, the proof of concept for electricity mini off-grid systems is already established and hence their slow diffusion for entrepreneurial use in Zambian off-grid areas is a matter that calls for in-depth understanding because the drive towards achievement of the goal for sustainable universal availability of energy by 2030 is adversely affected.

2.4 Empirical studies on constraints of mini grids diffusion

The empirical studies on constraints of mini grids diffusion were reviewed at Global, Africa and Southern African Development Community (SADC) levels as loosely presented in this section.

Globally and in Africa, countries in Latin America such as Costa Rica, Brazil, Mexico, Argentina and Chile and also developing Asia such as Thailand, Nepal, India Sri Lanka, Indonesia, Cambodia, Bangladesh and China have recorded success in rural electrification programs using mini-grid despite challenges. Further, several publications have reported diffusion of mini-grids in African countries such as; Nigeria, Mali, Senegal, Mauritania, Cameroon, Kenya, Uganda, Rwanda, Tanzania, Algeria, Madagascar, Lesotho, South Africa and Morocco (Azimoh *et al.*, 2017). Although successes have been recorded in other developing countries, the sub-Saharan African has lagged with limited success. Some of the constraints affecting the diffusion and sustenance of renewable energy electrification projects include; lack of technical knowledge needed to run and maintain the systems after start up, dispersed population leading to low population demanding energy, lack of spare parts to support installations, unsuitable models of financing the projects (Ibid*,* 2017).

A study carried out by Deshmukh *et al.* (2013) on provision of a framework for mini-grid policy design on the strength of specific application examples from seven different countries namely; China, India, Brazil, Nepal, Sri Lanka, Cambodia, and Tanzania found that there were many barriers to the successful installation of renewable energy mini-grids specially to ensure they operated sustainably over a long period of time. Some of the barriers were; high start-up cost of investment, low-capacity factors, usually higher domestic tariffs in comparison to tariffs for main grid customers, inadequate funding to support investment, failures in technology, absence of established institutions to ensure effective and dependable operations are maintained efficiently over time, absence of measures put in place to deal with complaints, and uncertainty due to possible main grid encroachment. The authors also observed that appropriately designed policies and having in place institutional measures along with adequate funding arrangements could deal with

most of the highlighted barriers thereby aid the application of renewable energy-based mini-grids successfully (Ibid).

On another hand, there is need to transfer skills when introducing an innovation to a developing country as it is perceived new within the social system. The process involved in transfer of knowledge and skills fosters the successful adoption of the innovation. A study to analyse the factors that influenced the adoption of renewable electricity through a mini-grid, from the individual household perspective at the village of Tiribogo in Uganda revealed three categories of factors affecting the adoption of the mini-grid innovation leading to intra-diffusion within the community. First, there were aspects of technology relating to the benefits of the new technology. Second, was in terms of the economic aspect regarding financial viability especially that adopters were in a low-income market. Third, was the social aspect, with respect to the collaboration of foreign firms with local actors to utilise appropriate channels of communication aimed at proper management of users' expectations. In view of the three highlighted aspects, diffusion could be adversely affected if any one of them was not efficiently managed (Eder *et al.*, 2015).

In addition, Payen *et al.* (2015) highlighted results for a survey conducted for selected hydro mini-grids, implemented by Practical Action or other organisations in Zimbabwe, Malawi and Zambia which form part of SADC that the barriers which hamper the sustainability of the mini-grids despite the schemes having their own operation specifics are the same as follows:

i) There are no specifically established regulatory frameworks for Mini-grids, hence administrative procedures are generally complex and usually require several places of contacts in order to implement;

ii) The initial cost of investment could be grant aided funded to start up the first mini-grids. However, the regulated socially acceptable tariffs charged by developers inhibit expansion because it means new grants would be needed for every new project;

iii) The existing legal framework lacks feedback on a suitable tariff structure that could be socially accepted as informed by the levels of revenue realised from the mini-grids business which are often very low and inadequate for the up keep to cover maintenance costs;

iv) Matching electricity supply with demand from the inception design to the routine operations (load factor optimisation) is important to ensure financial sustainability of the project, and

v) Lack of qualified personnel required throughout the project life cycle from installation to routine operation and maintenance of the mini-grid installation.

2.5 Thematic literature review

The thematic literature review presented in the subsequent sub-sections delves on aspects relating to; setting up mini-grid business, models of business for mini-grids, strategies for sustainability of mini-grid business, government support systems including policies and regulations and strategic resources required to achieve sustainable competitive advantage.

2.5.1 Setting up mini-grid business

When setting up an electricity mini-grid for entrepreneurial purposes, extensive surveys are carried out to profile and select a suitable site where to install the generation and distribution facility. Murunga *et al.* (2014) provides an example of the basic procedure for site selection based on five site parameters that are categorised and ranked to evaluate the basis for setting the selection criteria, evaluating the proposed sites, and final selection of the site as shown in table 2.1. Going by the categorised parameters and associated ranking criteria, it is apparent that sites that do not meet the requirements illustrated cannot be considered for mini-grid installation for entrepreneurial purposes if the private mini-grid developer prioritises the logic of economic viability because the focus is on responding to demands from investors whose focus is on the economic viability based on return on investment of the project within a short term to be assured of security resources. On the other

hand, mini-grid developers that do not have resource constraints tend to follow a long-term strategy where synergies are sought from combining the logics of social welfare and economic viability to achieve successful long-term organisational outcomes as found in the study by Pedersen (2017).

Table 2.1: Categories of site selection parameters

No.	Category	Parameters
1	Exact location of installation	a) Distance to existing power source (proximity to grid or off-grid power sources) b) Transmission distance based on population distribution (dense or sparse) c) Accessibility and topography (terrain)
2	Productivity	a) Water pumping (b) Irrigation c) Cottage industries (d) Commercial activities
3	Payment for services	a) Ability to pay (b) Willingness to pay
4	Magnitude of potential power consumers	a) Household units (b) Businesses c) Social institutions (d) Administrative e) Development organisations
5	Security	a) Cattle rustling (b) Clashes c) Highway banditry (d) Petty theft

Source: Murunga *et al.*, 2014

In addition to site selection, implementing learnt technology and customising it focused on generation capacity and balancing components that constitute the system with consideration to meet end use fitness for purpose is necessary to accomplish use of off-grid solutions aimed at increasing availability of electricity that support livelihoods in the selected off-grid rural areas (IRENA, 2018).

When designing rural electrification projects using renewable energy sources, there is a challenge known as AVEREMS problem, which involves balancing the electricity min-grid system components to match generation capacity to accurately meet the demand for a target community or the actual load consumption (Ranaboldo, 2015).

Earlier studies undertaken have provided methodology for load profiling based on which sizing of a mini-grid could be assessed (Ibid, 2015; Gambino *et al.*, 2019). Further, the design of the generation plant can be optimised using the simulation HOMER Pro Micro-grid Analysis Tool, which assists in the planning and design of renewable energy based multi-source generation systems (Weimar and Hardy, 2017; Tazvinga and Dzobo, 2018).

2.5.2 Models of business for mini-grids

The new fast growth in renewable electricity off-grid systems distribution is an outcome of great modernisation in financing and operation of models for business as well as delivery business models to avail affordable solutions for end users and to improve the sustainability of off-grid systems (IRENA, 2018). Further, Payen *et al.* (2015) supplement this perspective that establishing sustainable models of business with ability to be scaled up is essential for increasing the diffusion of mini-grids.

2.5.2.1 Financing and operation models

Financing and operation models for the mini-grids business refers to ownership and management with respect to provision of the start-up investment cost for installation and routine running and upkeep of the mini-grid. The Africa Progress Panel (2016) generally distinguishes the mini-grid financing and operation models into four categories being; utility, private, community and public-private models as briefly explained in the next subsections.

a) Utility model

Utility model is where a state-owned company or private utility company is in charge of establishing and running of the mini-grids distributing the generated electricity to customers through a network. The utility company is likely to be sponsored by the government. The utility model has emerged as the common model for electrifying rural areas in countries that are developing (Ibid).

For instance, the utility model includes; Tsumkwe PV Solar - Diesel hybrid mini-grid in Namibia financed using public and donors' funds. The regional

government through the Ministry of Public Works owns and operates the mini-grid. The installation with generation capacity of 202 kW supplies power to 3,000 domestic customers and 35 commercial and public-service customers (Ibid). Another example is the 620kW Kasanjiku hydro mini-grid installed at Kasanjiku falls in North Western Province of Zambia. The state-owned institution, REA installed the Kasanjiku hydro mini-grid and supplies electricity to Luwi Mission Hospital, eight (8) Primary Schools, three (3) High Schools, four (4) Rural Health Centres, one (1) Local Court, Churches, Trading Centres, and Households.

b) Private Model

Private model is where a private company does the installation, owns and is in charge of running and upkeep of the mini-grids distributing electricity through a network to customers who are directly connected. The private entities are usually small or medium in size. They source investment capital from various sources, which include; grants, commercial or concessional loans and equity to install and operate the electricity mini-grids (Ibid).

An example of the private model includes; mini-grids installed by Powerhive in Kisii and Nyamira in Kenya. The company runs four (4) Solar PV mini-grids supplying power to in excess of 1,500 consumers (Ibid). Similarly, Solera Power Vending Machines in Zambia operates PV mini-grids at Luangwa, Kacholola, and Katete supplying electricity to several local commercial customers. Also, Engie Power Corner operates a PV- Diesel hybrid mini-grid at Chitandika village in Chipangali constituency in Eastern Province supplying electricity to 131 households, 3 institutions with staff households, 5 large commercial productive uses (i.e., 1 Oil Expeller, 2 Hammer Mills and 2 Dehaulles). Another example is the Zengamina hydro mini-grid on Zambezi River in Ikelenge District of North Western Zambia. The facility supplies electricity to Kalene Hospital as well as the local clinics, the Kalene farm orphanage, schools and 1,000 households.

c) Community model

Community model is where ownership, running and upkeep of the mini-grid is done by community. A specialised tech agent is contracted by the community or the Non-Governmental Organisation (NGO) on behalf of the community to design and install the mini-grid for the community because the communities in rural areas tend to lack expertise for carrying out the design and installation of mini-grids in their midst. The cost of investment is obtained through grants that are complemented by contributions from the community in form of cash or in-kind. For purposes of operation and maintenance, a village committee or cooperative is put in place (Ibid).

An example of the community financing and operational model in Kenya include; the four (4) hydro power mini-grids at Thima, Kathamba, Tungu Kabiri and Kipin (Ibid). A recent installation which provides a similar example is the 32.5kW Solar PV Mini-grid operated by the Chibwika Chiefdom Trust in Mwinilunga District of Western Province of Zambia. The mini-grid has capacity to distribute electricity to about 300 households in Chibwika chiefdom and the schools and clinics within near proximity.

d) Public-private partnership model

Public – private partnership model approach is some form of hybrid model built on the strengths of the earlier discussed models to involve different public and private entities in owning and operating different portions of the of the mini-grid system in order to maximise effectiveness and efficiency. For instance, a private company can take responsibility for the electricity generation whereas the electricity distribution network is taken care of by a private technical support enterprise contracted by a community organisation. All the various combinations that are out there for the public-private financing and operation model run on contractual agreements entered into by the different participating organisations in order to establish successful operational order (Ibid).

Examples of such diverse hybrid business models are found in Senegal. In the first example, the government has entered into a 15 years concession with a private company contracted to operate and maintain the mini-grid owned by the government. A similar approach for the second example, a private enterprise has been contracted to operate 18 solar PV- Diesel generator hybrid electricity mini-grids supplying power to in excess of 38,000 domestic customers, 88 Schools and Clinics as well as commercial and public buildings (Ibid).

2.5.2.2 Delivery business models

Extant literature, has revealed that delivery business models for entrepreneurial mini-grids refers to the manner electricity is distributed to end users and can be classified into three categories being; lighting only, lighting - plus commercial services and anchor load model (Bhattacharyya, 2018). The delivery business model selected for the community is informed by the nature of the customers' or off-takers' electricity needs hereby briefly explained:

a) Lighting only model

This delivery model essentially provides elementary lighting services including at most mobile phone charging facility for 30–50 households using DC or AC local grids. The preferred power source is Solar PV whereby the service is generally available for few hours in a day. This business model does not cater to productive loads;

b) Lighting - plus commercial services model

This model expands the scope of the lighting only model by catering to commercial productive end use activities such as shops, food processing, saloon, welding, tailoring, bakery etc.; and

c) The anchor load model

The anchor load delivery is where a mini-grid services a bulk key commercial load including provision of elementary electricity for use by the surrounding

community. The key consumer avails the base load that supports the viability of the project, while elementary lighting supplements the peak demand.

2.5.3 Strategies for sustainability of mini-grid business

Renewable energy off-grid solutions such as mini-grids are able to power the basic services such as provision of health care, water and education through productive end-uses. Such is achievable once stakeholders across sectors of the community are engaged at the project design stage in order to bring on board potential productive end-uses that are envisaged to be powered from the planned mini-grid so that expected loads inform the required adequate generation capacity that should be installed (IRENA, 2018). Similarly, a study by Bello (2020) on sustainable energy delivery models for off-grid rural areas of Nigeria through an evaluation of institutional processes that lead to sustainable outcomes within decentralised electrification infrastructure found that institutional design for electricity access requires greater coordination between service providers and its users to make the mini grid model for electricity delivery a sustainable option. Further, Azimoh *et al.* (2017) in their study to identify success factors and challenges from the functioning mini-grid installation in Tsumkwe, Namibia concluded that the design of rural electrification systems should accommodate business interests, population growth and the corresponding load increases, to ensure long term sustainability of the systems.

Other strategies necessary for sustainability of mini-grids business includes adequate capacity building within the public and financial institutions crucial for creating a permitting environment to support establishment of off-grid renewable energy and execution of the strategy on national energy access. Sensitising stakeholders on the inherent characteristics of renewable energy off-grid solutions aimed at addressing some of the challenges encountered by using the new technologies with respect to user averse and stringent funding could be an additional strategy (Ibid, 2018).

A key strategy for operational sustainability of the mini-grid for entrepreneurial projects is to put in place planned arrangements for operations and maintenance of the system. A study on sustainability of rural electrification programs based on off-

grid photovoltaic (PV) systems in Chile by Féron (2017) revealed that different projects in particular small-scale projects persisted to struggle with maintenance issues.

2.5.4 Government support systems including policies and regulations

The policies and regulations seriously influence the growth of the off-grid renewable energy sector. Bringing off-grid solutions into the mainstream of national energy access strategies lays a strong foundation for market expansion and incentivises different stakeholders to devise tailored solutions to provision of energy services (IRENA, 2018). Unfortunately, although several governments have prioritised making electricity available, their policies are biased to electrifying through extension of the main grid through traditional utilities. Hence, decentralised mini-grids, regardless of their advantages, have received much less prominence. Mini-grid distribution to various parts of the country has often been left to private developers and non-governmental organisations with government support limited to the provision of capital subsidy. Where governments have taken responsibility for developing mini-grids, they usually tended to focus on installation and rarely provide enough continued support for the systems upkeep (Deshmukh *et al.,* 2013).

A study conducted by Féron (2017) across selected Andean countries namely; Chile, Ecuador and Peru found that sustainability of off-grid renewable energy solutions for electrifying rural such as mini-grids in developing countries is constrained by the unavailability of enhanced and empowered official government organisations that formulate policy and regulations in addition to ensuring the enforcement of laws. In agreement with the finding, IRENA (2018) highlights that many governments around the world establish an energy regulatory authority for such purpose. Deshmukh *et al.* (2013) observed that for mini-grids to play a substantial role to provide access to reliable and affordable electricity, a robust policy framework required. In Zambia, the Ministry of Energy formulates policies, whereas the Energy Regulation Board is responsible for formulating regulations and subsequent enforcing.

In addition, a suitable institutional framework is required to effectively carry out a national strategy for accessing energy that promotes diffusion of renewable energy off-grid solutions for electrifying rural areas. In the same vein, Féron (2017) in her study of sustainability of rural electrification programs based on off-grid photovoltaic (PV) systems in Chile found that a state energy agency mandated to operationalise off-grid systems was needed to spear head and supervise technological innovations. Some countries such as Zambia and several other countries in Sub-Saharan Africa have established such state agencies called Rural Electrification Agency, while others have empowered existing ministries to carry the responsibility for rural electrification.

2.5.5 Strategic resources required to achieve sustainable competitive advantage

The firm's resources consist of the entire assets, capabilities, organisational processes, firm attributes, information and knowledge etc. controlled by the firm to enable it to conceive and apply strategies that advance its efficiency and effectiveness (Barney, 1991:101).

Resources of the firm could be classified either as tangible or intangible. Tangible resources are physical assets such as; financial and human resources, real estate, raw materials, machinery, plant, inventory, brands, patents and trademarks and cash, whereas intangible resources may be embedded in organisational routines or practices such as an organisation's reputation, culture, knowledge, accumulated experience, relationships with customers, suppliers or other key stakeholders (Andriessen, 2011; Lev, 2001).

Further, Barney (1991) distinguishes strategic resources from other resources as assets that are; valuable, rare, difficult to imitate, and non-substitutable as elaborated:

a) Valuable resources

These are relatively acquired at high cost and are used to gain economic advantages and neutralises commercial pressures in a firm's environment (Edwards, 2019; Barney, 1991). Valuable resources for example in this case can be the equipment installed for an electricity mini off-grid system.

b) Rare resources

These are scarce resources among the firm's present and possible competition enabling the enterprise to implement value-adding strategies not simultaneously applied by many other enterprises (Barney, 1991). The business model adopted by a firm can be cited as example for rare resources.

c) Difficult to imitate

Resources that are valuable and rare provide a basis for sustained competitive advantage unless other firms are unable to acquire them. For example; certain resources are protected by various legal means, such as trademarks, patents, and copyrights, which ensures they are difficult for the competition to imitate (Edwards, 2019). In addition, Barney (1991) presents other aspects that enable a firm to acquire resources that are valuable and rare, which are difficult to imitate such as; (i) time dependent resources acquired during a unique time in history that allow only those firms that were available at that particular time to possess, (ii) casual ambiguity and imperfectly imitable resources which occur when the firm's resources and its sustained competitive advantage are not well understood thereby rendering others to fail to imitate as they are not able to identify which resources to imitate and (iii) social complexity constrains the firm's competitors to imitate very complex social phenomena that require ability to methodically control and influence e.g. the manner managers relate with each other in an enterprise, the enterprise's reputation among stakeholders and a its work culture among others.

d) Non-substitutable

A resource is known to be non-substitutable when competitors cannot find suitable substitutes or alternative ways to gain the benefits that are provided by that resource (Edwards, 2019), or there should be no strategically equivalent valuable resource that are themselves either not rare or imitable to avoid competitors to come up with and apply similar or same strategies that erodes the firm's competitive advantage (Barney, 1991).

2.6 Emerging learning points from the reviewed literature

The reviewed literature revealed a number of emerging learning points from the extant academic and professional publications on the research process and mini-grids as follows:

2.6.1 The philosophy should be established right when commencing the study in order to firm up the philosophical underpinning for one's study regarding the paradigm that guide the study and the underlying assumptions on ontology, epistemology, methodology and methods (Singh, 2019). The research process commences with ontology after which epistemology, methodology, and methods follow (Tuli, 2010; Singh, 2019).

2.6.2 The large-scale electrification networks enjoyed today evolved from mini-grids. The evolution is what has brought up the socio-economic scale-up of power systems seen today, where public actors are involved in regulation of the market to complement achievement of electrification between electricity generators and consumers to the furthest (Korkovelos *et al.*, 2020).

2.6.3 At Global and Africa level, rural electrification programs using mini-grid have recorded success despite challenges. Although successes have been recorded in other developing countries, the sub-Saharan African has lagged with limited success. Some of the constraints affecting the diffusion and sustenance of renewable energy electrification projects include; lack of technical knowledge needed to run and maintain the systems after start up, dispersed population leading to low population demanding energy, lack of

spare parts to support installations, unsuitable models of financing the projects (Azimoh *et al.*, 2017). A survey conducted for selected hydro mini-grids, implemented by Practical Action or other organisations in Zimbabwe, Malawi and Zambia which form part of SADC reported that the barriers which hamper the sustainability of the mini-grids despite the schemes having their own operation specifics are the same as follows: no specifically established regulatory frameworks for mini-grids; the regulated socially acceptable tariffs charged by developers inhibit expansion because it means new grants would be needed for every new project; existing legal framework lacks feedback on a suitable tariff structure that could be socially accepted as informed by the levels of revenue realised from the mini-grids business; load factor optimisation and lack of qualified personnel required throughout the project life cycle from installation to routine operation (Payen *et al.*, 2015).

2.6.4 Setting up mini-grid business for entrepreneurial purposes requires the area to be profiled through extensive surveys in order to select a suitable site for installing and operating the mini-grid. Profiling an area is based on established criteria on which site parameters are considered pursuant to the logic i.e., economic viability only or a combination of socio-economic welfare viability. The economic viability logic is solely focused on profitability so as to respond to investors' demands and prove the viability of the project economically within short period thereby safeguard resources. On the other hand, the socio-economic welfare and viability logic pursues a strategy that spans over a long-term where synergies are realised by combining the two logics to achieve successful long-term organisational outcomes (Murunga *et al.*, 2014; Pedersen, 2017).

In addition, when designing rural electrification projects using renewable energy sources, there is a challenge to match generation capacity to accurately meet the actual load consumption known as AVEREMS problem. Methodologies for load profiling based on which sizing of a mini-grid could be assessed have been developed. The design of the generation facility can

then be optimised using the simulation HOMER Pro Micro-grid Analysis Tool (Ranaboldo, 2015; Gambino *et al.*, 2019; Weimar and Hardy, 2017; Tazvinga and Dzobo, 2018).

2.6.5 The models of business for mini-grids may be considered in two-fold being; financing and operation business models as well as delivery business models. Financing and operation models for the mini-grids business refers to ownership and management based on provision of the upfront cost for establishing the mini-grid and the routine running and upkeep cost of the system, whereas delivery business models for entrepreneurial mini-grids is the manner electricity is distributed to end users and can be classified into; lighting only, lighting plus commercial services and anchor load model as informed by needs of the off-takers or customers.

2.6.6 Strategies for sustainability of mini-grid business include bringing on board potential productive end-uses that are envisaged to be powered from the planned mini-grid installation so that expected loads inform the required mini-grid generation capacity that should be installed adequately. A key strategy for operational sustainability of the mini-grid for entrepreneurial projects is to put in place planned arrangements for operations and maintenance of the system. (IRENA, 2018; Bello, 2020; Azimoh *et al.*, 2017; Féron, 2017)

2.6.7 Government support systems including policies and regulations strongly influence the setting up of the sector for off-grid renewable energy. Therefore, bringing off-grid solutions into the mainstream strategy for national energy access provides strength for market development and incentives. Although several governments have prioritised making electricity available, their policies are biased to electrifying through extension of the main grid through traditional utilities. A vigorous policy framework is necessary for mini-grids to play an important role in making electricity available effectively and efficiently. Many governments around the world establish energy regulatory authorities for such purpose. Some countries such as Zambia and several

other countries in Sub-Saharan Africa have established agencies responsible for rural electrification existing autonomously, while others have placed the responsibility for rural electrification under existing ministries or agencies (IRENA, 2018; Deshmukh *et al.*, 2013; Féron, 2017).

2.6.8 A firm requires to have strategic resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in its business environment in order to achieve sustainable competitive advantage (Edwards, 2019; Barney, 1991).

2.7 Knowledge gap

The knowledge or research gap is more broadly understood as the problem that the researcher would want to see addressed by their study or the gap that the researcher would fill with their proposed research project. Simply put, the research gap is simply defined as the question or problem that has not been answered and therefore establishes the need or importance or indeed the necessity for the proposed research (Philo-notes, 2020).

The subject matter on hand emanates from the United Nations' call based on the SDG7 for member states to ensure access to affordable, reliable, sustainable and modern energy for all by 2030. Going by the said call, the author observes that diffusion of electricity mini-grids which are known to be one of the solutions for rural electrification has to be done without preferences for some areas at the expense of others on such basis of economically productive areas as is the current practice for siting of mini-grids by private developers. Instead, measures to sensitise dwellers in rural areas ought to be carried out by striving to make all inhabited areas economically productive and improve people's well-being.

The electricity mini-grid systems are mostly installed for entrepreneurship purposes. In order to achieve the concept of diffusion (spreading widely to other areas), the successful implementation of a chosen business model for an electricity mini off-grid system at one area should be replicated to other areas based on the same business model or indeed

another suitable business model that applies to the proposed site since business models tend to be site specific.

While electricity mini-grids exist in many places of Zambia, few are installed for entrepreneurial purposes. The majority are installed for own use mostly donor sponsored for use at rural health facilities so as to provide lighting and power for operational support equipment. Other mini-grid installations are government funded to strategic facilities of national importance either as power backup or indeed as primary power supply. The cause of slow diffusion of electricity mini off-grid systems in rural areas of Zambia for entrepreneurial purposes is of concern because rural communities in off-grid areas continue to have no access to electricity supply.

Notable studies have been published relating to the topic of rural electrification in Zambia. However, there has been no study conducted to establish the constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia. Therefore, the identified knowledge gap was that “no study had been conducted to establish constraints of electricity mini off-grid systems diffusion for entrepreneurship in Zambia” thus this study sought to fill the identified knowledge gap using Zambia as a case study. The significance for the study is that it serves as a heads-up for future developers and policy makers so that they can formulate action plans to address the constraints to be identified through this study.

2.8 Chapter summary

The second chapter reviewed appropriate publications on the epistemology of electricity mini-grid systems in order to provide an underpinning of the study. Chapter two has discussed the history of electricity mini-grid systems followed by empirical studies and thematic literature review that discussed; setting up mini-grids, models of business for mini-grids, strategies for sustainability of mini-grid business, government support systems including policies and regulations and strategic resources. The chapter has also presented emerging learning points from the reviewed literature and has established the knowledge gap. The next chapter is on the theoretical and conceptual framework.

CHAPTER THREE

THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter begins by presenting theories used in the study followed by a critical review of the chosen theories. The chapter goes on to present the conceptual framework and operationalisation of conceptual framework variables. The chapter further presents the hypotheses and their operationalisation to the study prior to closing with a chapter summary.

3.2 Theories of the study

The philosophy underpinning this study as earlier established in the preceding chapter is pragmatism, co-founded by American philosopher and educator John Dewey who held the view that ideas such as theories are instruments or tools, that humans use to make greater sense of the world Gouinlock (2021).

Regarding theories, Liehr and Smith (2014) guides that a researcher may choose to use concepts resident in more than one theory to meaningfully explicate one's research problem. Therefore, the combined use of the diffusion of innovations theory together with resource-based theory concepts was to enable a consolidated output of the study regarding the constraints of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia.

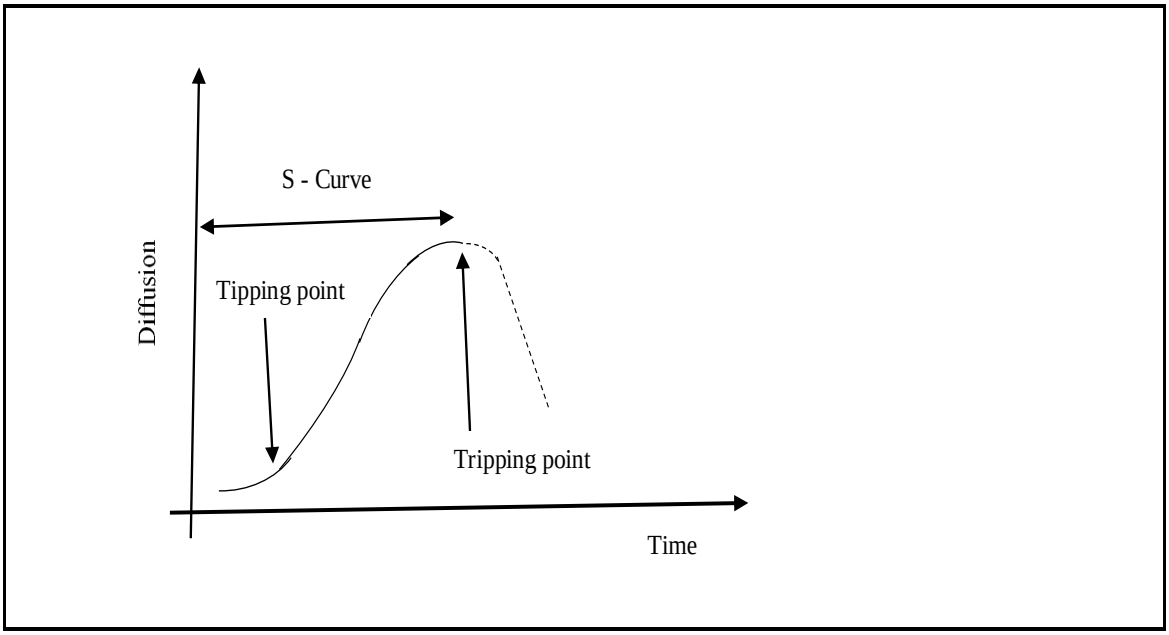
3.2.1 Diffusion theory of innovations

The diffusion theory of innovations explains how, why, and at what pace innovative ideas are spread (Rogers, 1983). In agreement, Johnson *et al.* (2011) express diffusion as the process of spreading innovations amongst users and advocate that because innovation is characteristically costly, its appeal commercially in terms pace of diffusion is an aspect that entrepreneurs could influence from either the supply or demand sides.

In this regard, the diffusion of innovations theory underpins this study to explain the rate of spreading of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia.

The pace of diffusion is known to widely fluctuate due to the nature of the innovation concerned. Some innovations take long to reach a certain level of diffusion, while others take short time. The pace of diffusion is illustrated using the S-curve pattern (diffusion curve) model. It is typically not steady though most successful innovations tend to broadly follow the pattern. The S-curve is an influential concept that highlights the diffusion of product acceptance over time on the market. The S-curve shape in figure 3.1 shows a course of early slow adoption of the innovation, followed by a rapid growth in diffusion that leads to a highland reflecting the limit to demand (Johnson *et al.,* 2011; Bygrave and Zacharakis, 2011).

Figure 3.1: Diffusion S-Curve



Source: Johnson *et al.*, 2011

Going by the S-curve pattern shown in figure 3.1, the extent of diffusion is depicted by the height of the S-curve, while the speed of diffusion is illustrated by the shape of the S-curve. The S-curve can assist managers and entrepreneurs to expect and plan for upcoming issues with respect to the tipping point and the tripping point:

a) Tipping point

Tipping point indicates a sudden explosive increase in demand as customer awareness and demand exceed supply when the market enters a fast-growth phase. Entrepreneurs can better plan for increased investment in capacity and distribution once they predict a possible tipping point ahead (Ibid).

b) Extent of diffusion

The extent of diffusion is shown by the S-curve though not necessarily imply overarching diffusion across possible users. Entrepreneurs ought to forecast the extent of diffusion by being cautious without assuming that tipping point growth will dominate the entire market. Ascertaining the plateau on the S-curve signals to entrepreneurs of likely decline in demand growth. Precautions should be taken not to extrapolate existing tipping point growth rates forward because increased capitalisation prior to down turn in growth could cause the firm to be left with excess capacity thereby incurring additional expenses (Ibid).

c) Tripping point

Tripping point refers to a sudden down turn in demand although the decline is often steadily slow in practice. The variations in customer preferences could lead to some customer defections thereby setting off a market landslide that may be very hard to reverse. Tripping point concept alerts entrepreneurs to be mindful of small slopes in defined periodic sales as they could signal a rapid collapse (Ibid).

The rate of diffusion is affected by a collaboration of supply and demand side aspects, whereby entrepreneurs hold substantial control (Johnson *et al.*, 2011).

For the supply side, rate of diffusion gets influenced by inherent characteristics of the product and features such as (Ibid):

i) Extent of improvement in performance: from a customer's perspective the new product should provide incentives exceeding current products to

cause desire in customers to change. In such cases, entrepreneurs have to make sure benefits of new innovations exceed price and performance of existing products;

ii) Compatibility with other products: entrepreneurs have to ensure suitable corresponding products and services are availability to permit supplementary usage. For example; digital TV is more attractive as the broadcasting networks change more of their programmes to that format;

iii) Pricing the product: simple pricing structures typically play a role in accelerating adoption of innovations. Unduly complex pricing structures that are difficult to understand put off customers. An example of complex pricing is those with many financial services like pensions;

iv) Experimentation: where eligible users are allowed to test the product to assess performance before committing a final purchase decision to buy. Product testing could be either having an encounter with the actual product or by word of others through their experiences. For instance; free initial trial periods of use in addition to reviews from early adopters on the website encourages diffusion; and

v) Relationship management: by suitable mechanisms put in place for new and potential users to access information about the product regarding; how to make purchase orders, after sales support and maintenance information.

The three main factors that tend to influence the rate of diffusion regarding demand aspects include:

i) Market sensitisation: several new products that could potentially have succeeded on the market tend to fail due to lack of consumer awareness usually when the promotional effort of the innovator is delegated to

intermediaries such as distributors (Ibid). Bygrave and Zacharakis (2011) point out that when a product or innovation is first introduced on the market, few people are aware of it. Therefore, the firm has to educate consumers about why they need this product and the value it offers;

ii) Network effects: as more people who interact with each other become aware about the new product or service, the rate of diffusion accelerates with demand growth for the product or service. At the point where a critical mass of users adopts the product or service, other consumers follow suit to adopt it too and the rate of adoption becomes self-sustaining (Rogers, 2003); and

iii) Customer innovativeness: innovations are often targeted initially at those that are keen to adopt – typically the young and the wealthy in order to build the critical mass that would encourage more laggardly groups such as the poorer and older ones to follow through. As observed from the clothing fashion, new fashion starts with the wealthy and is then diffused to the wider population. Likewise, entrepreneurs could target their innovations at likely early-adopters in order to quickly build the critical mass of users (Ibid).

3.2.2 The resource-based theory of entrepreneurship

Resource-based theory of entrepreneurship argues that individuals are likely to act on opportunities once they access necessary resources (Davidson and Honing, 2003). This study sought to ascertain whether resources were a constraint to explain the slow rate of spreading of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia.

The resource-based theory of entrepreneurship also referred to as the Resource-Based View (RBV) is a decision-making framework that guides on the strategic resources (as elaborated under 2.5.5) a firm could exploit to achieve sustainable competitive advantage over its rivals in the business environment.

3.3 Critical review of the theories chosen for the study

The two theories chosen i.e., diffusion of innovations theory and the resource-based theory of entrepreneurship are renowned for their achievements. However, they have been criticised for their inherent shortcomings which the user of the theories ought to be aware of and address for amelioration in order to effectively apply them successfully.

3.3.1 Diffusion of innovations theory

The Diffusion of Innovation theory which anchors this study contributes significantly to the advancement and knowing human behavioural transformation and the contributions are greatly regarded. However, its potential has also been impacted by limitations and biases. To note among other aspects is that quantifying diffusion is difficult because human interactions are complex and the network of interactions among humans intensify the difficulty to determine what precisely leads to adoption of an innovation. For example, promoters that encourage adoption of health behaviours or new medical technologies need to know the many forces acting on an individual for one to decide to adopt an emerging behaviour or technology. For instance, in healthcare, diffusion of innovation theory cannot explain the entire variables, and therefore may error on crucial indicators of adoption (Plsek and Greenhalgh, 2001).

Rogers (2003) highlights the following four criticisms, which ought to be thoroughly managed in order for the continued successful utilisation of the diffusion of innovation theory namely: pro-innovation bias, the individual blame bias, recall problem, and the issue of equality. Each criticism is discussed in the next subsections:

3.3.1.1 The pro-innovation bias

The pro-innovation bias is the insinuation of most diffusion studies that an innovation should spread and be adopted by every member of a social system, expecting that diffusion should be more rapid with no room for neither re-invention nor rejection (Rogers, 1983:92). This viewpoint is echoed by Botha and Atkins (2005) that the expectation of the theory is that it does not make provision for possible rejection of the innovation.

However, it should be noted that innovations may not all be acceptable ideas because inappropriate ideas must be rejected in best interest of the community before causing adverse results. The pro-innovation bias points diffusion researchers to disregard unawareness about the innovations, to understate the rejection or advocate for further utilisation of the innovation, to underplay the need for re-invention, and not pay attention to learning anti-diffusion procedures intended to avoid the spread of inappropriate innovations or discontinuance of already made products (Rogers, 1983; Fenech and Longford, 2014).

3.3.1.2 The individual blame bias

Individual-blame bias refers to the act of holding responsible an individual for one's problems, instead of the system to which that individual belongs. Botha and Atkins (2005) observe that this kind of bias causes the victim as an individual adopter to be blamed while ignoring social structures of the system. This view agrees with Rodgers (2003) who points out that as a result a certain level of individual-blame can be detected from sponsors of diffusion research rather than blame the system.

The individual-blame bias is a form of source bias that sides with changes agencies promoting an innovation and not the potential adopter. This position means that if your shoe doesn't fit you right, then there should be something wrong with your foot (Ibid, 2003). For example, development agencies responsible for agriculture extension services are not blamed for failure to provide appropriate remedies to the challenges of farmers. Rather, the individual farmers who because of low financial capacity, farm size, educational level and ignorance about modern technology among other factors are unable to adopt the modern agricultural technologies to achieve high productivity are blamed for their lack of response (Muneer, 2014).

3.3.1.3 Recall problem

Rogers (2003) highlighted that focusing on the time variable distinguishes diffusion research from most other social science research because diffusion

takes place over a period of time. Therefore, time is a key factor when one studies diffusion. For example, this study looks at the experience with mini-grids in Zambia for the period 2013 to 2019. Diffusion research depends on research subjects recalling data from when they adopted the new idea. This is a source of the recall problem because it entails the preservation of information accurately over time. In such case, the respondent is requested to review their history to reconstruct their past experience with the innovation but that may cause some inaccuracies in their hindsight for purposes of understanding the phenomenon being considered.

3.3.1.4 The issue of equality

From the beginning, spreading of an innovation is usually perceived as a process that assures the trickle-down of income and welfare-generating ideas that appears to guarantee their equal distribution across the entire population for a given community. However, the issue of inequality sets in seeing that diffusion of innovations widens the socioeconomic gap in distributing benefits of the innovation between the high and the low class status members of the population in a social system (Rogers, 2003; Phiri, 2017). This is a cardinal matter that has not receive enough consideration with respect to health care undertakings for the underprivileged or vulnerable populations that tend to benefit less from the health innovations. It is apparent that diffusion of innovations could broaden the socioeconomic gap regarding customer innovativeness where the young and the wealth are targeted first in order to build critical mass of sales. Diffusion strategies as are practiced by most change agencies, often lead to increased inequity in societies (Ibid*,* 2003; Röllng *et al.*, 1976; Phiri, 2017). Among other approaches to address the issue of equality includes the use of universally designed products and environments that cater for every user to an extent possible without carrying out any retrofitting, or applying special adaptation or modification to existing designs to assure access for all in buildings (Lidwell *et al.*, 2010).

3.3.2 Resource -Based Theory of Entrepreneurship

The critique on resource-based theory which is also known as the Resource-Based View (RBV) presented in this report is based on the paper by Kraaijenbrink *et al.* (2009) who cites Barney (1991a, 1994, 2002) that the central proposition of RBV is that a firm should obtain and be in-charge of; valuable, rare, inimitable, and non-substitutable (VRIN) resources and must have capabilities and an Organisation (O) where to deploy them in order to attain the state of Sustained Competitive Advantage (SCA),

Kraaijenbrink *et al.* (2009), note that the simplicity in presentation of the RBV's core message is appealing and understood without difficulty, yet the RBV has been widely criticised for its shortcomings. It is appreciated that critiques are relevant to advance the RBV since that is how opportunities for improvements known and applied. Further, Kraaijenbrink *et al.* (2009) put together and assessed eight categories of critiques as follows: (i) The RBV has no managerial implications, (ii) The RBV implies infinite regress, (iii) The RBV's applicability is too limited, (iv) SCA is not achievable, (v) The RBV is not a theory of the firm, (vi) VRIN/O is neither necessary nor sufficient for SCA, (vii) The value of a resource is too indeterminate to provide for useful theory and (viii) The definition of resource is unworkable. Each of these critique categories has been explicated in the subsequent sub sections:

3.3.2.1 The RBV has no managerial implications

The RBV appears to direct managerial attention to internal resources in order to acquire VRIN resources and establish an organisation suitable for purposes of attaining sustainable competitive advantages. However, a better least cost-effective strategy would be to imitate the competitors' actions in order to do better on favourable ones, and hence avoid the burden that comes with pioneering the activity (Andersen, 2010). In the same vein, Lado *et al.* (2006) pro-argues that there is underscoring the strain between descriptive and prescriptive theorising within the RBV. On the other hand, Van de Ven (2009) argues that the aforementioned strain is there throughout management studies and there has been no remedy in the adoption of research results. Therefore,

the critique should not especially be aimed at the RBV. Instead of stressing about the RBV's lack of managerial implications, we should perhaps be minding more about the apparent impact it has on management practice, especially that recent management theories are more causal or functional in their modes of enlightenment (Ghoshal, 2005).

In closing on this argument, Barney (2001) indicates that the resource-based logic has many significant real-world applications for managers. For instance, the logic is applicable to assist managers of firms having strategic difficulties to acquire strategic parity by finding valuable and rare resources which their firm presently do not have by indicating that the value of the resources could be copied through imitation or substitution. As such, resource-based logic could provide a theoretical underpinning for benchmarking with several other firms. Further, the resource-based logic is useful for Managers to ensure that they maintain and sustain those resources which provide the current strategic advantage for the firm.

3.3.2.2 The RBV implies infinite regress

This critique suggests that the RBV could lead firms into an endless search for superior capabilities as they differentiate their capabilities to decide, to innovate, and to change. The problem of infinite regress occurs because one can continuously interrogate where that superior performance originated by repeatedly asking in search. Although this challenge is true in an abstract sense, this critique hardly really works against the RBV because any applied theory, such as the RBV normally has many levels of analysis at every level advancing the analysis farther from the empirical level and hence from any feasible application (Kraaijenbrink *et al.*, 2009).

The task involves not only to clarify difference in performance but also to provide means of achieving the positive differences. Even so, latter is a challenge to prescribe because the rule could get disproved if some firms

attempted to follow it, but fail to achieve the positive performance differences (Arend, 2015).

3.3.2.3 The RBV's applicability is too limited

The critique is about the generalisability of the RBV, citing Gibbert (2006) opposing view on resources that are valuable, rare, inimitable, and non-substitutable to be used as the base for sustained competitive advantage. Generalisability or external validity refers to the degree of research findings being common (idiosyncratic) in the case or sample studied. In this case, generalisability expresses the degree to which research findings in one study or firm are also valid in others. Hence, once research findings about the firm resources are actually generalisable, they would violate the RBV criterion of uniqueness thereby eroding conduciveness of creating, managing, and sustaining the firms' competitive advantage.

Levitas and Ndofor (2006) oppose that the paradox between idiosyncratic resources and generalisable research findings is non-existent because the confusion that such a paradox exists results from the logical fallacy of confounding the characterisation of idiosyncrasy that applies to resource attributes and generalisability that refers to research findings. Further argument is that the pursuit for generalisability is counterproductive when applied to the RBV because it is simply not ready for generalisability. The concluding argument by Levitas and Ndofor (2006) is that incorporating RBV advancement that have happened since Barney (1991) such as the knowledge-based view and dynamic capabilities (Grant, 1996), many arguments by Gibbert (2006) and others are rendered obsolete because the focus of the RBV has evolved to the continuous creation and augmentation of resources and capabilities, and beyond the now-obsolete preservation of static competitive advantage.

3.3.2.4 Sustainable Competitive Advantage (SCA) is not achievable

The assumption that SCA is actually not achievable is yet another critique. However, the empirical study by Jafari and Rezaee (2014) has showed to the

contrary that RBV contributes significantly and positively to attainment of SCA. Once RBV practices are established, what the market requires could easily be identified and marketing strategy can be further enhanced to create value for the customers and accordingly increase profitability of the company.

While achieving SCA, inimitability get increasingly compromised as the firm's products and services continue to uncover strategic information about the production processes. Hence, the firm should continue innovating as its revenue stream is constantly exposed to new competitors, substitute products, and so forth (Porter,1980). Kraaijenbrink *et al.* (2009) agree with this assertion pointing out that firms are unable to derive a SCA from a static set of resources in a continually changing environment.

Although SCA does not last forever; it is still a powerful strategic concept on short term basis as management's focus is directed to the dynamics that support it, highlighting the search for practical methods having an edge on the markets own 'natural' timing, hastening innovation or reducing imitation for sustenance. Hence, the fourth critique was dismissed concluding that the RBV contribution responds to its ex-post sources to achieve SCA (Ibid).

3.3.2.5 The RBV is not a theory of the firm

The fifth critique is that the RBV does not meet criteria for a theory of the firm (Kraaijenbrink *et al.*, 2009). While extensive advancements have been achieved on the explanation and analysis of market performance, conduct of the firm and organisation have remained poorly understood (Holmstrom and Tirole, 1987). The proposal by Conner (1991) that the RBV may be taken as a new theory of the firm was drawn primarily from means through which firms attempt to realise their objectives affecting firm performance. As interest in knowledge grew as a strategic resource, deliberations around the RBV being a theory of the firm took the centre stage of dialogue in organisation science (Grant, 1996).

Kraaijenbrink *et al.* (2009) cite a crucial commentary by Foss (1996a, 1996b) concluding that the RBV is insufficient as a theory of the firm. That the RBV explains differences between firms and why firms are better at economic rent creation than individuals. Kraaijenbrink *et al.* (2009) cite that given the attention to coordinative and integrative capabilities of the organisations, it is in particular the knowledge-based versions of the RBV that provide such explanations (Dosi, Faillo, and Marengo, 2008; Foss, 2007; Grant, 1996a). However, for a clarification of why firms exist, why their boundaries and internal organisation exist that way, and why they are better at economic rent-creation than markets, specific references to incentives, asset ownership, and opportunism are needed. Based on proposition by Conner (1991), Kraaijenbrink *et al.* (2009) cite the RBV's originators who have maintained that RBV is not a reputed theory of the firm and that they had no intention of explaining the existence or boundaries of firms.

3.3.2.6 VRIN/O is neither necessary nor sufficient for SCA

The core of the RBV indicates that SCA can be achieved by deploying resources and capabilities which are; valuable, rare, inimitable, and non-substitutable (VRIN) plus having suitable organisation (O) in place ready and able to use the resource to capitalise on its value (Barney, 1994). The first axiom has been subject to a further critique, that the VRIN/O criterion is insufficient and unnecessary to explain SCA. Kraaijenbrink *et al.* (2009) cite the type of sufficiency critique concerning the lack of empirical support for the RBV. There have been two recent reviews indicating (Armstrong and Shimizu, 2007; Newbert, 2007), empirical research has generated only modest support, implying other factors must be considered when elucidating SCA. The sufficiency critique includes methodological issues as has been noted several times that the possession of resources is not sufficient until they are deployed to attain SCA (Makadok, 2001b; Peteraf and Barney, 2003). Yet, by applying the VRIN/O logic to such 'deployment capabilities' as well, the RBV skirts a full explanation for SCA because we are left without a theory of capability deployment.

Despite the sufficiency critique, the empirical findings of the studies conducted recently show that VRIN meaningfully affect company's competitive advantage and performance with indication for a positive effect of RBV practices on SCA (Talaja, 2012; Jafari and Rezaee, 2014)

3.3.2.7 The value of a resource is too indeterminate to provide for useful theory

A widely resonated critique is that the RBV is a tautology that fails to fulfil the criteria for a true theory. Kraaijenbrink *et al.* (2009) refer to the argument by Lockett *et al.* (2009) and Priem and Butler (2001a, 2001b) that the RBV does not contain the law-like generalisations that must be expected. Rather, it is based on analytic statements that are tautological, true by definition that cannot be tested. This was seen explicitly in Barney's original article: "Firm resources included all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" (Barney, 1991a:101).

In a counter argument, Barney (2001) rebuff that it is significant to recognise that, at this definitional level, all strategic management theories are tautological in the way Priem and Butler describe. For example, Porter's (1980) assertions about the relationship between industry attractiveness and firm performance could be termed tautology by observing that firms in attractive industries will outperform firms in unattractive industries and by defining industry attractiveness in terms of the ability of firms to perform well. How far each of the components of the resource-based theory are parameterised in ways that can generate testable propositions are also presented (Ibid, 2001).

3.3.2.8 The definition of Resource is Unworkable

A concluding critique to the RBV by Kraaijenbrink *et al.* (2009) aims at its axiomatic definitions, especially that of resource that are they overly inclusive definitions nothing strategically useful associates with the firm that is not a

resource. On the contrary, resource-based theory has evolved explain well how strategic resources and capabilities allow firms to enjoy SCA. Resources and capabilities are the stepping stone that organisations use to create strategies. These two building blocks are tightly linked in a manner that capabilities arise from using resources over a period of time and the all-inclusiveness is part of the RBV's strength (Barney, 2001).

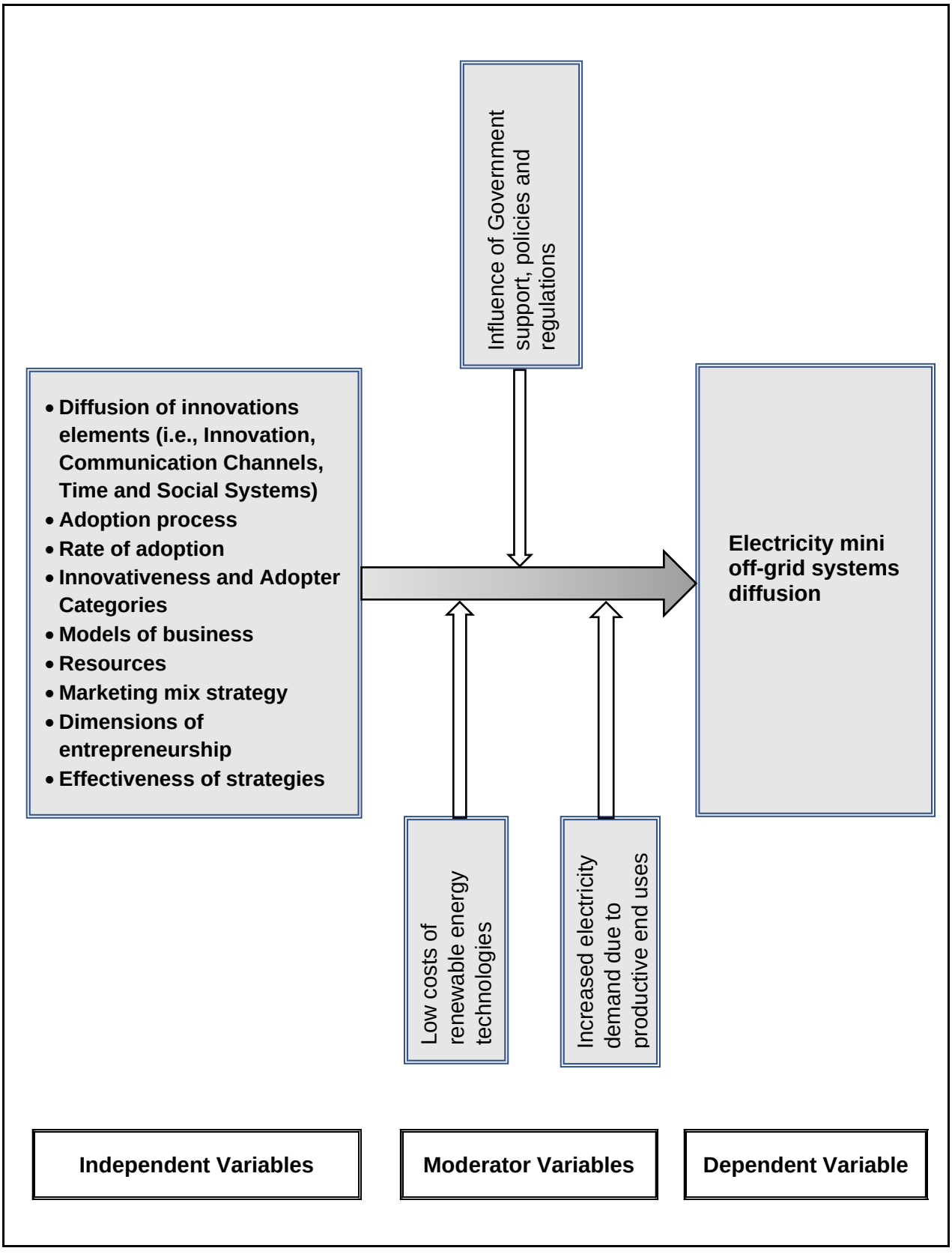
3.4 Conceptual framework

A conceptual framework could be understood as the outcome of bringing together a number of related concepts to explain or predict a given event, or give a broader understanding of the phenomenon of interest or simply, of a research problem (Imenda, 2014:189). The inherent variables of the diffusion theory of innovations were used to explicate how, why and at what pace mini off-grids as innovative ideas were spreading, while the characteristic variables of the resource-based theory established whether resources were a constraint causing the slow rate of spreading of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia.

According to the pragmatism paradigm chosen for this study, mixed methods using a case study (please refer to figure 2.1) is one of the permitted methodologies that can be used. As such, the constraints of electricity mini off-grids system diffusion for entrepreneurship in rural areas were identified through a case study of Zambia.

Figure 3.2 conceptualises electricity mini off-grid systems diffusion as dependent variable (output variable) that is influenced by the independent variables or predictor variables and moderator variables. Swaen (2021) describes moderator variables as those that alter the result that an independent variable causes on a dependent variable without themself being affected by the independent variable, yet they affect the dependent variable as well.

Figure 3.2: Conceptual framework



Source: Author, September 2021

3.4.1 Operationalisation of conceptual framework variables

This study on constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia has nine (9) independent variables that influence one (1) dependent variable and has three (3) moderator variables.

3.4.1.1 Independent variables

The independent variables for the study included; diffusion of innovations elements (i.e., Innovation, Communication Channels, Time and Social Systems), Adoption process, Rate of adoption, Innovativeness and Adopter Categories, Models of business, Resources, Marketing mix strategy, Dimensions of entrepreneurship and Effectiveness of strategies.

In order to operationalise the conceptual framework, independent variables are matched with respective research objectives so as to show how they are linked to influence the dependent variable.

3.4.1.1.1 Variables relating to first research objective

For the first specific research objective, to determine why diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia was slow, the independent variables include: diffusion of innovations elements (i.e., Innovation, Communication Channels, Time and Social Systems); Adoption process; Rate of adoption, Innovativeness and adopter categories, and Effectiveness of strategies.

3.4.1.1.1.1 Elements in the diffusion of innovations

The four main elements (variables) that are identifiable in every diffusion study are; (a) an innovation (b) is communicated through certain channels (c) over time (d) among the members of a social system (Rogers, 2003). The perspective of these four main elements of diffusion is accentuated as:

a) An innovation

An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Ibid). What makes an idea new for the individual determines one's reaction to it because newness in an innovation does not just involve new knowledge. For example, an individual could be aware of an innovation for some time but had not formed a favourable or unfavourable attitude toward it i.e., had neither adopted nor rejected it. The "newness" aspect of an innovation may be expressed in terms of knowledge, persuasion, or a decision to adopt (Ibid). In this case, the innovation is the electricity mini off-grid system – how it works and intended benefits to the target consumers.

b) Communication Channels

In communication process, participants exchange information with one another so as to reach a mutual understanding. A communication channel is the means by which messages get from one individual to another. The essence of the diffusion process is the information exchange by which one individual communicates a new idea to one or several others (Ibid).

At its most elementary form, the process involves: (i) an innovation, (ii) an individual or other unit of adoption that has knowledge of, or experience with using, the innovation, (iii) another individual or other unit that does not yet have knowledge of the innovation, and (iv) a communication channel connecting the two units. This imply that there has to be some degree of heterophily (the degree to which pairs of individuals who interact are dissimilar in certain attributes, such as beliefs, education, social status etc.) between the two participants in order for diffusion to occur. Otherwise, no diffusion can occur when two individuals are identical regarding their technical grasp of an innovation, as there is no new information to exchange (Ibid).

Interpersonal channels are effectively persuasive for an individual to adopt a new idea, especially if the interpersonal channel connects two or more individuals who are near peers. An obvious principle of human communication is that the transfer of ideas occurs most frequently between two individuals who are alike, similar, or homophilous (the degree to which pairs of individuals who interact are similar in certain attributes, such as beliefs, education, social status etc.). Such communication is more likely to be effective and rewarding (Ibid).

One of the most distinguishing problems in the communication of innovations is that the participants are usually quite heterophilous. A change agent, for instance, would be more technically advanced regarding electricity mini off-grids than his target clients in the market (Ibid).

c) Time

Time is an important element in the diffusion process as it is the basis for determining whether the innovation is slow or fast diffusing measured by the membership of the system that adopt the innovation in a given space of time (Ibid).

d) Social System

A social system is described as a set of interrelated units that collaborate to solve a problem as a common goal. The social system may be individuals, informal groups, organisations, and/or subsystems. For example; a social system may comprise the peasants in a selected village, high schools in a particular area, or all the companies involved in a particular line of business in a specific country etc. In any case, each unit in a social system is distinct from other units (Ibid).

All members of a social system collaborate to solve a common problem so as to reach a mutual goal. For example, when faced with a common objective like how the electricity supplied from a mini off-grid would be of

benefit can bind the social system together. It is vital to recall that diffusion occurs within a social system, because the social structure of the system affects the innovation's diffusion in several ways. The social system constitutes a boundary within which an innovation diffuses (Ibid).

3.4.1.1.1.2 Adoption process

An individual or organisation goes through a process to adopt an innovation from first knowing about the innovation to coming up with an impression about the innovation as in whether to accept using the innovation or reject its application (Ibid, 2003:20). The process of adoption can be conceptualised in the following five steps namely; knowledge, persuasion, decision, implementation, and confirmation as detailed hereunder:

i) Knowledge: happens once an individual or other organisation becomes aware of the innovation's existence and its application;
ii) Persuasion: follows when an individual or organisation forms an impression whether positive or negative regarding the innovation;
iii) Decision: occurs once an individual or organisation engages in making a choice leading to whether to adopt or reject the innovation;
iv) Implementation: occurs when an individual or organisation apply the innovation into use; and
v) Confirmation: occurs when an individual or organisation seeks second opinion about the decision already made regarding the innovation to an extent that the decision earlier made may be reversed once in doubt about the innovation.

The use of the marketing mix strategy complements adoption process as the individual or organisation goes through the adoption process.

Especially, the aspects of promotion are crucial at the stage of confirmation when a customer needs encouragement about the decision regarding an innovation.

3.4.1.1.1.3 Rate of Adoption

Rate of adoption refers to the pace at which users or customers adopt an innovation (Ibid). Time dimension is the basis for determining the relative speed in the diffusion of innovations such as the electricity mini off-grid. Rate of adoption can be illustrated using the diffusion s-curve shown in figure 3.1.

The entrepreneur that introduces electricity min off-grid to a selected area would monitor the number of connections over a period of time and then work to improve the pace in order to encourage intra -diffusion among the community of the target area.

3.4.1.1.1.4 Innovativeness and Adopter Categories

Innovativeness is the extent to which an individual or organisation hastens to adopt new ideas than the other members of a social system (Ibid). On the basis of innovativeness, members of the community or social class are classified into adopter categories. The five adopter categories are: (i) innovators, (ii) early adopters, (iii) early majority, (iv) late majority, and (v) laggards.

Each adopter category has distinct characteristics ascribed by Rogers (1983) as presented by Singer (n.d.):

i) **Innovators:** are generally adventurous and are interested in new ideas. They link less with their local peer networks but are more in touch with other innovators who may be located far geographically. Owing to their attraction to innovation, they required adequate monetary resources. They

understand technical concepts and the need to cope with uncertainty. Innovators play an important role in the diffusion of innovations because their link to other innovators enable them to bring in new ideas into their local peer networks. This also makes them entry points or brokers that have control over the flow of innovations between social systems (Ibid).

ii) **Early Adopters:** in comparison to innovators, early adopters enjoy closer links with their local peer networks. They command a level of respect among peers who usually consult them about innovations. Early adopters play the role model that influences other members of a social system. Whenever they adopt an innovation, their assessment reduces level of uncertainty among their peers and encourages others to adopt the innovation. By their actions, early adopters can promote an innovation to reach the critical as the innovation diffuses more widely (Ibid).

iii) **Early Majority:** by estimation, about a third of the adopters belong to the early majority of the social system. They come on board to adopt new ideas just in time before the average members. Although they do not influence adoption as opinion leaders, their interconnectedness in the social system makes them an important contact in the diffusion of innovations (Ibid).

iv) **Late Majority:** similar to the early majority, the late majority make up about a third of the adopters in a social system. They adopt new ideas after the average member have come on board, usually responding to economic necessity or build up in peer pressure. Members of the late majority are skeptical about innovations and take precautions to be sure

that their investment will be worthwhile because of their minimal resources (Ibid).

v) **Laggards:** are concerned with the past and use it as a reference for making decisions. They normally network with peers who are similarly traditional like themselves and keep isolated from the rest of their social system. The laggards' careful behavior when adopting innovations is usually informed by their limited resources. Hence, they need to be sure that it will not fail before adopting an innovation (Ibid).

3.4.1.1.1.5 Effectiveness of strategies

Operators of mini-grids revealed that among other strategies applied for promoting diffusion of electricity mini-grids systems for entrepreneurship in rural areas include: encouraging customers to use electricity for various small productive commercial activities in addition to lighting; make electricity tariffs affordable; provide convenience for payment using pay-as-you-go mechanisms and encourage use of efficient lighting appliances to manage consumer loads and thus offer more value to customers. Bhattacharyya, (2018) observed that due to lack of funding and income constraints among rural dwellers, intra -diffusion (number of connections in given period of time) tended to be quick for customers that use electricity for various small productive commercial activities.

3.4.1.1.2 Variables relating to the second research objective

To establish why mini-grid developers were not initiating additional projects after completion and operationalisation of the initial project according to the second research objective, availability of resources was the basis.

3.4.1.1.2.1 Resources

Resources include cash, vehicles, equipment and buildings among others. However, from the strategic view point of the resource-based model, a strategic resource is an asset that is valuable, rare, difficult to imitate, non-substitutable and enables exploitation of opportunities, while neutralising threats in the firm's environment (Barney, 1991).

Having decided on the business model, the entity then selects strategic resources that would enable it attain sustainable competitive advantages for establishing the electricity mini off-grid system venture to spur diffusion of the innovation and yield a market share that would exceed the projected breakeven point and attain profitability over a period of time.

3.4.1.1.3 Variables relating to the third research objective

Regarding the third research objective to examine whether developers' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages, the variables include: models of business, resources, marketing mix strategy and dimensions of entrepreneurship.

3.4.1.1.3.1 Models of Business for electricity mini-grids

An electricity mini off-grid system is established at a specific settlement and inhabitants of the selected area provide the market. The choice of the appropriate model of business is selected having regard to outcome of the prior profiling of the said area or settlement. In profiling, the area is surveyed to understand the characteristic life style and nature of commercial activities for the target population to be supplied the electricity services (Murunga *et al.*, 2014). Therefore, the delivery model of business chosen for a selected area is informed by the needs of the off-takers or customers i.e., lighting only, lighting plus commercial services or anchor load (Bhattacharyya, 2018) as earlier elaborated in chapter two.

3.4.1.1.3.2 Resources

Resources availability was examined as discussed in 3.4.1.1.2.1 regarding exploitation of opportunities, while neutralising threats in the firm's environment (Barney, 1991).

3.4.1.1.3.3 The Marketing Mix Strategy

With available resources, the electricity mini off-grid system is capable of providing desirable electrical services necessary. However, customers have to be convinced to purchase the electricity in order to forego close substitute products like candles and lanterns for lighting.

The marketing mix strategy which comprises the 4Ps (product, price, place, and promotion) is one of the tools an entity can use to articulate their offer to customers in a persuasive manner (Edwards, 2019). In this case, the product is the electricity, the price is the tariff (as approved by the Energy Regulation Board) that the entity charges for their electricity matching the value offered, the place is the distribution network up to customer premises and promotion comprises communications for marketing the electricity including tools of advertising, public relations, and other forms of direct and indirect selling.

3.4.1.1.3.4 Dimensions of entrepreneurship

The dimensions of entrepreneurship highlighted by Dollinger (2008) using the resource-based theory of entrepreneurship include; (a) new venture creation, (b) opportunity analysis, (c) the individual, (d) the environment and (e) the organisation hereby presented:

(a) New Venture Creation

Concerns entrepreneurship as the starting of a new business enterprise, usually referred to simply as new venture creation. On this concern, Dollinger (2008) agrees well with Barney (1991) that enterprises that use resources and capabilities which are valuable,

rare, hard to copy, and have no good substitutes in favourable industrial circumstances provide sustainable competitive advantage, except that Dollinger (2008) goes on further that the choice of appropriate resources is eventually a matter of entrepreneurial vision and instinct.

(b) Opportunity Analysis

Opportunity is the convergence of preparedness, external conditions, and responsiveness to change. Fluctuations in the business environment churn out opportunities for entrepreneurs. For example, extant firms normally have already arranged their resources, strategy, and organisation structure ready to exploit opportunities in the current environment. However, the new firm has an easier time spotting opportunity caused by changes in the business environment and configure a set of resources and an organisation to meet the new needs and the new realities than an existing organisation. Sources of change can be due to market disequilibrium, production factors and the opportunities created through entrepreneurial activities (Ibid).

According to the late management guru, Drucker (1985) the business environment comprises seven sources of opportunities to look out for such as:

i) The Unexpected: existing businesses usually fail to adapt quickly when they are surprised by an unexpected event to take advantage of events such as wars and new discoveries among others.

ii) The Incongruous: strangeness is dissension where something that “ought to be” but is not. Incongruity causes unpredictability and somehow opportunity. For example; experts that have

practiced for a long time in industry would use the words “never” and “always” to illustrate how things should be. Such unchecked assumptions could have been correct, but may now be incorrect and thus could create opportunities for the open-minded entrepreneur.

iii) The Process Need: processing is required to convert material from one form to another. Whenever the technology has an inability to provide a break through, there is need to carry out research projects in order to solve a single problem on hand. That way, opportunities for other products emanate.

iv) Industry and Market Structures: changes in technology due to innovations and inventions affect the market and industry structures owing to changes in cost of making undertakings, product quality requirements and process capabilities. Such alterations could potentially cause existing firms to become obsolete if they do not evolve with changes in the business environment. Similarly, customer preferences tend to fluctuate due to changes in social values and consumer tastes as well as a shift in demographics and economics of industries to a new equilibrium. Failure by markets of firms to adapt to change creates opportunity for the entrepreneur.

v) Demographics: refers to changes in the makeup of the population. The makeup of the population relates to changes in the size, age, structure, employment status, education, or incomes of the constituent groups. Such changes influence firms in industries due to changes in the mix of products and services required, the volume of products and services, and the purchasing power of customers.

The predictability of some changes likely to occur is based on trend analyses with respect to age groups, birth and death rates over time. Other changes such as natural disasters, war, social changes and immigration may not be predictable. Statistics for the population are available for assessment of demographic changes, but opportunities arise in accessing the data before publishing one the entrepreneur relates observations to happenings on the street what is being reported in the media such as newspapers.

vi) Changes in Perception: people view the same reality differently and the said differences inform the nature of products and services people require and also what and how much the spend. For example; some groups feel powerful and rich; others feel, disenfranchised and poor. The entrepreneur can sell power and status to the rich and powerful, and sell relief and comfort to the poor and oppressed simply by exploring perceptions.

vii) New Knowledge: is usually regarded as the core foundation of entrepreneurial opportunity. However, new knowledge alone is not adequate for entrepreneurs until they use the new knowledge to create products and also protect the profits of existing products from competition as the knowledge diffuses to others. Furthermore, judgement is crucial because it often takes the combination of many pieces of new knowledge to create products.

(c) The Individual

To start with, one's personal experience, knowledge, education, and training are the accumulated human resources that the founder contributes to the enterprise as the role that an individual plays in

entrepreneurship is undeniably core to the success of an enterprise. A person's psychological, sociological, and demographic characteristics adds or takes away from one's abilities to be an entrepreneur. People's perception attached to the enterprise during start up is the personal integrity of the entrepreneur and reputation as the enterprise is established in the "image" of its founder (Dollinger, 2008).

Further, an entrepreneur's most important responsibility is to establish an ethical climate for the newly found enterprise. Ethical behaviour among others, is any business decision to provide valuable products for the customer matching quality and price. The extent of ethical decisions includes providing the customer with; (i) valid description of the product and service, (ii) opportunity for customer to make free informed choice, and (iii) enable customer to commit to the product and the organisation that supplies it. Any breach of the three rules produces unethical behaviour that leads to low integrity and poor reputation for the firm. Eventually, the business creates own personality and way of carrying out activities as new leaders and managers come on board. The product and service mix changes and new management puts in place organisational changes. Although the business develops its own identity, the ethos and the values of the original entrepreneurs may be maintained (Ibid).

(d) The Environment

The environment presents both opportunities and threats for the new enterprise created. The opportunities come as a result of change and availability of resources: money, people and technology. The success of entrepreneurship entails the acquisition of resources from the environment, combine them with other resources currently available and build the new venture into a successful firm. The environment presents threats that are inherent in any competitive

marketplace. Therefore, the entrepreneur can overcome these constraints or protect against their worst effects by developing strategies that exploit the firm's resources (Ibid).

The main elements of the environment are; the government and politics, the economy, technology (i.e., innovation and invention), socio-demographics, and the ecosystem. Since change, uncertainty, and complexity are constituents of the environment, entrepreneurs must continually monitor events and trends and modify their organisational approaches (Ibid).

(e) The Organisation

The new organisation or the outfit is usually the outcome of nearly all entrepreneurial start-ups because do so enables the organisation to assume a form and structure. The organisation then forms a strategy that enables it to enter or create a market (entry wedges) and protect its position (isolating mechanisms) using resources it possesses to transform into value for its customers.

In addition, the organization could have a culture that it is known for such as a culture of high quality and performance. The ability to understand the organisational culture improves the entrepreneur's sustainable decision making (Ibid).

3.4.1.1.4 Variables relating to the fourth research objective

There were no variables relating to the fourth research objective. Instead, a table for proposed feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion as an innovation for entrepreneurship in rural areas of Zambia was developed.

3.4.1.2 Moderator variables

The moderator variables include; low cost of renewable energy technologies, influence of government support, policies and regulations and increased electricity demand due to productive end uses of electricity.

3.4.1.2.1 Low costs of renewable energy technologies

Among the known barriers to use of renewable energy technologies is the upfront cost for installing the generation facility and its associated distribution network. With the emergency of solar and wind power generation among other viable options, there has been a steady decline in the cost of renewable energy technologies for electricity generation especially since 2000. For example, Solar PV module prices fell by 90% from the end of 2009 as the wind turbine prices fell by 55 to 60% since 2010 (IRENA, 2017). The decline in cost for renewable energy technologies including the installation costs has increased their deployment and has accelerated technological progress as they become affordable (Timilsina and Shah, 2020; Samoita *et al.*, 2020).

3.4.1.2.2 Influence of government support, policies and regulations

In order to ease the capital cost burden, governments and donor agencies such Beyond the Grid Fund for Africa (BGFA) provide financial support to developers that invest in setting up and running of mini-grids. The funding enables the Operators of mini-grids to offer affordable tariffs for energy services for rural consumers as well as set up additional mini-grids (Bhattacharyya, 2018; Beyond the Grid Fund for Africa, 2021).

On the other hand, the policy direction and regulations to a great extent influence developments in the off-grid renewable energy sector. Regulations are rules that control the way business activities are carried out. They set a standard of what one can and cannot do when carrying out a business activity through an established systematic approach and they

are enforced by government agencies. Bringing off-grid solutions into the mainstream of national energy access strategies strengthens development of the market and thereby providing incentives for various stakeholders to come up with tailor made solutions for availing energy services (IRENA, 2018).

3.4.1.2.3 Increased electricity demand due to productive end uses

Electricity generated from mini-grid has more multiplying effects once used productively in socio-economic development of rural areas. Although people in low-income communities such as rural areas do not have electricity available, they have many productive energy needs such as; lighting, crops irrigation, food preservation and storage, powering entertainment equipment (radio and television sets), sewing machines and powering equipment for processing agriculture produce among others. Therefore, Operators of electricity mini-grids are keen to meet the income generating productive uses of energy since the economic viability of their enterprise as an energy service provider depends on their customers' earnings and demand for power (Best, 2016; Baral, 2012). Increase in demand for power by energy consumers necessitates diffusion of electricity mini-grids as capacity is built to cater for increased demand.

3.4.1.3 Dependent variable

The dependent variable regarding the study was electricity mini off-grid systems diffusion. Many people to an extent of 60% of the national populace live in off-grid areas which include the rural and peri-urban areas of the country not reached by the main electricity grid and therefore remain in need of modern energy services (NEP, 2019). Main grid extension to areas like that could be expensive and technically challenging due to the geography and widely dispersed populations among other barriers. Hence, installation and operation of electricity mini-grids provides cost effective and timely solution for meeting the electricity requirements to such areas (Beyond the Grid Fund for Africa, 2021; Samoita *et al.*, 2020).

3.5 Hypotheses and Operationalisation to the Study

Creswell (2009) guides that research questions and hypotheses considered by the researcher narrow and focus the purpose of the study. Hypothesis is a statement predicting how variables relate to each other and it can be tested not in order to be proven, but so as to guide whether to fail to accept or reject the hypothesis because evidence found in research is usually imperfect and fallible (Leavy, 2017; Creswell, 2009).

The two forms of hypotheses used in this study are the null (H_o) and Alternative (H_a) hypotheses. The null hypothesis (H_o) is a forecast statement indicating that there is neither a relationship nor significant difference existing between variables in the general population, while the alternative hypothesis (H_a) is a forecast statement about the expected outcome on the basis of prior literature review and know-how of the topic suggesting a potential outcome (Ibid*,* 2009).

Hypotheses One

H_{o1}: Operators **have no** resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages.

H_{a1}: Operators **have** resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages.

Hypotheses two

H_{o2}: The extent consumers in rural areas are aware of the electricity mini off-grid systems is high.

H_{a2}: The extent consumers in rural areas are aware of the electricity mini off-grid systems is low.

Hypotheses three

H_{o3}: The adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is widespread.

H_{a3}: The adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is not widespread.

3.6 Chapter Summary

Chapter three has presented the theoretical and conceptual framework. It has outlined theory of diffusion of innovations and resource-based theory of entrepreneurship as the theories chosen for this study. The combination of two theories was utilised in order to enable a consolidated output of the study outcomes regarding the constraints of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia. A critical review of the chosen theories was presented followed by a conceptual framework to specify how the variables are related in order to predict and explain the occurrence of diffusion of electricity mini-grids. The third chapter further operationalised the variables in the conceptual framework and has presented the hypotheses for the study. The next chapter is on research methodology.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

This chapter presents the methodology used for this study. The chapter begins by elaborating the assumptions of philosophy considered in this study and proceeds to discuss the study design, targeted population, sampling procedures and the sample. Further, the chapter describes the research instruments used in procedures for data collection, analysis techniques and presentation. Further, the chapter describes the pilot study and discusses the validity, reliability and ethical considerations for the study prior to a chapter summary.

4.2 Philosophical Assumptions

The philosophical assumptions of ontology and epistemology used for this study were applied according to the chosen paradigm of pragmatism. The axiology and phenomenology assumptions are discussed as applied for the study.

4.2.1 Ontology

The ontology of pragmatism holds that reality is non-singular, implying that every individual had their own interpretation of reality (Kivunja and Kuyini, 2017; Singh, 2019). In order to understand the nature of rural electrification phenomena and how diffusion of electricity mini-grids is affected in rural areas of Zambia, the author established how to acquire necessary knowledge from research subjects and other sources.

4.2.2 Epistemology

Under the pragmatism paradigm, the epistemology was relational as it was not aligned to anyone philosophical school i.e., neither objective nor subjective (Singh, 2019). According to the epistemological assumption adopted for this study, authenticated literature relating to the fields of entrepreneurship and renewable energy electricity mini-grids diffusion was reviewed for use. In doing so, relevant literature sources that were used, but belonged to others were duly acknowledged by citing, except for critical analysis where the author used own voice. Acknowledging

sources that belong to others was a way of expressing authenticity of knowledge according to the epistemological philosophy for this study.

4.2.3 Axiology

Axiology is an aspect of philosophy that is concerned with judgments about values (Saunders *et al.*, 2009; Chmielecki and Chmielecka, 2011). The values are categorised into ethics and aesthetics. Ethics deals with questioning of morals and personal values, while aesthetics examine what is beautiful, enjoyable, or tasteful (Lynch, 2018). Values affect one's research approach and what is valuable in study outcomes (Hogue, 2011).

The axiological assumption for this study focused on the author being transparent with research subjects, whereby informed consent was obtained and the study values were disclosed because the viewpoint of gathered information was mutually owned by the researcher and the research subjects. Processing of the collected data was done discretely (names or identities for research subjects were not required) to avoid harm to the research subjects or those affected by the study. In so doing, essential knowledge was gathered and the privacy of the research subjects was upheld.

4.2.4 Phenomenology

Phenomenology is a philosophical principle aimed at uncovering common experiences encountered by a specific group of people. Ideally, interviews are carried out for a target group of people that are endowed with first-hand knowledge about an event, occurrence or experience. After having an account of the interviewed target group of people, the researcher is then able to construct the universal description of the event, occurrence or experience and provide a profound comprehension of the phenomenon (Merleau-Ponty, 2012; Chambers, 2013; Creswell, 2014).

To understand the phenomenon of constraints of diffusion of electricity mini grids for entrepreneurship in rural areas of Zambia, the author adopted an empathetic approach when interviewing research subjects especially the operators of electricity mini-grids as guided by Saunders *et al.* (2009). This was to comprehend the world

from the view point of their lived experiences. The author was alive to the fact that information could vary regarding constraints encountered from one site to another due to dissimilarity in lifestyles of energy consumers. Therefore, the constraints of electricity mini-grids diffusion were diverse but within the confines since the provision of electricity services using mini grids are based on similar technology.

4.3 Research Design

Creswell (2009) and Saunders *et al.* (2009) provide that research designs (methodology) are the general plans and procedures for structuring the study to bring about the decisions from wide-ranging assumptions to specific detailed methods of collecting data and its analysis. There are three types of research designs which include; qualitative, quantitative and mixed methods. The mixed research design was chosen because it applies to the pragmatism paradigm (please refer to figure 2.1). Further, using either quantitative or qualitative research design as a separate approach would have been inadequate to suitably address the research problem. In fact, Patton (1999:1192) guides that using mixed methods in studies helps to eliminate errors that arise from using a single method because different types of data provide cross-data validity checks. The strategies of inquiry within the chosen research design i.e., whether qualitative, quantitative or mixed methods provide specific direction for procedures to be utilised for a study. The important aspect is the appropriateness of methods for a specific evaluation research purpose and question, not necessarily strict adherence to a single approach that declares one or the other approach to be inherently preferred (Patton, 1999:1206).

For the mixed method approach, the strategies involved are: the convergent parallel design; the explanatory sequential design; the exploratory sequential design and the embedded design. The embedded design strategy was chosen for this study; where the researcher collects and analyses quantitative and qualitative data in tandem to build from one phase of the study to another i.e., following up a quantitative study qualitatively in order to obtain detailed information (Creswell and Clark, 2011; Hafsa, 2019). In this regard, the author conducted a quantitative study and then embedded a small strand of the qualitative method as an enhancement. The collection and analysis of secondary data set occurred after the primary method. The purpose for the embedded design was to

address questions that called for different methods as need for a secondary data set emerged to explain reactions from research subjects.

In addition, using mixed methods approach enabled the author to address the important aspect of bias, whereby biases inherent in one method were countered or cancelled by biases of the other method as quantitative and qualitative data were integrated (Creswell, 2009). Biases that could arise from using unchecked information were addressed by using structured interview questions for research subjects to filter misleading responses which were not supported by views of other research subjects on the same point of inquiry. As such, the author ensured to maintain a factual approach-based study using information obtained from research subjects and document review and validating it with views from focus group members without allowing the inadvertent influence of the formal regulatory work environment of the author at Energy Regulation Board to shift the study focus of the ongoing inquiry.

4.4 Target Population

The target population comprised Operators of electricity mini off-grid systems in Zambia, Industry Experts among them Regulators dwelling in various parts of Zambia as described in the sampling frame.

4.5 Description of the Sample, Sampling Procedures and Sample Size

In the following sub-sections, the sample, the procedures used to collect the sample and the sample size are discussed.

4.5.1 Description of the sampling frame

The sampling frame is a list of all eligible sampling units (Hair Jr. *et al.*, 2017:138). However, the sampling frame could not outrightly be constituted or identified for this study because the target population was diverse in a manner that, while operators of the electricity mini-grids in Zambia could readily be identified as licensed by the Energy Regulation Board, the industry experts were hard-to-reach unless on referral basis. Studies on hard-to-reach populations or hidden populations raise methodological challenges in terms of research. For example, there are no

techniques whether census-based sampling frame or any other reliable source available to randomly sample such populations. Such scenario leads to the use of data collection methods which are non-probability or non-random such as snowball sampling (Faugier and Sargeant, 1997).

There were six (6) operators of electricity mini-grids in Zambia as licensees of the Energy Regulation Board (ERB) by the time of this study. Industry Experts who provide advisory and technical services were considered as an integral component of the target population. In addition, Regulators of the energy sector were also considered as part of the Industry Experts. Thus, the sampling frame comprised; Operators of electricity mini-grids, and Industry Experts who among them were Regulators. While some consumers of electricity from mini-grids constituted focus groups, this study was focus on Operators and Industry Experts that were able to share insights relevant for the study which the focus group members could not. Therefore, they were not part of the target population because they were not well informed to provide necessary information that could enable meeting objectives of the study.

From the pool of Operators and Industry Experts; two (2) Operators and three (3) Industry Experts were drawn as key informants. The key informants were identified through enquiry from Regulators of the energy sector who indicated them as having in-depth knowledge and were good sources of information about the electricity mini-grids subject. Their expertise made them primary data sources of the snowball sampling for referral to others who also shared further knowledge by responding on the subject.

4.5.2 Sampling Procedures

The non-probability (non-random) sampling technique called Snowball sampling, which is referred to as chain-referral sampling was utilised in this study because the sample had traits or characteristics that are rare and difficult to find. Snowball sampling by its nature does not yield a representative sample because it is dependent on referrals (Bhat, n.d.).

For instance; if one was to carry out a study of homeless people in Lusaka City, it could be difficult to identify a list detailing all homeless people available. But once, a homeless individual that agrees to take part in the study is found, the identified homeless person then provides the researcher with particulars of other homeless people they know. The first homeless individual found for the study becomes the primary data source who refers to others and the sample grows until there is adequate data collected for the study. An identical strategy could be used to carry out studies about individuals that belong to certain underground subculture, or individuals who have a hidden identity or are members of a cult who don't want to be easily identified. This type of research requires those who become subject of the study and the researcher to mutually trust each other.

Similarly, while the Operators of electricity mini-grids could readily be identified, Industry experts who among them are Regulators had to be identified by way of reference from one individual to another until the available resource of experts was exhausted.

There three (3) types of snowball sampling i.e., linear, exponential non-discriminative and exponential discriminative snowball sampling. This study utilised the exponential discriminative snowball sampling were each subject provided one or multiple referrals; except only a single new subject was selected among them. The selection of the new subject recruited was purposefully guided by the objectives of the study because not all referrals were well informed to provide information that met the objectives of the study (Bhat, n.d.; Dudovskiy, 2018).

Use of the exponential discriminative snowball sampling helped to maintain focus on inclusion of research subjects that could provide relevant information for the study relying on the judgement of the researcher. However, such non-random sampling introduces biases in the sample (Faugier and Sargeant, 1997). While snowball sampling is a non-random sampling technique whose sample is not regarded representative for statistical purposes, it is a very good sampling technique to yield a

representative sample for qualitative research (Biernacki and Waldorf, 1981; Faugier and Sargeant, 1997; Laerd, 2012).

4.5.3 Sample size

Through purposeful and snowball sampling, the study sample yielded 37 research subjects numerically broken down as six (6) Operators of electricity mini off-grid systems and 31 Industry experts who among them were 13 Regulators. Appendix 3 shows a summary list of institutions from where research subjects of the study were drawn.

4.6 Data Collection Procedures

Survey questionnaires with mostly closed-end-questions were utilised for collection of quantitative data, while qualitative data was collected through interviewing key informants based on structured questions, focus groups and field notes taken during site visits. Data collected through document reviews augmented the data collected from both quantitative and qualitative methods.

4.6.1 Survey Questionnaires

Survey questionnaires designed with mostly closed-ended-questions were administered for gathering quantitative data from operators of electricity mini grids and industry experts among whom were regulators. A total of **37** questionnaires were administered with a distribution breakdown of; six (06) operators of electricity mini grids and the remainder to industry experts/regulators. See **Appendix 3(a)** and **3(b)** for the administered quantitative questionnaires. The response rate for the distributed questionnaires was **100%** largely attributed to the purposive sampling method that was used.

4.6.2 Interviews

Personal interviews were conducted with key informants (who were identified through Operators that are licensed by the Energy Regulation Board) to gather qualitative data from operators of electricity mini grids and industry experts. Structured questions mostly open-ended were administered to solicit views on pertinent

questions regarding electricity mini grids. The results of the qualitative analysis were then embedded as a strand over analysis outcomes from the quantitative analysis forming the embedded mixed method research design for this study. **Appendix 3(c)** shows the structured questions used for qualitative data collection.

4.6.3 Document review

Document review considered grey literature on entrepreneurship and electricity mini grids operating within Zambia and beyond including articles on the ever-evolving technology. The information acquired not only formed the basis for literature review but also enhanced the author's intellectual rigor for better understanding to elucidate results for the study (Patton, 1999). Further, innovations in technology applied for installation of electricity mini grids were distinguished on the strength of document review.

4.6.4 Field Excursion Observations

Field notes were taken during the site visit to electricity mini grids situated at Luangwa Bridge, Kacholola, Sinda and Chitandika. Additional field notes were taken during interactions with some industry experts as they shared their experiences.

4.6.5 Focus Groups

Three focus groups were established; at Luangwa Bridge, Kacholola and Chitandika to enable the author gather information from operators of electricity mini grids and their consumers about their ideas and experiences following the advent of electricity mini grids in their areas. The focus groups enabled the researcher to gather more qualitative information in a brief period during a series of meetings held *at inception, during and close* of the study. The information obtained from focus groups served to augment the information sourced from Operators and Industry Experts. Further, the information gathered from focus groups also mainly served to validate survey results and information acquired from document review.

4.7 Data Analysis Techniques

As aforementioned, the mixed methods embedded research design strategy underpins this study. In this case, the author collected and analysed quantitative and qualitative data in tandem so as to build from one phase of the study to another i.e., following up a quantitative study qualitatively in order to obtain detailed information.

Quantitative data obtained using Likert-type items (questions) as a measurement tool was analysed using statistical methods. Likert-type items as a measurement tool are commonly used to measure attitudes or opinions and are mostly good in gathering data to subjective questions (Likert, 1932; Clason and Dormody, 1994; Tastle, Russell and Wierman, 2008; Jamieson, 2004). Qualitative data was analysed using thematic analysis which basically is a technique for identifying and analysing patterns in qualitative data (Braun and Clarke, 2006).

4.7.1 Statistical methods

The analysis statistical methods carried out for the quantitative data involved obtaining the weighted mean, followed by the coefficient of variation and then establish the degree of consensus on each study Likert-type item.

The weighted mean was obtained by assigning numerical values to a continuum of possible responses say from 1 to 5 for each Likert-type question to obtain the weighted mean using the formula, which provided a general overall numerical value that was used for indicative purposes.

$$\textbf{Weighted mean} = \frac{\Sigma \text{ (Arbitrary weight * Frequency)}}{\text{Total number of frequencies}}$$

The weighted mean was followed by applying the coefficient of variation (CV) to ascertain level of dispersion of actual values around the mean or variability (Vaz *et al.,* 2017). The coefficient of variation (CV) is the ratio of the standard deviation to the weighted mean and is normally expressed as a percentage (CV%). The coefficient of variation represents a more accurate estimate when a lower value is obtained (Ibid). The formulae for calculating CV as adopted from Vaz *et al.* (2017) are:

CV = (Standard Deviation (σ) / Mean (μ)) multiplied by 100 for a population, whereas;

CV = (Standard Deviation (s) / Mean ($\bar{x}$)) multiplied by 100 for a sample. In this case, the weighted mean denoted as "$\bar{x}$" is also called x-bar.

Having obtain the general overall indicative value by way of the weighted mean and ascertained the precision of the measurements using coefficient of variation, the author desired to obtain the level of agreement or consensus among research subjects on particular questions of interest (group decision-making), which can also be referred to as a measure of agreement. The degree of consensus (C) was determined as 1 - CV or 100 – CV% as adopted from Tastle, Russell and Wierman (2008). The author observed that the level of agreement is high or more precise when the coefficient of variation is small.

Likert-type items (questions) as a measurement tool are commonly used in agricultural education research, in education for assessment of students' performance over a period of time and have been used in some publications for Medical Education (Clason and Dormody, 1994; Tastle, Russell and Wierman, 2008; Jamieson, 2004). They have also been used in this study to seek responses from participants by rating Likert-type items for instance on a continuum of strongly agree to strongly disagree.

Despite abovementioned usage of Likert-type items for measurement, how measurement scales relate to statistical analysis has been an on-going argument concerning the application of traditional descriptive and inferential statistics for ordinal-level variables (Knapp, 1990).

To provide a way of understanding measurements, Stevens (1946) described measurement in the widest sense as the assigning of numerals to objects or events according to rules. Moreover, that measurement is available in assorted methods and that scales of measurement are classified into specific categories which are evaluated both by the empirical operations invoked in the process of measuring and

by the scale of formal mathematical properties. To this effect, the following guidance tabulated in 4.1 was provided (Ibid).

Table 4.1: Scales of measurement, empirical operation and permissible statistics

Scale	Basic Empirical Operations	Mathematical Group Structure	Permissible Statistics
Nominal	Determination of equality	• Permutation group • Means • Any one-to-one substitution	• Number of cases • Mode • Contingency correlation
Ordinal	Determination of greater or less	• Isotonic group • Means • Any monotonic increasing function	• Median • Percentiles
Interval	Determination of equality of intervals or differences	• General linear group	• Mean • Standard deviation • Rank-order correlation, Product-moment correlation
Ratio	Determination of equality of ratios	• Similarity group	• Coefficient of variation

Source: Adopted from Stevens, 1946

The highlighted scales are briefly described as follows:

i) **Nominal scales:** collection of classes used to accumulate data with no any form of ranking order. The nominal scale represents assignment of numerals without restrictions. Numerals and words are used for labeling (Tastle, Russell and Wierman, 2008; Stevens, 1946);

ii) **Ordinal scales:** are ordered categories or emanate from the operation of rank ordering. Likert scale is an example of Ordinal scales (Ibid, 1946);

iii) **Interval scale:** holds a definite and fixed interval about them and is a type that is quantitative in an ordinary sense of the word (Ibid, 1946); and

iv) **Ratio scales:** have an absolute zero base, holds an interval and implicitly possess order (Tastle, Russell and Wierman, 2008).

Knapp (1990) further outlined that the solutions to this dimension of the controversy are the concepts of "appropriateness" and "meaningfulness" as in what descriptive statistics is appropriate for ordinal scales? What statements regarding data reduction are meaningful? To edge forward, the author relied on the work of Tastle, Russell and Wierman (2008) who observed that use of Likert-type items continued to be a challenge when tabulating and comparing the values of ordinal scales. However, they noted that crucial to determining a value for an ordinal scale measure could be compared to another was the means by which the resulting value is interpreted. For example; the spreading of values about a central value, i.e., the weighted mean, permits an evaluation of the extent of agreement for the collective research subjects' perceptions without placing a focus on an arbitrary numerical interval assignment. Thus, a collective set of ordinal scale values that yield a narrow dispersion could interpreted as possessing a greater agreement than one with a wide dispersion. Consensus measure is a suitable measure of agreement using ordinal scales such as Likert-type items to resolve group decision-making dynamics challenges. In this case, zero (0) represents complete dissent or an absence of agreement, and one (1) represents complete agreement, or an absence of dissent (Ibid).

4.7.2 Thematic Analysis

Thematic analysis technique was used to identify, analyse and report patterns (themes) in collected qualitative data. Six steps for carrying out thematic analysis technique adopted from Braun and Clarke (2006) were utilised. The order of the steps in the thematic analysis technique was carried out as follows although applied in a recursive manner:

i) Familiarisation with the data: the author immersed oneself and became well conversant with their data by reading and re-reading the data and noting any initial analytic observations;

ii) Coding: involved generating concise labels for significant features of relevant data to the research question guiding the analysis. Coding captured both semantic and conceptual reading of the data. The author coded every data

item and completed the phase by collating all their codes and relevant data extracts;

iii) Searching for themes: coherent and meaningful patterns were sought in the data relevant to the research question. Therefore, theme searching was an active process were the author constructed themes and finished the phase by collating all the coded data relevant to each theme;

iv) Reviewing themes: this involved assessing that the themes were consistently operational with both the coded extracts and the full data-set. The author reflected on whether the themes communicated convincing and compelling information about the data, and defined the nature of each individual theme and the relationship between the themes. In some cases, it was necessary to combine two themes or split a theme into two or more themes, or throw away the candidate themes altogether and re-start the process of theme development;

v) Defining and naming themes: the author detailed an analysis of each theme by identifying the relevance of each theme and constructed concise, punchy and informative label for each theme; and

vi) Writing up: involved merging the analytic narrative and data extracts to inform the reader a coherent and persuasive narrative about the data, and contextualising it in relation to existing literature.

4.8 Pilot Study

A pilot study was conducted as recommended by Saunders *et al.* (2009:394) in order to enable the author, obtain an evaluation of the validity and reliability of the questionnaire that would be used to gather data for the study prior to actually using it for gathering data for the main study. In this regard, validity was about the accuracy, whereas reliability was about the consistency of measures that would be obtained (Middleton, 2019). In addition, the pilot study was conducted to enhance the questionnaire so that survey participants would have no challenges responding to the questions and the author would also have no challenges to record survey responses (Saunders *et al.*, 2009).

Consistent with the embedded research design chosen for this study, the author conducted a quantitative study and then embedded a small strand of the qualitative data to enhance the outcome of the study. The exponential discriminative snowball sampling was used to distribute the study questionnaires as aforementioned under sampling procedure.

The pilot study questionnaires for the quantitative study which comprised mostly closed ended questions were administered in two (2) parts; the main questionnaire with 20 questions was targeted at four (04) Operators of mini off-grid facilities, while a sub set questionnaire with 12 questions was targeted at six (06) Industry Experts and/or Regulators. The structured questions for qualitative study which were mostly open-ended were later administered to five (05) research subjects distributed as; two (02) Operators of mini off-grid facilities and three (03) Industry Experts and/or Regulators.

The number of research subjects for the pilot study was considered sufficient to provide indicative insights into any major variations likely to affect responses that could arise from the target population (Ibid).

4.8.1 Pilot study feedback

The following deficiencies were highlighted by research subjects for the pilot study:

i) Provide a background (preamble) of the research study within the questionnaire;
ii) The boxes for marking preferred answers for question 12 and 20 for Industry experts' and Operators' questionnaire respectively were not properly formatted to enable research subjects select the applicable box;
iii) Questions 1, 2, 3 and 10 were flagged as double barreled and were recommended to be revised in order to streamline and avoid confusing research subjects on what was being inquired;
iv) Question 11 was flagged as being very complex and was recommended to be revised in order to simplify it; and

v) There was a challenge finding one answer to fit all mini-grid scenarios because most parts of Zambia have a unique life style and that may affect the success of a particular mini-grid installation.

Additional assessment information about the pilot study questionnaire was obtained by providing a brief questionnaire on the cover page of the main questionnaire. Table 4.2 presents a summary of responses obtained regarding the pilot study questionnaire.

Table 4.2: Responses obtained on the pilot study questionnaire

No.	Question	Responses
1	How long did the questionnaire take to complete	Operators: Average 19 minutes
		Experts: Average 23 minutes
2	How was the clarity of instructions	Clear
3	Which, if any, questions were unclear or ambiguous	Operators: 5, 8 and 20
		Experts:1, 2, 3 and 10
4	Which, if any, questions you felt uneasy about answering	Operators: 17
		Experts: 9 and 12
5	Kindly indicate whether in your opinion there were any major topic omissions	None
6	Was the questionnaire layout clear and attractive	Layout was clear and good
7	Any other comments regarding the questionnaire	Provide a background of the research within the questionnaire, though the topic can be clearly picked from the flow of questions.

Source: Author/Field data

The results of the pilot study were found insightful and acceptable and are therefore reported as part of the main study in the next chapter.

4.8.2 Adjustment of the research instrument

The author adjusted the final questionnaires for the study based on research subjects' recommendations with respect to the accuracy and consistency of measures that would be obtained. Based on outcomes of the pilot study, the main study was undertaken thereby obtaining results presented in the subsequent chapter.

4.9 Reliability and Validity of the Study

The accuracy (validity) and the consistency of measures that would be obtained (reliability) are concepts used to evaluate the quality of the study. The two concepts indicate how well the utilised technique was able to measure something (Middleton, 2019).

4.9.1 Reliability of the study

Reliability refers to the degree to which your data gathering procedures or analysis techniques will yield consistent findings. If the same result could be consistently achieved by using the same method under the same circumstances, the measurement is considered reliable (Saunders *et al.*, 2009; Middleton, 2019; Hair Jr. *et al.*, 2017).

To ensure reliability in this study, the responses were obtained on the basis of the same questionnaire for data collection. The same quantitative questionnaire was administered to a given target group of research subjects for example industry experts. Similarly, the same qualitative questionnaire was administered to a given target group ensuring that the interview questions were phrased the same way to each respondent. Further, the approach for data collection was standardised to maintain the conditions as stable as possibly can to reduce external factors influence that could cause fluctuations in the outcomes. Any notable conditions that could cause variations were taken care of at pilot study stage.

The different reliability types include; test-retest, inter-rater and internal consistency reliability (Middleton, 2019) hereby discussed:

4.9.1.1 Test-retest reliability

When a measure is consistently giving the same result over a period of time i.e., obtaining the same results once a measurement is repeated over a period of time.

4.9.1.2 Inter - rater reliability

When a measure consistently gives same results across various raters or observers i.e., obtaining the same results even after different raters or people carry out the measurement.

4.9.1.3 Internal consistency reliability

When same results are obtained from different parts of a test that is intended to measure the same thing. For example; once outcomes of a measurement are randomly split into two parts, there should be a strong correlation between the two sets of results. Otherwise, low internal consistency could be seen from two results being very dissimilar.

For this study, internal reliability was established using Cronbach's Alpha, which is the widely used measure of reliability. Cronbach's Alpha is used to assess whether the scale can provide consistent results for multiple Likert questions of a survey questionnaire that forms a scale (Bonett and Wright, 2014; Laerd, n.d.). The overall reliability i.e., Cronbach's Alpha coefficient of 0.792 indicated an elevated level of internal consistency that was acceptable to proceed with the scale used for this study based on Gottems *et al.* (2018) classification of the Cronbach Alpha reliability coefficient as follows: Very Low for: $\alpha \leq 0.30$; Low for: $0.30 < \alpha < 0.60$, Moderate $0.60 < \alpha < 0.75$, High $0.75 < \alpha < 0.90$ and Very High for $\alpha > 0.90$. Table 4.3 shows the Cronbach's Alpha reliability coefficient for this study obtained using IBM Statistical Package for Social Sciences version 20 (SPSS - 20).

Table 4.3: Cronbach's Alpha reliability coefficient

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	No of Items
0.792	0.729	14

Source: Author/Field data

4.9.2 Validity of the Study

Validity refers to the extent of accuracy for a method of measurement intended to be quantified (Saunders *et al.*, 2009; Creswell, 2009; Middleton, 2019; Hair Jr. *et al.,* 2017). In order to ensure validity, the Author chose the sampling technique and methods of measurement (questionnaires) that are appropriate for the embedded research design.

The three validity types measurement namely; construct, content and criterion validity were used in this study as addressed in the ensuing sub-sections.

4.9.2.1 Construct validity

Construct validity refers to how a measure adheres to the present theory and criteria of the concept being measured or an valuation of how well ideas or theories are translated into programs or measures (Middleton, 2019; Trochim, 2020; Creswell, 2009). The study established the constraints of electricity mini off-grid systems diffusion in rural areas of Zambia using survey questionnaires that were completed by knowledgeable participants.

4.9.2.2 Content validity

Content validity refers to the degree to which the measurement covers the entire aspects of the measured concept. It is usually assessed by depending on the knowledge of people that are well informed regarding the measured construct (Creswell, 2009; Middleton, 2019; Study.com, 2015). In this regard, the industry experts were provided with the measurement tool (questionnaire) and were requested to respond on each question measuring the construct on hand. Collected data was then analysed to make informed decisions about the

construct being measured i.e., constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia.

4.9.2.3 Criterion validity

Criterion validity refers to how well a result of a measure compares to other valid measures of the same concept. To conduct criterion validity of a measure, the measure is calibrated against a known standard or against itself. Comparing the measure with an established measure is known as concurrent validity, while calibrating it over a period of time is known as predictive validity (Middleton, 2019; Kline, 2000; Shuttleworth, 2009). For this study, the criterion validity was carried out by comparing obtained results to the pilot study results earlier obtained and was therefore a concurrent validity.

4.10 Ethical Considerations

Ethics refers to the correctness of one's behaviour with respect to the rights of those who become the subject of the study, or the study affects them (Saunders *et al.*, 2009). The axiological assumption with respect to this study was strictly adhered to when; dealing with research subjects, handling and processing the collected data and manner of reporting the outcomes of the study. The author managed process of the research by ensuring that there was no harm to the research subjects or those affected by the study without compromising the pursuit of gathering knowledge.

Ethical principles considered when performing this study included; obtaining informed consent, absence of coercion, upholding confidentiality, minimising risk of harm, transparency, and avoidance of plagiarism (Leavy, 2017; Laerd, 2012; NMBI, 2007; Saunders *et al.,* 2009). Each of the ethical principles is further discussed as:

4.10.1 Informed consent

Informed consent is the position or status achieved once intended research subjects are made aware about the study; title, nature, purpose, use of the study outcomes, what their role entails and that once they accept to take part in the study, their consent is free and could not be construed as invasion of privacy (Saunders *et al.*, 2009; Leavy, 2017). In this case, an introductory cover letter as shown in appendix

4(d) was attached to all questionnaires that were distributed for data collection. Owing to the exponential discriminative snowball sampling procedure used, questionnaires were either hand delivered or emailed to research subjects after establishing informed consent. Hence, every participant in the study was duly aware regarding the study purpose in which they participated voluntarily.

4.10.2 Coercion

Coercion is the practice of persuading someone to do something by using force or threats (Pruzan, 2016; Saunders *et al.*, 2009). The author acted respectfully based on the obtained informed consent and avoided coercion even when research subjects delayed to respond to the research questionnaire due to pressing commitments in their business schedules. All research subjects willingly participated in the study and those that felt like withdrawing from the study were amicably allowed to do so without persuading them to continue by using force or threats.

4.10.3 Confidentiality

Confidentiality is concerned with the safeguards established to protect the data provided by individual research subjects in order to preserve the privacy of the (Saunders *et al.*, 2009). The author acted based on fidelity to protect the anonymity of participants for information that was shared in confidence because it was considered private or sensitive in nature. To protect the anonymity of research subjects, the questionnaires did not request any identity details of research subjects to safeguard their identities and the collected information was kept securely for research use only. For purposes of presenting research outcomes in report, reference was made to the institution from where data was collected and not the individual participant.

4.10.4 Minimising risk of harm

In this case harm refers to physical harm, psychological distress and discomfort (embarrassment), and social disadvantage to sentient beings and to the environment (Pruzan, 2016; Saunders *et al.,* 2009). The author avoided any harm (non-maleficence) to participants or those that were affected by the study in order to

uphold ethical issues in undertaking this study. Further, study outcomes were factually presented and objectively balanced not to cause harm to any study participants.

4.10.5 Transparency

Methodological transparency refers to a clear demonstration of the process by which the research was carried out. It is important so that those who are exposed to your research can understand the process by which you formed your conclusions from the raw data and appreciate the methodological rigor (Saunders *et al.,* 2009; Leavy, 2017). This study was conducted in such a way that it is easy for others to see what actions were performed i.e., explicit about the methods and procedures used and can be replicated.

4.10.6 Plagiarism

Plagiarism is when one does not clearly give credit in the form of quotes or references to sources of information used in their paper. The sources of the information may either be; published or not, written or oral or material on a website (Pruzan, 2016). Similarly, Saunders *et al.* (2009) cite Easterby-Smith *et al.* (2008:50) to define plagiarism as 'presenting the work and ideas of other people and passing them off as your own, without acknowledging the original source of the ideas. In this thesis, plagiarism was avoided in presenting this study report by appropriately referencing and acknowledging other authors/researchers for their work, whether published or unpublished including theories, concepts, data, source material, methodologies and results among others.

4.11 Chapter Summary

The outline for the research methodology used in the study has been presented in this chapter. Further, philosophical assumptions and views for the study have also been elaborated. The strategies of inquiry for the embedded research design chosen for the study provide specific direction for procedures that were utilised. The methodology of the study covers the target population, the sampling procedure and the sample. It goes on to transparently present the collection of data and techniques for analysis that were used.

To enable the author, obtain an evaluation of the validity and reliability of the data that would finally be collected, a pilot study was carried out by testing the questionnaire. Quantitative data was analysed using statistical methods i.e., weighted mean, the coefficient of variation and degree of consensus, whereas qualitative data was analysed using thematic analysis. Ethical principles were upheld when performing this study to ensure the authors' appropriate behaviour regarding the human rights of participants in the study or of those who were affected by the study.

Chapter four established the study design and methodology and precedes data presentation, analysis and reporting of results in the subsequent chapter.

CHAPTER FIVE

DATA PRESENTATION, ANALYSIS AND RESULTS

5.1 Introduction

The fifth chapter involves presentation of data, its analysis and results in order to establish the constraints of electricity mini-grids diffusion for entrepreneurship in rural areas of Zambia. The presented data, its analysis and subsequent results are based on the responses obtained from surveys, interviews and focus groups and enhanced by document review information.

According to the pragmatism paradigm as the philosophical underpinning for this study, the mixed methods methodology, specifically the embedded research design strategy was used in this study as aforementioned in chapter four. In this regard, the author collected and analysed quantitative and qualitative data in tandem to build from one phase of the study to another i.e., following up a quantitative study qualitatively in order to obtain detailed information especially on points of inquiry where quantitative analysis did not yield conclusive results (Creswell and Clark, 2011).

5.2 Data Presentation, Analysis and Results

This subsection presents the data, its analysis and subsequent results based on survey responses. The results are presented based on: the study objectives; independent variables and moderator variables. The following measures of statistics which are applicable to Likert-type items and any other ordinal responses were employed for data analysis:

(a) Weighted mean or average ($\bar{x}$): is a calculation of the average, which considers the significant contributions of the numbers in a set of data. When calculating a weighted average, each number in the set of data is multiplied by a predetermined weight before making the final calculation (Ganti, 2020).

(b) Standard deviation (SD): measures the variation of observations or how the observations are dispersed around the mean. When the value of the standard

deviation obtained is low, it indicates that the values are closely concentrated around the mean, while a value of the standard deviation obtained being high indicates wide concentration of the observations around the mean. In such a case, some observed values could even be far spread from the mean (Heumann and Shalabh, 2016).

(c) Variance: is a measure of how dispersed or spread out the set of data is. It is determined as the mean squared deviation of each number from the mean of a data set (Ibid, 2016).

(d) Coefficient of Variation (CV): is a measure of the extent of the research subjects' disagreement (dissention). It assesses precision of the measurements made using the Likert Scale technique on a particular point of inquiry by measuring the variability (Vaz *et al.,* 2017).

(e) Consensus (C): is the measure of the research subjects' degree of agreement on a particular point of inquiry. This measure is applied in combination together with the weighted mean to instinctively grasp the spread of values about the mean (Tastle, Russell and Wierman, 2008).

5.2.1 Data presentation, analysis and results based on study objectives

This section presents the data, it's analysis and results based on the main objective and the four specific objectives of the study.

5.2.1.1 Main constraints of electricity mini-grids diffusion for entrepreneurial purposes

The main objective of this study was to establish the main constraints of diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia. Survey results from both the main and pilot studies revealed the following five main constraints from the list of identified constraints shown in table 5.1 that affect diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia.

Although the responses percentages are not on parity, the concurrent validity of the measures for the main and pilot studies were notably in agreement.

i. Research subjects representing **81.1%** and **90%** from the main and pilot studies respectively indicated that inadequate income affects ability of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable;

ii. Research subjects representing **81.1%** and **100%** from the main and pilot study respectively indicated that low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas;

iii. Research subjects representing **78.4%** and **70%** from the main and pilot study respectively indicated that the profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion;

iv. Research subjects representing **46.0%** and **30%** from the main and pilot study respectively indicated that substitutes such as fire wood and petroleum products such as kerosene provide cheap energy sources compared to what electricity mini-grids offer; and

v. Research subjects representing **46.0%** and **10%** from the main and pilot study respectively indicated that the Operators are afraid to spread out electricity mini-grids to other rural areas of Zambia because the main grid may encroach on their exclusive supply territory before they attain the payback and obtain significant returns on their investment.

Table 5.1: Main constraints of electricity mini-grids diffusion for entrepreneurial purposes

Constraints of diffusion for electricity mini-grids	No. of Operators Responses (a)	No. of Industry Experts Responses (b)	Total No. of Responses (a + b)	Main study Results %	Pilot Study Results %
Inadequate income affects ability of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable	3	27	30	81.1	90
The electricity mini off-grid systems are a new innovation that is yet to be appreciated for adoption by rural dwellers	2	7	9	24.3	40
The profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion	6	23	29	78.4	70
Substitutes such as fire wood and petroleum products such as kerosene provide cheap energy sources compared to what electricity mini off-grid systems offer	1	16	17	46.0	30
Low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas of Zambia	6	24	30	81.1	100
Rural dwellers do not use the electricity for productive uses such as commercial activities hence they are unable to generate income to pay for the electricity services	3	12	15	40.5	50
Operators are afraid to spread out electricity mini off-grid systems to other rural areas of Zambia because the main grid may encroach on their earmarked territory before they attain the payback and obtain significant returns on their investment	2	15	17	46.0	10

Source: Author/Field data

5.2.1.1.1 Qualitative analysis on main constraints affecting diffusion of electricity mini-grids for entrepreneurial purposes

From the qualitative survey, the constraints that affect diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia were given as follows:

a) High upfront capital expenditure costs

The installation and operation of an electricity mini-grid has high upfront capital expenditure costs that present as a constraint. The costs could be categorised into; costs incurred for surveying to identify the possible site, obtaining the necessary approvals from various government agencies, and costs related to technical services such as; choice of appropriate technology to meet identified customer needs, and actual procurement costs for the generation plant and distribution network technology equipment that constitutes a mini-grid.

b) Taxes

The taxes that apply include; customs clearance tax on technology components for building the mini-grids are high, and undefined local taxes such as charging of exercise duty on produced electricity payable to Zambia Revenue Authority is detrimental to incentivising the upcoming mini-grids business.

c) Business seasonality

Seasonality of business in rural areas arises from the fact that rural customers tend to afford electricity and most other commodities after sales of their farm harvest produce. In order to take care of the “off business season” mini-grids developers train and support their customers (those running entrepreneurial activities supported by the mini-grid) to ensure they sustain entrepreneurial activities to avoid them closing since the success of customer’s business entails success for the mini-grid operator as the Energy Service Provider (ESP) as well.

d) Low population density

The Low population density avails limited customer base not only for the mini-grid operator, but also for those engaged in entrepreneurial activities productively using

the electricity supplied from the mini-grid. Low population density presents few customers thereby causing a challenge to attain a critical mass of sales for an enterprise to operate self-sufficiently and sustainably.

e) Access to Finance and Limited business ideas

Installation of mini off-grids is targeted for the rural areas where people generally have low capacity to pay for electricity services. In addition, there is limited access to finance or capital for most remote populations thereby inhibiting their access to efficient appliances needed to engage in income generation activities.

Rural communities tend to have limited business ideas. For example; if one starts a business, they all would want the same type of business instead of starting up own ideas that could cause diversification of services offered to the community.

f) Government policy and regulations

Government policy to promote installation and operation of mini-grids is not clear and that contributes to the business risk. The contribution of mini-grids in the national electrification strategy is not clear as seen from priority given to grid extension programs. The security of tenure for mini-grids in case of grid arrival or encroachment remains vague despite attempts to cover it under regulations.

g) Ignorance of people about mini-grids

Although mini off-grids are generally targeted for rural areas, the rural communities are ignorant about the existence of mini grids and their benefits. This was evidenced by interviews with key research subjects regarding the spreading of information by Operators and Stakeholders to sensitise consumers about mini-grids (refer to 5.2.2.2.1 (c)) which revealed that in some cases, language barrier inhibited communication on how to fully explain electricity mini-grids and their benefit to rural customers. The explanation of electricity mini-grid could have been made easier if there were demonstration projects in the near vicinity to showcase a proof of concept. In spite of communication challenges, survey results showed that **50%** of Operators of electricity mini-grids often got invitations to install electricity mini-grids at other sites

after spreading information about their existence and benefits (refer to 5.2.2.4 on frequency of invitations to install electricity mini off-grid at other sites).

h) Lack of support in form of incentives

Incentives in form of subsidies are one of the strategies to overcome barriers faced by the poor and vulnerable from accessing life necessities. In this case, provision of smart subsidies to eligible mini-grid developers in form of capital subsidies which related to capex material for the generation and distribution grid could have a direct impact on the final pricing or the tariff to be charged for the electricity supplied from a mini-grid. Access to cheap source of local financing for developing mini-grids may have a similar effect of making electricity from a mini-grid affordable.

5.2.1.2 Determine the cause of slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia

To address the first specific objective of the study regarding cause of slow diffusion of electricity mini-grid systems for entrepreneurial purposes in rural areas of Zambia, the research subjects in the main and pilot studies highlighted the following reasons listed in table 5.2.

i) Research subjects from the main study representing **94.6%** indicated that the business environment varies depending on specific locations. A similar high result of **100%** from research subjects was obtained from the pilot study;

ii) Research subjects from the main study representing **75.7%** indicated that challenging physical geographical conditions in rural areas outweigh the benefit of setting up electricity mini-grids considering limited customer base coupled with low ability to pay for electricity services, also **80%** of research subjects from the pilot study were of the same view;

iii) Research subjects from the main study representing **73.0%** indicated that the strategies currently applied for the diffusion of electricity mini–grids for

entrepreneurial purposes are not effective compared to **40%** research subjects obtained from the pilot study; and

iv) Up to **43.2%** research subjects from the main study indicated that current operators of electricity mini off-grid systems lack capacity to set up many sites to cause the desired diffusion, compared to **60%** research subjects obtained from the pilot study.

Table 5.2: Reasons for slow diffusion of mini-grids for entrepreneurial purposes

	Main Study Results				Pilot Study Results
Reasons for slow diffusion	**No. of Operators Responses**	**No. of Industry Experts Responses**	**Total No. of Responses**	**Percent Response**	**Percent Response**
	(a)	**(b)**	**(a + b)**	**%**	**%**
The strategies currently applied for the diffusion of electricity mini off-grid systems for entrepreneurial purposes are not effective	0	27	27	73.0	40
The business environment varies depending on specific locations. Some locations are not economically viable for electricity mini off-grid systems for entrepreneurial purposes	6	29	35	94.6	100
Current operators of electricity mini off-grid systems lack capacity to set up many sites to cause diffusion	6	10	16	43.2	60
Challenging physical geographical conditions in rural areas outweigh the benefit of setting up electricity mini off-grid systems considering limited customer base coupled with low ability to pay for electricity services	6	22	28	75.7	80
Rural dwellers are averse to the innovation because electricity is known to be for urban areas	0	6	6	16.2	0

Source: Author/Field data

5.2.1.2.1 Qualitative analysis of reasons for slow diffusion of electricity mini-grids for entrepreneurial purposes

In addition, research subjects from the qualitative study indicated that the following cause slow diffusion for electricity mini-grids for entrepreneurial purposes in rural areas of Zambia:

a) High capital expenditure for setting up mini-grids

That the high upfront cost required for setting up mini-grids poses twofold challenges; firstly, it is expensive for developers to raise the high upfront costs related to capex equipment required to install a mini-grid. Secondly, that target customers lack capacity to afford capital expenditure (capex) equipment in order to use the electricity produced from the mini-grid installed in their area.

b) Policies and Regulatory framework

Bureaucratic policies and regulatory framework increase the cost of setting up mini-grids and the project completion time. “Other than the cost, the approvals take long to be issued by the various government agencies,” retorted one of the key research subjects.

c) Risk associated with mini-grids

The high upfront cost for mini-grid installation entails putting “all eggs in one basket” thus increasing the risk in case of unsuccessful business take-off at a particular site.

d) Consumer Perception

Mini-grids are regarded as incompatible with the values of the community as the main grid is favored (even though the community had no access to the main-grid).

5.2.1.3 Establish why mini-grid developers are not initiating additional projects

The second specific objective was to establish why mini-grid developers were not initiating additional projects after completion and operationalisation of the initial project. With reference to results in 5.2.1.1 (iii) survey results revealed that **78.4%**

from the main study and **70%** from the pilot study responded that the profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion. Further, results in 5.2.1.1.1 (a) revealed that the installation and operation of an electricity mini-grid has high upfront capital expenditure costs that present as a constraint.

In view of the foregoing, the low profitability of the mini-grid business implies that the project payback period is long since the returns on investment from the initial project are low. Now, given that the installation and operation of an electricity mini-grid requires high upfront capital expenditure, it is challenging for Operators to set up additional mini-grid sites at other places by ploughing back the returns on investment from the initial project. Therefore, any additional installations would require Operators to source for additional funds from others sources.

5.2.1.4 Examine whether developers' firms have resources

The third specific objective was to examine whether developers' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages. With reference to table 5.3, the weighted mean of 2.73 = **3** when rounded off and the Likert Scale result was **neutral** with a degree of consensus of **66.3%** on whether Operators of electricity mini-grids in rural areas of Zambia are equipped with resources that are valuable, rare, difficult to imitate and non-substitutable to enable them exploit business opportunities, while neutralising threats in the firm's business vicinity to enable achievement of a sustainable competitive advantage.

Table 5.3: Operators of electricity mini-grids owning resources

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f2)				
Strongly Disagree	1	0	1	1	1	2.99	2.99
Disagree	2	1	17	18	36	0.53	9.54
Neutral	3	0	9	9	27	0.07	0.63
Agree	4	4	4	8	32	1.61	12.88
Strongly Agree	5	1	0	1	5	5.15	5.15
Total		**6**	**31**	**37**	**101**		**31.19**
Mean ($\bar{x}$)							**2.73**
SD							**0.92**
CV							**33.7%**
C							**66.3%**

Source: Author/Field data

Key for the symbols used in data analysis:

W – allocated Likert Scale weight, $\mathbf{f_1}$ – Operator's frequency score, $\mathbf{f_2}$ – Industry expert frequency score, **F** – sum of Operator's and Industry expert frequency score, **FW** – Weighted frequency score, $\mathbf{(W- \bar{x})^2}$ – Link to variance, $\mathbf{F (W- \bar{x})^2}$ **–** Link to standard deviation, **Mean ($\bar{x}$) –** weighted mean or average, **SD** – standard deviation, **CV** – Coefficient of variation, **C** – Consensus.

5.2.1.4.1 Qualitative analysis on Operators of electricity mini-grids owning resources

Follow up qualitative interviews revealed that Operators have resources that are valuable, rare, difficult to imitate and non-substitutable to enable them exploit business opportunities. The resources are aligned to the strategy the developer wishes to pursue. Although the mini-grid technology used is generally similar, the key difference that creates an advantage is the manner of service provision emanating from specific resources as explained in subsequent sections:

a) The user tariffs

Each mini-grid tries to operate on a model that suits the unique needs of the local market in the area of operation. For example, mini-grid do not charge tariffs on “per kWh” basis for electricity units. Rather, all the mini-grids operators have designed unique billing systems for electricity services supplied.

b) Tailor made mini-grid services

The developer works with the community to identify their needy areas that require electricity and then provide tailor made mini-grid to address the needs such as; processing agricultural produce, powering commercial equipment, preservation by refrigeration of foods such as fish, meat and other perishables, keeping refreshments cold in bottle store or grocery among others.

c) Service augmentation

The business of selling electricity from the mini-grids also provides additional services that the customers become aware of and respond to but are not part of the core product. Example of such services includes; automotive and phone battery charging, ice cubes vending from solar fridges, and play station for gaming all provided at a fee to make the mini-grid business economically viable.

d) Remote management of the mini-grid operation

Mini-grids are remotely managed as a way of significantly cutting down on operational and administrative costs. The mini-grids are equipped to provide a reliable and sustainable service and are fitted with smart metering gadgets that allow for remote monitoring.

5.2.1.4.2 Hypothesis testing on operators of electricity mini-grids owning resources

Hypothesis testing was carried out using the nonparametric chi-square test. Jamieson (2004) cited that standard reference literature guides that the appropriate inferential statistics for ordinal data such as Likert items utilise non-parametric tests such as Chi-square, Spearman’s Rho or the Mann–Whitney U-test because

parametric tests require data of interval or ratio level. Therefore, a nonparametric chi-square test using IBM Statistical Package for Social Sciences Version 20 (SPSS - 20) was used.

Null hypothesis, H_{o1}: Operators have no resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages.

Alternative hypothesis, H_{a1}: Operators have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages

Test	Total No.	Test Statistic	Degrees of freedom (Df)	Asymptotic Sig. (2-Sided test)
One – sample Chi-Square Test	37	26.649	4	0.000

Notes:

The value of the test statistic = 26.649

The corresponding p- value of the test statistic is p = 0.000

The significance level, α = 0.05

Decision rule:

If P-value < α, then reject H_o

If P-value $\geq$ α, then accept H_o

Comment:

Since p-value (p) = 0.000 is less the significance level, α = 0.05, we reject the null hypothesis. Therefore, we accept the alternative hypothesis and conclude that Operators' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages. This result agrees with the qualitative results in 5.2.1.4.1.

5.2.1.5 Proposed feasible solutions to identified constraints of electricity mini off-grid systems diffusion

The fourth objective of the study was to propose feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion as an innovation for entrepreneurship in rural areas of Zambia. From a considered perspective of the study results, the constraints of electricity mini off-grid systems diffusion identified could be categorised into two phases i.e., pre-installation and operational phases. Some constraints that occur in both phases would require applicable specific attention as they occur. In this regard, table 5.4 shows the proposed feasible solutions to address identified constraints of electricity mini off-grid systems diffusion.

Table 5.4: Proposed feasible solutions for identified constraints of mini-grids diffusion

No.	Identified Constraint	Proposed feasible solution
Pre-Installation Phase Constraints		
1.	Inadequate income that affects capability of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable	Developers to tailor the tariff based on how much consumers are willing and able to pay for the electricity services by conducting a feasibility study using the marketing concept
2.	Low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas	Developers to consider a wide enough catchment area for the target consumers that will directly and indirectly access benefits from the mini-grid during site selection stage. This has the effect of attaining critical mass of sales during operation phase.

No.	Identified Constraint	Proposed feasible solution
3.	Profitability of the electricity mini off-grid systems business is low	Developers to consider long payback periods and use funding that focuses on combined social welfare and economic viability logic as opposed to financiers that prioritises the economic viability logic.
4.	Substitutes products such as fire wood and petroleum products like kerosene provide cheap energy sources compared to what electricity mini-grids offer	Developers should offer electricity services that provide benefits that substitutes do not provide or they provide at higher cost than mini-grids e.g., petroleum generator sets
5.	Operators afraid of main grid encroachment on exclusive mini-grid territory prior to attainment of payback period and significant returns on investment	• Developers to obtain clearance for the proposed exclusive territory from Rural Electrification Authority based on Rural Electrification Master Plan (REMP) to guide on possible siting • Governments to encourage off-grid energy development by making information on grid extension plans available to stakeholders in renewable energy development.

Operational Phase Constraints

No.	Identified Constraint	Proposed feasible solution
1.	High upfront capital expenditure costs	Developers to consider a phased approach to installation of the mini-grid if self-financed. Alternatively, source funds from suitable financiers that care about the case for rural electrification especially focused on combined social welfare and economic viability logic.
2.	Taxes that apply to procurement of the mini-grid technology equipment and excise duty	Government to consider incentivising the electricity mini-grid business by providing for tax holiday for a period of time or occasion a waiver on payment of excise duty for electricity generated from mini-grids

No.	Identified Constraint	Proposed feasible solution
3.	Business seasonality	• Developers train and support consumers running entrepreneurial activities based on electricity supplied from the mini-grid so that they remain in business during low demand periods • Developers to provide electricity services to consumers offering diverse commercial services to ensure continuous demand for electricity
4.	Low population density	• Operators should ensure retention of existing customers since low population density avails limited customer base. Further, Operators should design a word-of-mouth strategy (referral marketing) for satisfied customers to share their experiences and attract others to connect so as to build on intra-diffusion that helps to attain a critical mass of sales. • Mini-grids should be sited far apart to allow each mini-grid to have an ample catchment area of customers in order to achieve critical mass of sales
5.	Access to Finance and Limited business ideas	• Operators should collaborate with other service providers such as micro-finance enterprises to come up with appropriate technology that provides solutions to challenges faced in the community. For example; Microfinance institutions could lend finances to those intending to engage in entrepreneurial activities that productively use the electricity supplied from the mini-grid. In addition, Operators should consider collaborating with anchor customers for a reliable revenue stream and enable other customers to access electricity to peak the demand. • Operators should have a policy to engage consumers with a diversity of entrepreneurial activities to break the limited business ideas syndrome.

No.	Identified Constraint	Proposed feasible solution
6.	Government policy and regulations	• Government policy to promote installation and operation of mini-grids should be explicit to eliminate threats of grid encroachment due to grid network extension. • Government through delegated regulatory authorities such as ERB to provide regulations that create an enabling business environment
7.	Ignorance of people about mini-grids	Government through the delegated Authority REA and Operators should intensify awareness campaigns for the target consumers in rural areas considering that demand for the product emanates from consumer awareness.
8.	Lack of support in form of incentives	Government through the delegated Authority REA to consider provision of subsidies to eligible mini-grid developers as this could have a direct impact on the tariff charged for the electricity supplied from a mini-grids.

Source: Author

5.2.2 Data presentation, analysis and results based on independent variables

This section presents data, its analysis and results based on independent variables shown in the conceptual framework in chapter three as follows; diffusion of innovations elements (i.e., Innovation, Communication Channels, Time and Social Systems), Adoption process, Rate of adoption, Innovativeness and Adopter Categories, Models of business, Marketing mix strategy, Dimensions of entrepreneurship and Effectiveness of strategies.

5.2.2.1 Extent of consumers' awareness about electricity mini-grids in rural areas

Demand for a product or service emanates from consumer awareness about the innovation, in this case the electricity mini-grids. With reference to table 5.5, the weighted mean of 1.95 = **2** when rounded off and the Likert Scale result was **Low.** The research subjects indicated with a degree of consensus of **60.5%** that the extent

of consumers' awareness about electricity mini-grids as an innovation in rural areas is **Low.**

Table 5.5: Extent of consumers' awareness on electricity mini-grids in rural areas

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W - \bar{x})^2$	$F(W - \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Very Low	1	1	9	10	10	0.903	9.03
Low	2	4	17	21	42	0.003	0.063
Neutral	3	1	3	4	12	1.103	4.412
High	4	0	2	2	8	4.203	8.406
Very High	5	0	0	0	0	9.303	0.000
Total		**6**	**31**	**37**	**72**		**21.91**
Mean ($\bar{x}$)							**1.95**
SD							**0.77**
CV							**39.5%**
C							**60.5%**

Source: Author/Field data

5.2.2.1.1 Hypothesis testing on extent of consumers' awareness about electricity mini-grids in rural areas

Hypothesis testing on extent of consumers' awareness about electricity mini-grids in rural areas:

The null hypothesis, H_{o2}: The extent consumers are aware of the electricity mini off-grid systems in rural areas is high.

Alternative hypothesis, H_{a2}: The extent consumers are aware of the electricity mini off-grid systems in rural areas is low.

Test	Total No.	Test Statistic	Degrees of freedom (Df)	Asymptotic Sig. (2-Sided test)
One – sample Chi-Square Test	37	23.649	3	0.000

Notes:

The value of the test statistic = 23.649

The corresponding p-value of the test statistic is p = 0.000

The significance level, α = 0.05

Decision rule:

If P-value < α, then reject H_o
If P-value ≥ α, then accept H_o

Comment:

Since p-value (p) = 0.000 is less the significance level, α = 0.05, we reject the null hypothesis. Therefore, the alternative hypothesis that the extent consumers are aware of the electricity mini off-grid systems in rural areas is low was accepted. This result is consistent with the finding of data analysis in 5.2.2.1.

5.2.2.2 Spreading of information by Operators and Stakeholders to sensitise consumers

Based on analysis in table 5.6, the weighted mean of 2.38 = **2** when rounded off and the Likert Scale result was low**.** Therefore, research subjects indicated with a degree of consensus of **58.0%** that spreading of information by Operators and other Stakeholders to sensitise target consumers about the existence of electricity mini-grids and their benefits is **Low.**

Table 5.6: Spreading of information to sensitise target consumers about mini-grids

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W - \bar{x})^2$	$F(W - \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Very Low	1	1	3	4	4	1.90	7.62
Low	2	4	19	23	46	0.14	3.31
Neutral	3	0	4	4	12	0.38	1.54
High	4	0	4	4	16	2.62	10.50
Very High	5	1	1	2	10	6.86	13.73
Total		**6**	**31**	**37**	**88**		**36.70**
Mean ($\bar{x}$)							**2.38**
SD							**1.00**
CV							**42.0%**
C							**58.0%**

Source: Author/Field data

5.2.2.2.1 Qualitative analysis on spreading of information by Operators and Stakeholders to sensitise consumers

Following up with a qualitative survey, research subjects gave the following reasons as to why spreading of information about electricity mini-grids and their benefits in rural areas of Zambia is low thereby causing low awareness among energy consumers as found in 5.2.2.2.

a) Myth that electricity is only about the main grid

There is a general myth among rural energy consumers that only electricity supplied from the main grid by Zesco Limited the national utility company is real electricity and as such, any other alternative from the main grid is regarded inferior.

b) Mini-grids are regarded as a temporal solution

Electricity services supplied from the national grid are not regarded as a business by most rural energy consumers but a “political gift” to the rural areas. Provision of mini-grids in especially those areas powered on solar, is therefore, in some cases interpreted as a political failure or a temporal measure, while

waiting for the “political gift” through the national utility Zesco Limited to be made available.

c) Language barrier and lack of proof of concept

In some cases, language barriers inhibit how to fully explain electricity mini-grids and their main uses for the benefit of rural customers. The explanation of electricity mini-grid could be made easier with demonstration projects. However, the absence of demonstration projects in the vicinity to showcase a proof of concept makes spreading of information a challenge as there appears a lack of synergy between the mini-grid developers and the community.

d) Low consumer awareness

The mini-grid market is yet to grow from its current infancy stage as people lack exposure which would make them get to know mini-grids and their benefits. Absence of clear guidelines for developers of mini-grids to carry out sensitisation of rural communities about mini-grids services. Further, the Regulators such as ERB and REA do not carry out awareness programmes for rural dwellers and the developers only carryout awareness programmes in the areas of interest.

5.2.2.3 Cross tabulation on extent of consumer awareness versus spreading information

A cross tabulation of survey responses in table 5.7 show that 15 out of 37 translating into **40.5%** research subjects indicated that the extent to which electricity consumers in rural areas are aware of the electricity mini-grids as an innovation was low because spreading of information by Operators and other Stakeholders to sensitise target consumers about the existence of the electricity mini-grids and their benefits is **low**.

Table 5.7: Extent of consumer awareness in rural areas versus spreading of information about the existence of the electricity mini-grids and their benefits

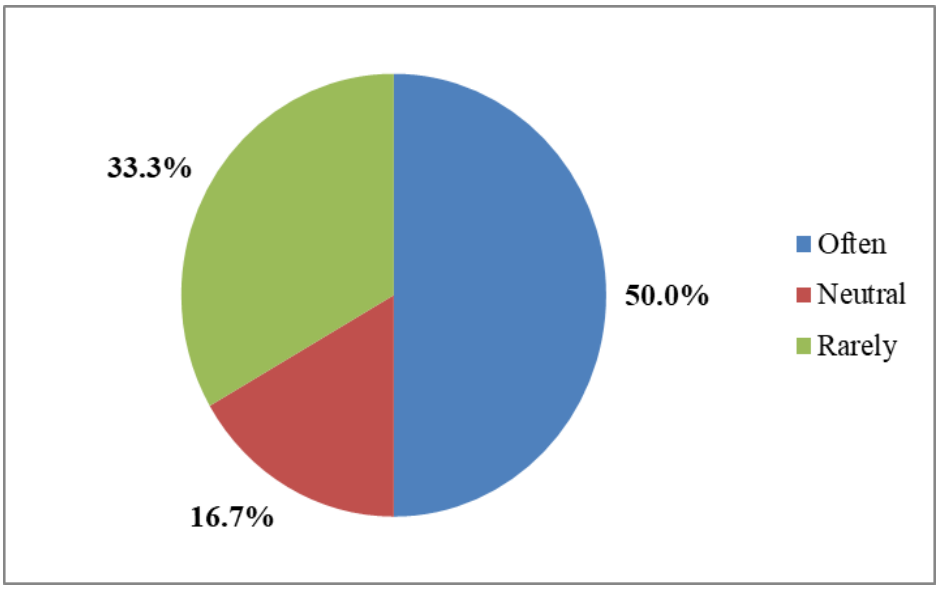
		Spreading of information by Operators and Stakeholders					
		Very low	**Low**	**Neutral**	**High**	**Very high**	**Total**
Extent of consumers awareness	**Very low**	2	6	0	1	1	**10**
	Low	2	**15**	2	2	0	**21**
	Neutral	0	1	2	0	1	**4**
	High	0	1	0	1	0	**2**
Total		**4**	**23**	**4**	**4**	**2**	**37**

Source: Author/Field data

5.2.2.4 Frequency of invitations to install electricity mini off-grid at other sites

Survey results from figure 5.1 showed that **50%** of Operators of electricity mini-grids often get invitations to install electricity mini-grids at other sites after spreading information about their existence and benefits. On the other hand, **33.3%** of the Operators indicated that they rarely get invitations, while **16.7%** remained neutral. shows the distribution of the survey responses received from the Operators of electricity mini-grids.

Figure 5.1: Frequency of invitations to install electricity mini-grids



Source: Author/Field data

5.2.2.5 Monitoring number of connections to the mini-grid

To ascertain market acceptance of electricity mini off-grids services, the number of consumers making connections (intra diffusion) is necessary (Herbig and Day, 1992). From table 5.8, the result for the weighted mean of **4** on the Likert Scale was **Agree**. Therefore, Operators of electricity mini-grids **agreed** with a degree of consensus of **75%** that they monitor the number of connections over a period of time after the electricity mini-grid is installed at any one site.

Table 5.8: Monitoring number of connections over a period of time

Likert Scale	Weight (W)	Operators Frequency (F)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
Strongly Disagree	1	0	0	9	0
Disagree	2	1	2	4	4
Neutral	3	0	0	1	0
Agree	4	3	12	0	0
Strongly Agree	5	2	10	1	2
Total		**6**	**24**		**6**
Mean ($\bar{x}$)					**4**
SD					**1**
CV					**25%**
C					**75%**

Source: Author/Field data

5.2.2.6 Communication through social systems as useful communication channels for spreading information about mini-grids

Social systems such as; dwellers in a selected village or community, schools in a particular area, or companies involved in a particular line of business such as farming in a specific area are useful communication channels for spreading information (Rogers, 1983). With reference to table 5.9 the weighted mean of 2.2 = **2** when rounded off and the Likert Scale result was low. The Operators indicated with a degree of consensus of **81.8%** that spreading information through social systems to communicate about the electricity mini-grids as a useful innovation in **Low.**

Table 5.9: Communication through social systems to spread information

Likert Scale	Weight (W)	Operators Frequency (F)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
Very Low	1	0	0	1.37	0
Low	2	5	10	0.03	0.15
Neutral	3	1	3	0.69	0.69
High	4	0	0	3.35	0
Very High	5	0	0	8.01	0
Total		**6**	**13**		**0.8**
Mean ($\bar{x}$)					**2.2**
SD					**0.4**
CV					**18.2%**
C					**81.8%**

Source: Author/Field data

5.2.2.7 Extent of spreading information about the electricity mini-grids through social systems versus frequency of getting invitations to install electricity mini off-grids

The cross tabulation in table 5.10 revealed that 3 out of 6 representing **50%** of Operators **often** get invitations to install electricity mini-grids at other sites despite the **Low** extent of communicating through social systems to spread information about the existence of electricity mini-grids and their benefits.

Table 5.10: Cross tabulation of spreading information through social systems versus invitation to install electricity mini-grids

		Frequency of invitations			
		Rarely	Neutral	Often	**Total**
Spreading information through social systems	Very low	1	0	0	**1**
	Low	1	0	**3**	**4**
	Very high	0	1	0	**1**
Total		**2**	**1**	**3**	**6**

Source: Author/Field data

5.2.2.8 Adoption process of electricity mini-grids as an innovation

With reference to 5.11, the weighted mean of 4.7 = 5 when rounded off and the Likert Scale result was very high**.** Operators of mini-grids indicated with a degree of consensus of **89.4%** that encouragement of new users to connect to their installed electricity mini-grids is **very high**. This was against the background that a consumer goes through an adoption process from knowing about an innovation such as the electricity mini-grid to forming an impression of the innovation as in whether to accept or reject using the new innovation followed by confirming one's decision by action (Rogers, 1983).

Table 5.11: Extent of Operators encouraging new users to connect to their mini - grids

Likert Scale	Weight (W)	Operators Frequency (F)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
Very Low	1	0	0	13.47	0
Low	2	0	0	7.13	0
Neutral	3	0	0	2.79	0
High	4	2	8	0.45	0.9
Very High	5	4	20	0.11	0.44
Total		**6**	**28**		**1.3**
Mean ($\bar{x}$)					**4.7**
SD					**0.5**
CV					**10.6%**
C					**89.4%**

Source: Author/Field data

5.2.2.9 Rate of Adoption for electricity mini-grid

Making reference to table 5.12, the weighted mean of 2.43 = **2** when rounded off and the Likert Scale was **Disagree.** Research subjects **disagreed** that the adoption rate of electricity mini-grids is widespread as an innovation for entrepreneurial purposes in rural areas of Zambia with a degree of consensus of **62.5%**.

Table 5.12: Adoption rate of electricity mini-grids

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Disagree	1	0	4	4	4	2.04	8.16
Disagree	2	3	17	20	40	0.18	3.6
Neutral	3	1	5	6	18	0.32	1.92
Agree	4	2	5	7	28	2.46	17.22
Strongly Agree	5	0	0	0	0	6.60	0
Total		**6**	**31**	**37**	**90**		**30.9**
Mean ($\bar{x}$)							**2.43**
SD							**0.91**
CV							**37.5%**
C							**62.5%**

Source: Author/Field data

5.2.2.9.1 Hypothesis testing on the adoption rate of electricity mini-grids

Hypothesis testing was carried out on the adoption rate of electricity mini-grids as an innovation for entrepreneurial purposes in rural areas of Zambia.

Null hypothesis, H_{o3}: The adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is widespread.

Alternative hypothesis, H_{a3}: The adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is not widespread.

Test	Total No.	Test Statistic	Degrees of freedom (Df)	Asymptotic Sig. (2-Sided test)
One – sample Chi-Square Test	37	17.162	3	0.001

Notes:

The value of the test statistic = 17.162

The corresponding p- value of the test statistic is p = 0.001

The significance level, α = 0.05

Decision rule:

If P-value < α, then reject H_o
If P-value $\geq$ α, then accept H_o

Comment:

Since p- value (p) = 0.001 is less the significance level, α = 0.05. Therefore, we reject the null hypothesis and accept the alternative hypothesis that the adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is not widespread. The result remained consistent with analysis finding in 5.2.2.9.

5.2.2.10 Innovativeness and Adopter Categories

Classification of consumers according to the relative time they register for connection as; innovators, early adopters, early majority, late majority and laggards aids the operator to formulate action plans for improving the adoption rate (Rodgers, 1983). The weighted mean of 2.83 = **3** when rounded off and the Likert Scale result was **neutral** with reference to table 5.13. Survey results revealed that Operators were **neutral** with a degree of consensus of **62.2%** on whether consumers are classified according to the relative time they register for connection to their electricity mini-grid.

Table 5.13: Classification of consumers

Likert Scale	Weight (W)	Operators Frequency (F)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
Strongly disagree	1	1	1	3.35	3.35
Disagree	2	1	2	0.69	0.69
Neutral	3	2	6	0.03	0.06
Agree	4	2	8	1.37	2.74
Strongly Agree	5	0	0	4.71	0
Total		**6**	**17**		**6.84**
Mean ($\bar{x}$)					**2.83**
SD					**1.07**
CV					**37.8%**
C					**62.2%**

Source: Author/Field data

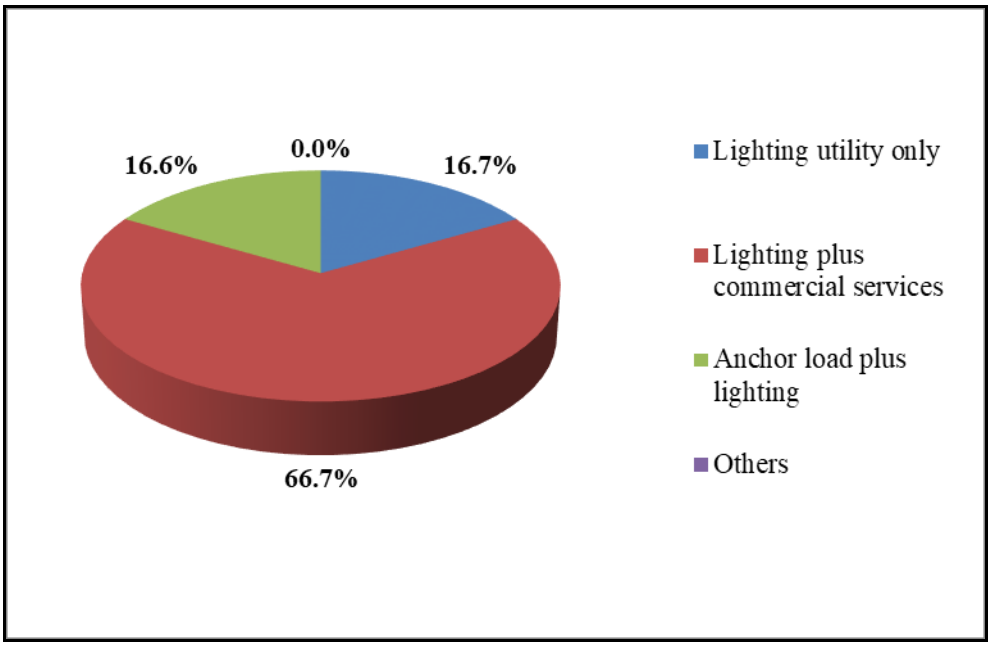
5.2.2.10.1 Qualitative analysis on Innovativeness and Adopter Categories

Following up with interviews on Operators revealed that their practices vary as some operators classify consumers according to the relative time they register for connection, while other operators do not. Categorising customers in tier bands based on their ability to pay with respect to uptake of electricity or load is a common practice among Operators because it enables them to plan for the generation capacity according to demand. The customers are placed in the said respective categories for ease of monitoring their electricity usage.

5.2.2.11 Models of business for electricity mini-grid operation

Electricity mini-grids models of business are classified according to method of service delivery. The study outcome revealed that majority **66.7%** of the mini-grid Operators use the lighting plus commercial services business model, while **16.7%** of the mini-grid Operators use the lighting utility only model and the other **16.6%** uses the anchor load plus lighting model as shown in figure 5.2. There were no other business models specified by the research subjects.

Figure 5.2: Models of business used by electricity mini-grid Operators



Source: Author/Field data

5.2.2.12 Leveraging 4Ps of the marketing mix to increase number of connections

Marketing mix consists of a set of tools for marketing used by an enterprise to pursue own marketing objectives in order to elicit desired responses from its target market. The marketing tools are categorised into four broad groups that are referred to as 4**P**s of the marketing mix namely; product, price, place, and promotion (Kotler, 2000; McCarthy, 1964). The concept of the 4**P**s of the marketing mix, is applicable to the entrepreneurial activity of electricity mini-grids where the **P**roduct is the electricity, the **P**rice is the tariff the enterprise charges for the electricity supplied, the **P**lace is the distribution network/channel up to customer premises and **P**romotion comprises the various communications used to market the electricity including forms of advertising, public engagements, and techniques for achieving the direct and indirect selling.

As shown in table 5.14, the weighted mean of 3.83 = **4** when rounded off and the Likert Scale result was **Agree.** Operators of electricity mini-grids **agreed** with a degree of consensus of **76.5%** that they purposefully leverage the 4**P**s of the marketing mix to increase the number of connections to their electricity min-grids.

Table 5.14: Leveraging 4Ps of the marketing mix to increase number of connections

Likert Scale	Weight (W)	Operators Frequency (F)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
Strongly disagree	1	0	0	8.01	0
Disagree	2	1	2	3.35	3.35
Neutral	3	0	0	0.69	0
Agree	4	4	16	0.03	0.12
Strongly Agree	5	1	5	1.37	1.37
Total		**6**	**23**		**4.84**
Mean ($\bar{x}$)					**3.83**
SD					**0.90**
CV					**23.5%**
C					**76.5%**

Source: Author/Field data

5.2.2.13 Dimensions of entrepreneurship to enhance diffusion of electricity mini-grids

The issue of entrepreneurship is very often discussed in relation to the strategic process that leads to success in business (Tanţău, 2005; Dollinger, 2008). With reference to table 5.15, **32.4%** constituting the majority of the research subjects indicated the combination of entrepreneurship dimensions; new venture creation, entrepreneurs' seizing opportunity and the business environment can enhance diffusion of electricity mini-grid systems in rural areas of Zambia for entrepreneurial purposes if properly executed. On another hand, **16.2%** of the research subjects opted for the entrepreneurship dimensions combination of; entrepreneurs' seizing opportunity, the business environment and the organisation, while **13.5%** of the research subjects indicated the entrepreneurship dimensions combination of; entrepreneurs' seizing opportunity, the entrepreneur and the business environment. Another notable combination of entrepreneurship dimensions; entrepreneurs' seizing opportunity, the entrepreneur and the organisation was selected by **10.8%** of the research subjects. Other entrepreneurship dimensions combinations constituted less than **10%** of the total responses.

Table 5.15: Dimensions of entrepreneurship

Dimensions of entrepreneurship	Frequencies		Total Frequencies (a + b)	Percent (%)
	Operators (a)	Industry Experts (b)		
New venture creation, entrepreneurs' seizing opportunity and the business environment	2	10	12	32.4
Entrepreneurs' seizing opportunity, the business environment and the organisation	1	5	6	16.2
New venture creation, entrepreneurs' seizing opportunity and the entrepreneur	0	3	3	8.1
Entrepreneurs' seizing opportunity, the entrepreneur and the business environment	1	4	5	13.5
New venture creation, the entrepreneur and the business environment	2	1	3	8.1
Entrepreneurs' seizing opportunity, the entrepreneur and the organisation	0	4	4	10.8
New venture creation, entrepreneurs' seizing opportunity and the organisation	0	1	1	2.7
New venture creation, the business environment and the organisation	0	2	2	5.4
The entrepreneur, the business environment and the organisation	0	1	1	2.7
Totals	**6**	**31**	**37**	**100**

Source: Author/Field data

5.2.2.14 Effectiveness of the strategies applied for diffusion of electricity mini-grids

The weighted mean of 2.84 = **3** when rounded off and the Likert Scale result was neutral as shown in table 5.16 (a). Therefore, the quantitative survey responses were **neutral** with a degree of consensus of **63.7%** for the main study on whether the strategies currently applied to achieve diffusion of electricity mini off-grids for entrepreneurial purposes in rural areas of Zambia are effective. On another hand, the survey responses in table 5.16(b) showed the weighted mean of 2.44 = **2** when rounded off, giving the Likert Scale result of **Agree.** Hence, the pilot study revealed in contrast that both Operators and Industry Experts **agreed** with a degree of consensus of **61.1%** that the strategies currently applied for diffusion of electricity mini off-grid systems are effective for entrepreneurial purposes in rural areas of Zambia. The difference in the outcome of the actual and pilot study could be attributed to the influence of the sample size. The actual strategies were the same for both the pilot and main study as shown in table 5.16 (c).

With reference to table 5.16(c) regarding the strategies currently applied for operations and promoting number of connections to installed mini-grids, it was found that **83.3%** of the Operators of electricity mini-grids encourage customers to use electricity for various small productive commercial activities in addition to lighting, **50%** of the Operators encourage use of efficient lighting appliances to manage consumer loads and thus offer more value to customers, **33.3%** of the Operators indicated that they make electricity tariffs affordable and provide convenience for payment using smart metering, payments through mobile phones and other pay-as-you-go mechanisms, while **16.7%** of the Operators encourage customers to set up anchor loads to be enjoyed together with lighting services.

Table 5.16 (a): Effectiveness of the strategies currently applied for diffusion of mini-grids

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Disagree	1	0	1	1	1	3.39	3.39
Disagree	2	2	16	18	36	0.71	12.78
Neutral	3	0	6	6	18	0.03	0.18
Agree	4	4	6	10	40	1.35	13.5
Strongly Agree	5	0	2	2	10	4.67	9.34
Total				**37**	**105**		**39.19**
Mean ($\bar{x}$)							**2.84**
SD							**1.03**
CV							**36.3%**
C							**63.7%**

Source: Author/Field data

Table 5.16 (b): Effectiveness of the strategies currently applied for diffusion of mini-grids (for pilot study)

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Agree	1	1	0	1	1	2.07	2.07
Agree	2	3	2	5	10	0.19	0.95
Neutral	3	0	1	1	3	0.31	0.31
Disagree	4	0	2	2	8	2.43	4.86
Strongly Disagree	5	0	0	0	0	6.55	0
Total		**4**	**5**	**9**	**22**		**8.19**
Mean ($\bar{x}$)							**2.44**
SD							**0.95**
CV							**38.9%**
C							**61.1%**

Source: Author/Field data

Note: *One response was none indicative for Industry Experts hence total frequency = **9** instead of 10.*

Table 5.16(c): Strategies currently applied by operators for entrepreneurial purposes

Strategies applied by Operators	Frequency	Percentage (%)
Make electricity tariffs affordable and provide convenience for payment using pay-as-you-go mechanisms	2	33.3
Encourage use of efficient lighting appliances to manage consumer loads and thus offer more value to customers	3	50.0
Encourage customers to use electricity for various small productive commercial activities in addition to lighting	5	83.3
Encourage customers to set up anchor loads, while also enjoying lighting services	1	16.7
Total	**11**	**183.3**

Source: Author/Field data

Comment: Some of the operators apply multiple strategies hence total percentage sums up to more than 100%.

5.2.2.14.1 Qualitative analysis on effectiveness of the strategies currently applied for the diffusion of electricity mini-grids for entrepreneurial purposes

Findings from the follow up qualitative survey revealed that electricity mini-grid operators apply the marketing concept and referral marketing as the effective strategies for promoting the number of connections to an electricity mini-grid for entrepreneurial purposes.

Marketing concept refers to application of marketing information focusing on the customer needs in order to develop a segmented approach solution that is based on appropriate technology for which consumers are willingness and able to pay (Kotler, 2001). This approach may require mini-grid developers to partner with other service providers to come up with appropriate technology that provides solutions to challenges faced in the community. In such cases, the identified solutions are powered by the mini-grid and serves as the direct anchor load. Some examples include; tailor-made mini-grid to generate and supply electricity for powering telecommunication towers that enable financial technology business (fintech

business) activities such as mobile money booths and micro financing institutions to thrive in rural areas, then micro finance enterprises lend their customers money to purchase energy efficient capex equipment that run on the electricity supplied from the mini-grid in a win-win situation for all parties. Further, mini-grid developers could offer a combo package such as each connection coming with a Radio in addition to lighting to entice consumers.

Kotler (2001, p. 11) observes that there are five competing marketing concepts employed by organisations to carry out marketing functions namely; production, product, selling, marketing and societal marketing concepts and each of these orientations toward the target market has its own merits. Of interest in this case is the marketing concept which starts with focusing on customer needs of a well-defined market then coordinating entrepreneurial activities to generate profits by satisfying customers' requirements.

As the electricity mini-grid Operator gains more satisfied customers, the customers in turn begin to share their experiences with others and that soon becomes a recipe for referral marketing, which can simply be described as a word-of-mouth strategy designed by an enterprise to incentivise existing customers to recommend to their family, friends and contacts to become new customers thereby cause diffusion of the innovation (Jaffe, 2010), which in this case is the diffusion of electricity mini-grids.

5.2.3 Data presentation, analysis and results based on moderator variables

This section further presents data, its analysis and results based on moderator variables shown in the conceptual framework in chapter three as follows; low costs of renewable energy technologies, influence of government support, policies and regulations and increased electricity demand due to productive end uses.

5.2.3.1 Low costs for renewable energy technologies

One of the known economic barriers to use of renewable energy technology such as solar and wind is the high upfront expense for installing the electricity generation facility and associated distribution network (Samoita *et al.*, 2020). As shown in table

5.17(a), the weighted mean of 4.24 = 4 when round off and the Likert Scale result was **Agree.** Survey results for the main study showed that research subjects **agreed** with a degree of consensus of **80.7%** that the benefits of declining costs for renewable energy technologies like solar panels, cheaper and more efficient lighting appliances, new payment mechanisms such as smart metering enhanced by remote monitoring technologies and pay-as-you-go mechanisms can accelerate diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia. In the same vein, the weighted mean of 4.5 = 5 when round off giving the Likert Scale result of **Strongly Agree** as shown in table 5.17(b) for the pilot study. Research subjects for the pilot study **strongly agreed** with a degree of consensus of **88.9%** in the same way as research subjects for the main study.

This finding agrees well with the finding of the study by Pedersen (2017) on solar-fuelled mini-grid development in Kenya that Solar PV diffusion could be explained with reference to a decline in the world market prices for PV modules, prolonged support from international donors and the supportive framework conditions provided by national governments. The finding is also validated by IRENA (2020) quoted as, “electricity costs from renewables have fallen sharply over the past decade, driven by improving technologies, economies of scale, increasingly competitive supply chains and growing developer experience. As a result, renewable power generation technologies have become the least-cost option for new capacity in almost all parts of the world.” Further, IRENA (2017) highlights that, “the cost of electricity from renewable energy technologies has fallen steadily, and even dramatically, in recent years. This is especially the case since 2000, with the rise of solar and wind power generation as viable commercial options. Today, power generation from renewable energy sources and technologies has become increasingly competitive with, or indeed, least costly than, fossil-based or nuclear power.”

Table 5.17 (a): Benefits of declining costs for renewable energy technologies (main study)

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Disagree	1	1	0	1	1	10.50	10.50
Disagree	2	0	1	1	2	5.02	5.02
Neutral	3	0	0	0	0	1.54	0
Agree	4	4	17	21	84	0.06	1.26
Strongly Agree	5	1	13	14	70	0.58	8.12
Total				**37**	**157**		**24.90**
Mean ($\bar{x}$)							**4.24**
SD							**0.82**
CV							**19.3%**
C							**80.7%**

Source: Author/Field data

Table 5.17 (b): Benefits of declining costs for renewable energy technologies (pilot study)

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Disagree	1	0	0	0	0	12.25	0
Disagree	2	0	0	0	0	6.25	0
Neutral	3	0	0	0	0	2.25	0
Agree	4	1	4	5	20	0.25	1.25
Strongly Agree	5	3	2	5	25	0.25	1.25
Total		**4**	**6**	**10**	**45**		**2.5**
Mean ($\bar{x}$)							**4.5**
SD							**0.5**
CV							**11.1%**
C							**88.9%**

Source: Author/Field data

5.2.3.2 Government support through REA

Féron (2017) in her study of sustainability of rural electrification programs based on off-grid PV systems in Chile found that a government energy agency focused on the running of off-grid systems was required for technological support and supervision. In the same vein, IRENA (2018) observed that several countries in Sub-Saharan Africa have established institutions with a mandate to promote electrification of rural settlements, whereas the others have put the responsibility for electrification of rural areas within existing government ministries or agencies.

In Zambia, the Rural Electrification Authority (REA) is a statutory body established through an Act of parliament No. 20 of 2003 and is mandated to provide infrastructure for electrifying the entire rural areas of the country using appropriate technologies. REA collaborates with others to avail mechanisms for extending the main grid network to electrify rural areas including use of other rural energy supply options such as electricity mini-grids.

Research subjects indicated that firms involved in installation and operation of electricity mini-grids enjoy the following benefits from REA as shown in table 5.18:

- That REA uses the Rural Electrification Master Plan (REMP) to guide on possible siting of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia according to **67.6%** research subjects;
- That REA encourages private sector participants in rural electrification through provision of smart subsides, competitive bidding, and community mobilisation according to **48.7%** research subjects;
- That REA finances project preparation studies for rural electrification based on identified growth centers in rural areas throughout the country according to **21.6%** research subjects;
- That REA protects potential and existing electricity mini off-grid systems installed for entrepreneurial purposes in rural Zambia from possible main grid encroachment according to **10.8%** research subjects; and

- That none of the mentioned benefits are enjoyed from REA according to **8.1%** research subjects;

Table 5.18: Benefits enjoyed by Operators of electricity mini-grids from REA

Benefits enjoyed from REA by Operators of mini-grids	No. of Operators Responses (a)	No. of Industry Experts Responses (b)	Total No. of Responses (a + b)	Total Response %
REA encourages private sector participants in rural electrification through provision of smart subsides, competitive bidding, and community mobilisation	0	18	18	48.7
REA uses the Rural Electrification Master Plan (REMP) to guide on possible siting of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia	4	21	25	67.6
REA protects potential and existing electricity mini off-grid systems installed for entrepreneurial purposes in rural Zambia from possible main grid encroachment	1	3	4	10.8
REA finances project preparation studies for rural electrification based on identified growth centers in rural areas throughout the country	0	8	8	21.6
None of the above benefits are enjoyed from REA	1	2	3	8.1

Source: Author/Field data

5.2.3.3 Influence of regulations to promote mini-grids installation and operation

The recent National Energy Policy (2019) in Zambia succeeds earlier policies of 1994 and 2008. It is supported by the Seventh National Development Plan (7NDP) and Vision 2030. One of National Energy Policy (2019) specific objective measures is to

increase availability of electricity for improving the livelihoods of citizens by expanding generation, transmission and distribution capacity and to increase availability of electricity for rural areas.

In table 5.19, the weighted mean of 3.22 = **3** when rounded off and the Likert Scale result was **neutral.** Research subjects were **neutral** with a degree of consensus of **70.2%** on whether there was availability of adequate and effective regulations to promote the setting up and running of electricity mini-grids for entrepreneurship in rural areas of Zambia.

Table 5.19: Availability of adequate and effective regulations to support mini-grids

Likert Scale	Weight (W)	Research Subjects		Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F (W- \bar{x})^2$
		Operators Frequency (f_1)	Industry Experts Frequency (f_2)				
Strongly Disagree	1	0	1	1	1	4.93	4.93
Disagree	2	0	9	9	18	1.49	13.41
Neutral	3	4	6	10	30	0.05	0.5
Agree	4	2	13	15	60	0.61	9.15
Strongly Agree	5	0	2	2	10	3.17	6.34
Total		**6**	**31**	**37**	**119**		**34.33**
Mean ($\bar{x}$)							**3.22**
SD							**0.96**
CV							**29.8%**
C							**70.2%**

Source: Author/Field data

5.2.3.3.1 Qualitative analysis on regulations to promote the installation and operation of electricity mini off-grids

Further, findings following the qualitative study conducted on the same point of inquiry revealed that the current policy and regulations on promotion of installation and operating electricity mini-grids were inadequate and ineffective due to the following reasons:

a) Grey area in policy and regulations

Mini-grids are widely talked about by many sector players but the policy and regulations around them in reality remain vague to support a wider adoption. For example, it was not clear in any policy or regulatory instrument on who takes up the responsibility to compensate a mini-grid developer in case of main grid arrival or encroachment. In fact, the specific regulatory framework for mini-grids was being made about the time this study was carried out and so options for what happens in the case of main grid arrival or encroachment were not yet approved though some considerations were that mini-grids distribution network infrastructure should conform to the main grid standard so that merging could be easy in case of main grid arrival according to the regulations on technical requirements for mini-grid renewable energy generation, storage, distribution and supply (2019) under development.

Further, provisions in the mini-grid: grid encroachment regulation (2019) under development were that main grid and mini-grid licensees could with or without variation agree on one of the following grid encroachment options for purposes of coming to an agreement:

i) The main grid licensee acquires only the customer base of the mini-grid licensee and builds, owns and operates a new distribution network and related assets in the licensed area of the mini-grid, and the mini-grid licensee abandons all its assets and removes it;

ii) The main grid licensee acquires the customer base and the existing distribution network and related assets from the mini-grid licensee, and the mini-grid licensee disconnects and abandons all its generation, storage and related assets and removes it from the mini-grid licensed area;

iii) The main grid licensee acquires the customer base and all of the generation, distribution network, storage and related assets of the mini-grid licensee, whether the mini-grid is subsequently connected to the main grid or not;

iv) The mini-grid licensee retains its customer base and existing distribution network and related assets and purchases electricity from the main grid licensee for re-sell to its customers, and abandons the operation of its generation, storage and related assets;

v) The mini-grid licensee becomes an Independent Power Producer (IPP) and sells all of its generated energy to the main grid licensee, and the main grid Licensee acquires the customer base and the existing distribution network and related assets from the mini-grid licensee; and

vi) The mini-grid licensee and the main grid licensee concludes purchase and sales contracts, where in the case of excess energy availability from the mini-grid, the mini-grid licensee has the right to sell excess energy to the main grid licensee, and in the case of an energy deficit in the mini-grid, the main grid licensee provides the required energy to the mini-grid licensee.

Thus, until the mini-grid regulations under development get approved for use, the grey area remains a constraint to diffusion of electricity mini-grids for entrepreneurship in rural areas of Zambia.

b) Manner of Regulation

The current regulations being applied were progressive. However, the heavy handedness aspects for the current regulation may need to be revisited to ensure that all aspects are light handed with respect to electricity mini-grids. Out rightly the current policy and regulations are not adequate and effective because they lack the phased approach for regulating licenced enterprises whereby, they treat the main grid and mini-grid licensees the same without regard for the services being offered.

This submission emanated from the fact that mini-grids regulations were not available and hence the main grid and mini-grids were handled the same way. Therefore, it is expected that the manner of regulating mini-grids would change once the mini-grids regulations on technical requirements currently under development are finalised and enacted.

c) Grid extension

Government policy on grid extension does not support diffusion of mini-grids which are a proven economical method of rural electrification. Moreover, grid extension is a threat to mini-grids as it may extend to areas that are already serviced by a mini-grid for entrepreneurial purposes.

Implementation of the government programme on grid extension projects for rural electrification undertaken by REA commenced in 2006 covering all the ten (10) provinces in Zambia. The petroleum fuel (diesel) based mini-grids in North Western and Muchinga Provinces have since been phased out by grid extension to electrify rural areas that were served by the mini-grid. Areas covered by the grid extension projects are published on REA website for ease of reference.

Deshmukh *et al.* (2013) observed that, while many governments prioritise the provision electricity, their policies tend to favour electrification by way of main grid extension implemented through traditional utilities. For example, it was found that most efforts in Nicaragua of Central America to electrify rural areas were focused on grid extension (Ranaboldo, 2015). But then, such solutions based on grid extension-based solutions were uneconomical and unviable economically due to dispersed nature of most rural settlements. Hence, diesel powered micro-grids represented the historically preferred remedy for off-grid populated centres. With improved technology, mini-grids fuelled by naturally replenished energy sources such as wind and solar were found suitable alternatives for electrifying isolated communities reliably and free from pollution by greenhouse gases.

d) Siting of mini-grids

The current improvement following the development of the website at ERB which provides information on procedure to be followed to develop mini-grids is progressive. However, the policy and regulations lack clear guidance on geographical location allocation for potential mini-grid developers. The Rural Electrification Master Plan (REMP) managed by REA is progressive. However, it is not regularly updated to

reflect real happenings on the ground thereby leaving room for potential conflict between mini-grid developers that would be sited near each other.

The siting of mini-grids remains a preserve of REA who are responsible for electrification of the rural settlements using the Rural Electrification Master Plan (REMP) as their fundamental tool. The REMP is a systematic implementation plan that indicates rural electrification targets, electrification order, electrification method, time schedule and budget required. While regular updates of the REMP may be required, the current plan was prepared to provide a blueprint for electrification for the 2008 – 2030 period and was done with the support from the Government of Japan somewhat implying that updates of the REMP require funding and technical support.

5.2.3.4 Increased electricity demand due to productive end uses

People in low-income communities such as rural areas experience several productive energy needs that are not serviced such as; preservation and storage of food, welding, crop irrigation, powering a computer (Best, 2016). Therefore, Operators of electricity mini-grids are keen to meet the Productive Uses of Energy (PUE) since the economic viability of their enterprise as an Energy Service Provider (ESP) depends on customers' earnings and their demand for power.

With reference to table 5.20, the weighted mean of 3.08 = **3** when round off and the Likert Scale result was **neutral.** Survey responses were **neutral** with a degree of consensus of **68.5%** on whether consumers in rural areas apply the electricity supplied from mini-grids for economic productive uses that stimulate entrepreneurial activities and in turn enable their ability to pay for the electricity service**.**

Table 5.20: Productive end use of electricity by consumers

Likert Scale	Weight (W)	Research Subjects: Operators Frequency (f_1)	Research Subjects: Industry Experts Frequency (f_2)	Total Frequency, F ($F = f_1 + f_2$)	FW	$(W- \bar{x})^2$	$F(W- \bar{x})^2$
Strongly Disagree	1	0	0	0	0	4.33	0
Disagree	2	1	13	14	28	1.17	16.38
Neutral	3	0	8	8	24	0.01	0.08
Agree	4	3	10	13	52	0.85	11.05
Strongly Agree	5	2	0	2	10	3.69	7.38
Total		**6**	**31**	**37**	**114**		**34.89**
Mean ($\bar{x}$)							**3.08**
SD							**0.97**
CV							**31.5%**
C							**68.5%**

Source: Author/Field data

5.2.3.4.1 Qualitative analysis on productive end use of electricity by consumers

Follow up interviews with operators revealed that a wide variety of entrepreneurial activities are undertaken specific to the site according to the needs of communities, but can be categorised broadly as; food processing, body care and power tools as briefly illustrated in subsequent sub-sections. The pictures of mini-grid installations and the productive end uses for electricity supplied from mini-grids were taken during field visits to some of the electricity mini-grids installed and operated for entrepreneurial purposes in rural Zambia.

i) Food processing

Food processing entrepreneurial activities include operating: hammer mills for grinding maize to produce mealie-meal or maize meal for cooking the staple food Nshima; oil press for extracting cooking oil from sunflower seeds or groundnuts; freezers for making ice cubes for food preservation; freeze-it machines for making edible ice blocks for cooling the human body; refrigeration units for butchery, bottle

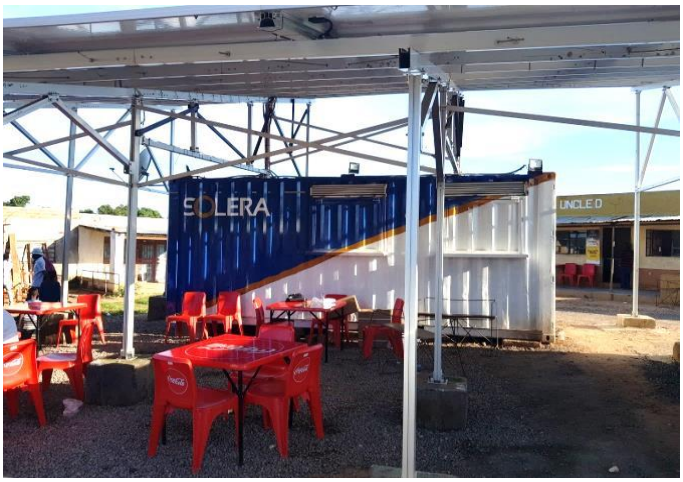
stores and preservation of other food products. For example, plate 5.1 shows pictures of Bottle and Grocery Stores at Luangwa Bridge powered by Solera Power Vending Machine mini-grids.

Plate 5.1: Pictures of Bottle and Grocery Stores at Luangwa Bridge

Source: Author/Field Picture, taken on 27 February 2020, 13:49 pm

Distribution lines from Solera Power Vending mini-grid supplying electricity to Bottle and Groceries Stores at Luangwa Bridge

Plate 5.2: Picture of Bottle Store and Pleasure Resort at Kacholola



Source: Author/Field Picture, taken on 27 February 2020, 17:03 pm

A Bottle Store and Pleasure Resort for recreation equipped with fridges powered by Solera Power Vending mini-grid. Customers are able to enjoy cold beverages.

ii) Body care

Entrepreneurial activities relating to body care refers to operating hair saloons using such tools as barbing machines and hair dryers among others.

Plate 5.3: Picture of a Hair Saloon at Kacholola

Source: Author/Field Picture, taken on 27 February 2020, 17:13 pm

Hair Saloon using equipment such as Hair Dyers and Barbing Machines that use electricity supplied from Solera Power Vending Machine mini-grid at Kacholola.

iii) Power tools

Entrepreneurial activities include; welding, irrigation pumping and carpentry workshops.

Plate 5.4: Carpentry Shop at Kacholola

Source: Author/Field Picture, taken on 27 February 2020, 17:13 pm

The carpentry shop power tools for planing, turning and cutting timber among other activities powered by electricity supplied from Solera Power Vending Machine mini-grid.

Plate 5.5: Mini-grid Installation for Engie Power Corner at Chitandika Village in Chipangali Constituency

Source: Author/Field Picture, taken on 28 February 2020, 12:39 pm

Plate 5.6: Mini-grid Installation for Solera Power Vending Machine at Luangwa Bridge

Source: Author/Field Picture, taken on 28 February 2020, 13:51 pm

Plate 5.7: Engie Power Corner electricity mini-grid distribution lines supplying electricty to Chitandika Village

Source: Author/Field Pictures, taken on 28 February 2020, 10:49 pm

Plate 5.8: Solera Power Vending Machine electricity mini-grid distribution lines supplying electricty to Kacholola Market Shops

Source: Author/Field pictures, taken on 28 February 2020, 17:12 pm

5.3 Presentation of information obtained from focus groups

The information gathered from focus groups was used mainly to validate survey results and information acquired from document review. Pertinent take away points included inter alia the following:

i) Consumers were excited with the advent of electricity mini-grids in their rural areas;

ii) Some consumers set up productive uses of the electricity from mini-grids to generate revenues used to make their lives better and enable them pay for the electricity services enjoyed. For example; setting up Barber shops, Bottle stores, Carpentry workshops and Butchery etc.;

iii) Some consumers resorted to ration the use of electricity in order to manage living within a tight budget they could afford e.g., lighting for a short time only in the evening;

iv) All consumers complained that the electricity tariffs were high compared to the national utility company tariffs i.e., Zesco Limited's tariffs. The author observed that the tariff difference was largely attributed to economies of scale. Zesco Limited services a large market, hence its fixed expenses are widely spread over a large quantity of production thereby effectively reducing the unit cost of each electricity unit produced, thus can afford low tariff as opposed to the mini-grid with a small customer base serving a localised area on which the fixed costs are met and hence the high tariff. Further, tariffs for both mini-grids and main grid are scrutinised and approved by the Energy Regulation Board;

v) Consumers called upon the national energy regulator, the Energy Regulation Board to intervene so that Operators of electricity mini-grids could reduce the tariffs and make them more affordable; and

vi) Consumers with productive uses encouraged Operators of electricity mini-grids to increase generation capacity so as to cater for bigger loads than what was currently being serviced.

5.4 Chapter Summary

This chapter involved presentation of data, its analysis and provided results based on: the study objectives; independent variables and moderator variables. Statistical methods were used for analysis of quantitative data, while qualitative data was thematically analysed to yield outcomes that have been presented regarding constraints of electricity mini-grids diffusion for entrepreneurship in rural areas of Zambia.

According to the embedded research design approach opted for the study, the researcher collected and analysed quantitative and qualitative data sequentially so as to obtain detailed information on points of inquiry where quantitative analysis did not yield conclusive results. Information gathered from focus groups was also presented. Chapter six (6) coming next presents the discussion and interprets of the study findings.

CHAPTER SIX

DISCUSSION AND INTERPRETATION OF STUDY FINDINGS

6.1 Introduction

This chapter involves discussion and interpretation to give relevance to the study findings that were arrived at in the immediately preceding chapter. The findings are articulated to highlight any new information or insights that emerged from studying the problem based on study objectives and factors affecting electricity mini off-grid systems diffusion.

6.2 Study objectives

To recap, the main objective of this study was to establish the main constraints of diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia and the specific objectives of the study were to:

i. Determine the cause of slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia;
ii. Establish why mini-grid developers are not initiating additional projects after completion and operationalisation of the initial project;
iii. Examine whether developers' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages; and
iv. Propose feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion as an innovation for entrepreneurship in rural areas of Zambia.

6.2.1 Main constraints of electricity mini off-grid systems diffusion for entrepreneurial purposes in rural areas of Zambia

The findings of the study for the main objective were obtained through both quantitative and qualitative survey approaches. With reference to 5.2.1.1, the main constraints of diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia using the quantitative approach are; research subjects from the

main study **81.1%** and from the pilot study **90%** indicated that inadequate income affects ability of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable; research subjects from the main study **81.1%** and **100%** from the pilot study indicated that low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas; research subjects from the main study **78.4%** and **70%** from the pilot study responded that the profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion; research subjects from the main study **46.0%** and **30%** from the pilot study indicated that substitutes such as fire wood and petroleum products such as kerosene provide cheap energy sources compared to what electricity mini-grids offer; and research subjects from the main study **46.0%** and **10%** from the pilot study responded that Operators are afraid to spread out electricity mini-grids to other rural areas of Zambia because the main grid may encroach on their exclusive supply territory before they attain the payback and obtain significant returns on their investment.

In tandem, the qualitative study findings highlighted the following constraints of diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia: the installation and operation of an electricity mini-grid has high upfront capital expenditure costs that present as a constraint; high taxes that apply to procured technology components for building the electricity mini-grids such as customs clearance tax and local taxes such as exercise duty on produced electricity payable to Zambia Revenue Authority; seasonality of business in rural areas which arise due to economic fluctuations when rural customers tend to have funds to afford electricity and most other commodities after sales of their farm harvest produce, low population density avails limited customer base not only for the mini-grid operator, but also for those engaged in entrepreneurial activities productively using the electricity supplied from the mini-grid, limited access to finance and limited business ideas in rural areas, government policy to promote installation and operation of mini-grids is not clear and that contributes to the business risk, ignorance of people in

rural areas about mini-grids, and lack of support in form of incentives to developers of mini-grids.

From the extant body of knowledge, it was learnt that while the quantitative approach findings are indeed significant and could potentially negatively affect the overall project sustainability to deliver on the social and economic benefits for energy consumers, such constraints are dealt with by developers at the stage of feasibility studies by exploring the prospective market prior to installation of the electricity mini-grid. Each developer devises their own criteria for profiling and selecting a suitable site where to install the electricity mini-grid. An example of the criteria as provided by Murunga *et al.* (2014) is discussed in chapter 2 under literature review for setting up of mini-grids. However, developers ought to guard against the pro-innovation bias, which hold that the innovation should be diffused and adopted by every member of a community and should not be re-invented or rejected (Rogers, 1983) as discussed under critical review of the diffusion of innovation theory in chapter three because not everyone in the target community shall adopt the innovation and connect to the mini-grid. Also, some individuals adopt innovation relatively earlier than others. Therefore, developers may classify their customers into adopter categories such as; innovators, early adopters, early majority, late majority, and laggards (Ibid*,* 1983) as highlighted in chapter three in order to formulate action plans on how to improve diffusion of the mini-grids as an innovation for entrepreneurial purposes.

Further, learning points from the existing body of knowledge with respect to the qualitative findings and their relevance to this study are discussed as follows:

i) High upfront capital expenditure costs

The installation and operation of an electricity mini-grid has high upfront capital expenditure costs that present as a constraint. The costs can be broken down into costs related to:

- ✓ Surveying potential areas for site identification and selection;
- ✓ Obtaining the necessary approvals from various government agencies such as the ERB, ZEMA, National Heritage Commission among others and traditional

leaders (where applicable for sites that are situated on customary land). The lengthy time for issuance of regulatory approvals further increases the investment cost. Moreover, the applicable fees for some government agencies are not clearly defined making it further difficult for investors to plan and acquire needed investment for mini-grid development;

- ✓ Technical advisory services such as choice of appropriate technology to meet identified customer needs;
- ✓ Procurement of the actual technology equipment needed to be installed; and
- ✓ Actual specialised labour to carry out the setting up of the electricity generation plant and associated distribution network.

The impact of the high upfront cost is most felt when all the costs are met by the private developer for the projects without external financial assistance. The impact is less felt for projects with external financiers' assistance, where the developer meets initial costs until financial close and then there is some relief as the financiers then begin to fund the project.

ii) Taxes

The taxes that apply to procurement of the mini-grid technology equipment installed include; import Value Added Tax (VAT) and customs clearance tax. After installation, there are local taxes such as excise duty paid based on produced electricity to Zambia Revenue Authority. Developers appreciated that only Import VAT is payable for imported solar products, but the other technology intended for Hydro power generation attract both VAT and excise duty which makes importation of the technology components expensive. On another hand, according to the Customs and Excise Act, Chapter 322 of the Laws of Zambia, excise duty is a tax on certain goods or products whether imported or locally produced, imposed at any stage of production or distribution, based on the criteria of reference to weight, strength or quantity of the goods or products, or by reference to their value. Electricity produced from the mini-grid is eligible for payment of excise duty because it is considered as a manufacturing process. Developers cited excise duty especially as the tax that does not incentivise the mushrooming electricity mini-grids business. In order to stimulate investment in

the electricity mini-grids business, options such as tax holiday or waiver of excise duty could be considered by the government. Likewise, the accrued benefits would translate into reduction of electricity tariffs for consumers in rural areas. Otherwise, excise duty remains one of the constraints that affect diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia because it adds to existent high tariffs charged by the mini-grid operators in an effort to make it an aspect of remittance as opposed to it being a cost to the business.

iii) Business seasonality

There is a window for sale of harvested farm produce when rural communities tend to have enough money and are willing to pay for commodities such as electricity. As their money runs low, spending reduces as expenditure is prioritised by avoiding things, they can do without such as electricity in preference for substitutes such as petroleum-based fuels and firewood. The variation in the spending pattern introduces a distinct feature characterised by peaks and troughs in electricity sales causing business seasonality for rural areas which happens to be a constraint to diffusion of mini-grids.

In order to address the “off business season” or troughs in electricity sales, mini-grid developers train and support their customers (those running entrepreneurial activities based on electricity supplied from the mini-grid) to ensure they sustain their enterprises to avoid them closing since the success of customer’s business entails success for the mini-grid operator as the Energy Service Provider (ESP) as well. Some training involves cash management and business diversification that ensures the customer remains connected to the electricity mini-grid. For example; the customer can operate a hammer mill and also run an automotive battery charging facility, similarly a customer can operate a hair salon and also provide facility for phone battery charging. Furthermore, a customer can operate a bottle store and butchery side by side as long as there is controlled access for patrons for each business.

iv) Low population density

The Low population density avails limited customer base not only for the mini-grid operator, but also for those engaged in entrepreneurial activities that productively use the electricity supplied from the mini-grid. Low population density causes a challenge to attain a critical mass of sales that cover fixed costs for a company to operate self-sufficiently and sustainably due to low demand for the products or services. Critical mass is reached when the sales for a product or service becomes self-sustaining as there is retention of existing customers, while new customers come on board adopting the new innovation and result in profitability over time as explained by Interaction Design Foundation (2020). If critical mass of sales is not reached, the enterprise would lose money and quickly go out of business due to low or no profitability. With reference to figure 3-1 in chapter 3, critical mass is attained at the tipping point where demand for a slow-moving product or service explodes onto rapid upwards path of growth (Johnson *et al.*, 2011).

For the case of electricity mini-grids, achieving a critical mass of sales requires the catchment area for communities deriving benefit from a particular mini-grid (customers) to be wide enough. The foregoing implies that electricity mini-grids should be sited far away from each other so that there would only be a single electricity mini-grid within an estimated radius. That is how low population density affects diffusion of electricity mini off-grids for entrepreneurial purposes in remote rural areas of Zambia.

v) Access to Finance and Limited business ideas

Installation of electricity mini-grids is targeted for the rural areas where people generally do not have access to connect to the main grid. Coincidentally, communities in the rural areas experience high poverty levels such that they have low income thus rendering them low capacity to pay for electricity services. The foregoing entails limited access to finance or capital by most remote rural populations thereby inhibiting their access to efficient appliances needed to engage in income generation activities.

People in rural communities tend to have limited business ideas. For example; if one starts a bottle store business and appears successful, they all would want the same type of business instead of starting up own ideas that could cause diversification of services offered to the community. Haanyika (2008) observed that electricity can enable various business ideas in rural areas such as; irrigation of crops, agro-processing, mining at a small scale and promote tourism.

Electricity mini-grids thrive where there is apparent potential for entrepreneurial activities and where communities are open minded to exploit opportunities. Once a site fails to meet the site selection criteria pursuant to the economic viability logic, the Developer cannot risk setting up an electricity mini-grid there. Thus, access to finance and limited business ideas inhibit diffusion of electricity mini off-grids for entrepreneurial purposes in rural areas of Zambia.

vi) Government policy and regulations

Government policy to promote installation and operation of mini-grids is not clear and that contributes to the business risk. For example, security of tenure for mini-grids in case of main grid arrival or encroachment remains vague despite attempts to cover it under regulations that are being developed. Growth of the off-grid renewable energy sector in Zambia can strongly be influenced by the policy direction coupled with effective implementation and enforcement of the regulations. For instance, public policy strongly influences diffusion of Energy Technology Innovation Systems (ETIS) such as mini-grids through application of relative energy prices and other policy instruments, such as taxes and performance standards (Gallagher *et al.,* 2012).

The role of mini-grids in the national electrification strategy is not clear as seen from priority given to grid extension programs. The Rural Electrification Authority (REA) has carried out 152 grid extension projects in total from 2006 to 2017 with more accomplished in later years. These projects were undertaken in all the 10 provinces of Zambia.

The Nation Energy Policy (2019 p.4) highlights that although 60% of the national population is resident in rural areas, there is inadequate participation of the private sector in the provision of electricity in rural areas. In addition, there is no systematic manner for coordinating players in rural electrification especially in the off-grid space. The policy hastens to clarify that REA experiences the challenge of insufficient funding to achieve its mandate. From the view point of this study, diffusion of electricity mini off-grids for entrepreneurial purposes in rural areas of Zambia continues to struggle owing to limited government support resulting from inadequate funding challenges of REA.

While the setting up of REA demonstrates governments' resolve to support rural electrification activities, the inadequate funding erodes its institutional strength to carry out its mandate. Further, for mini-grids to perform an important contribution in providing access to reliable and affordable electricity, an influential policy framework is required. As pointed out by IRENA (2018), bringing off-grid solutions into mainstream of the national energy access programmes creates a lasting foundation for market growth and stimulates different stakeholders to devise tailored solutions for availing energy services.

vii) Ignorance of people about mini-grids

Although mini off-grids are generally targeted for the rural areas, rural communities are ignorant about the existence of mini grids and their benefits as attested by findings of this study under section 5.2.2.1 that the extent of consumers' awareness about electricity mini-grids in rural areas is low. Rural communities are ignorant about the existence of mini grids because they have not been sensitised about their existence and they also lack exposure to mini-grids since they are absent in near vicinity where they could have perhaps learnt by observing. The effect of their ignorance affects the pace of diffusion of mini-grids because demand for a product or service emanates from consumer awareness regarding potential benefits of an innovation.

viii) Lack of support in form of incentives

Governments assist businesses in a particular industry as a control measure to maintain prices for their goods or services competitively affordable aiming at improving the availability of goods and services for the society. In this case, provision of smart subsidies to eligible mini-grid developers in form of capital subsidies which relate to capex material for the generation and distribution network could have a spill over effect to the final pricing or the tariff charged for the electricity supplied from the mini-grid. Further, access to cheap source of local financing for developing mini-grids could have a similar effect of making electricity supplied from mini-grid affordable.

The Rural Electrification Authority (REA) is established to among other key functions encourage private sector involvement in rural electrification through provision of smart subsides, competitive bidding, and community mobilisation. Unfortunately, there was no evidence among electricity mini-grids operators interviewed that REA provides smart subsides despite **48.7%** of the research subjects in the quantitative survey indicating as such (refer to section 5.2.3.3 on government support through REA). Eventually, electricity mini-grid tariffs remain cost reflective subject to regulatory approval and are generally high as complained by all consumers of electricity supplied from the mini-grids as captured from focus groups under section 5.3 (iv).

In comparison, the study on sustainability of rural electrification programs based on off-grid photovoltaic (PV) systems in Chile established that programs focused on promoting agricultural activities had widespread success with systems from big scale rural electrification projects conducted by the Ministry of Energy. However, the operational sustainability of various projects especially small-scale projects continued to struggle with issues of upkeep. The researcher observed that a national energy agency aimed at the operation of off-grid systems was required for making technological options available and overseeing. In addition, funding to cross subsidise could go towards the economic sustainability of the systems, since there was no funding committed for running and upkeep contrary to the case for off-grid PV

systems in remote areas of Peru where a cross subsidy arrangement assured the affordability of the systems and covered running and upkeep costs (Féron, 2017).

6.2.2 Determine the cause of slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia

Renewable energy solutions like electricity mini-grids have developed to become part of the mainstream electrification solution to boost availability of modern energy services timely and also in an environmentally sustainable way (IRENA, 2018).

Quantitative survey results from both the main and pilot studies from section 5.2.12 revealed a consistent perspective of the industry experts and operators for the electricity mini-grid market. One of the causes for slow diffusion of electricity mini-grid systems for entrepreneurial purposes in rural areas of Zambia is that the business environment varies depending on specific locations whereby some locations are not economically viable for electricity mini off-grid systems for entrepreneurial purposes (**94.6%** and **100%** research subjects from the main and pilot studies respectively). This is owing to varying unique life style in various rural areas, which impacts how a community responds to the presence of the electricity mini off-grid in their area. For instance, a community that is entrepreneurial oriented like at Kacholola area where Solera Power Vending's mini-grid is installed, the community has embraced the electricity services offered by the mini-grid to enhance their small businesses such as; carpentry, hair saloon, butchery and bottle store etc. and intra diffusion was found to be quick to a point of exhausting the generation capacity of the mini-grid, while in other places like Sinda area where Muhanya Solars' min-grid is installed the community uses electricity mainly for lighting purposes.

Another aspect causing slow diffusion of mini-grids was that the challenging physical geographical conditions in rural areas outweigh the benefit of setting up electricity mini-grids considering limited customer base coupled with low ability to pay for electricity services (**75.7%** and **80%** research subjects from the main and pilot studies respectively). Usually, physical geographical locations tend to cause dispersed population thereby posing a challenge of expanding the electricity distribution

network to reach consumers. The situation is exacerbated by the populations' low ability to pay for electricity services thus defeating the economic essence of installing an electricity mini-grid for entrepreneurial purposes.

Further, **73%** and **40%** research subjects from the main and pilot studies respectively indicated that the strategies currently applied for the diffusion of electricity mini–grids for entrepreneurial purposes were not effective.

Furthermore, **43.2%** and **60%** research subjects from the main and pilot studies respectively indicated that current operators of electricity mini off-grid systems lack capacity to set up many sites to cause diffusion. It should be noted that Operators initially set up a pilot electricity mini off-grid to assess its performance with respect to; return on investment (contribution towards payback period), customers' ability and willingness to pay for the electricity services and number of connections (intra diffusion) among others. Later. a decision would be made whether to scale up generation capacity or indeed set up another mini-grid elsewhere considering the high upfront cost of setting up an electricity mini off-grid system.

Research subjects from the qualitative study indicated the following as causes of slow diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia:

a) High capital expenditure for setting up mini-grids

The high upfront cost required for setting up mini-grids poses the challenge that it is expensive for developers to raise the high upfront costs related to capex equipment required to install a mini-grid. The said cost includes actual cost of equipment, customs clearance and costs arising from obtaining various authorisations from government agencies such as; the Energy Regulation Board, Zambia Environmental Agency (ZEMA), National Heritage Commission and others. Moreover, the fees with some government agencies are not clearly defined making it further difficult for investors to plan and provide needed investment for mini-grid installation. In addition, target customers lack capacity to afford capital expenditure (capex) equipment in

order to effectively use the electricity produced from the mini-grid for commercial purposes.

b) Policies and regulatory framework

Bureaucratic policies and regulatory frameworks increase the cost of setting up mini-grids and affect the project completion time as the approvals take long to be issued by the various government agencies. This is because government approvals have to be obtained from many places such as the Energy Regulation Board (ERB), Zambia Environmental Agency (ZEMA), National Heritage Commission, Local Authority or Traditional Leadership whichever is applicable, Rural Electrification Authority (REA), Office for Promoting Private Power Investment (OPPPI) and others. The policies and regulations are tailored to favour the main grid as opposed to mini-grids.

c) Risk associated with mini-grids

The high upfront cost for mini-grid installation entails putting “all eggs in one basket” thus increasing the risk in case of unsuccessful business take-off at a particular given site. To mitigate the risk of business failure and financial loss, most successful mini-grids require anchor clients with steady load profile. However, this is not easy to attain especially in rural areas due to sparsely populated areas and limited economic activities.

Woods *et al.* (2019) point out another view point concerning local financing where lenders perceive mini-grids to be very risky because the concept is not well known and therefore local financing is very expensive or not considered by financial institutions that rather consider more conventional investment opportunities which demonstrate both higher return and lower risk profiles.

d) Consumer Perception

Mini-grids were regarded as incompatible with the values of the communities whereby the main grid was favored (even though the said communities had no access to the main grid) and mini-grids were regarded as inferior source of energy. To understand consumer behavior in adopting or rejecting the innovation, the

researcher must be capable of taking their various points of view because they are based on how the individuals perceive the innovation (Rogers,1983). In such case, eligible rural consumers require to be made aware on the benefits of the mini-grid as an innovation in order to encourage wide rollout of the technology.

6.2.3 Establish why mini-grid developers were not initiating additional projects after completion and operationalisation of the initial project

From the problem statement, it was highlighted that for the period 2013 to 2019, Operators took long to initiate additional projects after completion and operationalisation of the initial pilot project installed at one location, thereby slowing the much-desired diffusion of mini off-grid systems. With reference to 5.2.1.1 (iii) research subjects indicated **78.4%** and **70%** from the main and pilot studies respectively that profitability of the electricity mini off-grid systems business is low. This, therefore implies that the project payback period is long and hence it is a challenge for Operators to set up sites in many places to cause the desired wide diffusion by ploughing back the returns on investment from the initial project since every installation of the mini-grid requires a high upfront capital. Based on the foregoing, any additional installations would require Operators to source for additional funds from others sources such as donors and/or debt. As such, there were no additional mini-grid installations until other funds were sourced.

Woods *et al.* (2019) indicate that one of the key barriers remains the access to capital, and how more developers and business ventures can successfully access the many existing financing options. Further, that securing a tariff that could allow for an adequate return on investment and was within the customers' ability to pay remains crucial. Also, if commercial customers were to set up anchor loads could help but the viability gap financing may still be necessary in the initial years. Oji and Weber, 2017 cite that Scholars have argued that the situation with financing rural electrification is unconventional, and for this reason, conventional financing methods and risk assessment procedures used in financing standard Renewable Energy Projects (REPs) would not be applicable. Rather, appropriate business and financing

models should be developed to establish the economic viability of smaller REPs in developing countries.

6.2.4 Operators of electricity mini-grids owning resources

With reference to section 5.2.1.4, the finding of the quantitative study was inconclusive or neutral with a degree of consensus of **66.3%** on whether Operators of electricity mini-grids in rural areas of Zambia are equipped with resources that are valuable, rare, difficult to imitate and non-substitutable to allow them to exploit business opportunities, while neutralising threats in the firm's business environment in order to attain a competitive advantage that is sustainable.

Based on the embedded research design, a follow up qualitative study revealed that Operators of electricity mini-grids have resources that are valuable, rare, difficult to imitate and non-substitutable to permit them to exploit business opportunities. This result was confirmed by hypothesis testing to accept the alternative hypothesis and conclude that Operators' firms have resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages.

It was established that resources owned by Operators are aligned to the business strategy pursued. Although the technology used is generally similar for mini-grids, the key differentiation that creates a sustainable competitive advantage is the manner of service provision based on specific resources deployed as follows:

6.2.4.1 The user tariffs

During site selection, a financial model that takes into consideration the key inputs for setting the tariff is established to ensure all the costs for setting up the mini-grid plus returns on investment are covered. The preliminary tariff is determined based on projected demand; while the final tariff is subject to regulatory approval.

Each mini-grid operates on a financial and operations model that suits the unique needs of the local market in the area. Tariffs for a mini-grid are not based on “per kWh” basis for electricity units. Rather, all the mini-grids operators have designed unique billing systems for their electricity services supplied. An example of billing is where the mini-grid operator acquires land and erects shops around the installed mini-grid. Tenants pay a rental that is inclusive of electricity tariff on monthly basis. In order to ensure business success, the mini-grid operator provides business management support to the tenants such as cash management training, diversifying the services offered by each shop to avoid replication of what is already offered in the other shops, and assist the tenants acquire loans at affordable rates from micro finance institutions to use for purchase of energy efficient equipment for engaging in economic productive end use activities of the electricity supplied from the mini-grid.

6.2.4.2 Tailor made mini-grid services

The developer works with the community to identify their areas of need that require electricity and then provide tailor made mini-grid to address the needs like processing of agricultural produce such as; peanut butter from groundnuts, grinding maize to produce the staple food mealie meal and refrigeration to preserve food stuffs such as fish and meat in a Butchery. In addition, mini-grids are tailor made to power; music system for a recreation club or bottle store, machines for barbershop and saloon etc.

6.2.4.3 Service augmentation

In order to sustain the economic viability of the business of selling electricity from the mini-grids, customers enjoy additional services such as automotive and phones battery charging, produce ice cubes for keeping products cold in households, a “play station” for entertaining kids and other such services all coming at a fee. The revenue realised from additional services subsidises the core electricity tariff to make it more affordable for the rural consumers.

6.2.4.4 Remote management of the mini-grid operation

Mini-grids are remotely managed as a way to significantly cut down on operational and administrative costs. A single caretaker carries out physical maintenance checks on site and attends to concerns from existing customers including registering new customers, while the mini-grid equipment is remotely controlled using reliable smart metering gadgets.

6.2.5 Proposed feasible solutions to address identified constraints of mini-grids diffusion

From a considered perspective, the constraints of electricity mini off-grid systems diffusion identified in this study could be broken down into two phases i.e., pre-installation and operational phases. Some constraints that occur in both phases would require applicable specific attention as they occur. Table 5.4 presents the identified constraints and proposed feasible solutions.

6.3 Factors affecting electricity mini off-grid systems diffusion

The following factors are discussed to bring about comprehension of how they affect electricity mini off-grid systems diffusion. The said factors include; extent of consumers awareness about electricity mini off-grid systems in rural areas, communication through social systems, adoption process of electricity mini-grids as an innovation, rate of adoption for electricity mini-grid, innovativeness and adopter categories, models of business for electricity mini-grid operation, leveraging 4Ps of the marketing mix to increase number of connections, dimensions of entrepreneurship to enhance diffusion of electricity mini-grids and effectiveness of strategies.

6.3.1 Extent to which consumers in rural areas are aware of the electricity mini off-grid systems

The survey responses in section 5.2.2.1 indicated that the extent of consumers' awareness about electricity mini-grids in rural areas is **Low** with a degree of consensus of **69.74%.** In addition, the result of hypothesis testing remained consistent with the survey finding.

The low level of awareness among the people in rural areas about mini-grids is a result of Operators and other Stakeholders not sensitising target consumers about the existence of the electricity mini-grids and their benefits. For instance, results of the cross tabulation performed under section 5.2.3 attest that the extent to which electricity consumers in rural areas are aware of the electricity mini-grids as an innovation was low because spreading of information or sensitisation of consumers in rural areas is low.

Whenever communities in rural areas are sensitised about the existence of the electricity mini-grids and their benefits, they responded favourably. The analysis under section 5.2.2.4 as shown by figure 5.1 illustrate that **50%** of Operators of electricity mini-grids often got invitations to install electricity mini–grids at other sites after spreading information about their existence and benefits. Thus, it was evident that diffusion of electricity mini off-grids for entrepreneurial purposes in rural areas of Zambia was slow because spreading of information by Operators and other Stakeholders to sensitise target consumers about the existence of the electricity mini-grids and their benefits is low.

6.3.2 Communication through social systems

Social systems such as; dwellers in a selected village or community, schools in a particular area, or companies involved in a particular line of business such as farming in a specific area are useful communication channels for spreading information (Rogers, 1983). Spreading of information could be through referral marketing where information or news is passed by word of mouth as people inform each other to develop the business (Kotler, 2001 p. 276).

This study found that spreading of information through social systems to communicate about the electricity mini-grids as a useful innovation was low based on a degree of consensus of **81.8%** among research subjects (refer to section 5.2.2.6). The low spreading of information constrains diffusion of electricity mini-grids for entrepreneurship in rural areas of Zambia. The outcome from the study is like the study finding by Eder *et al.* (2015) to assess diffusion of electricity from a biomass-

based electricity mini-grid in a rural Ugandan village of Tiribogo. The biomass-fuelled electricity mini-grid was operated by a Swedish Energy Services Company (SESC) where the study revealed that the company needed to collaborate with local actors (local inhabitants) to partner with experts and utilise proper communication channels in order to manage users' expectations properly on a social front and encourage user acceptability of the electricity services supplied.

6.3.3 Adoption process of electricity mini-grids as an innovation

A consumer goes through an adoption process from knowing about an innovation such as the electricity mini-grid to forming an impression about the innovation to either adopt or reject using the recent invention followed by confirming one's decision by action (Rogers, 1983). This implies that Operators need to encourage customers to connect to their installed electricity min-grids from within their target markets so as to accelerate the customers' decision making and enhance intra-diffusion. With reference to section 5.2.2.8, the study revealed that Operators of electricity mini-grids encouragement for new users to connect to their installed electricity mini-grids was **very high** degree of consensus of **89.4%.**

6.3.4 Rate of Adoption for electricity mini-grid

With reference to section 5.2.2.9, the study established that the adoption rate of electricity mini-grids as an innovation for entrepreneurial purposes in rural areas of Zambia is slow with a degree of consensus among research subjects of **62.5%.** Further, the finding was consistent with the hypothesis testing result which also confirmed by rejecting the null hypothesis that the adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is widespread. The author agreed with the research outcome based on literature review that adoption rate of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia was not widespread especially for the period 2013 to 2019 where it was observed that once an electricity mini off-grid system was installed at one location, the developers took long to replicate a similar system elsewhere in order to cause the much-desired diffusion of mini-grids. As pointed out by Rogers

(2003), the time variable cannot be ignored since diffusion is a process that happens and is measured over a period of time.

6.3.5 Innovativeness and Adopter Categories

Classification of consumers according to the relative time they register for connection as; innovators, early adopters, early majority, late majority and laggards serves for formulating an action plan to improve the adoption rate (Rogers, 1983). However, survey responses (refer to section 5.2.6) revealed that Operators were **neutral** with a degree of consensus of **62.2%** on whether consumers are classified according to the relative time they register for connection to their electricity mini-grid. A following up with the qualitative approach (refer to 5.2.6.1) on Operators revealed that their practices vary as some operators classify consumers according to the relative time they register for connection, while other operators do not. Categorising customers in tier bands based on their ability to pay with respect to uptake of electricity or load was found to be a common practice among Operators because it enables them to plan for the generation capacity according to demand. The customers are placed in respective categories for ease of monitoring their electricity consumption.

6.3.6 Models of business for electricity mini-grid operation

Models of business refer to the manner the upfront cost for installation and routine running and upkeep of the mini-grid is provided and also the way electricity services are delivered to make off-grid solutions available for end users to afford but also improve the sustainability of off-grid infrastructure (IRENA, 2018; The Africa Progress Panel, 2016).

From the analysis in section 5.2.2.11, electricity mini-grids models of business are classified based on the method of service delivery. Outcomes of the study revealed that up to **66.7%** of the electricity mini-grid Operators use the lighting plus commercial services model of business, while **16.7%** of the mini-grids Operators use the lighting utility only model and the other **16.6%** uses the anchor load plus lighting model.

With reference to section 2.4.2 where models of business are discussed in detail, all the mini-grids in Zambia operate under the private business model, except from mini-grids installed and operated by the Rural Electrification Authority (REA) which operates through the utility business model.

6.3.7 Leveraging 4Ps of the marketing mix to increase number of connections

The study found that Operators of electricity mini-grids **agreed** with a strong degree of consensus of **76.5%** (refer to section 5.2.2.12) that they purposefully leverage the 4Ps of the marketing mix to elicit the desired responses such as increasing the number of connections to their electricity min-grids from their target markets (intra-diffusion).

The concept of the 4Ps of the marketing mix, is applicable to the entrepreneurial activity of electricity mini-grids where the **P**roduct is the electricity, the **P**rice is the tariff the entity charges for the electricity, the **P**lace is the distribution network/channel up to customer premises and **P**romotion comprises marketing communications for the electricity including; advertising, public engagements, and techniques for direct and indirect selling.

The mini-grid enterprise is constrained by internal and external factors occasioned in the overall business environment. By using the concept of the 4Ps, enterprises identify key factors of their business such as; what customers need, extent of how their product or service meets customer needs, customer perception of their product or service in the market, how they stand out from their competitors, and how they interact with their customers (Kotler, 2001). Based on such realisations, action plans are formulated to counter constraints and ensure business success.

6.3.8 Dimensions of entrepreneurship to enhance diffusion of electricity mini-grids

The study finding with reference to section 5.2.2.13 revealed that most of the research subjects (**32.43%)** selected the combination of entrepreneurship dimensions

of; new venture creation, entrepreneurs' seizing opportunity and the business environment as the combination that can enhance diffusion of electricity mini-grid systems in rural areas of Zambia for entrepreneurial purposes **if** properly executed. The dimensions of entrepreneurship are elucidated in section 3.4.1.1.3.4. The author noted that while the other combinations of entrepreneurship dimensions that were selected by less than **20%** of the research subjects are equally important, the selected combination holds well for furthering the spread of electricity mini-grids for entrepreneurship in rural areas of Zambia.

6.3.9 Effectiveness of the strategies applied for diffusion of electricity mini-grids

With reference to 5.2.2.14, main study quantitative survey responses were **neutral** with a degree of consensus of **63.7%** on whether the strategies currently applied to achieve diffusion of electricity mini off-grids for entrepreneurial purposes in rural areas of Zambia are effective. On another hand, the pilot study survey responses in revealed in contrast that both Operators and Industry Experts **agreed** with a degree of consensus of **61.1%** that the strategies currently applied for diffusion of electricity mini off-grid systems are effective for entrepreneurial purposes in rural areas of Zambia. The difference in the outcome of the actual and pilot study was attributed to the influence of the sample size.

The study found that the current strategies used by operators include: **83.3%** of the Operators of electricity mini-grids encourage customers to use electricity for various small productive commercial activities in addition to lighting, **50%** of the Operators encourage use of efficient lighting appliances to manage consumer loads and thus offer more value to customers, **33.3%** of the Operators indicated that they make electricity tariffs affordable and provide convenience for payment using smart metering, payments through mobile phones and others pay-as-you-go mechanisms, while **16.7%** of the Operators encourage customers to set up anchor loads to be enjoyed together with lighting services.

Findings from the follow up qualitative survey revealed that electricity mini-grid operators apply the marketing concept and referral marketing as the effective strategies for promoting the number of connections to their electricity mini-grid for entrepreneurial purposes.

Using the marketing concept, the operators are to respond to customers' needs (Kotler, 2001), whereas the referral marketing causes customers to recommend to their family, friends and contacts to become new customers thereby cause diffusion of the innovation (Jaffe, 2010).

6.4 Chapter Summary

Chapter six has discussed and interpreted outcomes of the study arrived at in the previous chapter by explaining any new understanding or insights that emerged from studying the problem based on study objectives and factors affecting diffusion of mini off-grids systems. The next and final chapter outlines among other aspects, the conclusion and recommendations of the study.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Introduction

This final chapter presents the conclusion based on outcomes of the study and further provides recommendations. In addition, the chapter considers limitations of the study and opportunities for future possible research areas which could be built upon this study.

7.2 Conclusion

The United Nations (UN) adopted Seventeen (17) Sustainable Development Goals (SDGs) in September 2015. Among them, UNSDG number 7 set out to ensure access to affordable, reliable, sustainable and modern energy for all by 2030 coming with ambitious targets as highlighted in the background of this study i.e., section 1.2. Member states of the UN including Zambia have since formulated policies and regulations to achieve the UNSDGs.

On the strength of the Seventh National Development Plan (7NDP) and the Vision 2030, Zambia has positioned oneself to achieve UNSDG number 7 by setting the specific objective measure in the National Energy Policy (2019) to increase availability of electricity in order to enhance the livelihoods of citizens by expanding; generation, transmission and distribution capacity but also increase availability of electricity in rural areas as a building block to reduction of poverty and facilitating expansion of businesses.

In order to accelerate the availing of electricity for rural areas, the Zambian government established REA through the enactment of the Rural Electrification Act No. 20 of 2003. The mandate of REA is to provide electricity infrastructure to rural areas of Zambia using suitable technologies such as; extending the main grid, installation of electricity mini-grids and provision of standalone home systems.

Increasing electrification for rural areas using electricity mini-grids as an appropriate technology necessitates their diffusion so as to cater for wide rural communities. This study sought to establish constraints of electricity mini-grids diffusion for entrepreneurship

in rural areas of Zambia as the identified knowledge gap to be filled using Zambia as a case study. The study was guided by the pragmatism paradigm and achieved through the mixed methods methodology in particular the embedded design strategy; where the author collected and analysed quantitative and qualitative data in tandem to build from one phase of the study to another in order to obtain detailed information.

In view of the foregoing, the conclusion of the study is as follows:

7.2.1 This study established that the main constraints of diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia are: inadequate income affects capability of rural dwellers to pay for electricity services; low population density due to dispersed population; the profitability of the electricity mini off-grid systems business is low; substitutes such as fire wood and petroleum products provide cheap energy sources compared to what electricity mini-grids offer; Operators are afraid of the main grid encroachment on their exclusive supply territory; high upfront capital expenditure costs; high applicable taxes; business seasonality; access to finance and limited business ideas; government policy does not promote installation and operation of mini-grids; rural communities are ignorant about the existence of mini grids which affects their demand; and lack of support in form of incentives such as subsidies for mini-grid developers.

7.2.2 Further to answer the first specific research question, the reasons for slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia include: the variations in the business environment depending on specific locations due to the life style adopted by the community. Diffusion is fast where communities are entrepreneurial oriented to take advantage of the presence of electricity in their area by engaging in income generation activities and use the revenue obtained to pay for the electricity services. Communities that are not entrepreneurial oriented view electricity as a cost and rather use it for lighting only or not adopt the innovation; challenging physical geographical conditions in rural areas tend to cause dispersed populations thereby posing a challenge of expanding the electricity distribution network; the benefits brought about by the

electricity mini-grid are outweighed by limited customer base coupled with low ability of consumers to pay for electricity services; operators of electricity mini off-grid systems lack capacity to set up many sites to cause the desired diffusion; high upfront cost required for setting up mini-grids poses the challenge that it is expensive for developers to raise the capital; bureaucratic policies and regulatory frameworks increase the cost of setting up mini-grids and affect the project completion time because approvals take long to be obtained from various government agencies; the high upfront cost for mini-grid installation increases the risk in case of unsuccessful business take-off at a particular given site; and communities prefer the main grid to mini-grid even though they are not connected to the main grid.

7.2.3 Based on the second research question, mini-grid developers took long to initiate additional projects after completion and operationalisation of the initial project installed at one location because the profitability of the mini-grid business is low. The study found that the low profitability of the electricity mini off-grid systems business causes the project payback period to stretch very long and thus challenging for Operators to set up additional sites in many places by ploughing back the returns on their investment. The foregoing imply that any additional installations would require Operators to source for additional investment funds from other sources such as donors and/or debt in order to meet the high upfront capital required for a mini-grid installation.

7.2.4 Based on the third specific research question, the study revealed that Operators of electricity mini-grids have resources that are valuable, rare, difficult to imitate and non-substitutable to permit them to exploit business opportunities, while neutralising threats in the firm's business environment and achieve sustainable competitive advantage. Although the technology for mini-grids is generally similar, the key differentiation that creates a sustainable competitive advantage is the manner of service provision based on specific resources deployed aligned to the business strategy pursued. Example of the strategic resources deployed are: each mini-grid operator has uniquely designed billing systems suitable for their electricity services offered; tailor made mini-grid to address the needs of the target

market; service augmentation in order to sustain the economic viability of the business by offering additional services such as automotive and phones battery charging; and remote management of mini-grids in order to significantly cut down on operational and administrative costs.

7.3 Recommendations

In view of the foregoing, the recommendations are as follows:

7.3.1 In order for the mini-grid developer or indeed operator to effectively deal with the main constraints that have been established by this study, it is required that the identified constraints are segregated into; pre-installation and operational phase constraints. The pre-installation phase constraints should be dealt with at the stage of feasibility studies to ensure all foreseeable constraints are mitigated before selecting a location for electricity mini-grid installation based on the logic to be pursued i.e., either the economic viability only or the combined socio-economic welfare and viability logic. The operational phase constraints can then be dealt with using suitable solutions as they arise. For example, the study revealed that communities in rural areas respond positively once enlightened about existence of electricity mini grids and their benefits for entrepreneurial purposes. Therefore, spreading of information by Operators and Stakeholders (government agencies such as REA and ERB) to sensitise rural communities about the existence of electricity mini grids and their benefits should be intensified by establishing a proof of concept at one site and then enlighten communities in surrounding rural areas based on the success of that proof of concept for entrepreneurial purposes. Further, low population density due to dispersed population entails that additional mini-grids should be installed such that each installation should have a wide enough catchment area of customers in order to allow for attainment of a critical mass of sales. This implies that electricity mini-grids should be sited far away from each other. Otherwise establishing mini-grids near each other could cause them to be economically unsuccessful in the event that critical mass of sales is not attained. Regarding Operators being afraid of the main grid encroachment on their exclusive supply territory, governments can encourage off-grid energy

development by making information on grid extension plans available to stakeholders in renewable energy development for planning purposes. Further, the government through the ministry of Energy and its delegated regulator agency should finalise the regulations on renewable energy to safeguard the industry players on the aspect of grid encroachment and efficiently promote mini-grid diffusion.

7.3.2 Among the reasons for slow diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia include the variations in the business environment depending on specific locations due to the life style adopted by the community and that diffusion is fast where communities are entrepreneurial oriented to take advantage of the presence of electricity in their area by engaging in income generation activities using the revenue obtained to pay for the electricity services. In this regard, the developers should at the stage of feasibility study ensure to identify economically viable centres when selecting mini-grid installation sites. On developers lacking capacity to set up many sites to cause the desired diffusion, the financial institutions should be made aware on the operations and economic benefits of mini-grids as investments for entrepreneurial purposes. This can be an initiative of the developers in collaboration with the sector regulators i.e., REA and ERB to conduct awareness seminars so as to eliminate the notion that mini-grid technologies are not well known and are risky. Further, the Ministry of Energy through the delegated sector regulators (REA and ERB) should consider establishing an integrated one-stop-shop to reduce on bureaucratic policy implementation as various regulatory mandates are exercised. This could reduce the cost of setting up mini-grids and the project completion time.

7.3.3 The study established that any additional electricity mini-grid installations would require Operators to source for additional investment funds from other sources such as donors and/or debt in order to meet the high upfront capital required for a mini-grid installation. The Ministry of Energy through the delegated authority REA should seriously explore the mobilisation of resources (from donors) to incentivise the renewable energy sector to grow through diffusion of mini-grids and standalone systems in addition to the renowned but expensive grid extension as

ways of electrifying the rural areas. Aspects of debt could be explored by respective operators based on their ease of access to borrow funds especially from lenders that promote the socio-economic welfare and viability logic, as such lenders would not apply much pressure to recoup returns on investments based on a short payback period.

7.3.4 Since Operators of electricity mini-grids have strategic resources to achieve sustainable competitive advantage as established by this study, the Ministry of Energy through REA and ERB should leverage their strength to promote diffusion of electricity mini-grids. This could be by creating an enabling business environment through putting in place appropriate progressive regulations that help attract donor funding and boost investor confidence. For priority consideration, the regulations could address the current heavy-handed manner of regulating mini-grids, provide guidance on recourse in the event of main grid arrival or encroachment in the territory exclusively licensed for the mini-grid, streamline the process of acquiring relevant approvals to set up mini-grid installation. In addition, the Zambian government through the Zambia Revenue Authority should consider awarding tax holidays for payment of excise duty on electricity produced from mini-grids for a given period (say 2-3 years) after mini-grid commencement of operations. This is specifically to incentivise the mushrooming electricity mini-grids business to allow it to stabilise through teething issues after start-up operations.

To further incentivise the mini-grid installations, provision of smart subsidies to eligible mini-grid developers in form of upfront capital subsidies that relate to capex material needed for the generation plant and distribution network could have a direct impact on keeping tariffs charged for electricity supplied from the mini-grid affordable for the rural communities. REA being the institution mandated by government to encourage involvement of the private enterprises in electrifying rural areas by way of providing smart subsides should be sufficiently funded or it should mobilise funds by other means in order to execute its mandate. Otherwise, tariffs for electricity supplied from mini-grids could remain cost reflective subject to regulatory approval, which are generally high as complained by all consumers of

electricity supplied from the mini-grids as learnt from focus groups. Electricity mini-grids need government support as they continue to hold a potentially huge promise to alleviate poverty among rural communities with benefits that spillover to improve their quality of life through access to various amenities; and

7.3.5 Regarding feasible solutions to address the identified constraints of electricity mini off-grid systems diffusion, the identified constraints could be categorised into two phases i.e., pre-installation and operational constraints. Table 5.4 is submitted herein as a guide to address the identified constraints of electricity mini off-grid systems diffusion.

7.4 Areas for future studies

This study has unveiled areas for future research as follows:

7.4.1 The study has established that one of the constraints to diffusion of electricity mini-grids for entrepreneurial purposes is low profitability. Given the potential of electricity mini-grids to enhance the quality of life and lessen poverty for rural communities, there is need to investigate how the electricity mini-grids business profitability can be improved so as to attract more private developers and cause further diffusion of mini-grids; and

7.4.2 The study also established that the quality of life for the rural community endowed with an electricity mini-grid improves as they engage in productive use of the electricity. Therefore, an evaluation study to determine the impact of the productive end uses of electricity on poverty alleviation among communities that derive benefits from the mini-grid can be undertaken. Such study would establish the proof of concept to further motivate diffusion of electricity mini-grid among rural communities of Zambia.

7.5 Limitations of the study

The following limitations were experienced during the pursuit of this study:

7.5.1 The study limitation arose from the use of the nonprobability sampling method known as snowball sampling technique also referred to as network, chain referral or reputational sampling method for a quantitative research approach. The snowball sampling technique although not suitable for quantitative research design was utilised because the study was measuring a hard-to-reach population and relied on referrals from one respondent to the next;

7.5.2 The electricity mini-grids are located in different districts and provinces of Zambia. Due to budget and time limitations, not all sites were visited for the study. The limitation was that not all the installed electricity mini-grids were physically visited during the course of this study, but the author relied on the sites visited to represent the rest since the technology used is generally the same for each type of mini-grids (i.e., Solar and Hydro) of course being mindful that innovativeness in technology involves arranging extant technologies in various ways as observed by Gallagher et al. (2012). The learning points were deemed sufficient for the study based on the correspondence with survey participants; and

7.5.3 There was a notable attempt to withhold “business secrets” especially on details of effective strategies applied to increase number of connections to the mini-grid (intra diffusion) from research subjects to qualitative survey interviews, which after analysis boiled down to the same point for all of them i.e., use of the marketing concept. The limitation to the study in this case was the attempt to hold back information which required a lot of assurance and tact to obtain the information as the research subjects were protective of their business secrets.

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APPENDICES

APPENDIX 1: Reviewed studies on mini-grids from Zambia and other countries

Topic	Author, Year Published	Country
Sustainable Development of Renewable Energy Mini-grids for Energy Access: A Framework for Policy Design	Deshmukh *et al.,* 2013	United States of America
Design of off-grid renewable energy community electrification projects: analysis of micro-scale resource variations and development of optimisation methods	Ranaboldo, 2015	Spain
Mini-grids and renewable energy in rural Africa: How diffusion theory explains adoption of electricity in Uganda	Eder *et al.,* 2015	Uganda
Terminal Evaluation of the UNEP/GEF Project Report, "Renewable Energy-based Electricity Generation for Isolated Mini-grids in Zambia	Grøn and Chisonga, 2015	Zambia
Developing Mini-grids in Zambia: How to build sustainable and scalable business models?	Payen *et al.,* 2016	Zambia
Business case analysis for the island village of Shungnak	Weimar and Hardy, 2017	United States of America
Sustainability of off-grid Photovoltaic Systems for Rural Electrification: Empirical Evidence from selected Andean Countries	Féron, 2017	Andean countries: Chile, Ecuador, and Peru
Replicability and scalability of mini-grid solution to rural electrification programs in sub-Saharan Africa	Azimoh *et al.,* 2017	South Africa
Rural electrification through private models: the case of solar-powered mini-grid development in Kenya: Exploring the hybrid nature of private business models and the interplay between new players and existing structures in the Kenyan rural electrification regime	Pedersen, 2017	Kenya
Hybrid energy systems for rural communities	Tazvinga and Dzobo, 2018	Zimbabwe
Mini-grids for the Base of the Pyramid Market: a critical review	Bhattacharyya, 2018	--
Methodology for the Energy Need Assessment to Effectively Design and Deploy Mini-Grids for Rural Electrification	Gambino *et al.,* 2019	Switzerland
A Retrospective Analysis of Energy Access with a Focus on the Role of Mini-Grids, Sustainability	Korkovelos *et al.,* 2020	--
Sustainable Energy Delivery Models for Off Grid Rural Areas of Nigeria: An evaluation of institutional processes that lead to Sustainable Outcomes within Decentralised Electrification Infrastructure	Bello, 2020	Nigeria

APPENDIX 2: List of Institutions where research subjects were drawn

Category of Research Subjects	Research Subjects' Institution	No. of Research Subjects
Operators of Electricity Mini-grids	Engie Power Corner Zambia Limited	01
	Solera Power Vending Machine Zambia Limited	01
	Rural Electrification Authority	01
	Standard Micro-grid Initiatives Limited	01
	Muhanya Solar Limited	01
	Zengamina Power Limited	01
Sub Total (a)		**06**
Industry Experts	Energy Regulation Board	13
	AB & David Legal Practitioners	01
	Copperbelt Energy Corporation Plc	02
	GET Fit Zambia_ Multiconsult	01
	Ministry of Energy	03
	Swedish Embassy	01
	Zesco Limited	02
	I-Convenience Solar Store	01
	Ambro Power t/a Green Energy	01
	Rural Electrification Authority	03
	Solera Power Vending Machine Zambia Limited	01
	Common Market for Eastern and Southern Africa (COMESA)	01
	Kazang Solar Limited	01
Sub Total (b)		**31**
Grand Total (a+b)		**37**

APPENDIX 3 (a): Questionnaire for Operators of Electricity Mini Off-grid Systems

INSTRUCTIONS

- Please read through the question and the answers that have been provided
- Mark a Cross (**X**) or Tick (✓) in the applicable box to indicate the answer of your choice
- Only one answer is to be chosen per question to indicate your response **unless** you are requested to select more responses from the options provided
- Please complete the questionnaire by answering **all** the twelve (20) questions

Preamble to the Study

Satisfying the growing demand for electrical energy in a safe and environmentally responsible manner is currently a global pressing challenge especially in developing Asia and Sub-Saharan Africa where Zambia is part of. Despite electricity mini off-grid systems being available and known to be cost effective to provide timely solution for meeting the electricity requirements in rural areas of Zambia, their diffusion (wide spreading) or adoption rate has been slow and hence rural communities who have no option of connecting to the main grid continue to live without access to electricity supply.

The main objective of this study is to establish why diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia is slow despite being known to be a solution for rural electrification through the topic; "Constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia."

Thank you very much for accepting to be a respondent in this study.

1. To what extent are consumers in rural areas aware of the electricity mini off-grid system?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

2. In your opinion, spreading of information by Operators and Stakeholders to sensitise target consumers about the existence of the electricity mini off-grid systems and their benefits is?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

3. How often do you get invitations to install electricity mini off-grid systems at other sites after spreading information about their existence and benefits?

☐ Never ☐ Rarely ☐ Neutral ☐ Often ☐ Very Often

4. Once the electricity mini off-grid system is installed at one site, is the number of connections over a period of time is monitored?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5. Are consumers classified according to the relative time they register for connection as; innovators, early adopters, early majority, late majority and laggards for the purpose of formulating action plans to improve the adoption rate?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6. In your opinion would you say the adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes in rural areas of Zambia is fast?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

7. What are the main constraints that affect diffusion (spreading out widely) of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia? **[**Please select **four (4)** suitable responses**]**

☐ Inadequate income affects ability of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable

☐ The electricity mini off-grid systems are a new innovation that is yet to be appreciated for adoption by rural dwellers

☐ The profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion

☐ Substitutes such as fire wood and petroleum products such as kerosene provide cheap energy sources compared to what electricity mini off-grid systems offer

☐ Low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas of Zambia

☐ Rural dwellers do not use the electricity for productive uses such as commercial activities hence they are unable to generate income to pay for the electricity services

☐ Operators are afraid to spread out electricity mini off-grid systems to other rural areas of Zambia because the main grid may encroach on their earmarked territory before they attain the payback and obtain significant returns on their investment

8. Social systems such as; dwellers in a selected village or community, schools in a particular area, or companies involved in a particular line of business like farming in a specific area are useful communication channels for spreading information. To what extent do you communicate through social systems to spread information about the electricity mini off-grid system as a useful innovation?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

9. A consumer goes through an adoption process from knowing about an innovation such as the electricity mini off-grid system to forming an attitude toward the innovation as in whether to adopt or reject the usage of the new innovation followed by confirming one's decision. To what extent do you encourage new users to make connections to your mini off-grid system?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

10. Why is diffusion of electricity mini off-grid systems for entrepreneurial purposes slow despite being known to be a solution for rural electrification? **[**Please select **three (3)** suitable responses from the options provided**]**

☐ The strategies currently applied for the diffusion of electricity mini off-grid systems for entrepreneurial purposes are not effective

☐ The business environment varies depending on specific locations. Some locations are not economically viable for electricity mini off-grid systems for entrepreneurial purposes

☐ Current operators of electricity mini off-grid systems lack capacity to set up many sites to cause the desired diffusion

☐ Challenging physical geographical conditions in rural areas outweigh the benefit of setting up electricity mini off-grid systems considering limited customer base coupled with low ability to pay for electricity services

☐ Rural dwellers are averse to the innovation because electricity is known to be for urban areas

11. Would you say the benefits of declining costs for renewable energy technologies such as Solar panels, cheaper and more efficient lighting appliances, and new payment mechanisms such as pay-as-you-go can accelerate diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural Zambia?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

12. What strategies do you currently apply for operations and promoting the number of connections to your electricity mini off-grid systems for entrepreneurial purposes?

☐ Make electricity tariffs affordable and provide convenience for payment using pay-as-you-go mechanisms

☐ Encourage use of efficient lighting appliances to manage consumer loads and thus offer more value to customers

☐ Encourage customers to use electricity for various small productive commercial activities in addition to lighting

☐ Encourage customers to set up anchor loads, while also enjoying lighting services

13. Would you say your strategies currently applied are effective for the diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

14. Are there benefits you enjoy from the Rural Electrification Authority (REA) of Zambia? **[**Please select **one or more** applicable benefits your firm enjoys or has enjoyed so far**]**

☐ REA encourages private sector participants in rural electrification through provision of smart subsides, competitive bidding, and community mobilisation

☐ REA uses the Rural Electrification Master Plan (REMP) to guide on possible siting of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia

☐ REA protects potential and existing electricity mini off-grid systems installed for entrepreneurial purposes in rural Zambia from possible main grid encroachment

☐ REA finances project preparation studies for rural electrification based on identified growth centres in rural areas throughout Zambia

☐ None of the above benefits are enjoyed from REA

15. Which one of the following business models are you using for operation of your electricity mini off-grid systems? **[Please select the applicable business model]**

☐ Lighting utility only

☐ Lighting plus commercial services

☐ Anchor load plus lighting

☐ Other. Please specify
…….

16. Do your customers use the electricity for economic productive activities that stimulate entrepreneurial activities and in turn enhance their ability to pay for the electricity service?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

17. From the strategic view point, would you say your firm has resources that are valuable, rare, difficult to imitate and non-substitutable to enable exploitation of opportunities, while neutralising threats in the firm's business environment in order to achieve sustainable competitive advantages?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

18. Are the regulations to support the installation and operation of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia adequately available and effective?

☐ Strongly ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly

☐ Disagree ☐ ☐ ☐ ☐ Agree

19. With reference to the 4**P**s of the marketing mix, it is noted that the **P**roduct is the electricity, the **P**rice is the tariff your entity charges for the electricity, the **P**lace is the distribution channel up to customer premises and **P**romotion consists of the communications used to market the electricity including advertising, public relations, and techniques for direct and indirect selling. Does your firm intentionally leverage the mentioned 4Ps of the marketing mix to increase the number of connections?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

20. Which ones among the following five (5) dimensions of entrepreneurship provided below **if properly** executed can enhance diffusion of electricity mini off-grid systems in rural areas of Zambia? **[**Please select **any three (3)** applicable dimensions in your opinion**]**

☐ **New venture creation:** concerned with entrepreneurship as the formation of a new business enterprise that employ resources and capabilities to provide sustainable competitive advantage. Choice of the appropriate resources is ultimately a matter of entrepreneurial vision and intuition.

☐ **Entrepreneurs' seizing opportunity**: concerned with entrepreneurs utilising opportunities that arise from changes in the business environment. Opportunity being the convergence of preparedness, external circumstances, and sensitivity to changes in the business environment. For example; unavailability of electricity in rural areas of Zambia can be alleviated using electricity mini off-grid systems.

☐ **The Entrepreneur:** concerned with individual Entrepreneurs' playing their role based on personal experience, knowledge, education, and training which accumulate as human resource that the founder of the firm contributes to establishing and growing the enterprise.

☐ **The Business Environment:** concerned with the entrepreneurial challenge to acquire resources from the business environment, combine them with other resources already possessed, and configure the new venture into a successful organisation that can grow and cause diffusion of electricity mini off-grid systems.

☐ **The organisation:** concerned with the organisation assuming a form and structure that has a strategy to enable it to penetrate or create a market and protect its position. The organisation possesses resources that it transforms into value for its customers and builds a culture that it is associated with. For example, a culture of high quality and reliability.

END

APPENDIX 3 (b): Questionnaire for Regulators and Industry Experts

INSTRUCTIONS

- Please read through the question and the answers that have been provided
- Mark a Cross (**X**) or Tick (✓) in the applicable box to indicate the answer of your choice
- Only one answer is to be chosen per question to indicate your response **unless** you are requested to select more responses from the options provided
- Please complete the questionnaire by answering **all** the twelve (12) questions

Preamble to the Study

Satisfying the growing demand for electrical energy in a safe and environmentally responsible manner is currently a global pressing challenge especially in developing Asia and Sub-Saharan Africa where Zambia is part of. Despite electricity mini off-grid systems being available and known to be cost effective to provide timely solution for meeting the electricity requirements in rural areas of Zambia, their diffusion (wide spreading) or adoption rate has been slow and hence rural communities who have no option of connecting to the main grid continue to live without access to electricity supply.

The main objective of this study is to establish why diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia is slow despite being known to be a solution for rural electrification through the topic; "Constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia."

Thank you very much for accepting to be a respondent in this study.

1. To what extent are consumers in rural areas aware of the electricity mini off-grid system?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

2. In your opinion, spreading of information by Operators and Stakeholders to sensitise target consumers about the existence of the electricity mini off-grid systems and their benefits is?

☐ Very Low ☐ Low ☐ Neutral ☐ High ☐ Very High

3. From your opinion, would you say the adoption of electricity mini off-grid systems as an innovation for entrepreneurial purposes is fast in rural areas of Zambia?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4. What are the main constraints that affect diffusion (spreading out widely) of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia? **[**Please select **four (4)** suitable responses**]**

☐ Inadequate income affects ability and willingness of rural dwellers to pay for electricity services because the connection charges and tariffs are unaffordable

☐ The electricity mini off-grid systems are a new innovation that is yet to be appreciated for adoption by rural dwellers

☐ The profitability of the electricity mini off-grid systems business is low, hence challenging for Operators to set up sites in many places to cause the wide diffusion

☐ Substitutes such as fire wood and petroleum products such as kerosene provide cheap energy sources compared to what electricity mini off-grid systems offer

☐ Low population density due to dispersed population makes expansion of the distribution network not economically feasible in most rural areas of Zambia

☐ Rural dwellers do not use the electricity for productive uses such as commercial activities hence they are unable to generate income to pay for the electricity services

☐ Operators are afraid to spread out electricity mini off-grid systems to other rural areas of Zambia because the main grid may encroach on their earmarked territory before they attain the payback and obtain significant

☐ returns on their investment

5. Why is diffusion of electricity mini off-grid systems for entrepreneurial purposes slow despite being known to be a solution for rural electrification? **[**Please select **three (3)** suitable responses**]**

☐ The strategies currently applied for the diffusion of electricity mini off-grid systems for entrepreneurial purposes are not effective

☐ The business environment varies depending on specific locations. Some locations are not economically viable for electricity mini off-grid systems for entrepreneurial purposes

☐ Current operators of electricity mini off-grid systems lack capacity to set up many sites to cause diffusion

☐ Challenging physical geographical conditions in rural areas outweigh the benefit of setting up electricity mini off-grid systems considering limited customer base coupled with low ability to pay for electricity services

☐ Rural dwellers are averse to the innovation because electricity is known to be for urban areas

6. Would you say the benefits of declining costs for renewable energy technologies such as Solar panels, cheaper and more efficient lighting appliances, and new business models such as pay-as-you-go can accelerate diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural Zambia?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

7. Would you say the strategies currently applied are effective for the diffusion of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

8. Are the regulations to support the installation and operation of electricity mini off-grid systems for entrepreneurship in rural areas of Zambia adequately available and effective?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

9. What benefits do firms involved in installation and operation of electricity mini off-grid systems in rural areas of Zambia enjoy from the Rural Electrification Authority (REA) of Zambia? **[**Please select **one or more** applicable benefits enjoyed**]**

- ☐ REA encourages private sector participants in rural electrification through provision of smart subsides, competitive bidding, and community mobilisation
- ☐ REA uses the Rural Electrification Master Plan (REMP) to guide on possible siting of electricity mini off-grid systems for entrepreneurial purposes in rural areas of Zambia
- ☐ REA protects potential and existing electricity mini off-grid systems installed for entrepreneurial purposes in rural Zambia from possible main grid encroachment
- ☐ REA finances project preparation studies for rural electrification based on identified growth centres in rural areas throughout the country
- ☐ None of the above benefits are enjoyed from REA

10. From your industry knowledge and/or observations, do consumers in rural areas of Zambia use the electricity for economic productive activities that stimulate entrepreneurial activities and in turn enhance their ability to pay for the electricity service?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

11. From the strategic view point, would you say firms involved in installation and operation of electricity mini off-grid systems in rural areas of Zambia have resources that are valuable, rare, difficult to imitate and non-substitutable to enable them exploit business opportunities, while neutralising threats in the firm's business environment in order to attain sustainable competitive advantages?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

12. Which ones among the following five (5) dimensions of entrepreneurship provided below **if properly** executed can enhance diffusion of electricity mini off-grid systems in rural areas of Zambia? **[**Please select **any three (3)** applicable dimensions in your opinion**]**

- **New venture creation:** concerned with entrepreneurship as the formation of a new business enterprise that employ resources and capabilities to provide sustainable competitive advantage. Choice of the appropriate resources is ultimately a matter of entrepreneurial vision and intuition.

- **Entrepreneurs' seizing opportunity**: concerned with entrepreneurs utilising opportunities that arise from changes in the business environment. Opportunity being the convergence of preparedness, external circumstances, and sensitivity to changes in the business environment. For example; unavailability of electricity in rural areas of Zambia can be alleviated using electricity mini off-grid systems.

- **The Entrepreneur:** concerned with individual Entrepreneurs' playing their role based on personal experience, knowledge, education, and training which accumulate as human resource that the founder of the firm contributes to establishing and growing the enterprise.

- **The Business Environment:** concerned with the entrepreneurial challenge to acquire resources from the business environment, combine them with other resources already possessed, and configure the new venture into a successful organisation that can grow and cause diffusion of electricity mini off-grid systems.

- **The organisation:** concerned with the organisation assuming a form and structure that has a strategy to enable it to penetrate or create a market and protect its position. The organisation possesses resources that it transforms into value for its customers and builds a culture that it is associated with. For example, a culture of high quality and reliability.

END

APPENDIX 3 (c): Structured questions for qualitative data collection

Preamble to the Study

Satisfying the growing demand for electrical energy in a safe and environmentally responsible manner is currently a global pressing challenge especially in developing Asia and Sub-Saharan Africa where Zambia is part of. Despite electricity mini off-grid systems being available and known to be cost effective to provide timely solution for meeting the electricity requirements in rural areas of Zambia, their diffusion (wide spreading) or adoption rate has been slow and hence rural communities who have no option of connecting to the main grid continue to live without access to electricity supply.

The main objective of this study is to establish why diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia is slow despite being known to be a solution for rural electrification through the topic; "Constraints of electricity mini-grid systems diffusion for entrepreneurship in rural areas of Zambia."

Thank you very much for accepting to be a respondent in this study.

1. Why is diffusion of electricity mini-grids for entrepreneurial purposes slow?

   ……

   ……

2. What strategies would you consider as effective to be applied for promoting the number of connections to your electricity mini-grid for entrepreneurial purposes?

   ……

   ……

3. What are the constraints that affect diffusion of electricity mini-grids for entrepreneurial purposes in rural areas of Zambia?

   ……

   ……

4. Why is spreading of information about electricity mini-grids and their benefits low in rural areas of Zambia thereby causing low awareness among energy consumers?

   ……

   ……

5. Do you classify consumers in categories according to the relative time they register for connection such as; innovators, early adopters, early majority, late majority and laggards for the purpose of formulating action plans to improve the adoption rate? **(Question for Operators only)**

   ……

   ……

   ……

6. Are Operators of electricity mini-grids in rural areas of Zambia equipped with resources that are *valuable*, *rare*, *difficult to imitate* and *non-substitutable* to enable them exploit business opportunities, while neutralising threats in the firm's business environment in order to attain *sustainable competitive advantage?*

   ……

   ……

   ……

7. Is the current policy and regulations to promote the installation and operation of electricity mini-grids adequate and effective?

   ……

   ……

   ……

8. What are the entrepreneurial productive end uses that your consumers engage in to enable them pay for the electricity service?

   ……

   ……

   ……

END

APPENDIX 3 (d): Cover letter for all questionnaires

UNIVERSITY OF LUSAKA

SCHOOL OF POST GRADUATE STUDIES

SURVEY QUESTIONNAIRE

Dear respondent,

This questionnaire is part of the research to understand **constraints of electricity mini off-grid systems diffusion for entrepreneurship in rural areas of Zambia**. Your responses are important in enabling me to understand this topical subject.

This questionnaire shall take you few minutes to complete. Kindly answer the questions according to instructions provided for each question. The information you provide will be solely for the study and will be treated in the strictest confidence as you shall notice that you are not required to provide your name or other contact details on the questionnaire.

The responses from your questionnaire and others will be used as the main data set for the research project for my Doctor of Philosophy in Entrepreneurship at the University of Lusaka.

I hope that you will find completing the questionnaire enjoyable and informative. Please complete the questionnaire in a weeks' time to allow collecting back for processing. If you have any questions or would like any further information, please do not hesitate to contact me on mobile phone number: **+260 977 490 202** or email: **mtongawilliam@gmail.com**.

Thank you very much for your help to complete the questionnaire.

William Mtonga
Student