THE RELIABILITY OF UNCONVENTIONAL SOURCES OF ENERGY IN PUBLIC HEALTHCARE DELIVERY IN RURAL ZAMBIA: THE CASE OF SOLAR ENERGY IN MUMBWA DISTRICT

By

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements of the degree of Master of Public Administration.

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DECLARATION

I hereby declare that this dissertation represents my own work, and that it has not previously been submitted for a degree or other qualification at this or any other university.

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APPROVAL

This dissertation of Betty Mtonga has been approved as partial fulfilment of the requirements for the award of the degree of Master of Public Administration (MPA).

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ABSTRACT

Electricity has over the years played an important role in influencing development in almost, if not all, areas of life, including healthcare delivery. Access to reliable electricity plays a cardinal role in healthcare delivery and is deemed as an important determinant for providing quality healthcare. Despite electricity being recognized as an essential input necessary for good healthcare delivery, literature shows that only 25 percent of the Zambian population is connected to hydroelectricity, out of which 20.7 percent are urban connections and 4.3 percent are rural connections. Because of the low electrification rate, unconventional sources of energy, such as Solar Photovoltaic(PV), have been adopted, especially in rural areas with very low electrification rates.

The study sought to investigate the reliability of unconventional energy, Solar PV, used in rural healthcare facilities, particularly rural health facilities in Mumbwa District. The study specifically sought to examine the affordability and continuity of healthcare delivery using Solar PV energy sources in rural healthcare facilities as well as to identify challenges they faced using this source of energy for healthcare delivery. The research was a case study of Mumbwa District which used semi-structured researcher administered questionnaires for end-users and healthcare facility personnel. Interview guides were used to collect primary data from key informants. A total of 116 research instruments were administered with a response rate of 98 percent. The respondents were as follows 85 percent end users, eight percent healthcare personnel, and seven percent key informants, comprising the District Medical Officer, The District Technician and an Engenderer from Rural Electrification Authority (REA). Qualitative data collected from open ended questionnaires and interview guides were analysed using content analysis methods while quantitative data collected from closed ended questionnaires were analysed using Statistical Package for Social Science (SPSS) and Excel.

The study identified that: none of the rural healthcare facilities had complete Solar PV systems to facilitate the production and storage of sufficient Solar PV energy for healthcare delivery. None of the rural healthcare facilities had a resident electrical technician on site to handle any faults that the systems encountered nor does conduct necessary maintenance checks on the Solar PV systems. Most of the healthcare facilities could not make use of important medical equipment such as autoclave and suction machines because of insufficient energy production. Replacement of Solar PV system equipment and inability to provide night time services were among the major challenges faced by RHCs using Solar PV as a primary source of energy. Based on the findings, all District Medical Offices (DMOs) in collaboration with the Ministry of Health (MOH) should ensure that solar PV system capacities are increased and properly maintained by recruiting more technicians who should be readily available on cite for maintenance and attend to faults whenever they occur at the Rural Healthcare Facilities. Additionally, MOH must ensure that healthcare staff houses are also equipped with Solar PV systems so as to prevent healthcare personnel from tempering with the healthcare facility's solar PV system so as to ensure a longer lifespan of the Solar PV equipment.

Key Words: *RuralHealthcare Delivery, Solar PV Energy, Energy and Health*

DEDICATION

To Mr James Mtonga and Mrs Jennifer Mukuka Mtonga

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ABBREVIATIONS

AC - Alternating Current

ACCA - Association of Chartered Certified Accounts

ART - Antiretroviral Therapy

ASD - African Solar Design

BCM - Billion Cubic Meters

BRICS - Brazil, Russia, India, China and South Africa

CBO - Community Based Organisation

CEC - Copperbelt Energy Cooperation

CSO - Central Statistics Office

CSP - Centralized Solar Power

DC – Direct Current

DDMO – District Medical Office

ERB – Energy Regulation Board

EU – European Union

FLH – First Level Hospital

GWH – Giga Watt Hour

HC – Health Centre

HF – Health Facility

HGL – Hydrocarbon Gas Liquid

HP – Health Post

IEA – International Energy Agency

IHME – Institute for Health Metrics and Evaluation

INTOSAI – International Organisation of Supreme Audit Institutions

IRENA –	Renewable Readiness Assessment
JIBC –	Japan Bank for International Cooperation
JICA-	Japan International Cooperation Agency
Kw –	Kilowatt
KWh –	Kilo watt hour
KWp –	Kilo Watt Power
LOCE –	Levelized Cost of Electricity
LPG –	Liquefied Petroleum Gas
LTD –	Limited
MCL-	Maamba Collieries Limited
MDGs –	Millennium Development Goals
MOH –	Ministry of Health
Mt -	Metric Tons
MW –	Megawatts
NDP –	National Development Plan
NHSP –	National Health Strategic Plan
OECD –	Organisation for Economic Cooperation and Development
ORC –	Organic Rankine Cycle
PV –	Photovoltaic
REA –	Rural Electrification Authority
REF –	Rural Electrification Fund
RET –	Renewable Energy Technology
RHC –	Rural Health Centre
SAPP –	Southern Africa Power Pool

SDGs –	Sustainable Development Goals
SE4ll-	Sustainable Energy for All
SG –	Secretary General
SIDA –	Swedish International Development Agency
SLH –	Second Level Hospital
SNDP –	Seventh National Development Plan
SPSS –	Statistical Package for Social Sciences
SSA –	Sub-Saharan Africa
SSMP -	Sustainable Solar Marketing Packages
TLH –	Third Level Hospital
TWH -	Tera Watt Hour
UHC –	Urban Health Centre
UN -	United Nations
UNDP -	United Nations Development Plan
UNZA –	University of Zambia
USAID-	United States Agency for International Development
UTH-	University Teaching Hospital
V –	Volt
W –	Watt
WB -	World Bank
WER –	World Energy Report
WHO –	World Health Organisation
ZESCO –	Zambia Electricity Supply Cooperation

CHAPTER ONE

BACKGROUND

1.1 Introduction

Almost more than half of the world's population lacks access to essential healthcare services such as primary and specialised healthcare services. World Health Organization (WHO) and World Bank (WB) (2017) indicate that most of the world's population does not have access to healthcare services. This population is characterised by people and families that are forced to pay to access services which are in most cases deemed expensive for people living in developing counties due to high poverty levels.

Despite the recognition of the role of healthcare being relevant through issues of access to preventive and curative health services, equitable and sustainable access to properly functioning healthcare systems have not been attained in Africa. Mainly because of geographical differences which have become worse over the years. This has mostly affected healthcare seekers in rural areas who have to travel long distances to receive basic healthcare services. Even so, the quality of services is normally low and limited due to lack or poor availability of infrastructure, such as electricity and manpower. Such areas tend to be riddled with increasing burdens of communicable and non-communicable diseases, high child and maternal mortality rates, and many recurring epidemics (WHO, 2010-2019).

On average, the traditional source of energy used in most parts of the world is grid electricity. Grid electricity is mainly generated in large quantities using coal and water resources at a national level.This electricity is then used for many activities in many sectors including operating healthcare facilities. However, in the African context, grid electrification has remained relatively low, especially in rural communities, due to factors such as cost of purchasing, installing and maintaining step-down transformers in extremely remote areas.This has led to the use of other unconventional sources of electricity such as solar PV, wind turbines, geothermal, bio fuel, nuclear and tidal sources of energy.

Electricity has proven to play a very important role in the provision of healthcare all over the world regardless of the size of a healthcare facility. Many technologies have over the years emerged that require electricity to operate in order to help improve and broaden the range of healthcare services provided at all levels of healthcare facilities. Most of these technologies operate with a steady supply of energy and may become dysfunctional once discharged or disconnected from electricity supply. The World Health Organisation (WHO) (2014), states that, without energy many life-saving interventions cannot be undertaken. In this regard, energy has been recognized as an enabler and enhancer of healthcare service delivery worldwide. Knoth (2014) argues that lack of access to modern forms of energy has both direct and indirect harmful effects on health and medical care facilities in sub-Saharan Africa.

Without reliable supply of electricity in healthcare facilities, many challenges are likely to be faced. Among such challenges include; doctors struggling to provide clinical services after sunset; inability to perform lifesaving operations, inability to perform medical examinations; inability to store vaccines, blood samples and medication in proper conditions or ideal temperatures; inability of small healthcare facilities such as Health Posts (HPs) to communicate with specialists for emergency cases or inability to transport patients to other health facilities due to poor communication attributed to unavailability of energy to operate telephones. Other challenges include inability to power laboratory equipment such as ultrasound machines and x-ray machines as well as incubators. Without electricity, healthcare facilities will also experience poor or no lighting, cooking and heating provisions which inevitably lead to high use of open indoor or outdoor fires and kerosene lamps which are regarded as pollutants. Healthcare facilities without electricity will also find it difficult to sterilize medical equipment for surgical use.

In order for healthcare facilities to operate as intended, they need to have good sources and reliable supply of electricity. Literature shows that on average, healthcare facilities in developed countries require around 27.5kWh of electricity produced per year for healthcare delivery, depending on the size of the healthcare facility. In some African countries it is estimated that solar PV systems produce about 440W, which is about 0.44kW per day, in small healthcare facilities such as rural healthcare facilities and health posts. However, African Solar Design (2015) shows that on average, small healthcare facilities require between 1.2kW to 6 kW per day and this in most cases should be backed by a standby generator in order to adequately meet the energy needs of the facilities.

Many developing and developed countries strive to achieve improved healthcare delivery and availability of electricity is a key ingredient to achieve this goal. Many policies have been put in place in an attempt to improve healthcare service access and delivery which have greatly improved many categories of healthcare such as the reduction of mother and child mortality rates in many countries in the world. In Zambia, several National Development Plans (NDPs) have been developed to address various issues, including health issue. The Seventh National Development Plan (SNDP), among other things, seeks to ensure that the health sector focuses on rehabilitating and expanding existing healthcare facility infrastructure and installation of cutting-edge diagnostic and treatment equipment (SNDP, 2017; p.21). In order to achieve these plans, it has been acknowledged that there is need for reliable supply of electricity in both rural and urban healthcare facilities. Knoth (2014) shows that healthcare facilities in any given country will operate better if they have a good supply of electricity which enhances healthcare services. He states that availability of electricity ensures longer working hours, performing emergency services swiftly, conducting lab tests for diagnostic services, and provision of treatment services faster and more accurately.

Over the years, governments around the world have actively worked to provide quality healthcare services to their citizens. In so doing, many health related interventions have been developed to address health delivery issues worldwide. The World Health Organisation (WHO) has made many attempts to encourage quality healthcare delivery through the enforcement of a number of world health programs. The WHO first introduced Millennium Development Goals (MDGs) at a Millennium Summit in 2000 which among other things aimed at reducing child mortality; improving maternal health; and combating HIV/AIDS, malaria and many other diseases. Thereafter, other health indicators focusing on proposed health and health-related Sustainable Development Goals (SDGs) were developed in September 2015. The SDGs attempt to bring together available data on health indicators from its member countries. Some of the indicators include providing good health and well-being; providing clean water and sanitation; and achieving the goal to provide affordable and clean energy. In response to wanting to attain quality healthcare, many countries, including Zambia have adopted the SDGs (WHO, 2017).

Before the SDGs were introduced, there was realization about the importance of energy in the health sector, which was expressed in 2012 by the United Nations (UN) Secretary

General (SG). The Secretary General launched the Sustainable Energy for all (SE4All) program which, among other things, aims at achieving universal access to clean energy and modern energy sources by 2030. The program also targets the need for healthcare facilities to have sufficient access to energy in order to support quality healthcare delivery (Adair-rohania et al, 2013).

It has been realized that energy is not only essential for generally improving living standards, development and attainment of economic growth, but it also plays a critical role in delivery and improvement of healthcare services in countries all over the world. This goes without saying, that energy is an important aspect in healthcare delivery, regardless of the size of a healthcare facility (Franco, Shaker, Kalubi and Hostettler, 2017).

It is however important to note that there are a number of factors that influence the type and quality of healthcare services provided in any given healthcare facility. These factors include; qualified staff, availability of relevant drugs, adequate infrastructure and medical equipment, clean water and a reliable and consistent supply of electricity. These factors have been recognised to play a key role in the provision of good healthcare services in any type of healthcare facility. However, this study focuses on solar Photovoltaic (PV), a form of energy, as a factor that influences healthcare delivery in the primary health sector, particularly rural healthcare facilities.

Energy can be defined as power derived from the utilization of physical or chemical resources to provide light and to provide heat which is used to work machines. In simple terms, Ehrlich (2013. p 2) defines energy as '"the ability to do work" and that "it cannot be created or destroyed" '. Ehrlich (2013) however shows that energy exists in a number of forms which can be converted from one form to another. The forms in which energy exists include kinetic, potential, heat, light, magnetic and nuclear energy. This study uses the term energy to refer to solar PV electrical energy which is measured in kilowatt (k) or kilowatt-hours (kWh).

1.1.1 Solar Photovoltaic (PV) Energy

Solar PV energy is electricity that is absorbed directly from the sun and it can be used directly as Concentrated Solar Power (CSP). Solar PV energy can also be converted into electrical energy by Photovoltaic technology (PV). A PV is an electronic material or device that converts light energy (photons) into electronic or electrical voltage and current. Solar PV modules can be generally classified into three groups, crystalline, silicon cells, and thin film cells and nano-structured cells. Solar energy can be traced as far back as 1839. By 1940 crystal silicon solar PV began to be developed and dominated the PV industry up to date. Around 1980 and 1996, PV modules become cheap to produce and hence they dominated the industry. On average, a simple solar PVinstallation produces 5KWh/m²/day, which is more than enough solar energy for domestic consumption (Mwaba, 2015).

Solar PV energy can be used to produce Direct Current (DC) which can be used directly by DC appliances or it can be converted into an Alternating Current (AC) using an inverter which can be used by AC appliances. It is worth noting that some appliances cannot operate using DC but instead work using AC, while other appliances cannot work using AC but instead operate using DC (Admasu, 2010).

This dissertation exclusively focuses onsolar PV energy, as it is widely used in many African countries, especially for healthcare facilities that are not connected to hydroelectricity grids. (Das and Sikdar, 2016; Sen, Awtar, and Bohidar 2015).

1.1.2 Solar PV Energy in Zambia

Apart from hydroelectricity, solar PV systems are the second most dominantly used sources of energy in Zambia accounting for 37 percent healthcare facilities in the country. This is followed by generators at nine percent and the least are wind energy and geothermal sources of energy (MOH, 2013).Zambia is recorded as one of the countries with the highest potential to produce solar energy in Africa. According to Kapumpu (2015), Zambia does not have much discrepancy among regions in annual solar radiation which is so far recorded to be high and stable. Solar radiation in Zambia ranges between 6,600MJ/m² and 7,700MJ/m² on a bright and sunny day.

Despite Africa being endowed with vast resources for energy generation, the WHO (2014) reviled that about one in four healthcare facilities in 11 sub-Saharan African countries do not have access to electricity and most of the healthcare facilities that do have access do not have a reliable supply of energy. As a result, many healthcare facilities, especially those located in rural areas have resorted to using other sources of energy such as solar PV systems to produce energy that enables them to carry out various day to day healthcare activities.

1.1.3 Structure of Healthcare Facilities in Zambia

In 1992, a health policy was created in Zambia which operated hand in hand with the health services act of 1995. According to Ministry of Health(MOH) (2005) the health policy was created to "provide the people of Zambia with equity of access to cost effective quality healthcare as close to the family as possible." The policy among other things saw a shift from a centralized system, to a decentralized system of decision making which enabled local authorities in district health management boards to become responsive to local needs in all healthcare facilities in Zambia. In 2005, the health policy became outdated together with the health service act. The following year, 2006, a four tire health structure was established, in response to seeking a more decentralized healthcare system. The health structure comprised of Third Level Hospitals (TLHs) at Central level , Second Level Hospitals (SLHs) at Provincial level, First Level Hospitals(FLHs) at District level and Community Healthcare Centres comprising Urban Health Facilities (UHFs) and Rural Health Facilities(RHFs) and Health Posts (HPs), all mandated to provide quality healthcare services to the citizens of the country.

According to a report by Ministry of Health (MOH, 2013), there are currently 1,958 Health Facilities (HFs) in Zambia. According to Chankova, Slavea andSulzbach (2016), 81 percent of these HFs are government owned, 13 percent are privately owned, and six percent are owned by faith based organisations. Among these HFs, six are Third Level Hospitals, 19 are Second Level Hospitals, 84 are First Level Hospitals, 1,131 are Rural Health Facilities, 409 are Urban Health Facilities and 307 are classified as Health Posts. The Zambian healthcare system is hierarchically structured, providing different levels of healthcare services ranging from specialized to basic healthcare services depending on the type or level of a healthcare facility.

Out of the recorded 1,958 healthcare facilities in Zambia, the MOH (2013) shows that only 41 percent are either connected or have access to hydroelectric energy, while 37 percent use solar energy and only nine percent use generators as a source of electricity. Out of the 1,958 healthcare facilities in Zambia, 204 are located in central province, ofwhich, 33 are based in Mumbwa District. Mumbwa is a District located in the central part of Zambia and is largely regarded as a rural district. Central Statistics Office (CSO, 2017), shows that Mumbwa District is 87 percent rural and 13 percent urban. Out of the 33 healthcare facilities in Mumbwa, two are FLHs and are both located in urban areas. Mumbwa has one UHC, 26 RHCs and six HPs. Majority of HCs, except one, arelocated in rural areas. Similarly, majority of HPs are located in rural areas. A report by MOH (2013) shows that out of the 33 healthcare facilities in Mumbwa District, only 10 are connected to the national grid, while the remaining healthcare facilities are reported to depended on solar PV systems and generators.

The energy consumption rate for each type of healthcare facility varies depending on factors such as the size of the healthcare facility, available equipment and the type of healthcare service provided. A report by Institute for Health Metrics and Evaluation (IHME) and the University of Zambia (UNZA, 2014) indicates that FLHs consume an average of justless than 24 hours of daily electricity. SLHs, private hospitals and UHCs average about 22 hours of electricity each day. While on the other hand, smaller healthcare facilities such as RHCs and HPs are reported to average consumption of 12 hours of electricity each day. The report also shows that an average of 43 percent of healthcare facilities in Zambia use six or fewer hours of electricity per day.

In terms of energy consumption estimates and healthcare facility type, Al-Akori (2014) shows that small sized healthcare facilities that mostly provide basic healthcare services and has between 0-60 beds consume up to a maximum of 10kWh per day. Medium sized healthcare facilities that provided other services other than basic services and has between 60-120 beds has an energy consumption rate between 10-20kWh per day. Larger healthcare facilities that are fully equipped with various healthcare equipment that consume more than 20kWh per day.

1.1.4 Energy and Healthcare Delivery in Rural Zambia

Despite the abundance of water bodies for hydroelectricity generation, Zambia has suffered insufficient energy production over the years. ZESCO's current generation capacity is outweighed by the increasing demand for energy in the country. As of 2015, ZESCO has had the capacity to produce 1,281 megawatts (MW) through hydropower, while the demand for energy stands at 1,949 megawatts (MW). This means that the energy sector has a deficit of 668 megawatts (MW) (SNDP, 2017).

Due to the increased demand for energy, many citizens especially those in rural areas suffer poor or completely have no access to electrical energy. This greatly affects many social-economic activities, including healthcare delivery, especially in rural parts of the country. In response to the poor energy generation capacity coupled with low electrification rates in rural areas, the government of Zambia in 2004 developed the

Rural Electrification Authority (REA) and Rural Electrification Fund (REF) through the Rural Electrification Act No.20 of 2003. REA has been established to provide electricity infrastructure to rural parts of the country using appropriate technologies such as grid extensions, mini hydro (200KW-10MW), Solar Home Systems, biomass and biogas, and also wind technologies, in order to increase access to electricity in the country. Since REA's inception, it has been in charge of managing rural electrification programs (Musonda, 2017).

Despite being established in 2004, REA began to operate in 2006, and has so far undertaken a number of electrification projects. As of 2005, CSO shows that rural electrification access in Zambia stands at four percent grid power connections and seven percent solar power connections. Between the period 2006 and 2015, REA recorded 358 connections of rural healthcare facilities in various parts of the country which so far have been electrified.

REA, through the government, has also worked in collaboration with other cooperating partners namely, European Union (EU), Japan Bank for International Cooperation (JBIC) now Japan International Cooperation Agency (JICA), the Swedish International Development Agency (SIDA) and the World Bank (WB), (USAID, 2009; WB, 2016).

Despite the effort to increase the electrification rate in rural areas, REA has faced many challenges along the way. Some of the major challenges include inadequate funding, high investment costs for mini grid installation and poor private sector participation in rural electrification projects. However, strategies have been put in place to mitigate the challenges that REA has faced so far. Some of the solutions include promoting renewable energy use by implementing various renewable energy projects and conducting renewable energy sensitization programs on national television (Musonda, 2017).

1.2 Statement of the Problem

Despite energy being identified as an essential infrastructure for quality healthcare delivery, a study by the WHO (2013) shows that one in four healthcare facilities in 11 sub-Saharan countries have no access to electricity.Most of the healthcare facilities that have access to grid electricity have an unreliable supply. Central Statistics Office(2016)shows that only 25 percent of the Zambian population are connected to the hydroelectricity grid, of which 20.7 percent are urban and only four percent are rural connections.

The Ministry of Health (2013) shows that only 41 percent of healthcare facilities have access to hydroelectricity as a primary source of energy while 37 percent rely on solar PV energy systems as a primary source of energy. The remaining 22 percent of healthcare facilities rely on generators and thermal energy sources.

The Ministry of Health (2013), shows that Mumbwa District has over 33 percent of rural healthcare facilities that use solar PV energy systems as a primary source of energy. Despite the increasing use of solar PV energy systems in rural healthcare facilities as a primary source of energy, there is lack of knowledge about the levels of its reliability in the provision of rural healthcare as it relates to the affordability and continuous delivery of healthcare, particularly in rural areas.Essendi (2015) indicates that in rural areas maternal and new born deaths continue to remain unacceptably high due to various infrastructural challenges that limit provision of emergency and basic routine services.

This study, therefore, seeks to investigate the reliability of solar PV sources of energy in public healthcare delivery in Mumbwa District.

1.3 Research Objectives

1.3.1 Main Objective

To investigate the reliability of solar PV sources of energy in public healthcare delivery in rural Zambia.

1.3.2 Specific Objectives

1. To examine the affordability of solar PV sources of energy in public healthcare delivery in Mumbwa District.
2. To examine the continuity of healthcare delivery using solar PV sources of energy in public healthcare facilities in Mumbwa District.

1.3.3 Research Questions

1. How affordable are solar PV sources of energy in public healthcare delivery in Mumbwa District?

2 Does solar PV energy ensure continuity of healthcare deliveryin public healthcare facilities in Mumbwa District?

1.4 Rationale of the Study

Mumbwa District has a majority of its healthcare facilities using solar PV sources of energy in healthcare delivery. The study is done because data on energy access in most parts of rural Zambia is not available. Feasible literature merely states that solar PV sources of energy are used by rural healthcare facilities but does not provide information on how efficient and effective solar PV energy systems are. Without this study being undertaken, this information gap will persist.

1.5 Scope of the Study

Mumbwa District has been selected for the study because it is largely a rural area, 87 percent rural and has great potential for installation of solar plants (CSO, 2017). Mumbwa is one of the seven districts in central province, and is about 140-160Kilometres from Lusaka, the capital city of Zambia. Mumbwa is 23,800 km^2 and has a population of 176,620 people as of 2015. Its population is composed of 87.3 percent rural and 12.7 percent urban. Mumbwa's main economic activities are agriculture and agro processing. Mumbwa currently has 16 wards namely:Chibolyo, Chisalu, Choma, Kalwanyembe, Lutale, Mpusu, Mumba, Mupona, Myooye, Nakasaka, Nalubanda, Nalusunga, Nambala, Nangoma, Sichanzu, and Shimbizhi (CSO, 2017).

Mumbwa District has 33 healthcare facilities, of which 24 are RHCs, six HPs, two FLHs and one UHC. This study seeks to investigate the reliability of solar PV energy in rural healthcare deliveryin Mumbwa District.

1.6 Conceptual Framework

The study uses a conceptual framework to show the relationship between availability of reliable solar PV energy and rural healthcare delivery. Reliability is the extent to which a system is expected to perform its functions under specific conditions for a specific period of time. In the study, reliability is used to refer to the ability of solar PV energy system to continuously make available sufficient energy, of satisfactory quality, to meet a rural healthcare facility's energy needs (Willis, 2004). When a solar PV system is installed at a rural healthcare facility, it is expected to be used to support healthcare delivery. Healthcare is the provision of diagnosis, prevention, cure and rehabilitation of patients affected by one or more health disorders. Healthcare caters to the needs of affected populations in terms of physical and psychological illnesses by offering treatment and management services.

Primary healthcare includes at least education concerning prevailing health problems and the methods of preventing and controlling them; the promotion of food supply and proper nutrition; adequate supply of safe water and basic sanitation; maternal and child healthcare including family planning; immunization against major infectious diseases; prevention and control of locally epidemic diseases; appropriate treatment of common diseases and injuries; and provision of essential drugs (Gillies, 2003).

The study uses two functions to measure the reliability of solar PV energy systems at rural healthcare facilities in Mumbwa District. These functions are affordability and continuous delivery of healthcare.

1.6.1 Affordability

Affordability in this dissertation refers to the ability to purchase, install and utilize a solar PV system at a rural healthcare facility without having to forfeit or curtail other essential healthcare inputs.Affordability in this study is used to refer to total input, of the least amount of resources, in a process required to get desired outputs of goods and/or services. In this study, the affordability of a solar PV system is determined by taking into account solar PV system equipment capacities and maintenance practices implemented at a rural healthcare facility.

In order for a solar PV system to be work as expected, it is required to have all the basic system equipment which include; solar panel(s), rechargeable battery (batteries), inverter(s), and charge controller(s). It is important to note that before any solar PV system is installed at a rural healthcare facility, its energy needs should be known so that an appropriate solar PV system capacity can be installed. When the energy needs are known, the solar PV system would be easy to adjust when the load happens to increase or decrease. When the solar PV system meets the day-to-day energy needs of a rural healthcare facility for healthcare delivery, it is regarded as a reliable system. However, if the solar PV system fails to meet the day-to-day energy needs of a rural healthcare facility due to poor production of solar electricity, it is regarded as an unreliable system.

Affordability is also measured by taking into account the solar PV maintenance practices that are put in place at a rural healthcare facility. Literature shows that if maintenance practices are done on a regular basis by a rural healthcare facility technician, the number of faults that are expected to be experienced on the system tend to reduce (Admasu, 2010). Maintenance reduces the likelihood of faults concurrently arising on the solar PV system. It ensures that batteries on the solar PV system do not easily get damaged because battery fluids are closely observed and replenished and this contributes to their durability. However, if batteries are not properly maintained on the solar PV system, they easily become discharged and sometimes get damaged due to frequent discharge and hence would reduce the energy storage capacity. When this happens, it affects the storage of energy in the batteries for use in the healthcare delivery process.

Proper maintenance of the solar PV system also entails ensuring that the solar panels are kept clean to prevent accumulation of dust, leaves or any other particles which would affect solar panel irradiation levels. If the solar panels are not regularly cleaned by a technician, the amount of sunlight absorbed by the solar panels is reduced from the initial capacity to absorb energy on a normal sunny day. Maintenance also entails that the solar PV system connections are kept from developing eroded terminals. Solar PV systems are modular meaning that their capacities can either be increased or decreased depending on desired energy needs of the user. This means that the solar PV system has many connections that need to be checked regularly to ensure that they are correctly connected. Battery terminals for example, tend to develop rust over a given period of time which affects the overall performance of the solar PV system. As a result, this tends to negatively affect the amount of solar PV energy stored or utilised at a rural healthcare facility if the eroded terminals are not regularly or consistently cleaned.

Additionally, in terms of maintenance, battery fluids have to be well maintained in order for the solar PV system to be utilised during the night when sunlight is not available. Some batteries begin to develop faults when their fluids are not regularly replenished by a healthcare facility technician. If not well taken care of, the life span of the battery reduces, consequently it easily gets damaged and would require to be replaced many times over, and this hence becomes expensive and undesirable to the healthcare facility using solar PV energy. In the long run, this affects optimal utilization of the solar PV system for rural healthcare delivery.

Maintenance of the solar PV system also requires that the solar PV panels are kept at a correct angle at a rural healthcare facility so as to ensure maximum irradiation. After installation of solar PV panels, there is need for constant checks to ensure that the panel angles do not get interfered with or changed unintentionally. If the solar panels are not regularly checked, environmental conditions such as strong winds and heavy rains can change the positioning of the solar PV panels. As a result, this can decrease the amount of solar energy absorbed and cause system underperformance or system failure. If not addressed, such problems affect the energy generated by the solar PV systems in rural healthcare facilities which ultimately affect healthcare delivery.

1.6.2 Continuity of Healthcare Service Delivery

Continuity of healthcare services in this study refers to uninterrupted provision of healthcare services to healthcare seekers at a healthcare facility. It also refers to whether a healthcare facility is able to meet it’s set objectives which is to provide healthcare services to its patients as close to their homes as possible.

Continuity of healthcare delivery also refers to the extent to which solar PV energy influences a rural healthcare facility achieve its goal to provide primary healthcare services. It is expected that the availability of solar PV energy at a rural healthcare facility should enhance the provision and variety of healthcare services. The availability of solar PV energy at a rural healthcare facility should ensure that a rural healthcare facility is able to extend working hours by providing consistent night time emergency services and also, be able to provide in-patient services for cases that require overnight observation. This can be achieved by having a solar PV system that provides sufficient energy for lighting during the night time. This ideal situation makes it easy for healthcare personnel to attend to patients who are brought in during the night as opposed to cases when there is no light available to aid healthcare personnel to conductmedical examinations and treatment on patients. Availability of sufficient solar PV energy also makes it possible for rural healthcare facilities to operate medical equipment when needed. For example the use of autoclave machines for sterilizing surgical equipment, suction machines for removal of excess fluids and microscopes for conducting blood and fluid tests.

Availability of reliable solar PV energy also enables continuity of healthcare provision by enablinga rural healthcare facility to store drugs and vaccines in the required cold temperatures. This is because some drugs need to be kept in cold temperatures and this can only be done by keeping them in refrigerators. Refrigerators require a reliable supply of energy that can only be met by a reliable solar PV system for healthcare facilities not connected to hydroelectricity. If there is no solar PV energy to operate refrigerators at a rural healthcare facility, then storage of drugs and vaccines becomes a challenge and hence negatively affect healthcare delivery because important drugs and vaccines will not be readily available to serve the needs of the communities.

When reliable solar PV systems are installed at a rural healthcare facility, it is made possible for healthcare personnel to charge mobile devices which can are used for either communicating with other healthcare facilities for consultations or for making emergency requests when need arises. For example, it is easy for a rural healthcare facility to make a request for a specialised doctor to visit a rural healthcare facility when a patient is not in good condition to travel to another healthcare facility for specialised treatment.

Additionally, the continuity to provide quality healthcare services requires the presence of qualified and experienced staff at any given rural healthcare facility. If solar PV is not available, it makes the work environment unattractive for qualified and experienced healthcare staff. If there is no reliable solar PV energy, qualified and experienced staff may not wish to stay in rural areas for long periods of time. This makes it difficult to attract and retain experienced staff and their absence affects the quality of healthcare delivery in rural areas. The above information in the conceptual framework is illustrated in Figure 1.6 below.

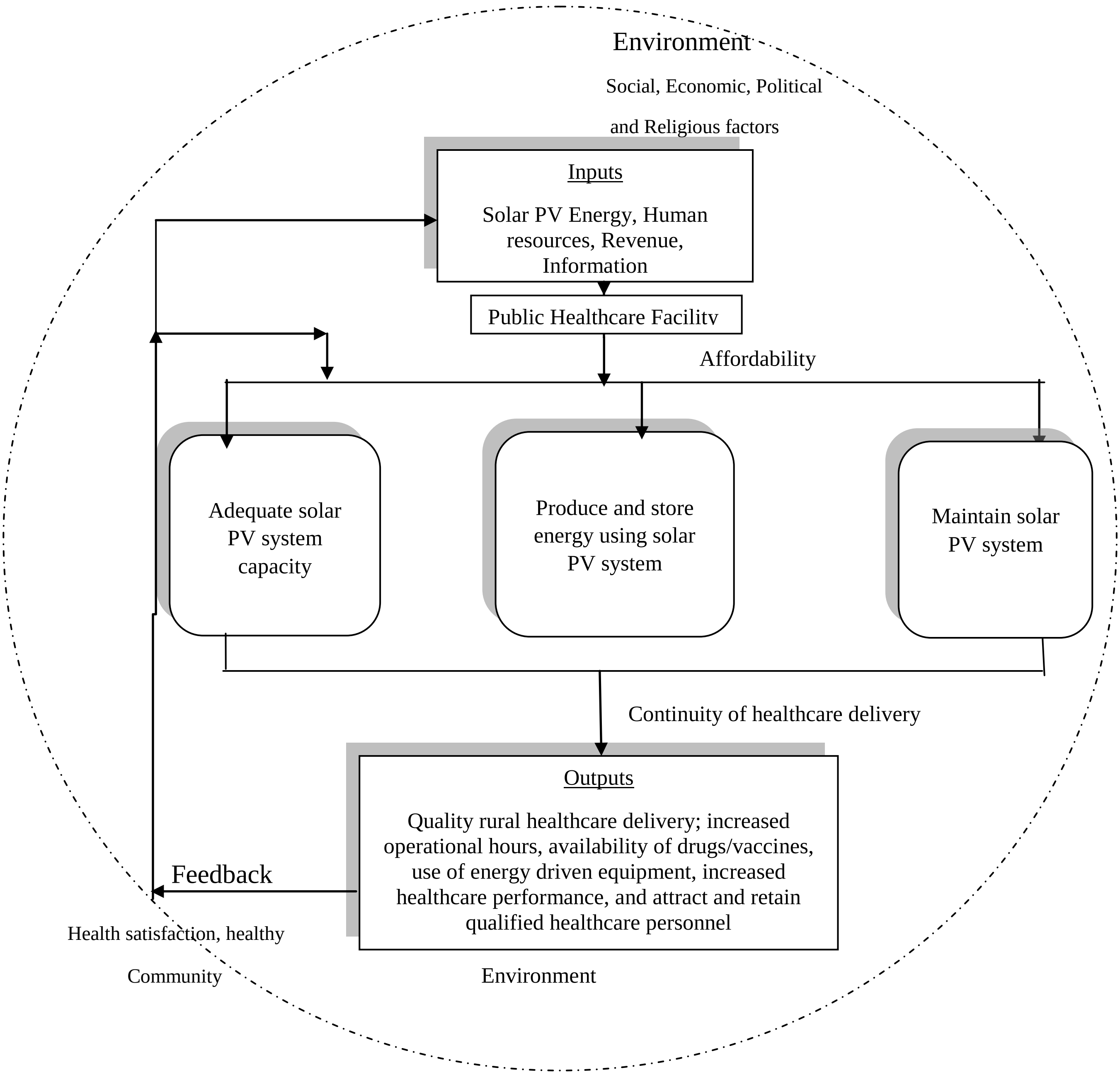

Figure 1.6 Conceptual Framework Illustrating Reliability of Solar PV Energy in Rural Healthcare Delivery

Source: Adapted by the author from Bhatia et al, 2014

The conceptual framework in this dissertation is based on concepts derived from the systems theory. The systems theory shows that a system is composed of various sub systems that work together to achieve specific set goals. The system is generally composed of inputs, throughputs/processors, outputs, feedback and the environment. In this dissertation, the inputs comprise of various materials required to achieve a desired set of goals, which include providing quality healthcare services. These inputs include human capital, solar PV energy, revenue, infrastructure and information, all of which contribute to the provision of quality healthcare delivery. The inputs that are fed into the system are acquired from the environment. The environment is controlled by social, economic, political and religious factors. These factors can sometimes, affect the inputs that are available in the environment. However, once the required inputs have been identified, they are acquired and fed into the healthcare system.

In the throughput/processor stage, inputs acquired from the environment are converted or utilised in order to produce desired goods or services. The quality of goods or services produced in this process is closely linked to the quality and quantity of inputs acquired from the environment. In this study, solar PV energy is acquired from the environment as an input that is converted into electricity and is used in the throughput process of healthcare delivery to provide healthcare services. The quality of electricity produced using solar PV systems has a direct effect on some of the healthcare services that are provided in a rural healthcare facility. In order for a healthcare facility to provide quality energy driven services, it has to have adequate solar PV system capacities, be able to produce and store energy, and it must be able to maintain the solar PV systems properly. Therefore, if the quality of solar energy produced at the rural healthcare facility is good, then the likelihood of the quality of healthcare services provided are also good.

The outputs produced in the system are as a result of the processes undertaken in the system. The outputs can be finished or unfinished goods or services. In this dissertation, the outputs comprise of various healthcare services that are provided by the healthcare facility. It is at this point that the quality of healthcare services can be examined. If the quality of out is good, then the services are said to be good. There are a number of factors that affect the output of any system, and in this case, solar energy has an effect on healthcare delivery as it affects some services provided. If solar PV energy is available at the healthcare facility, it increases the operational hours of the facility, makes it possible to store special drugs and vaccines in cold temperatures, enables the use of energy driven medical equipment and also plays a role in the retention of qualified healthcare personnel.

The feedback stage in the system is composed of acquisition of information from the environment regarding the systems performance. This is done by assessing the output services released to the systems environment. In this case, the system can generally be assessed by taking into account the general health conditions of a given healthcare facility's community. It can also be determined through the collection of information to examine the satisfaction level of end-users that use the healthcare facility. If the quality of healthcare is good, the system can either maintain or improve its inputs acquired from its environment. However, if the feedback is poor, the healthcare facility has to identify its shortfall so that it can adjust its inputs so as to achieve its desired goal, which is to provide quality healthcare service delivery.

Organization of Dissertation

This dissertation is composed of seven chapters. Chapter One is composed of introduction to the study, background information, statement of the problem, research objectives, rationale of the study, significance of the study, scope of the study, and theoretical framework.

Chapter Two is composed of literature review.

Chapter Three discusses the research methodology.

Chapter Four discusses the efficiency of solar PV sources of energy in healthcare delivery in Mumbwa district.

Chapter Five discusses the effectiveness of solar PV energy sources in healthcare delivery in Mumbwa district.

Chapter Six discusses the challenges faced in the use of solar PV sources of energy by healthcare facilities in Mumbwa district.

Chapter Seven presents conclusions and provides recommendations of the study.

1.6.3 Conclusion

This chapter has provided information on the background of the study, statement of the problem, research objectives, and the conceptual framework guiding the study.

This chapter showed that solar PV energy has been identified as an important infrastructure in rural healthcare delivery. The conceptual framework used in the study shows that if solar PV energy is produced in adequate quantities, it is expected to enhance healthcare delivery services in rural healthcare facilities. However, despite their installation, no information has been provided relating to solar PV reliability in rural healthcare delivery in Zambia. The specific objectives of the study is to investigate the affordability of solar PV energy; and continuity of healthcare services and the challenges faced by rural healthcare facilities using solar PV systems as primary sources of energy in rural healthcare delivery. The study is guided by a conceptual framework that shows how the reliability of solar PV energy affects rural healthcare delivery.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter examines studies done by other researchers and scholars on the relationship that exists between healthcare delivery and the availability of solar PV energy in rural healthcare facilities. The literature review section comprises literature from journals, research reports, theses, and reviews done by individual researchers and research institutions in Zambia, Africa and the world. The literature review provides information on where the research was done, the purpose and objective(s) of the study, methodology used, relevance of the study, main findings of the study and the critique of the study, where applicable. Thereafter the chapter ends with a conclusion about the literature reviewed.

2.2 Reviewed Literature

An assessment done by International Renewable Energy Agency (IRENA, 2013) titled "*Renewables readiness assessment"* was conducted in Zambia. The purpose of the assessment aimed at undertaking a thorough renewable energy resource assessment so as to enable Zambia to have a chance to deploy renewable energy sources in Africa. The study adopts purposive sampling methods to include relevant key stakeholders to take part in the assessment project. The assessment focuses on three categories which include on-grid electricity, off-grid electricity and bio fuels. The relevance of this study is that it provides information about the commonly used sources of energy in Zambia, and the extent to which they are used. It also provides information on various energy projects that have been implemented in Zambia by various stakeholders in the energy sector. The key findings of the assessment are among others, include data on renewable energy resources is not readily available. This is because not many researches regarding renewable energy and their impact on healthcare delivery have been done consecutively in the Africa. However, the assessment only focuses on the energy sector in general. It does not provide relevant information on the importance of energy in the healthcare delivery system. The assessment does not also provide a clear methodology on which areas are included for the study in the country.

An assessment done by Institute of Health Metrics and Evaluation University of Washington(IHME) and University of Zambia(UNZA) (2014) titled "*Assessing facility capacity, costs of care, and patient perspectives"*was done in Zambia. The assessment aims at helping policy makers understand the cost of healthcare delivery, facility-based characteristics of Antiretroviral Therapy (ART) programs and health facility performance in Zambia. The study adopts desk research enabling the researcher to collect vast information on healthcare facilities. Primary information is also collected from both healthcare facilities and patients using questionnaires and interview guides respectively. This assessment is relevant to this study because it provides comprehensive information about healthcare facility performance in Zambia. It shows the healthcare facility capacity for service delivery, costs of care and patient perspectives on the services they receive. It also provides relevant information on facility based services, capturing experiences reported by patients seeking various services. The findings of the study, among many others, show that there are existing gaps in service capacity. Many healthcare facilities that were reported to have provided various services actually lack capacity to properly deliver the service due to unavailability of sufficient equipment and reliable energy. Most healthcare facilities do not have the capacity to keep vaccine materials in recommended temperatures and hence despite reporting that they provide immunization services, they do not because vaccines cannot not be stored in correct conditions. However the study does not focus on energy as an integral driver of healthcare provision. It also does not pay attention to one specific type of healthcare facility in order to understand its particular needs.

A research done by Mudenda, Johnson, Parks and Van Stam (2014) titled "*Power instability in rural Zambia, case Macha"*aims at providing insight on the nature of electricity supply in rural Macha. The research is relevant because it provides information on some of the challenges that hinder proper use of solar PV equipment in rural areas such as Macha. The findings of the study show that even though four percent of households have access to grid electricity in rural Zambia, such electricity supply is erratic and diurnal when it is available. This leads to use of solar PV systems in Macha. The study reveals that solar PV energy supply varies considerably and many users experience voltage dips and burnouts which cause equipment to become unstable, fail and in some cases get damaged. Because of voltage fluctuations, various appliances cannot be used for long periods of time.However,the study does not show the methodology used to collect data nor the analytical tools used to process the collected data.

A research by Nozaki, Dube, Kakimoto, NyamadaandSimpungwe (2013) titled *"Social factors affecting ART adherence in rural settings in Zambia"*aims at assessing factors influencing access to Antiretroviral Therapy (ART) treatment in rural settings in the country. Face-to-face interviews and semi-structured questionnaires are used to collect primary data for the research. The data collected is analysed using Statistical Package for Social Sciences (SPSS). This study is relevant because it discusses some of the challenges that are faced regarding healthcare delivery, specifically in rural areas. The findings of the study reveal that most of the health seekers in the study are farmers and that there are various factors that limited access and proper use of medication in rural health facilities as compared to urban areas. Healthcare delivery of essential vaccines is affected by lack of capacity to store them in correct temperatures. This could be attributed to the fact that there is no reliable source of energy to operate refrigerators at the rural healthcare facilities.

A study done by World Vision Zambia (2016) titled "*Final evaluation report world vision child health now project"*focuses on selected areas in Zambia including Mumbwa, Luampa, Mwamba and Mbala. The purpose of the study is to help reduce maternal new born and child mortality rates in targeted communities in Zambia by 2015. The studyadopts mixed methods of data collection including document reviews, stakeholder interviews and process tracing. The study is relevant because it shows the challenges that healthcare seekers face in rural healthcare facilities in various parts of Zambia, including Mumbwa district. The findings of the study reveal that there is inadequate availability of skills and equipment for quick response to healthcare seekers for services such as birth complications for pregnant mothers.However, the study does not provide specific information on the factors that bring about inadequacy of equipment for quick response to health seekers.

A research done by Walsh, Mullambia, Brugha andHanefeld (2012) titled *"The problem is ours, it is not CRAIDS: evaluating sustainability of community HIV/AIDS in a rural district in Zambia"*aims at evaluating whether or not the global programme contributes to the sustainability of Community Based Organisations (CBOs) working in the area of HIV/AIDS in Zambia. The study adopts in-depth interviews, and a thematic analysis of data is conducted after data collection. This research is relevant to this study because it focuses on health related matters and also conducted in Mumbwa district. The findings of the study reveal that most CBOs between 2015 and 2017 faced challenges in receiving their funding for up to three years, while others received lump sum funds and still others received their funding in instalments. This negatively affects healthcare delivery of HIV/AIDS service provided by CBOs in the district. The study is relevant because it indicates how the delay of funding affects healthcare service delivery which can be linked to the maintenance aspect of energy systems installed in rural healthcare facilities. However, the study does not provide strong information on the effects delayed funding has specifically on availability of energy at the healthcare facilities.

A research done by Mfune and Boon (2008) titled *"Promoting renewable energy technologies for rural development in Africa: experience of Zambia"* was conducted in Zambia's Lundazi district located in the eastern province of Zambia. The study aims at examining Zambia's efforts towards the use of Renewable Energy Technologies (RTEs). The study adopts both primary and secondary data sources. International and national literature on renewable energy is reviewed to identify the renewable energy trends and main debates relating to renewable energy in the world. Primary data is collected through questionnaires and interviews. A sample of 80 households was selected in Lundazi district. Four group discussions are used to collect primary data in the study area. The relevance of the study is that it provides information on factors and dynamics relating to renewable energy potential, its adoption by households and public institutions and its contribution to the socio-economic wellbeing of the rural population. The main findings of the study indicate that RETs such as solar PV energy have proven to have a wide range of application in households, health, education and natural resource management and the telecommunications sectors. These findings are relevant because they highlight the role of solar PV energy on a wide range of applications, including in the health sector. However, the study does not specify what criterion is used to select the focus group members and the method used to select healthcare facilities sampled in the study. The study does not also indicate the amount of energy that is produced and consumed in the study area.

A research study done by Kaibung'a, Mavole and Okuku (2017) titled "*Infrastructure and healthcare service delivery in Tiaty sub-county, Baringo county"*was conducted in Kenya. The purpose of the study is to establish the extent to which poor infrastructure affects healthcare service delivery in Tiaty sub-county. A descriptive survey search design isused whose target population are employees and patients who visited the healthcare institutions in Tiaty sub-county. The study uses stratified random sampling techniques to select a sample of 126 respondents. The research uses questionnaires to collect data. Quantitative data collected isanalysed using SPSS (version 21) and the findings are presented through percentages, means, standard deviations and frequencies. The relevance of this study is that it considered how various infrastructure impacts healthcare delivery. Among the important infrastructure considered is the availability of power coverage and its influence on healthcare delivery at the healthcare facilities. However, not much information is provided to highlight the key issues of how power coverage contributes to healthcare delivery. The main findings of the study show that infrastructure such as power coverage, water and telecommunications affect healthcare service delivery.

A review done by Adair-Rohani, Zukor, Bonjour, Willburn, Kuesel, Hebert and Fletcher (2013) titled "*Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources and reliability"*, aims at assessing electricity access in healthcare facilities in selected surveyed sub-Saharan African countries. The study adopts desk research using publicly available data from reviews of PubMed articles, and through websites from development agencies, Ministries of Health and National Statistics Bureaus which show that access to electricity is critical to healthcare delivery and attainment of universal health coverage. This review is relevant because it shows that as far as the authors are concerned, their study is the first multi-country analysis on electricity access in health facilities presented in the peer-reviewed literature, and Zambia is one of the countries that are studied in the review.

The review shows that access to healthcare in sub-Sahara African countries varies. The study shows that an average of 26 percent of health facilities in the surveyed countries do not have access to any form of electricity while an average of seven percent of facilities rely solely on a generator. The study supposes that it is likely that poor and vulnerable groups suffer the most from lack of access to electricity in healthcare delivery, especially in rural locations. However, the study does not provide an estimated input on the extent to which energy affects healthcare delivery.

A research done by Bazilian et al. (2012) titled"*Energy access scenarios to 2030 for the power sector in sub-Saharan Africa",* which aimed at improving understanding about the scale of reaching universal access to electricity services in sub-Saharan Africa (SSA) and clarifying the role of the international community. This research is relevant because it shows that there is a relatively small existing literature on scenarios for the energy sector in relation to healthcare delivery in sub-Saharan Africa. The report showsthat sub-Saharan Africa suffers from lack of access to electricity and poor quality of supply, in terms of cost reliability, especially in areas where electricity generation does not exist. It shows that there are approximately 580 million people in the continent without access to electricity most of whom live in rural areas. Additionally, the review shows that if the goal to attain universal access to modern energy services in Africa by 2030 is to be achieved, there will be need to take into account various electricity sector pathways in order to help inform policy makers and investors. However, the shortfall of this research is that it does not necessarily focus on the effects of poor availability of energyon the healthcare delivery.

Matungwa (2014) in his Master's Thesis titled, "*An analysis of PV solar electrification on rural livelihood transformation: a case of Kisiju-pwani in Mkuranga District, Tanzania".* The study is conducted in Kisiju-pwani village in Mkuranga District, Tanzania. The aim of the study is to analyse energy electrification in the livelihood transformation process in rural areas. The study also aims at understanding people's perceptions, attitudes and sense of ownership over the solar PV systems installed in the village.The study seeks to understand people's electricity consumption behaviour in the rural areas. The methodology of the study includes the use of different interview guides, conducting focus group discussions which targets at least 68 households. Data collected reveal that only two percent of the rural population in Tanzania are connected or have access to grid electricity. The study reviles that solar PV energy is an effective alternative approach to mitigating challenges faced by populations that are located far away from the main grid of electricity lines in rural areas. Solar PV systems have transformed people's livelihood in terms of lighting homes, creating opportunities such as employment and enabling them to live the way they would have liked to live, instead of relying on limited options. The study findings also showthat there is a positive attitude over solar PV electricity installed in the village, due to benefits obtained as opposed to the previous setup before solar PV systems were introduced. The introduction of solar PV systems enable socialization time for most of the people in the village, more time to exchange ideas, during the evening and night hours while businessmen and women continue with their business for a longer time than it was before. The study considers both populations with connections to grid electricity access and those without connection to the main grid. The relevance of this study is that itlooks at the solar PV energy consumption behaviour in rural areas. Additionally, the study also provides detailed information on how activities such as businesses are enhanced in terms of operation hours because of the installation of solar PV as compared to before, when businesses would be closed early due to lack of electricity. However, the study does not provide detailed information on the specific challenges faced by healthcare facilities in these areas before and after the solar PV systems were installed. The study has mainly focused on the existing businesses in the village and little emphasis is given on healthcare related usage of solar PV.

A research by Muhammadi (2010) titled "*Public health cost of electricity shortage: a Ghanaian case study"*, was conducted in Ghana. The study aims at demonstrating the importance of availability of electricity as a determinant of healthcare delivery and emphasizes the need for energy to be included in the list of 150 World Health Organisation (WHO) health indicators. The methodology used for the study is desk research using secondary data from Medline and PubMed databases. The relevance of this research is that it points out the importance of sustainable access to electricity for economic development and healthcare delivery enhancement of public healthcare facilities. The study shows that electricity is important in any community's infrastructure because of its direct and indirect impacts on public healthcare delivery which, according to Muhammadi, has been neglected.The study also shows how absence or inadequate electricity causes inefficient healthcare delivery which, according to Muhammadi (2010), makes it very difficult to attain the goal to improve healthcare services because electricity has been identified as one of the important factors that affect healthcare delivery. This is illustrated in the research by showing that, for many people around the world, hospitals and clinics serve as sources for primary healthcare which need consistent supply of electricity for effective healthcare delivery of services ranging from illumination, refrigeration and storage, sterilization, running water, good sanitation amenities, scanning, patient monitoring and many others healthcare services(Muhammadi, 2010).

The study shows that the presence of electricity influences maternal mortality rates, child mortality rates, education, gender equality, poverty and income, number of health facilities, number of health workers, reforms in the health sector, quality of healthcare delivery, and the overall healthcare system performance.

The research also emphasizes the relationship between electricity and public healthcare delivery outcomes that are essential for motivating stakeholders to take quick action to address electricity shortages. The research also shows how international institutions such as the World Bank have attempted to address electricity shortages by pointing out initiatives to increase the number of power plants in sub-Saharan Africa.

However, the study does not provide information on alternative sources of energy that can be adopted by healthcare facilities that are not connected to ahydroelectric grid. The study also does not focus on the alternative sources of energy used to support healthcare delivery and the challenges that rural healthcare facilities face using these alternative sources.

In a study done by Aglina (2014) titled "*Energy access and development indicators: case of Ghana",* aims at finding out how energy use, electricity access and consumption impacted poverty reduction using some selected world development indicators. The study adopts the use of world development indicators such as healthcare data from the World Bank. In cases where data is not available, other data sources are opted for from 16 countries which include Brazil, Russia, India, and China (BRICs), and South Africa and 10 selected European countries with some World Bank categorizations. The study uses regression analysis to analyse the data collected.This study is relevant because among the development indicators considered in the thesis, the relationship between energy access and health are discussed. It points out that access to energy enables healthcare facilities to serve the people after dark, to power the communication gadgets and retrieve client's information. The findings of the study reveal the significance or effect energy has on world development indicators. The study also shows that in order to reduce poverty in all its forms, energy availability has to be at the centre of development policy planning in both developed and developing countries. However, the study does not clearly present the methodology used for the study. The methodology does not clearly indicate where exactly in Ghana the study is conducted and how long the study is conducted. No population and sample size are provided. The study does not provide extensive information on the extent to which energy enhances healthcare delivery in rural setups and the challenges that are faced by healthcare facilities that are not connected to an electricity grid.

A survey done by Africa Solar Designs (ASD) (2015) titled "*Health facility needs assessment Uganda country report"* aims at evaluating the electrification status and power needs of un-electrified and under-electrified healthcare facilities in Africa. The survey also aims at providing recommendations on proposed energy system designs to address energy needs. The methodology used in the survey involves the consideration of all public healthcare facilities and their electrification statuses. This is followed by energy audits conducted at 100 health centres across 13 districts in Uganda, especially those that provide services for women and new born babies. The findings of the survey show that there aren't any readily available data on energy access within healthcarefacilities in Uganda. Despite solar PV systems providing critical energy, it is said tobe an insufficient energy source for the surveyed healthcare facilities that are not connected to an electricity grid. Additionally, the study shows that accessibility, quality and reliability of energy dependent healthcare services vary from one healthcare facility to another and such services are inadequate for maternal and child healthcare service delivery. The relevance of this survey is that it examines the energy needs of health facilities that are not connected to a national electricity grid in Uganda. The survey provides recommendations that prompt the need for another study to be conducted in order to assess the viability of the given recommendations. However, this study does not provide extensive information on how accessibility, quality and reliability vary specificallyin different healthcare facilities in rural areas.

AMaster'sthesis by Orewole (2013) titled "*Solar energy: a sustainable solution to rural electricity problems in Nigeria*" shows that rural communities can use solar PV energy to meet their electricity needs. The study is conducted in the rural parts of Nigeria. The purpose of the study is to find the best alternative technology that offers the best energy source at the least possible cost for off-grid communities and how to regulate and finance theses sources of energy. The study methodology used is documentation of personal experiences of the researcher and theoretical analysis of studies. The relevance of the study is that it gave insight on various energy sources that can be used and how they can be maintained by the off-grid communities. The major findings of the study reveal that off-grid electrification is the best alternative for rural communities such as mini-grids or different home systems depending on factors such as the type of loads, population concentration, resource and equipment availability, and income levels. However, the study solely focuses on households and not healthcare facilities.

A study by Muhammad (2017) titled *"Renewable electrification in Nigeria: renewable energy potentials and distribution for rural development"*. The study aims at assessing the potential of limitless, untapped renewable energy sources, how to support, innovate, cost effective and easily accessible renewable energy for 60-70 percent of Nigerians that do not have access to energy. The study examines secondary data of rural solar PV electrification of particular communities in Nigeria. The relevance of the study is that it focuses on the importance of rural electrification through solar PV and it also provides insight on the benefits of solar PV systems in rural areas of Nigeria. Among the findings of the study, solar energy provided in some states general healthcare facilities in Zurmi,Kaura-Namode, and Gusau, helps to provide electricity during the night for operations and other clinical activities. The study does not provide a clear methodology that is used to select the healthcare facilities in the three states.

A study by the Uganda Ministry of Energy and Mineral Development (2016) titled*"Implementation of solar energy infrastructure in selected education and health facilities under the energy for rural transformation project II (ERT II)"*which aims at assessing whether or not the planning and implementation of solar PV energy infrastructure under rural energy infrastructure component is properly undertaken to achieve the expected timelines, coverage and fine-tuning of the infrastructure. The methodology used in the study is in accordance to the International Organisation of Supreme Audit Institutions (INTOSAI). The study population comprises of 560 schools in 99 districts and 464 health centres from 25 districts. Various methods of data collection and analysis are used in the study. The findings of the study reveal that there are times when solar PV packages installed at facilities are not functioning due to various reasons such as system overload, poor maintenance by system contractors, theft and vandalism of batteries, panels, and switches. The relevance of this study is that it provides insight on some of the challenges faced by healthcare facilities using solar PV for healthcare delivery.This study however, does not extensively propose how the identified problems can be addressed, especially regarding the issues of vandalism and theft of solar PV equipment in rural healthcare facilities.

A study titled *"Feasibility study of a sustainable power system for health facilities: case study of Kolandoto hospital-Tanzania"* was conducted by Twizeyimana and Ndisanga (2016). The purpose of the study is to investigate and evaluate ways solar PV can be used to improve reliability of existing power supply in health facilities in Tanzania. The study adopts an exploratory case study approach with a qualitative method of collecting and analysing data. Data collection methods include measurements, participatory observations, participatory workshops, interviews and discussions. The relevance of this study is that it focuses on solar PV use in healthcare delivery. Among the key findings of the study is that solar PV with backup systems interconnected with power grid and diesel generators is feasible and it provides solutions to energy security problems in Kolandoto hospital. The relevance of the study is that it focuses on highlighting the importance of using hybrid systems for healthcare facilities to have an uninterrupted supply of electricity as opposed to healthcare facilities that only use solar PV systems as the only source of energy.On the other hand, the study limitation is that it does not emphasise how rural healthcare facilities using only solar PV energy can enhance or improve their systems because not all of them can manage to adopt the use of hybrid systems to enhance energy production.

A study bone by Diemuodeke, Addo, Dabipi-Kalia, Oko and Mulugetta (2017) titled *"Domestic energy demand assessment of coastline rural communities with solar electrification"* was done in Nigeria in coastline rural communities of Higer Delta region. The study aims at examining the domestic energy demand of the coastline rural communities in order to determine the best PV solar energy system. The study methodology utilizes questionnaires designed to capture all aspects of energy consumption and basic family background of households. Community visits and interviews are done to examine the existing and future electrical energy demands of rural communities. Interviews are done both in person and on phone due to security concerns in some of the selected communities. The relevance of the study is that it seeks to establish the optimal solar PV system that rural communities require to meet their energy needs. The study provides an idea of the RETs relevance in healthcare delivery in such rural areas. The study shows that the design of an efficient and reliable renewable energy system depends on well-established energy demands of a healthcare facility, its location and its economic status. However, the study mainly focuses on households and does not consider the importance of healthcare facilities energy needs even though it is highlighted as useful for energy to exist in healthcare facilities.

A research conducted by Klunne, Westra, Cox and Gys (2001) tilted "*Improving the availability of PV-systems at South African schools and clinics"* was conducted in two provinces, namely Northern Province and Eastern Cape Province. The study aims at evaluating the technical performance aspects of the PV electrification of rural schools and clinics in South Africa. The study population comprises of 2340 schools and 200 clinics provided with solar PV systems in the Northern Province and Eastern Cape province of South Africa. The population of schools and clinics are stratified according to the program that provides the PV system (RDP, EU and IDT). A representative sample is taken from each project by using simple random sampling. All the schools and clinics in the sample are visited and physically inspected. Headmasters and nurses present at the location are interviewed to learn more about the solar PV system. The study looks at solar PV system performance and identifies challenges faced in the rural health clinics. Among the findings of the study is that clinics suffer technical problems of worn out batteries on the solar PV system despite not facing any other challenges with the system. In this study, the solar PV systems are maintained by the system installers at least twice in the first year of installation.However, the study does not clearly quantify the amount of energy that the healthcare facilities use per day despite indicating that the solar systems installed work well and have less complications for clinics as compared to schools. Additionally the study does not have a clear conceptual model.

A study conducted by Oswald (2012) titled *"The effect of working environment on workers performance: the case of reproductive and child health care in Tarime District"* aims at determining the effect of the working environment on the performance of reproductive and child healthcare providers in Tarime district in Tanzania. The study uses a cross sectional exploratory study in 12 healthcare facilities in the district. The sample comprises one hospital, three health centres and eight dispensaries. The sample also includes 30 healthcare providers and 147 clients for interviews.Data is collected using closed and open ended questionnaires. The data collected isanalysed using SPSS. The relevance of the study is that it shows that the work environment has an effect on the performance of healthcare provider's performance. The study shows that lack of various infrastructures including electricity affects healthcare personnel performance in providing reproductive and child healthcare services. The major findings of the study reveal that the work environment has a significant effect on the performance of healthcare providers in the reproductive and child health unit. The elements identified that affect healthcare delivery include presence of office buildings, availability of drugs and availability of equipment. The study however does not indicate the type of hospitalsampled and why it is used in comparison to the three health centres and eight dispensaries.

A review done by Franco, Shaker, Kalubi and Hostettler (2017) titled, "*A review of sustainable energy access and technologies for healthcare facilities in the global south",* is conducted in the global south, specifically in African countries. The countries included in the study are Egypt, Ghana, Ethiopia, Kenya, Malawi, Rwanda, Tanzania and Uganda. The review aims at providing information about energy needs in health facilities that are in off-grid locations. This review is relevant because it focuses on providing information on alternative energy sources of off-grid healthcare facilities and provides insight for satisfying peak demands off grid-connected hospitals. The findings of the study reveal that estimates on energy needs of different levels of healthcare facilities are a function of patient capacity and type of healthcare services provided. The review pinpoints out strengths and limitations of several energy sources that are used to meet healthcare needs in healthcare facilities. The review also showsthat fossil-fuel generators are the main energy sources in large healthcare facilities because of their low investment cost. Despite fossil-fuel generation being the main source of energy for many healthcare centres, the review shows that new methods of energy production using renewable sources such as solar PV have emerged over the years. The review, further points out that depending on a health facility size, and the services it offered, it is of great importance that it had certain equipment that require a stable supply of electricity in order for them to be used. The study also elaborates that healthcare equipment are classified into three categories; basic services, medical equipment and laboratory equipment which all require energy to be used. Additionally, the review emphasizes the need for healthcare facilities to have access to reliable, affordable, sustainable energy in order to provide quality healthcare services, regardless of the size of the healthcare facility. Health facilities located in remote areas are required to be equipped with on-site energy production systems to meet the development of affordable energy and good health for all. This review is relevant because it provides insights on the need to consider the size and types of services provided so as to help estimate its energy consumption patterns. However, the review does not provide insight on the methodology used on the group of countries sampled to generate the information that is reviewed in the document on the studies that have been conducted in the global south. This implies that there could have been a biased toward the selection of African countries in the global south. The research should have considered selecting countries from other continents in the global south so as to eliminate bias.

A World Bank (2010) research titled "*Addressing the electricity access gaps, background paper for World Bank group energy sector strategy",* aims at addressing the electricity access gap in sub-Saharan Africa and South Asia. The research uses desk research methods to collect data from case studies done by various specialists and publications associated to the World Bank. This research is relevant because it provides information on success reviews on how energy has been supplied to rural communities through electrical mini-grids powered by diesel and/or mini-hydro generators. The research points out that achieving universal access to electricity is one of the most important goals set for the energy sector by governments in the developing world. The research shows that energy is important for basic activities ranging from lighting, refrigeration, running household appliances and operating equipment. The research also shows that sustainable availability of electricity can help promote better health and education services. Emphasis is shown in the research on how low electrification rates arein sub-Saharan Africa, which is rated the lowest in the world at only 29 percent, while Asia is rated at 60 percent, Middle East 89 percent, East Africa and the Pacific 90 percent, Latin America 93 percent and the highest being North America with 99 percent electrification rate. These findings show that there is need for more studies to be conducted on how to improve the low percentage rate of electrification in sub-Saharan African countries. Also, much has to be done to assess the reliability of sources of electricity such as solar PV systems. The document however does not necessarily focus on how energy would improve the health sector, but merely considers all other social economic benefits of electricity, especially in sub-Saharan Africa. Health is a very important sector and hence the role of energy in the healthcare sector has to be further researched on.

A Ph.D thesis done by Grosh (2015) titled "*The role of access to electricity in development processes: approaching energy poverty through innovation",* was conducted in two different places, Peru and Bangladesh. The general aim of the study is to address the role of electricity in development processes with an aim to provide better understanding of the measurement and design of interventions targeting energy poverty in developing countries. The methodology adopted in the study is a mixed methodology of case studies. The relevance of this study is that it looks at off-grid solar PVelectrification market, the successes and drawbacks encountered. The findings of the study show how different sources of energy performed in provision of healthcare delivery. The study however does not provide insight on specific services that are affected by energy shortages in Peru and Bangladesh.

A research done Jimenez and Olson (1998) titled "*Renewable energy for rural health clinics",* aims at assessing healthcare electrical needs, select appropriate and cost-effective technologies for health facilities in rural areas in the United States of America. The research also aims at helping readers to be able to accurately assess their health facilities electrical needs and be able to select relevant and cost effective technologies to meet and maintain their energy needs. Data is collected through desk research. This research is relevant because it provides a broad understanding of technical, social and organisational aspects of healthcare facility energy needs for healthcare delivery. The findings of the research reveal that despite solar PV systems being resourceful other micro/mini renewable sources of electricity can be considered because solar PV systems are expensive to buy, setup, and also have maintenance costs. The research shows that some scholars regard the solar PV system maintenance costs to be minimal. In fact, the PV systems require careful setup, installation and maintenance by experts in order for them to serve their life expectancy of more than five years. If poor installation is done, the solar PV system will require constant replacement of parts such as batteries. The research shows that there is poor planning and budgeting at national level for batteries, equipment, manpower and transportation to sites where solar PV systems are installed or required. Because of this, excellent technologies become useless and increase the number of dead systems sitting around in remote areas, decreasing the image of renewable energy systems. This study is relevant because it provides information on some challenges encountered by healthcare facilities using solar energy. However, it does not provide specific information on how some of the challenges are addressed.

2.3 Conclusion

This chapter has reviewed literature that pertains to the role that energy plays in public healthcare delivery. The literature shows that majority if the rural healthcare facilities use solar PV energy systems while others use hybrid systems of mini-hydroelectric power systems and solar PV systems. Much of the literature shows common challenges that healthcare facilities face due to lack of adequate source and supply of energy which as a results impedes efficient and effective healthcare delivery. Common challenges faced include poor system installation and maintenance practices which as a result destroy system equipment such as batteries. Other challenges include poor availability of drugs and vaccines, inability to work after sunset because of poor energy generation. The literature also shows that there is little consistent research that has been conducted of this nature in many African countries. The literature reviews shows that in as much as energy is considered as an important requirement in healthcare delivery, information is not readily available on the reliability of solar PV systems in rural healthcare delivery. However, little research has been undertaken focussing on the extent of reliability of solar PV systems in provision of rural healthcare delivery as it relates to healthcare delivery. It is hence the reason that this study aims at filling the gap of reliability by investigating the efficiency and effectiveness of solar PV in rural healthcare delivery in Mumbwa District. Additionally this study also seeks to investigate the major challenges faced by rural healthcare facilities using solar PV systems as a primary source of energy for healthcare delivery in Mumbwa District.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This section presents themethodology used in the study. It specifically focuses on the research design, research population, sample size, sources of data, sampling methods, methods of data collection and analysis are presented and explained.

3.1.1 Research Design

A mixed methods design was adopted as the research design. The mixed methods design was adopted because its nature provided detailed consideration on the development of solar PV energy use in rural healthcare delivery in Mumbwa District. Also, this approach to the study enabled the researcher acquire insights about the phenomena.

Both quantitative and qualitative methods of data collection were used. Quantitative data was used because it enabled the researcher to quantify information that was collected from the field. On the other hand, qualitative data was also collected because it enabled the researcher to acquire in-depth information about the study. The use of both quantitative and qualitative data ensured that the shortfall of the quantitative data collected would be compensated for by addition of qualitative data that was collected.

3.1.2 Research Population

Mumbwa District is located in Central province of Zambia alongside six other districts. These districts include Chibombo, Itezihi-Tezhi, Kabwe, Kapiri-Mposhi, Mukushi and Serenje Districts. Mumbwa District, as of 2016, had a population of about 225,659 people. The population comprises 50.4 percent females and 49.6 percent males, of which 87.3 percent were located in rural areas while 12.7 percent were in urban areas (CSO, 2016). Despite the fact that Mumbwa District had 33 healthcare facilities, it did not have Third and Second Level Hospitals. However, it had two First Level Hospitals, one Urban Healthcare Facility, 24 Rural Healthcare Facilities and six Health Posts (MOH, 2013).

3.1.3 Sample Size

The overall sample size of the study comprised 116 respondents. Mumbwa District had a total of 16 wards, from which four wards were selected into the sample. From the four wards selected, five rural healthcare facilities were drawn. From each of the five healthcare facilities selected into the sample, the following samples were selected: five healthcare facility administrator/superintendent/in-charge, 10 healthcare personnel, three key informants and 98 end-users. The sample of end-users selected from each healthcare facility were broken down as follows: 23 end-users from Lutale, 28 end-users from Lungobe, 14 end-users from Nakanjoli, eight end-users from Nalusanga and 25 end-users from Nambala. Additionally, three key informants, namely the Mumbwa District Medical Officer, Mumbwa District Healthcare Facility Technician and an Engineer from REA were also included in the sample.

3.1.4 Sources of Data

The study used both primary and secondary sources of data.Secondary data was collected through desk research from various sources such as relevant literature and studies done by various scholars,organisations, health facility reports and publications, as well as relevant information from the internet. Secondary data was used because it provided information and insight on what had been researched on in the world regarding the topic.Primary data was collected from key informants, healthcare personnel and end-users.

3.1.5 Sampling Methods

Mumbwa District had 33 healthcare facilities out of which 11 were not connected to hydroelectricity. The 11 rural healthcare facilities were spread across eight wards in the district. From the eight wards, four wards were selected into the sample through simple random sampling, using the lottery method.The wards selected were Chibolyoward, Lutale ward, Nalusanga ward, and Nambala ward. The four wards selected had a total of six rural healthcare facilities. Chibolyo ward and Nalusanga ward each had two rural healthcare facilities while Lutale ward and Nambala ward each had one rural healthcare facility.Chibolyo ward hadLutale healthcare facility and Nakanjoli healthcare facility; Nalusanga ward had Nalusanga healthcare facility and Chunga healthcare facility; Lutale ward hadLungobe healthcare facility; and Nambala ward hadNambala healthcare facility.

Five healthcare facilities were selected from the six healthcare facilities in the four wards. Two healthcare facilities were purposively selected from Lutale and Nambala wards because each ward had only one healthcare facility. The purposively selected healthcare facilities were Lungobe and Nambala healthcare facilities. Threemore healthcare facilities were further selected using lottery method of simple random sampling from the remaining two wards, Chibolyo ward and Nalusanga ward. The three healthcare facilities randomly selected were Nalusanga,Lutale and Nakanjoli. The aim of sampling rural healthcare facilities was initially to ensure that in each ward one healthcare facility was sampled. However, because Lutale ward and Nambala ward each had one healthcare facility, they were purposively sampled and the remaining healthcare facilities were selected using simple random sampling using the lottery method.

After selecting the five rural healthcare facilities, end-users from each healthcare facility's catchment population were selected using weighted stratified sampling. This was done by dividing each healthcare facility into strata by the total population of the five rural healthcare facilities and multiplying by the required number of respondents. This was done for each healthcare facility as illustrated: Lutale 8,744/37,817 x 98 = 23 respondents; Lungobe 10,930/37,817 x 98 = 28 respondents; Nakanjoli 5,465/37,817 x 98 = 14 respondents; Nalusanga 3,060/37,817 x 98 = 8 respondents; and Nambala 9,618/37,817 x 98 = 25 respondents.

Table 3.1.5 below illustrates the sampling procedure used and the number of end-users sampled from each of the five healthcarefacilities' catchment population in Mumbwa District:

Table 3.1.5 (a): Healthcare Facility, Catchment Population and End-user Sample Size

No.	Health Facility	Catchment Population	Stratum/population x 98
1.	Lutale	8,744	23
2.	Lungobe	10,930	28
3.	Nakanjoli	5,465	14
4.	Nalusanga	3,060	8
5.	Nambala	9,618	25
	Total:	**37,817**	**98**

End-users from each healthcare facility's catchment population were conveniently sampled, specifically, heads of households.

Then at each of the sampled healthcare facilities, one healthcare facility administrator/superintendent/in-charge was conveniently sampled and two non-administrative healthcare personnel were randomly sampled after an establishment list was requested for each of the five rural healthcare facilities. This information is presented in Table 3.1.5 (b) below.

Table 3.1.5 (b): Healthcare Facility Administrator/Superintendent/In-charge and Non-Administrative Healthcare Personnel Sample Size

No.	Healthcare Facility Administrator/Superintendent/In-charge and Non-Administrative Healthcare Personnel	Sample Size
1	Healthcare Facility Administrator/Superintendent/In-charge	5
2	Non-Administrative Healthcare Personnel	10
	Total	**15**

The other categories of respondents were Key informants comprising one official from REA, the Mumbwa District Medical Officer, and District Healthcare Facility Technician who were purposively sampled. This information is illustrated in Table 3.1.5 below.

Table 3.1.5 (c): Key Informants

No.	Category of Key Informants	Sample Size
1.	REA official	1
2.	District Medical Officer	1
3.	District Healthcare Facility Technician	1
	TOTAL	**3**

The sample comprises of one REA official, the District Medical Officer, the District Healthcare Facility Technician, five hospital administrators/superintendents/in-charge, 10 health personnel, and 98 end-users, which comes to a totalsample size of 116 respondents.

3.1.6 Methods of Data Collection

Data were collected from both primary and secondary sources. Primary data were collected using structured interview guides and semi-structured questionnaires. The interview guides comprised a list of structured questions that were used to collect qualitative data. The interview guides were used to collect data from key informants.

Semi-structured questionnaires were used to collect both qualitative and quantitative data from healthcare personnel and end-users. The semi-structured questionnaires contained closed ended questions, open ended questions and partially closed ended questions. Open ended, closed ended and partially closed ended questionnaires enabled collection of both quantitative and qualitative data. All the semi-structured questionnaires were administered by the researcher because rural areas were considered to be mostly characterized by low levels of literacy meaning that most of the respondents in some locations would be unable to read and write properly on their own. This enabled the researcher to acquire more specific information as well as other information that was relevant to the study. Primary data was collected in order to gain more detailed insight about the research.

Secondary sources of data were collected using desk research, journal articles, visiting the library and reading relevant literature on rural healthcare delivery and energy. This information helped provide a broader view on what had been written relating to the research topic.

Data was collected from the 12th of February to the 19th of February, 2018.

3.1.7 Methods of Data Analysis

Qualitative data collected from the semi-structured questionnaire was analysed using content analysis where data were categorized onto sets of responses and insights. Quantitative data collected from the same semi-structured questionnaires wereanalysed using Statistical Package for Social Sciences (SPSS) to generate frequency tables and simple descriptives. Excel was used to create tables and graphs for data generated using SPSS. Data collected from interview guides from key informants was analysed using content analysis where information was coded according to themes that were developed from the analysis of data collected. The themes used to analyse the data were categorised as cost, continuity of service provision and challenges.

3.1.8 Ethical Consideration

The researcher ensured to obtain permission from relevant authorities before collecting data from the field. This was done by ensuring that the research was ethically cleared and the researcher was granted clearance by the School of Humanities and Social Sciences Ethical Clearance Committee with ethical clearance reference No. HSSREC: 2018-AUG-004. Furthermore, during data collection the researcher ensured that respondents were clearly explained to about their rights as participants and how confidentiality of their identities would be ensured during data collection and at the time of writing the final research report. None of the respondent's personal details have been published in this dissertation.

3.1.9 Limitations of the Study

The researcher encountered some challenges in the field during data collection. The challenges are listed below:

During the time of data collection, some end-users that were located near the healthcare facility were unavailable as they were in their fields and in some cases had to be followed into their fields in order to be interviewed. This was because most of the end-users lived near their fields. This however did not affect the quality of data collected; it only prolonged the time taken to collect the data.

Some of the end-users of the healthcare facilities could only communicate in Tonga and Kaonde hence a translator was required to collect data from such respondents because the researcher could not speak Tonga and Kaonde. A translator was used to help translate the questions to the respondents and also to translate the responses to the researcher. This challenge may have made it difficult to probe certain responses given by some end-users, but it did not affect the quality of the data collected.

Another challenge faced by the researcher was that the healthcare personnel at the healthcare facilities were understaffed and hence was a challenge to create sufficient time to interview them. On several occasions the researcher had to wait for hours before healthcare personnel could be available for interviews.This as a result increased the number of days the researcher spent in the field collecting data. This may have affected the quality of responses given by healthcare personnel as they may have not been able to fully articulate their experiences or views regarding the research.

CHAPTER FOUR

AFFORDABILITY OF SOLAR PV ENERGY IN RURAL HEALTHCARE DELIVERY

4.1 Introduction

The aim of this chapter is to present and discuss the research findings on the affordability of solar PV sources of energy in rural healthcare delivery inMumbwa District. The chapter begins by presenting and discussing the findings related to affordability which includes capacity to purchase solar PV systems, production and storage capacity of solar energy and capacity to maintain solar PV systems. Thereafter a conclusion is provided.

As stated in the theoretical framework in chapter one, affordability in this dissertation refers to the ability to purchase, install and utilize a solar PV system at a rural healthcare facility without having to forfeit or curtail other essential healthcare inputs. Affordability is assessed by taking into account a rural healthcare facilities solar PV system capacity, ensuring that the system has all the basic system equipment for it to function. The basic solar PV system equipment includes, solar panels, deep-cycle batteries, inverters, and charge controllers. Affordability is also assessed by taking into account a healthcare facility's solar PV system's ability to produce and store solar energy for day to day use, especially after sunset. Affordability is also determined by taking into account a healthcare facilities ability/capacity to properly maintain its solar PV system. This is done by understanding how the solar PV energy system is equipped, maintained or how well the system is kept.

As earlier stated, the identified measures of affordability are the ability to purchase a basic solar PV system, ability to produce and store energy using the solar PVsystem and ability to maintain the solar PV system by the healthcare facility. These factors are used in the discussion as they help provide responses from the District Medical Officer, Healthcare Facility Technician, HealthCare Personnel, End-users, and Healthcare Facility Administrator/Superintendent/In-charge. Thereafter, based on the findings and discussions, the chapter is closed with a conclusion.

4.2 Rural Healthcare Facilities' Solar PV System Capacities

The findings of the research show that out of the five sampled healthcare facilities, Lutale, Lungobe, Nakanjoli, Nalusanga and Nambala, one healthcare facility, Lutale, has 14 solar panels, Lungobe has five, Nakanjoli has three solar panels, Nalusanga has three solar panels and Nambala has four solar panels. However despite Lutale having the most number of solar panels, the rural healthcare facility only has one inverter and two 12V deep-cycle batteries on its solar PV system for energy storage. Despite having a good number of solar panels, Lutale is hardly better off than the other rural healthcare facilities sampled because it only has one inverter and two batteries installed on its entire solar PV system. Such a system is only more useful during the day when the sun is shining and DC appliances are directly connected to the solar PV system can be used. However, in order for Lutale to successfully utilize the benefit of having 14 solar panels, it requires at least two or more inverters and four or more deep-cycle batteries for energy storage to use during the night or in seasons when the sun is not always shining, such as the cold and rainy seasons. Otherwise, the 14 solar panels are only useful for DC appliances, such as refrigerators during the day but not so useful for during the night, after sunset. This finding relates to the conceptual framework in the study that shows that if one part of a system is not working, it affects other functions of the entire system.

The study also reveals that Lungobe rural healthcare facility has five solar panels, one inverter and two 12V deep-cycle batteries whileNakanjoli and Nalusanga rural healthcare facilities each have three solar panels. The study reveals thatNalusanga used to have four solar panels but one was stolen at the time of data collection. An interview with the administrators/superintendents/in-charge at Nalusanga reveals that "the solar panels we have are just for the vaccine fridge, so the facility has no lighting… there were four panels but one was stolen in the night so there are now three" (administrators/superintendents/in-charge). This indicates that other than facing an already existing challenge of inadequate solar PV system capacities at most of the rural healthcare facilities, there also exists a problem of theft of solar PV panels in rural areas. This as a result affects the provision of healthcare delivery, because in this particular case, the healthcare facility is left in darkness during the night and hardly provides night time services. This can be attributed to poor security measures put in place due to the fact that most of the healthcare facilities are left empty during the night.

The study also shows that Nakanjoli rural healthcare facility hasthree batteries, one of which is a car battery and one inverter while Nalusanga does not have any battery or inverter on its solar PV system. This shows that even if some rural healthcare facilities have batteries, some of the available batteries on the solar PV systems are not the appropriate ones and hence affects the entire solar PV system. This is so because according to the District Healthcare Facility Technician, car batteries are not as durable as deep cycle batteries and hence easily get discharged after being used for a short period of time (District Healthcare Facility Technician, 20 February, 2018). Once a car battery is discharged consistently for a short period of time, it easily gets damaged and cannot be used again, unlike deep-cycle batteries that can withstand discharge for a much longer period of time. Additionally, as earlier pointed out, some of the rural healthcare facilities do not have any batteries at all on their solar PV system which as a result makes it impossible to provide medical services using medical appliances that use AC electricity and it also makes it hard for such a healthcare facility to provide nigh time services. This as a result makes the solar PV system seem unreliable in rural setups.

On the other hand, the study shows that Nambala rural healthcare facility has four solar panels, two inverters and three batteries, two 12V deep-cycle batteries and one car battery. In addition, the findings of the study also show that on average, majority of the healthcare facilities have five or less solar panels and also have three or less recommended deep-cycle batteries for energy storage on their solar PV systems. Some of the rural healthcare facilities that do not have batteries do not use the recommended types after the ones they received from the District Medical Office stop working. Majority of the rural healthcare facilities therefore resort to using car batteries as a substitute for deep-cycle batteries as means of energy storage, which as a result cripples the functionality of the solar PV system. This information is shown in Table 4.2 below.

Table 4.2: Rural healthcare Facilities' Solar PV System Equipment

RHC Facility name	No. Solar Panels	No. Batteries	No. Invertors
Lutale	14	2	1
Lungobe	5	2	1
Nakanjoli	3	3 (1 car battery)	1
Nalusanga	3 (were 4, one stolen)	0	0
Nambala	4	3 (1 car battery)	2

Source: Field data, 2018

4.3 Rural Healthcare Facility’s Ability to Produce and Store Energy using Solar PV Systems

A solar system installed at a rural healthcare facility enables the absorption of sunlight, through irradiation, to be converted into electrical energy and then either directly used as electricity to power appliances or medical equipment or stored in batteries electrochemically for later use. Solar PV energy generating equipment available at the rural healthcare facilities plays an important role in determining the reliability of the energy produced. A basic solar PV system according to Admasu (2010) is expected to consist of solar panel(s), charge controller(s), inverter(s), and battery(s), preferably deep-cycle batteries for energy storage. However, some solar PV systems do not necessarily require inverters because some appliances use Direct Current to function. It is Important to note though, that the number of solar panels and number of batteries installed on a solar PV system has a huge bearing on the amount of energy that is produced and stored at a rural healthcare facility for its day and night energy needs. The higher the number of solar PV panels and number of deep-cycle batteries installed on the solar PV system, the more energy is expected to be produced and stored in batteries for immediate or later use.

The research findings reveal that none of the rural healthcare facilities visited in Mumbwa District has the capacity to adequately produce and store energy using their existing solar PV systems. The District Healthcare Facility Technician reveals that majority of the rural healthcare facilities do not have adequate amount of equipment installed on their solar PV systems to support sufficient absorption, conversion and storage of energy from the sun. The District Health Facility Technician revealed in an interview conducted on 20 February, 2018, stating that

> Many of these rural healthcare facilities do not have enough [solar PV] equipment, especially deep-cycle batteries which are very expensive to buy for storage of energy electrochemically to be used when it gets dark… they depend on car batteries which are not recommended because they are designed for vehicles (Mumbwa District Health Facility Technician).

The District Health Facility Technician further states that a rural healthcare facility using solar PV as a primary source of energy needs at least four or more 12V or 24V deep-cycle batteries installed on the system in order to produce energy that can be properly utilized for various medical appliances. However, the study shows that majority of the rural healthcare facilities have two or less deep-cycle batteries on their solar PV systems. On the other hand, the study also reveals that some of the rural healthcare facilities do not even have a single battery installed on their solar PV system. Instead, the rural healthcare facility in question only has two solar panels connected directly to a refrigerator. This implies that the rural healthcare facility cannot store energy absorbed from the sun and hence cannot use the solar PV system for anything else other than powering the refrigerator during the day. The District Healthcare Facility Technician was asked about the average amount of electricity produced using existing solar PV systems installed in rural healthcare facilities, he indicated that on average majority of the rural healthcare facilities that used solar PV systems produced and consumed around 4kWh or less per day as opposed to producing around 10kWh/day as recommended by Al-Akori (2014) when all system equipment is available. The shortfall of energy required in more than 90 percent of the healthcare facilities was 6kWh, which was not a good sign. Most of the systems installed could not even produce half of the amount of energy needed to operate a rural healthcare facility. This was mainly attributed to the existing incomplete solar PV systems at the rural healthcare facilities.

The District Healthcare Facility Technician was also asked to state the required or minimum required solar PV system equipment needed to produce energy at a rural healthcare facility which would enable it to utilize electricity for avariety of medical and non-medical equipment. The District Healthcare Facility Technician indicated that in order for sufficient energy to be produced by a solar PV system to aid rural healthcare delivery it needed to have at least seven 100W solar panels, four 12V deep-cycle batteries (installed in parallel), two charge controllers and two invertors (with a capacity to convert 1000W to 1kW/hour). Such a solar PV system is estimated to produce about 8.784-10kWh/day. However, most of the rural healthcare facilities are unable to produce this amount of energy because most of them lack complete solar PV system equipment.

Healthcare administrators/superintendents/in-charge at all the five rural healthcare facilities were asked about their facilities' ability to produce and store sufficient energy using the existing solar PV systems. The findings reveal that all the five healthcare facilities were able to produce energy but not in sufficient quantities. Healthcare administrators/superintendents/in-chargeindicated that despite being able to produce electricity using their solar PV systems, medical equipment could not be used because the amount of energy produced was not enough to operate the equipment. One administrators/superintendents/in-charge stated that “the only thing we are able to use solar energy for is to keep lights on inside, but we do not use it to operate medical equipment such as electrical beds for patients” (Interview with Nambala RHF administrators/superintendents/in-charge, February, 2018).

When asked about the amount of energy their solar PV systems produced, none of the Healthcare administrators/superintendents/in-chargeknew how much energy was produced. Additionally, the findings revealed that none of Healthcare administrators/superintendents/in-chargeknew how much energy their healthcare facilities needed on a daily basis to support healthcare delivery. The healthcare facility In-charge at each healthcare facility indicate that the District Healthcare Facility Technician was in a better position to know the amount of energy that is produced and the amount of energy needed on a daily basis to support the daily energy needs of the healthcare facility. The results show that none of the Healthcare administrators/superintendents/in-chargecategory of respondents have knowledge of their solar PV system’s capacity and their healthcare facility daily energy consumption requirements.The findings of this study are similar to a study done by Klunne, Westra, Cox, and Gys (2001) whose study found that even though some clinics in rural areas of South Africa have solar PV systems installed, the clinics face challenges with energy storage once the batteries on the system getworn out. This greatly affects rural healthcare delivery especially in times of cloud cover in the rainy and cold seasons whensolar PV panels cannotabsorb sunlight energy in large quantities to produce electricity. Also, it was difficult to charge batteries at a normal rate in these seasons when sunshine is not at its peak for long periods of time.

The study findings also show that despite having solar PV systems installed at the rural healthcare facilities, the energy output isnot sufficient because it cannot be properly used for lighting various rooms at the healthcare facilities. The study reveals that only one or two rooms would have light while the rest of the healthcare facility was left in total darkness.The study shows that majority of the end-users indicate that their rural healthcare facilities that offered night time services normally only had one room with light available and the rest of the rooms at the rural healthcare facilities were left in darkness.

The study reveals that 10 percent of the rural healthcare facilities cannot even offer night time services because they do not have any batteries on their solar PV systems to store energy for use at night. This implies that if an emergency occurs, the end-users within the community have to follow the healthcare personnel at his or her staff house to seek medical assistance. In addition to the inability to provide night time services, some healthcare facilities are reported to open as late as 9 hours in the morning and would be closed by 15:30 in the afternoon. This drastically reduces the number of working hours of some healthcare facilities and hence also reduces the hours of service access for the end-users. These findings are similar with a study done by Welland (2017), which found that poor energy infrastructure or lack of adequate energy infrastructure affects the quality of healthcare delivery provided by rural healthcare facilities as it reduces operation hours which result into an underserved and unsatisfied population and at the same time lead to reduced staff morale.

4.4 Rural Healthcare Facilities Ability to Maintain the Solar PV System

The ability of a healthcare facility to maintain the solar PV system, as a primary source of energy plays an important role in determining the reliability of the system over a given period of time. Proper maintenanceof the solar PV systems entails that the system components are in the correct condition and are cleaned and replaced as soon as need arises. Proper maintenance involves cleaning the solar panels to remove dust and water that affect irradiance over time. Additionally it is important to ensure that battery terminals do not develop rust and that battery fluids are kept at the required level as well as ensuring that all components of the system are properly connected. If the system is properly maintained, it produces an estimated quantity of energy and lasts much longer. USAID (2009) indicates that it is estimated that a properly maintained solar PV system can last up to 20-30 years. If the system is not properly maintained, it becomes prone to many breakdowns and has a shorter lifespan and hence lowers the quantity of energy produced.

In order to determine the ability of the facility to maintain the source of energy, the District Healthcare Facility Technician, Healthcare Administrator/Superintendent/In-charge, Healthcare Personnel and End-users were asked about their views on the solar PV systems maintenance practices available at the rural healthcare facilities in Mumbwa District.

Note that this research component is mainly qualitative because the instruments used to collect information are interview guides and the targeted respondents are key informants. However, responses related to the discussion provided by healthcare personnel and end-users are also included.

An interview with the Mumbwa District Healthcare Facility Technician on 14 February, 2018 reveals that most of the healthcare facilities that are using solar PV as their primary source of energy have solar PV systems that have been installed by donors and hence required less maintenance from the technician at the time they had been installed. However, the Mumbwa District Healthcare Facility Technician reveals that maintenance of the solar PV systems is initially conducted quarterly and mainly requires contacts in the system to be checked for corrosion and ensuring that water does not enter the solar panels during the rainy season. Maintenance also requiresensuring that dust and leaves do not settle on the solar PV panels. The interview reveals that the solar PV systems, however, are only checked on request by Administrator/Superintendent/In-chargethrough the District Medical Office when a problem is reported. This is due to the fact that there is only one technician in the district who is responsible for overseeing all the healthcare facility solar PV technical needs and hence has to move from one healthcare facility to another attending to both solar PV system faults and other electrical challenges. Because of being the only technician in the district, the technician is overwhelmed with work as he most often gets requests to visit healthcare facilities in different locations concurrently within a short period of time. Sometimes the Mumbwa District Healthcare Facility Technician has to work overtime to ensure that the solar PV systems are working correctly (Interview with the Mumbwa Healthcare Facility Technician, 14 February 2018). Lack of technicians on site at the rural healthcare facilities is attributed mainly to unavailability of finances to ensure that each healthcare facility has its own technician. This implies that not only do rural healthcare facilities lack adequate medical staff, but they also have inadequate technical staff in the district.

The Mumbwa District Healthcare Facility Technician also revealed that finances/resources required tomaintain solar PV panels and batteries are another factor that makes it difficult for rural healthcare facilities to maintain and utilize their solar PV systems correctly. The Mumbwa District Healthcare Facility Technician disclosed that resources are released based on request in an annual budget compiled by the District

Medical Office. When funds are released, healthcare facilities listed in the budget receive the equipment they requested for purchased and installed onto their solar PV system so that the existing fault can be eliminated. If a part of the solar PV system needs replacement and the budget hasalready been submitted, the healthcare facility in question has to wait for the next budget to be drawn and submitted to MOH or the rural healthcare facility itself has to find alternative means to sustain the solar PV system as they wait for the equipment to be purchased by the District Medical Office (Interview with the Mumbwa Healthcare Facility Technician, 14 February 2018). The fact that these rural healthcare facilities depend on the MOH through the DMO to acquire and replace solar PV system equipment makes it difficult to ensure proper maintenance practices. This is because every time any component of the solar PV system malfunctions or gets damaged, the healthcare facility has to wait for long periods of time to have it replaced. The district health facility technician indicated that it sometimes took the District Medical Office over five years just to replace a solar panel or deep-cycle batteries as they are very expensive and cannot be sourced by the rural healthcare facilities on their own. This is the reason my most of the rural healthcare facilities use car batteries on the solar PV system when the deep-cycle batteries get damaged.

Healthcare Administrator/Superintendent/In-chargeat all the sampled rural healthcare facilities in Mumbwa District indicates that the healthcare facilities on their own do not temper with the solar energy systems once installed. Whenever a fault occurred they have to request for the District Healthcare Facility Technician through the DMO to visit the healthcare facility to attend to a problem whenever one is encountered. This is because the healthcare facilities do not have an expert technician on site readily available to check the functionality of the system on a regular basis. However, one healthcare personnel at one of the five healthcare facilities revealed that sometimes when a fault occurred on the solar PV system, he would take it upon himself to fix the problem because he had personal interest in electronics despite being a medical personnel. The healthcare personnel further revealed that, he would sometimes attend to the fault on the sola PV system because it sometimes took days for the District Healthcare Facility Technician to arrive on site to fix a fault that had been reported to the District Medical Office. This entails that due to the fact that there is lack of adequate technicians, some members of the healthcare system would temper with the system hence making it weaker because these systems require the attention of a trained technician to attend to them.

The findings implied that if the healthcare facilities experienced a fault on the solar PV system, they themselves had no capacity to rectify the problem. They had to wait on the District Healthcare Facility Technician to travel to the respective site to fix the problem. This meant that any service that required energy to be provided had to be postponed to a later time when energy was restored by the District Healthcare Facility Technician. In cases of an emergency and the District Healthcare Facility Technician is not available at a given point the healthcare facility has to establish alternative measures or operate without electricity until the problem has been sorted. This as a result affects rural healthcare delivery of some services in the process (Interview with Rural Healthcare Facility Management, In-charge, Mumbwa, February 2018).

End-users were asked to state whether or not they thought that the solar PV systems were properly maintained by their healthcare facilities. The research results revealed that 52 percent of the end-users felt that the solar PV systems were not properly maintained, while 44 percent of the end-users felt that the solar PV systems were properly maintained. The remaining four percent of end-users indicated that they were not sure whether or not the solar PV systems were properly maintained. This information is presented in the Figure 4.4 below.

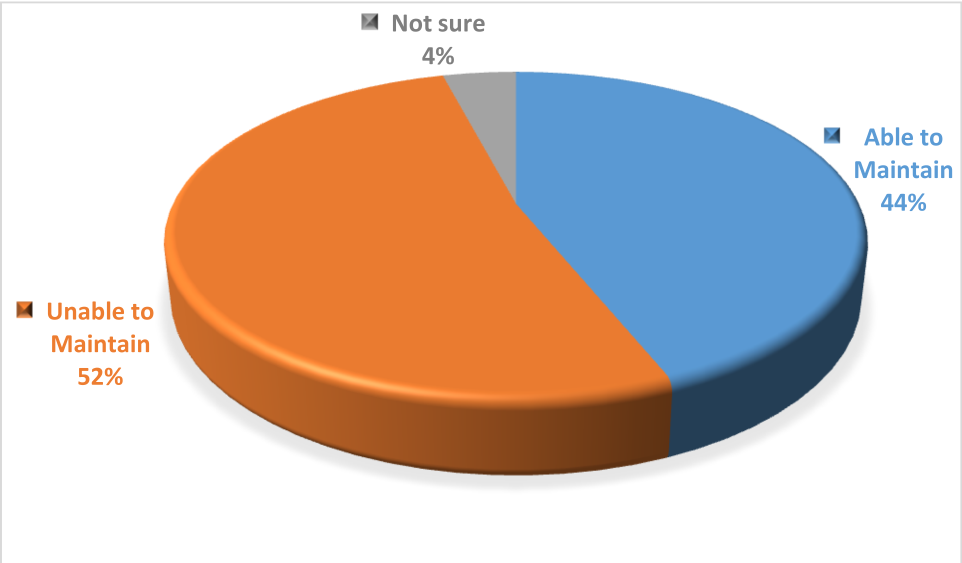

Figure 4.4 Healthcare Facilities' Ability to maintain Solar PV Energy System as reported by End-users

4.5 Time that Public Healthcare Facilities have to Provide Healthcare Services using Solar PV Energy

If a healthcare facility has a good and reliable supply of electricity from its solar PV system, service delivery is expected to become faster and easier. This isbecause services and tests can easily be done especially during the night when light is needed to see properly for examination and or observation purposes. If electricity is absent, services such as simple operations cannot be done because equipment cannot be properly sterilized. Healthcare personnel therefore cannot see properly when light is not available. Additionally, night time services or treatment cannot be provided without electricity available at the rural healthcare facility (Knoth, 2014).

End-users were asked whether or not the availability of electricity affects the rate at which healthcare services are accessed. The findings are presented in Figure 4.5 below.

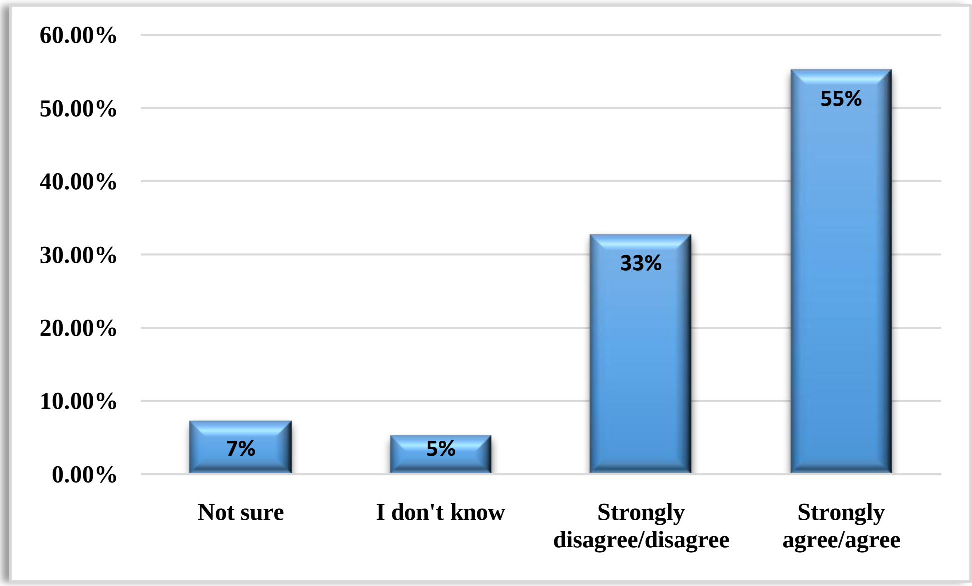

Figure 4.5 End-users' Response to whether Availability of Solar PV Electricity Affected Healthcare Access

The findings of the study show that majority of the end users,19 percent 'agreed', 35 percent 'strongly agreed',totalling to 55 percent, that the absence of solar PV electricity increased the amount of time it took to receive attention from the healthcare personnel, especially during the evening and night hours. The study showed that 31 percent of end-users 'disagreed', two percent of end-users 'strongly disagreed'that time taken to receive healthcare services was not affected.Thistotalled to 33 percent of the end-users. On the other hand, five percent of the end-users indicated that they did not know while seven percent of the end-users indicated that they were not sure.

The interpretation of the findings is that the end-users feel that they receive healthcare servicesmuch faster on days they visit the healthcare facilities and find that electricity was available as opposed to days when they do not find electricity. When the rural healthcare facility does not have solar PV energy it affects the condition of service deliveryas the healthcare providers are unable to examine and determine how critical some ofthe illnesses or conditions are. Lack of electricity makes it difficult to identify some illnesses when equipment needed to examine patients cannot be used because there is no electricity. One of the healthcare personnel revealed that they have to transport samples of blood and fluid to Mumbwa district hospital for necessary tests to be done and hence patients have to be requested to return on specific dates for them to get their medical results.

This makes it difficult to eliminate some illnesses before they advance to critical stages because by the time tests results are returning, a patient's condition may have become advanced. Also, when electricity is not available, it is difficult to conduct simple surgery services immediately because healthcare personnel have to start a brazier or set up firewood in order to sterilize surgical equipment before it can be used. This increases the amount of time it takes to attend to patients as opposed to scenarios whenreliable quantities of solar PV energy are readily available. The study found that when there is no electricity healthcare personnel take longer to attend to patients and their moral to work is also to an extent negatively affected. The findings of this study are similar to a research done by Oswald (2012) which shows that the work environment has the strongest effect on the rate at which employees in healthcare facilities provided services to patients. One of the environmental factors identified in Oswald's study is that what affects healthcare personnel performance is the availability of energy which is required to make use of various medical activities such as preserving drugs and operating various medical equipment. Staff demoralization entails that they do not want to work for a long time in such an area and hence most of the experienced staff prefer to transfer to places that are not in remote areas.

4.6 Adequacy of Healthcare Services Received at the Rural Healthcare Facilities

End-users of the rural healthcare facilities in Mumbwa District were asked if they are always able to receive all the healthcare services that they visited the healthcare facilities for.The study revealed that 55 percent of the end-users said ‘no’, while 39 percent of the end-users said ‘yes’ and six percent said ‘sometimes’. The findings are presented in Figure 4.6 below.

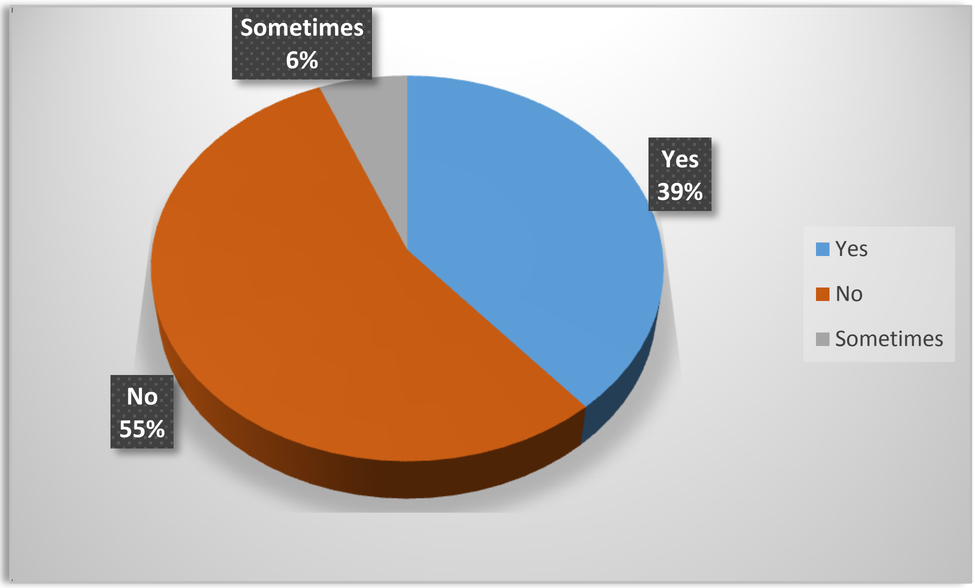

Figure 4.6 Ability to Receive Healthcare Services when Solar PV Electricity was not Available

The findings show that majority of the respondents, 55 percent, do not always manage to receive certain healthcare services because of unavailability of electricity at the rural healthcare facilities. While only six percent indicated that they are always able to access the service they visited the healthcare facility for. The services that are accessible include under five services, malaria treatment, T.B detection and treatment, and HIV/AIDS swabs. End-users that do not always receive desired services are, in most cases, given referrals to other higher healthcare facilities in Mumbwa District. Such services include surgery, blood transfusion, complicated and premature births and advanced disease conditions such as cancer detection and treatment.

In order to further understand the adequacy of services provided at the rural healthcare facilities, end-users who stated that they do not always receive the service they had visited the rural healthcare facility for were asked to identify which services are notreadily available. The findings of the research reveal that two percent of the end-users did not respond, while this question was not applicable to 32 percent because they felt that they always have access the services at they needed at their healthcare facilities. However, 13 percent said maternal health services are not readily available, six percent said that there is no health sensitization available, 34 percent said that there is poor or no inpatient services and 11 percent said that vaccination services are not readily available at the rural healthcare facility. This information is presented in the Figure 4.6.2below.

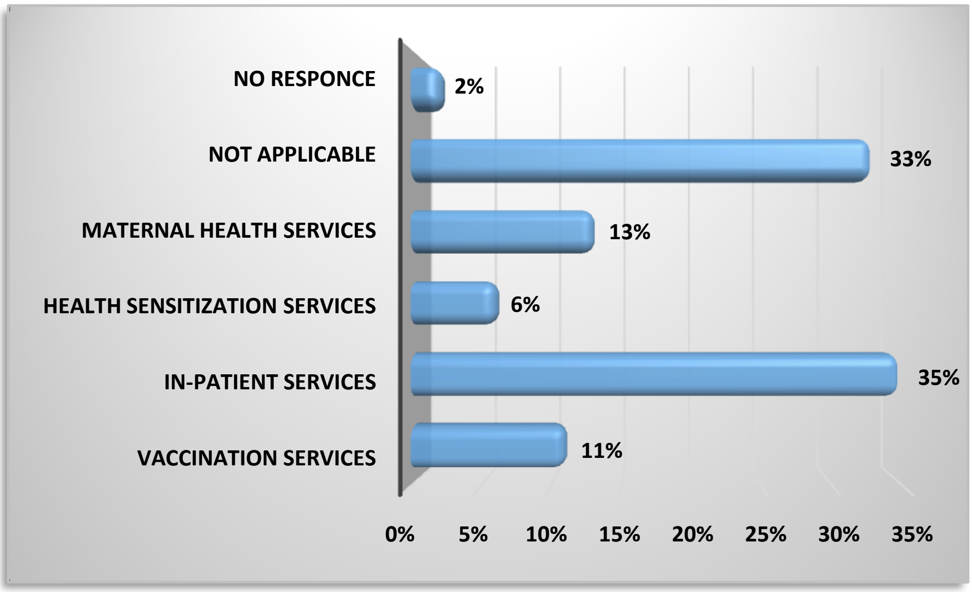

Figure 4.6.2 End-users' Response to Inaccessible Healthcare Services in Rural Healthcare Facilities

The study found that lack of reliable solar PV energy affects adequacy of some healthcare services. One respondent indicatesthat blood samples sometimes have to be transported to Mumbwa general hospital the same day after collection in order for tests to be conducted. In other cases patients have to be referred to Mumbwa General Hospital so that samples can be drawn in order for accurate tests to be conducted using microscopes and other energy driven medical equipment. This proves to be an expense on the part of the end-users as they sometimescannot afford proper transport in good time in a comfortable manner for patients considering the fact that motorbikes are the most commonly used means of transport in rural parts of Mumbwa District. This is because motor vehicles are not commonly used by residents in rural areas where the road network is still poor. The accuracy of some services provided are deemed questionable especially by some mothers at the rural healthcare facilities that expressed concern for their infants that cannot yet talk and had fallen ill. One mother at one of the healthcare facilities expressed dissatisfaction about diagnostic services stating that she had once taken her daughter to the healthcare facility where she was given wrong medication because of wrong diagnosis that had been made in the first place. After several days of no response to medication, she arranged to travel to Mumbwa general hospital without a referral letter to seek treatment for her daughter. When she arrived there her daughter was diagnosed with a different illness that had not been detected by the healthcare personnel at the rural healthcare facility. This finding is similar to a study done by Mohammadi (2010) which found that healthcare personnel had expressed frustration because their levels of service delivery was been greatly affected by electricity shortage. The study also found that people no longer trusted healthcare facilities because of some of the stories they heard and experiences they had about how people died because of surgery delay or due to lack of basic care provision because of energy shortages. This is also similar to a research done by Oswald (2012) which assesses the effects of the working environment on the performance of healthcare personnel. Oswald indicates that healthcare personnel need to be provided with adequate work equipment so that their work can be made easier and as a result minimize error that can cause possible end-user dissatisfaction. Oswald's research findings show that the work environment affects the quality and rate of healthcare provision in healthcare facilities. He identifies buildings, drugs and electrical equipment as elements necessary to ensure productivity in healthcare provision.

4.7 Conclusion

The study findings and discussions in the chapter indicated that solar energy used in rural healthcare facilities in Mumbwa District were characterized by inadequate system capacities.The chapter concludes that the only reasons why solar PV systems are not adequate is because none of the sampled healthcare facilities hade complete solar PV system equipment 90 percent of the healthcare facilities did nor either have the correct combination of solar panels, deep-cycle batteries, inverters and charge controllers. Because of this the amount of electricity produced was not enough, which at that time was estimated to have been 4kWh/day as opposed to producing at least 8kWh/day or more, for rural healthcare facilities of that size.

In terms of maintenance, none of the rural healthcare facilities were reported to have had a resident technician on site to ensure proper maintenance practices. Additionally, none of the rural healthcare facilities had their own means of financing to replace worn out or damaged equipment on the systems. They all depended on grants from MOH through the DMO.

CHAPTER FIVE

CONTINUITY OF HEALTHCARE SERVICE DELIVERY USING SOLAR PV ENERGY IN RURAL HEALTHCARE FACILITIES

5.1 Introduction

The purpose of this chapter is to present findings and discussions on the continuity of healthcare delivery using solar PV energy in rural healthcare delivery in Mumbwa District. Continuous delivery of healthcare services in this dissertation refers to uninterrupted provision of healthcare services to healthcare seekers at a rural healthcare facility. The chapter begins by presenting and discussing the findings related to continuity of healthcare delivery using solar PV energy using the following variables: operational hours, availability of drugs/vaccines, availability and use of energy driven medical equipment and healthcare personnel performance. These variables are used in discussing responses from the District Medical Officer healthcare administrators/superintendents/in-charge, healthcare personnel, and end-users. A conclusion is provided thereafter.

5.2 Operational Hours

The District Medical Officer, administrators/superintendents/in-charge and healthcare personnel were asked about the operational hours of the healthcare facilities. The study revealed that all the rural healthcare facilities in Mumbwa District were mandated to open between 07:30-08:00 and close at 16:00 hours from Monday to Friday and close half day during the weekends. Additionally, all the rural healthcare facilities were also mandated to offer nigh time emergency services to patients in the community.

However, the study reviled that 80 percent of the healthcare facilities operated at night to cater to emergency cases as opposed to 20 percent which did not offer night time emergency services at all. The lack of emergency service provision for the 20 percent was attributed to not having any batteries to store energy for night time use at the rural healthcare facility. The findings are presented in Figure 5.2.1 below.

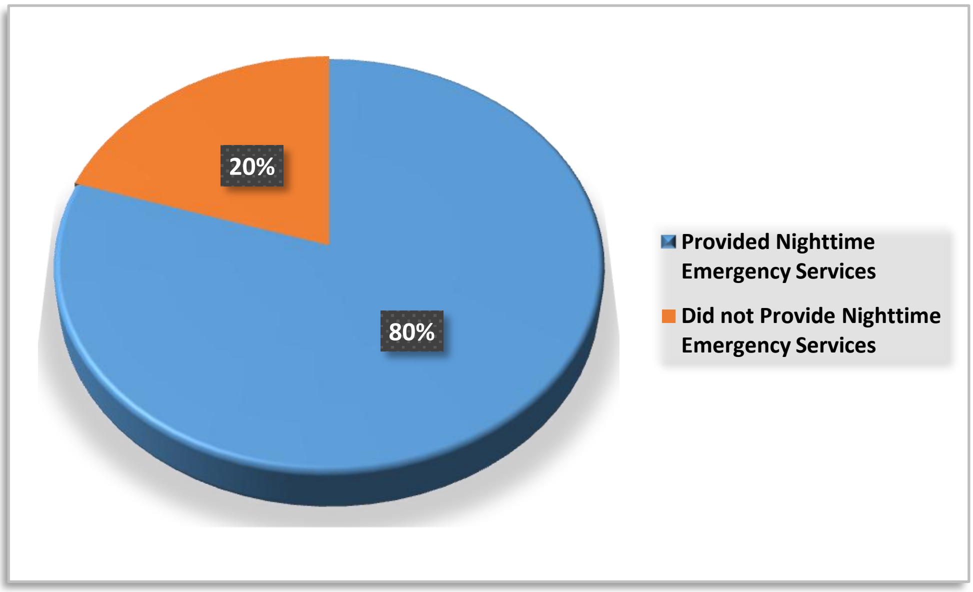

Figure 5.2.1 Healthcare Personnel Responses to Provision of Emergency Services at Night

End-users' were asked about the time that the healthcare facilities in their respective communities opened. According to the findings of the study, it is revealed that 70 percent of end-users indicated that the rural healthcare facilities opened around 07:00 hours and closed around 16:00 hours, while 29 percent indicated that the rural healthcare facilities operated 24hours/day and only one percent indicated that the healthcare facilities opened much later than 07:00 hours in the morning and would be closed by 15 hours.One respondent went on to state that their healthcare facility would sometimes offer night time services, mostly emergency cases and sometimes it did not because the healthcare provider would decide whether or nota case brought in was an emergency. The findings are illustrated in Figure 5.2.2 below.

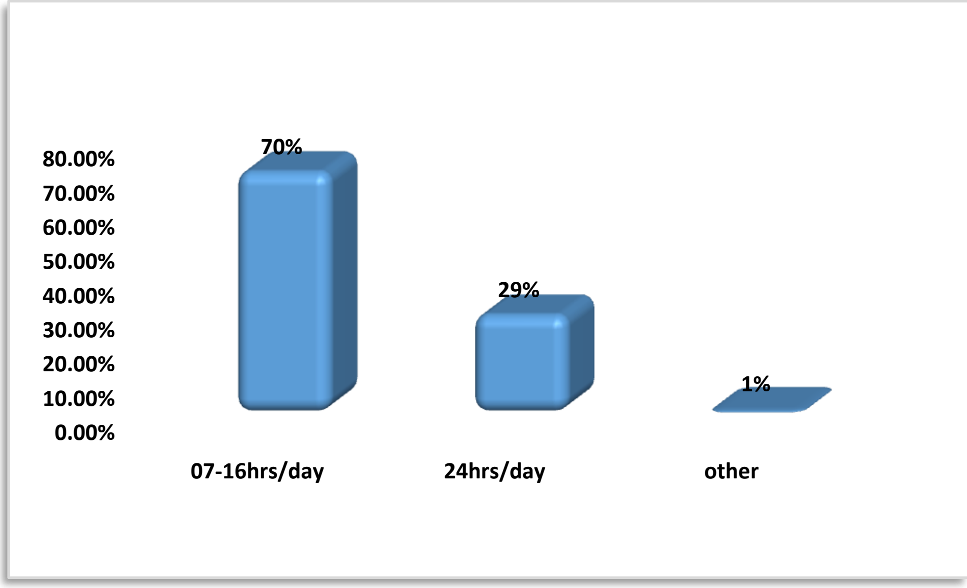

Figure 5.2.2 End-users' Response on Operational Hours of Healthcare Facilities

Based on the findings of the study, majority of respondents revealed that the rural healthcare facilities operate mostly during the day from 07:30 to 16:00 hours. It is observed based on the information provided by two categories of respondents that opening and closing hours were not uniform. Healthcare personnel indicated that rural healthcare facilities would be open to the public as early as 07:00 and closed at 16:00, while some end-users indicated otherwise. Some end-users indicate that the rural healthcare facilities would open much later than 07:00 and sometimes they would close as early as 15:00 despite having opened late in the morning. However, the study reveals that most healthcare facilities do not offer night time services to members of the community except for emergency cases. The findings of the study reveal that because of inadequate solar PV energy produced using solar PV systems, none of the rural healthcare facilities have healthcare personnel working night shifts. This is because the rural healthcare facilities do not have the capacity to support night time services throughout the night because there is inadequate solar PV energy to facilitate night time healthcare delivery. This is the reason why the rural healthcare personnel stated that they only accept to attend to emergency services as compared to other medical cases. The findings are similar to a study done by Franco et al (2017) titled "*A review of sustainable energy access and technologies for healthcare facilities in the global south*" which found that lack of reliable and affordable energy for vital needs reduce and affect healthcare facilities operational hours. Similar to Franco's review, healthcare services in

Mumbwa District are only provided during the day and no services are offered at night because of unreliable solar electricity. However, healthcare personnel that live nearby the healthcare facilities are called in cases of an emergency during the night. The study shows that some end-users state that despite emergency services being offered at night, it is not a guarantee that the healthcare personnel would respond to the request. Sometimes the healthcare personnel would not respond stating that batteries have not been charged during the day hence not being possible to have anything done at that particular time except wait until morning came in order to be attended to. This was the case at Lutale rural healthcare facility where a woman expressed grief about how sad the situation is where women sometimes would give birth in the corridors at the healthcare facility with the help of people who brought them as they tried to mobilize healthcare personnel to attend to them.

Additionally, due to unavailability of reliable electricity from the solar PV systems, end-users had to carry their own means of light, such as flashlights, kerosene lamps and candles during emergencies just in case they do not find any electricity at the healthcare facilities. The findings of the study show that despite healthcare facilities operating during the day and offering night time emergency services, the night time services are restricted to emergency cases which are also dependent on the availability of solar PV energy. Despite solar PV systems being installed, end-users still have to go with their own means of light just in case they do not find electricity at the healthcare facility. This indicates how unreliable the existing solar PV system capacities areat majority of the rural healthcare facilities in Mumbwa District.

5.3 Availability and Storage of Drugs/Vaccines

An interview with the District Medical Officer reveals that medical supplies are sometimes dispatched to healthcare facilities from the Ministry of Health through the District Medical Office. Drugs and vaccines that need to be kept in cold temperatures are kept in gas refrigerators that are solar PV operated. However, the interview reveals that the solar PV systems available at the rural healthcare facilities are insufficient because despite the solar PV system being available, energy is not produced in adequate quantities consistently (Interview with the District Information Officer, February, 2018.). This finding shows that the inconsistency of the energy produced using solar PV systems that have poor capacity makes it difficult for rural healthcare facilities to always have medical supplies that require cooler temperatures to be kept.

Healthcare personnel were also asked whether they felt that their healthcare facilities had sufficient storage space for medical supplies. The study shows that 40 percent agree that they had sufficient storage space for ordinary drugs on shelf while 30 percent felt that they do not have sufficient storage space because despite having drugs on shelf, they most times did not have a variety of drugs that required to be kept refrigerated and that even if they have one refrigerator for storage, it is not enough to cater for all the patients in their communities.

The findings of the study reveal that even though there isn't a big gap between responses from different categories of respondents. Majority of them show that solar PV energy does not adequately facilitate proper storage of drugs and vaccines in rural healthcare facilities. This can be attributed to the fact that the solar PV system capacities at the rural healthcare facilities are not fully equipped with sufficient solar PV equipment required to producereliable quantities of solar PV energy.

Even though most of the healthcare personnel in all the sampled healthcare facilities show that storage space is sufficient, they also reveal that because of lack of reliable solar PV energy produced, medication for illnesses such as pneumonia and other vaccines are not readily available and in some cases it would simply go bad because of the inability to consistently operate refrigerators using solar PV energy. One of the healthcare personnel at Nambala rural healthcare facility reveals that they experienced cases where they could not keep vaccines because the solar PV electricity at the healthcare facility could only be used for lighting purposes and no other appliances could be connected to the system. The refrigerator available at the healthcare facility has its own solar panel which is not sufficient to keep the refrigerator running throughout the night because it is connected directly to a solar panel. Because of this, medication and vaccine storage are greatly affected when there is cloud cover especially in rainy and cold seasons. The findings of this study were similar to a research done by Mohammadi (2010) titled "*Public health cost of electricity shortage: a Ghanaian case study"* which reveals that lack of reliable electricity disadvantages the cardinal role of retaining essential vaccines through consistent refrigeration which is crucial for effective healthcare delivery.

5.4 Utilization of Basic Energy Driven Medical Equipment

Healthcare personnel were asked the question;do you think the healthcare facility has sufficient basic medical equipment to support the nature of the healthcare services that are offered by your facility?As shown in Figure 5.4.1 below, 71 percent, did not feel that their healthcare facilities have sufficient machinery while only 29 percent, felt that they do.The rationale of the question is to determine whether medical equipment such as microscopes, autoclaves, and suction machines are available and utilized at the rural healthcare facilities. The responses provided show that most of the healthcare personnel do not feel that they have sufficient medical equipment to support healthcare delivery. It indicates that in addition to not having sufficient energy at the healthcare facilities, they also do not have majority of the basic medical equipment needed to support the nature of the services they provide. This can be considered as a reason why many of the rural healthcare facilities could depend on incomplete solar PV systems for mere lighting purposes.

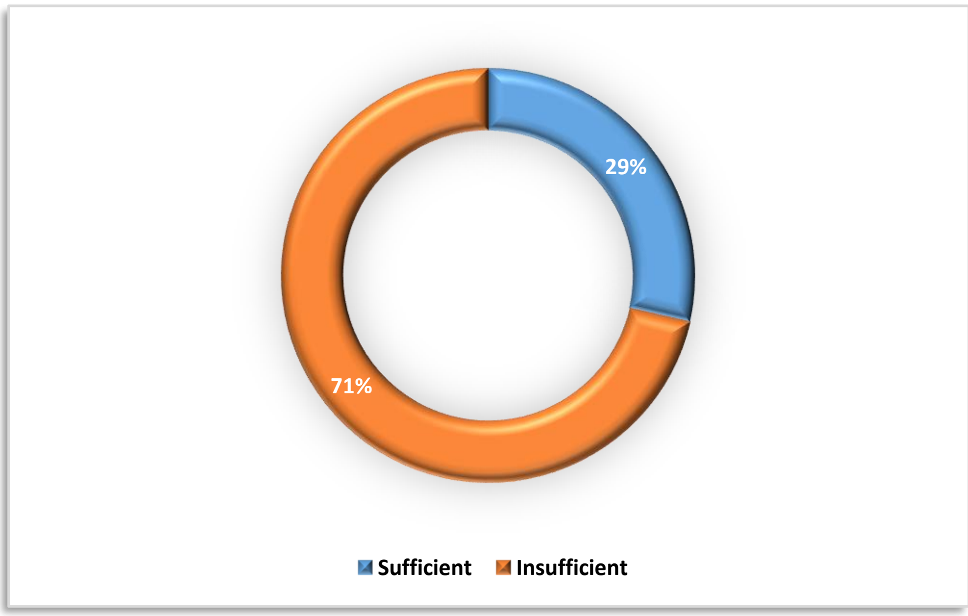

Figure 5.4.1 Healthcare Personnel Response to Adequacy of Medical Equipment

In order to gain a different perspective to the view given by healthcare personnel regarding adequacy of medical equipment available in rural healthcare facilities, end-users are asked to give reasons why they feel that service delivery is inadequate at their healthcare facilities. The findings show that a slightly higher number of end-users', 49 percent, cite electricity shortage as a cause of inadequacies experienced in rural healthcare delivery, while 46 percent cite inadequate rural healthcare medical equipment as a reason for inadequate service delivery. Only a small number of end-users, five percent, cite unqualified staff as a reason for inadequate rural healthcare delivery. This information indicates that inadequate medical equipment is regarded as one of the major reasons healthcare services are inadequate from the end-users point view as service recipients. This information is presented in Figure 5.4.2 below.

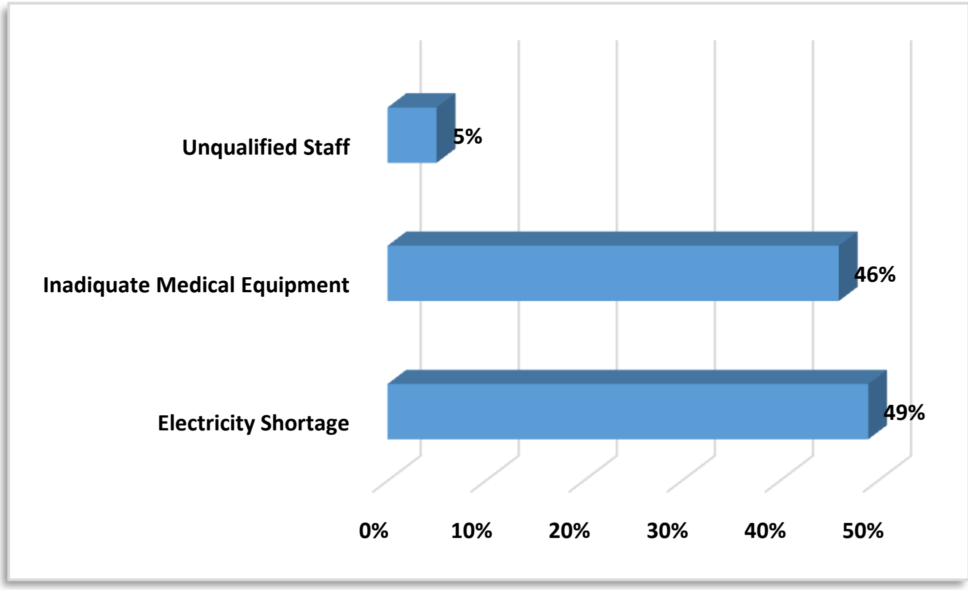

Figure 5.4.2 End-users' Response to Reasons for Poor Services

The presence of reliable electricity plays an important role in enabling the use of basic electricity driven medical equipment such as microscopes for diagnostic services, suction machines for excess fluid extraction and autoclave machines for surgical equipment sterilization. The findings of the study show that majority of healthcare personnel, 71 percent, feel that the available medical equipment is not sufficient and in most cases are incomplete. In addition, even though some medical equipment are available, they cannot be used because of insufficient and intermittent electricity supply from the solar PV systems. One of the healthcare personnel at Lungobe healthcare facility revealed that because of insufficient electricity that could only be used for lighting, most medical equipment cannot be used to aid healthcare delivery. In an interview held on 19 February, 2018, one healthcare personnel said "we have a lot of medical equipment that need power to operate, but at the moment we cannot use them because solar is mostly used for lighting and refrigeration". Similarly, an in an interview held at Nambala healthcare facility, on 16 February, 2018, a respondent disclosed that despite having medical equipment, the healthcare facility cannot utilize useful equipment such as autoclaves and beds that operated with electricity because of the insufficiency of energy produced using the solar PV systems. Majority of healthcare facilities in Mumbwa District reported that the electricity produced is mainly used for lighting at night and for refrigeration but cannot be used for anything else.

On the other hand, end-uses cited inadequate medical equipment as the second most prominent reason why rural healthcare services are not adequate. This is in line with the response given by the healthcare personnel. End-users reason for citing inadequate medical equipment is possibly because some services cannot be offered simply because electricity is not sufficient and not because equipment is not available. The findings of the study are similar to a study done by Essendi et al (2015) titled "*Infrastructure challenges to better health in maternity facilities in rural Kenya: community and health worker perceptions"*, which found that resuscitation and assisted delivery at both Kitonyoni and Mwania healthcare facilities could not be performed at the healthcare facilities due to lack of oxygen masks and suction machines which both required electricity to function.

5.5 Effect of Solar PV Electricity on Healthcare Provider's Performance

Healthcare personnel were asked whether the absence of electricity had in any way affected rural healthcare delivery at their healthcare facilities. The study reveals that 50 percent of the healthcare personnel said yes, while 20 percent said no and 30 percent did not respond. The findings are presented in Figure 5.5.1 below.

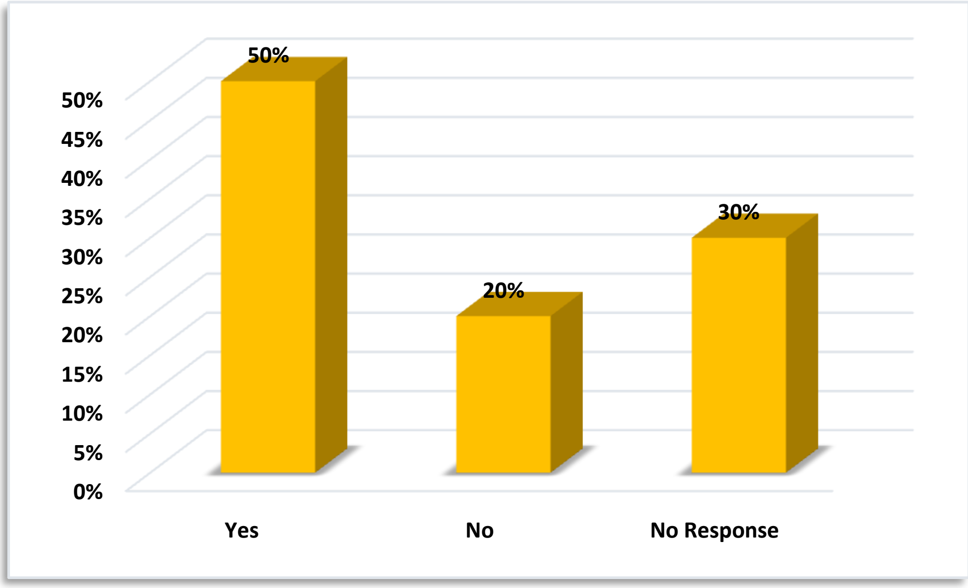

Figure 5.5.1 Healthcare Personnel Response to Whether Absence of Solar PV Electricity Affects Work Output

On the other hand, end-users' were asked to rate healthcare personnel's performance at their healthcare facilities on days when electricity was unavailable. The study reveals that majority, 49 percent, described it as 'bad/very bad', while 33 percent described it as'good/very good' and 18 percent of end-users indicated that they did not know. The findings are presented in Figure 5.5.2 below.

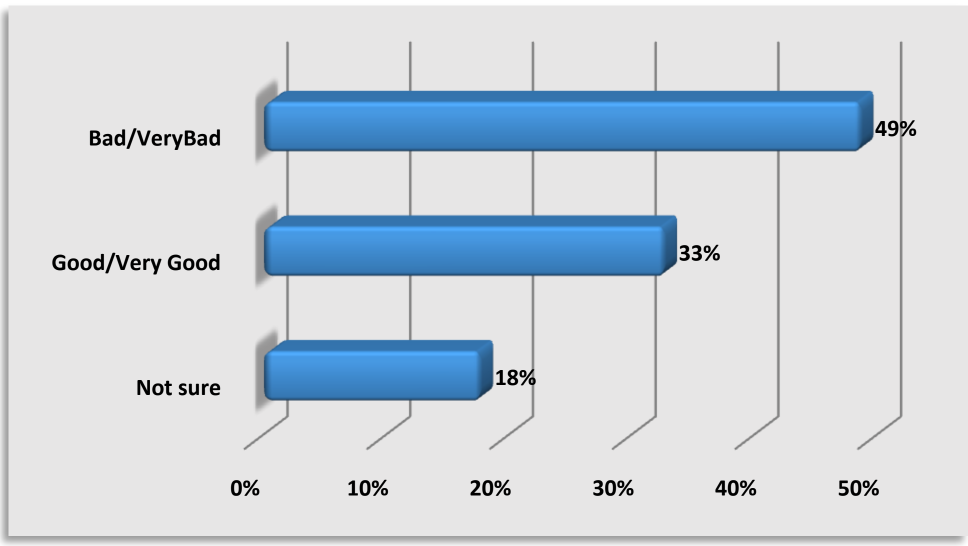

Figure 5.5.2 End-users Responses to Healthcare Personnel Service When Solar PV Energy was Absent

The findings of the study show that majority of healthcare personnel feel that lack of reliable electricity at the healthcare facilities affects the delivery of a number of healthcare services. The findings of the study are in line with the findings of a research done by Mohammadi (2010) titled "*Public health costs of electricity shortage: a Ghanaian case study"*, which found that hospital staff have become frustrated because their level of service has been greatly affected by electricity insufficiency at their healthcare facilities.

Lack of electricity or intermittent availability means that healthcare providers cannot provide certain services such as using an autoclave machine to sterilize surgical equipment for performing simple surgery on patients or suturing activities especially for pregnancy related cases. During an interview with healthcare personnel at Lutale healthcare facility on 17 February, 2018, the study shows that due to lack of reliable electricity, surgical equipment are oftensterilized using braziers so that surgery can be conducted when an emergency case is brought in.

5.6 Conclusion

Based on the findings of the study it can be concluded that despite rural healthcare facilities having solar PV systems installed for energy generation and storage, the amount of electricity produced is highly insufficient and does not positively impact on rural healthcare delivery. Many of the healthcare services could not be adequately provided because of unreliable electricity which could not enable services such as increased operational hours, storage of drugs and vaccinations in recommendedconditions, operate basic medical equipment and also provide an enabling environment for healthcare providers to adequately perform their tasks. Services that cannot be readily provided include providing safe operations, removing excess fluids in children and pregnant women, providing overnight observation services and conducting blood and fluid examination. However, services that can be provided include consultation, normal child delivery, administration of drugs that do not require special temperatures to be stored and health sensitization services.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter provides the conclusions and recommendations of the dissertation. The general objective of the study was to examine the reliability of solar PV systems as a primary source of electricity in rural healthcare facilities in Mumbwa District. The specific objectives of the study were: firstly to examine the affordability of solar PV energy in rural healthcare delivery in Mumbwa District. The second objective was to examine the continuity of healthcare delivery using solar PV energy in rural healthcare delivery in Mumbwa District. Generally the study showed that solar PV systems were a reliable source of energy but their reliability had been affected by insufficient system capacities, among other things as already discussed in the previous chapters. The chapter begins by providing conclusions on the two research objectives discussed in this dissertation. Thereafter, policy recommendations and further research area information are provided.

6.1.1 Conclusions

6.1.2 Affordability of Solar PV System and Maintenance Practices

The study concluded that despite solar PV systems being installed at the rural healthcare facilities, all categories of respondents held a common view regarding the inadequacy of solar PV systems because individual rural healthcare facilities could not replace their worn out PV equipment. Equipment capacity, funding and poor maintenance practices are identified as the main reasons why solar PV energy systems are inadequate in rural healthcare facilities. Poor system capacity is attributed to lack of funding as most of the solar PV systems were previously installed by donors. The solar PV system components that are difficult to add or replace on the solar PV system are deep-cycle batteries (see appendix G) meant to store energy electrochemically. The findings of the study reveals that the healthcare facilities have challenges receiving the requested deep-cycle batteries from the District Medical Office once a request had been made. Because of this delay, rural healthcare facilities resort to installing car batteries (see appendix E) on their system so that energy can be stored for use during the night for emergency cases.

On the other hand, the study also concludes that, inefficiency of the installed solar PV systems is attributed to lack of resident technicians on site at the rural healthcare facilities to conduct maintenance checks to ensure that the systems are operating in good condition. The study reveals that the entire district depends on one technician who is responsible for attending to all sorts of technical faults experienced on the solar PV systems at the rural healthcare facilities. This has made it difficult for the technician to conduct maintenance checks on all the solar PV systems consistently in Mumbwa District. Instead the Healthcare Facility Technician only goes to the rural healthcare facilities when he is called to attend to a fault. In some cases a healthcare facility has to wait for several days before the technician has chance toattend to a fault because he had been working on different technical system problems at other healthcare facilities in the district.

The study also concludes that the unreliability of the solar PV system is also attributed to healthcare personnel who would remove equipment from the system such as batteries and would carry them to their staff houses to use during the night. This is due to the fact that most healthcare personnel do not have any solar PV systems installed at their staff houses. As a result the solar PV system weakens because reinstallation of the batteries to the system are not properly done and hence further weakening it. It also contributes to batteries wearing out faster than they are supposed to as they are being used both at the healthcare facilities and at the healthcare personnel staff houses.

6.1.3 Continuity of Healthcare Service Delivery

The study concluded that all the rural healthcare facilities open between 07:30 hours - 08:00 hours and close at 16:00 hours every weekday. On Saturdays' the rural healthcare facilities would be open from 08:00 hours to 12:00 hours and do not opened on Sundays. Despite the rural healthcare facilities closing at 16:00 hours during weekdays, they are mandated to provide night time emergency services whenever they were reported. The study shows that 80 percent of the healthcare facilities are able to offer night time emergency services while 20 percent that are unable to because the healthcare facilities do not have any batteries installed on their solar PV systems. This does not enable such healthcare facilities to store energy for lighting at the healthcare facility during the night. This is because the available solar panels are directly connected to refrigerators and hence cannot be used for other activities. However, the study shows that despite solar PV systems being available at the healthcare facilities, end-users had to carry their own means of light in order to be attended to when an emergency occurred at night. In cases where end-users do not have their own means of light, they have to wait until the following morning to be attended to by healthcare personnel.

The study also concludes that even though most of the healthcare personnel indicate that they have sufficient storage for drugs at their healthcare facilities, storage of cold chain drugs and vaccines are a challenge because of the insufficient capacity of the solar PV systems. This makes it difficult to constantly keep drugs and vaccines in cold temperatures especially in the cold and rainy seasons. During the cold and rainy seasons batteries on the solar PV system do not get fully charged and hence would become difficult to keep the refrigerators running throughout the night and as a result drugs and vaccines go to waste. For other refrigerators that are connected directly to solar panels, once the sun sets, the solar energybecomes unavailable to power the refrigerators hence making it difficult to preserve drugs and vaccines which as a result go to waste.

The study also concludes that 71 percent of the healthcare personnel who do not feel that their healthcare facilities have sufficient medical equipment could be attributed to lack of reliable solar PV energy at the rural healthcare facilities. This could be due to the fact that most of the equipment unavailable could have been energy driven and hence would not be sustainable to keep them around without being made use of consistently. For instance, majority of the rural healthcare facilities do not have electrical microscopes which are an important tool for diagnostic services. On the other hand 49 percent of end-users cited lack of adequate electricity and 46 percent cited inadequate availability of medical equipment as reasons as to why rural healthcare delivery was not very effective. This indicates that availability of solar PV energy is an important enabler of healthcare service delivery in rural healthcare delivery.

Also, the study concludes that poor availability of solar PV energy affects staff performance regarding rural healthcare delivery of some healthcare services. The findings show that 50 percent of healthcare personnel stated that lack of reliable solarPV energy affects their performance during the night or during the day in cases where deliveries became complicated. In such cases healthcare personnel are required to use energy driven equipment such as suction machines, autoclaves and even use electrical beds for healthcare delivery. This is in line with end-users responses that indicated that they receive better attention and treatment when electricity is available at night than on days when electricity is unavailable or when they had to use lamps or torches that they had come with.

6.2 Recommendations

6.2.1 Policy Recommendations

The MOH through the District Medical Office must ensure that all rural healthcare facilities using solar PV systems as a primary source of energy must have all the basic system components which are solar panels, deep-cycle batteries, charge controllers and inverters. Additionally, it should be ensured that there is a set standard, a policy that sets the minimum number of the solar PV system components installed on a system at a rural healthcare facility in order for it function efficiently. In this case, as proposed by the Mumbwa District Technician who indicated that components of solar PV systems installed in rural healthcare facilities should have had a minimum of seven 100W solar panels, four or more12V (or 24V) deep-cycle batteries, two or more inverters each with a capacity to convert 1000W into 1KW/h and at least one or more charge controllers. Such systems, as stated by the District Health Facility Technician, are estimated to produce more than 8.784 KW/h per dayfor an average rural healthcare facility for healthcare delivery.

The MOH through the District Medical Office should consider training and deploying more technicians to be stationed at each of the rural healthcare facilities using solar PV systems in Mumbwa District. These technicians would be mandated to attend to any technical challenges and also conduct maintenance checks on the solar PV system regularly so as to ensure that the healthcare facilities fully benefit from utilization of the installed solar PV systems in the district.

The study also recommends installation of solar PV system at staff houses as means to encourage higher chances of staff retention.Therefore, the MOH through the District Medical Office should ensure that staff houses are also equipped with solar PV systems to meet the energy needs of healthcare personnel working in the rural parts of the district. This would greatly increase staff performance and also ensure retention of qualified healthcare personnel in Mumbwa District.

6.3 Further Research Area

This study focuses on the reliability of solar PV energy in rural healthcare delivery. There is need for future research to focus on how solar PV system capacity can be improved in this area.

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APPENDICES

Appendix A1: Interview guide for District Medical Officer

Interview Guide

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been purposively selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

1. Do not write your name on the questionnaire
2. Read the questions carefully before answering
3. Where boxes are provided, tick the relevant option [√]
4. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

HEALTH SECTOR- District Medical Officer

1. What is the major source of energy used by healthcare facilities in your district other than hydroelectricity?
2. What is your opinion about healthcare facilities that use unconventional energy such as solar, generators, wind and geothermal for healthcare delivery?
3. Are healthcare facilities such as RHCs and HPs user fee funded or they rely on grants to sustain their energy needs for healthcare delivery? If they are funded, how often do they receive these funds? If not do you think that healthcare facilities that use these sources of energy have adequate resources to maintain these sources of energy for healthcare delivery?
4. Are there any policies put in place that guide the type of energy installed in different types of healthcare facilities in your district?
5. What is the average energy consumption range of the types of healthcare facilities that are in your district? i.e SLH, FLH, HCs and HPs
6. Have you worked in partnership with other organisations regarding energy installation and access in healthcare facilities in your district?
7. Do you think that unconventional energy such as solar, generators, wind and geothermal are the best alternative source of energy to meet the demand for energy for healthcare facilities that are in remote locations?
8. What are the most common types of a refrigerators healthcare facilities use for storage of medication, vaccine and blood samples in your district?

Appendix A2: Interview guide for Rural Electrification Authority Engineer

Interview Guide

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been purposively selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

1. Do not write your name on the questionnaire
2. Read the questions carefully before answering
3. Where boxes are provided, tick the relevant option [√]
4. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

ENERGY SECTOR-Rural Electrification Official (Engineer)

1. What are the main sources of energy that have been installed in rural Mumbwa district?
2. Do you plan to connect Mumbwa district to hydroelectricity in the long run, if yes when?
3. During installation of energy in rural areas, are healthcare facilities considered as key connection areas?
4. On average, what percentage and type of healthcare facilities have you connected to a given source of unconventional energy, ie hydroelectricity, solar, wind, geothermal?
5. Who is responsible for the cost of energy installation at healthcare facilities in rural areas?
6. Have you partnered with any organisations to facilitate the improvement of energy access in rural areas?
7. Are there any policies put in place that guide such energy installation projects/partnerships?
8. What are the major challenges that you have faced in connecting healthcare facilities to energy such as hydro, solar, wind and geothermal sources of energy in rural areas?
9. In your expert opinion, how best do you think the rural healthcare facilities can fully improve and benefit from the use of solar, generators, wind and geothermal sources of unconventional energy?

Appendix A3: Interview guide for Health Facility Manager

Interview Guide

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been purposively selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

1. Do not write your name on the questionnaire
2. Read the questions carefully before answering
3. Where boxes are provided, tick the relevant option [√]
4. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

Healthcare Facility Manager

1. What is the major source of energy used at your healthcare facility?
2. How much energy is produced on a daily basis using this source of energy?
3. Based on your current load of appliances and machinery available at your healthcare facility, how much energy is required per day to cater for the day to day operations?
4. What are the peak hours of energy use for service delivery at your healthcare facility?
5. Are there any energy interruptions experienced during peak hours of service delivery?
6. How would you describe the ability of this source of energy to meet the day to day energy needs of the healthcare facility?
7. Has there been any reports at your healthcare facility regarding loss of lives or equipment damage because of the type of energy used at your healthcare facility?
8. Have you worked in partnership with any NGOs and other organisations regarding the installation and access to energy for healthcare delivery in your district?
9. What would you describe as the biggest challenge of using the current source of energy used at your healthcare facility?

Appendix A4: Interview guide for District Technician

Interview Guide

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been purposively selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

1. Do not write your name on the questionnaire
2. Read the questions carefully before answering
3. Where boxes are provided, tick the relevant option [√]
4. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

Healthcare Facility Technician (Engineer)

1. What is the primary source of energy used at your healthcare facility and when was it procured/installed?
2. How much energy does this source produce on average for day to day healthcare delivery at the facility?
3. What are the major peak hours of energy consumption at the healthcare facility?
4. What are the main requirements used to keep this source of energy operating in order to meet the healthcare facilities energy needs and how readily available are these resources?
5. Have you ever had to work overtime to ensure that this source of energy was operating well? Did you get paid over time for such services?
6. What is your view about the maintenance cost of the source of energy used at your healthcare facility?
7. Are there any routine checks that are done to ensure that the energy source meets the day to day needs of the healthcare facility?
8. Have you experienced any problems with this source of energy at your healthcare facility?
9. Do you think that solar, generators, wind and geothermal are best alternative sources of energy in healthcare delivery for healthcare facilities located in remote areas?
10. What factors do you think hinder the successful utilization of solar, generators, wind and geothermal for healthcare delivery?
11. What professional advice would you recommend to improve (solar, generators, wind and geothermal) the source of energy for healthcare delivery at your healthcare facility?

Appendix B1: Questionnaire for Healthcare Personnel

Questionnaire No: ………..

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

5. Do not write your name on the questionnaire
6. Read the questions carefully before answering
7. Where boxes are provided, tick the relevant option [√]
8. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

Section A: Personal Information

1. Sex

   1. Male ☐ 2. Female ☐

2. Age

   1.18-25 ☐ 2. 26-33 ☐ 3. 34☐ 4. 52-59 ☐ 5. 60 and above ☐

3. What is your highest level of education?

   1. Secondary ☐ 2.College ☐ 3. University ☐ 4. Other, specify…………………………………………………………………………
   …………………………………………………………………………………

4. What is your area of specialization?...
   …………………………………………………………………………………
   …………………………………………………………………………………

5. What position do you hold in the healthcare facility?..
   …………………………………………………………………………………

6. How long have you worked for the facility?

   1. 1 year or below ☐ 2. 2-5 years☐ 3. 6- 10 years☐ 4. More than 10 ☐ years

Section B: Efficiency

7. What is the name of the ward where your healthcare facility is located?...
   …………………………………………………………………………………

8. What is the main source of energy used at your healthcare facility?

	Yes	No
1. Solar	☐	☐
2. Generator	☐	☐

   3. Other……………………………………………………………………

9. Are there any other sources of energy used at your healthcare facility?

   1. Yes ☐ 2. No ☐

10. If Yes to question 9, specify the other sources

used……………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

11. Is the main source of energy used by your healthcare facility reliable?

1. Yes ☐ 2. No ☐

12. If No to question 11, give reasons for your

answer……………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

13. Is the main source of energy affordable?

1. Yes ☐ 2. No ☐ 3.Not sure ☐

14. If No to question 13, give

reasons…………………………………………………………………………..

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

15. Is the current energy supply sufficient for day to day healthcare activities at the facility?

1. Yes ☐ 2. No ☐

16. If No to question 15 give reasons for your

answer……………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Cost

17. Is the healthcare facility self-reliant in raising resources to meet its energy needs?

1. Yes ☐ 2.No ☐

18. If Yes to question 17, how does the healthcare facility mobilize these resources?

1. User fees ☐ 2. Donations ☐

4.

Other………………………………………………………………………………

……………………………………………………………………………………

Time/Duration

19. Has there ever been times when patients came to seek healthcare services and they found that there was no electricity at the healthcare facility?

1. Yes ☐ 2.No ☐

20. If Yes to question 19, in such a case, when there is no energy,

1. It takes more time to attend to patients ☐ 2. It takes less time to attend to patients ☐ here is no difference 4 ☐ atients are sent back home ☐

5. Patients are referred to another healthcare facility ☐ 6. Any other, specify…………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

21. Does absence of energy affect the number of patients attended to?

1. Yes ☐ 2.No ☐

22. If Yes to question 21, explain how it affects healthcare delivery at the healthcare facility

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

Accuracy/Reliability

23. Which of the following services do you as a healthcare facility provide?

	Yes	No
1. Specialized healthcare	☐	☐
2. Curative healthcare	☐	☐
3. Primary healthcare	☐	☐
4. Preventive healthcare	☐	☐

24. Mark some of the services that are readily available at your healthcare facility

	Yes	No
1. Immunization	☐	☐
2. Vaccination	☐	☐

3. Outpatient services ☐ ☐

4. Health sensitization services ☐ ☐

5. Maternal healthcare ☐ ☐

25. Do you provide the required medical services at your healthcare facility?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

26. If No to question 25, which services don't you provide?...

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

27. If No to question 25, is it due to

	Yes	No
1. Poorly qualified healthcare personnel	☐	☐
2. Inadequate medical equipment at the facility	☐	☐
3. Electricity shortage	☐	☐

28. As a health-care provider, are you able to provide diagnostic services to patients even when there is no electricity at the facility?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

29. If Yes to question 28 are you able to provide the curative treatment needed by the patient without the presence of electricity at the healthcare facility?

1. Yes ☐ 2.No ☐

30. If Yes to question 29, how often does this occur?

1. Very often ☐ 2. Often ☐ 3. Not often ☐ 4. Not very often ☐

31. Do you offer referral services?

1. Yes ☐ 2.No ☐

32. What kind of health conditions do you refer to other healthcare facilities?...

……………………………………………………………………………………

……………………………………………………………………………………

33. Have there been times when you would request patients to come back another day because there was no electricity for determining and treating the illness of a patient?

1. Yes ☐ 2. No ☐

34. If yes to question 33, how often has this happened?

1. Very often ☐ 2. Often ☐ 3. Not often ☐ 4. Not very often ☐

35. What would you suggest to improve this situation from occurring at your healthcare facility?..
……………………………………………………………………………………
…………………………………………………………………………………….

Section C: Effectiveness

36. Which of the following services does your healthcare facility provide?

	Yes	No
1. Specialized healthcare	☐	☐
2. Curative healthcare	☐	☐
3. Primary healthcare	☐	☐
4. Preventive healthcare	☐	☐

37. What are some of the most critical healthcare services provided at your healthcare facility that require constant supply of energy?...
……………………………………………………………………………………
……………………………………………………………………………………

38. How often are these critical services provided to patients in the absence of energy at the facility?

1. Very often ☐ 2. Often ☐ 3. Not often ☐ 4. Not very often ☐

39. Do you think that the healthcare facility has sufficient machinery to support the nature of the healthcare services that are being provided by your facility?

1. Yes ☐ 2.No ☐

40. Give reasons for your answer to question 39………………………………………………………………………………….

…………………………………………………………………………………

…………………………………………………………………………………

41. Which machinery don't you have at the healthcare facility that you think are critical for healthcare delivery? ………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

42. Why don't you have this machinery?..

…………………………………………………………………………………

…………………………………………………………………………………

43. If this machinery was made available at your healthcare facility, would it work properly using your current source of energy?

1. Yes ☐ 2.No ☐

44. In No to question 42, give reasons………………………………………………

……………………………………………………………………………….

…………………………………………………………………………………

45. What are some of the most sought for healthcare services provided at your facility that do not require constant supply of energy?...

…………………………………………………………………………………

…………………………………………………………………………………

46. Do you think that the facility would operate better with a different source of energy?

1. Yes ☐ 2.No ☐

47. If Yes to question 46 above, explain…………………………………………….

…………………………………………………………………………………

…………………………………………………………………………………

48. Is the healthcare facility's lack of access to hydroelectricity affecting healthcare delivery at your healthcare facility?

1. Yes ☐ 2.No ☐

49. Give reasons for your answer to question 48…………………………………….

…………………………………………………………………………………

…………………………………………………………………………………

50. What advice would you give the healthcare facility on how to improve energy supply for healthcare delivery?...

…………………………………………………………………………………

…………………………………………………………………………………

Section D: Challenges

51. Does your healthcare facility provide night time services to patients?

1. Yes ☐ 2. No ☐

52. Does your healthcare facility offer emergency services to patients?

1. Yes ☐ 2. No ☐

53. How would you rate the efficiency of services provision mentioned in question 50 and 51 during peak hours of operation at the healthcare facility?

1. Very efficient ☐ 2. Efficient ☐ 3. Very inefficient ☐ 4. Inefficient

54. What kind ☐ of emergency services are provided by the healthcare facility?……………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

55. How would you describe the quality of the night time services provided at the healthcare facility?

1. Very effective ☐ 2. Effective ☐ 3.Very Ineffective ☐

4. Ineffective ☐ 5.I'm not sure ☐

56. Does the healthcare facility have sufficient storage equipment for storing medication, vaccines and blood samples?

1. Yes ☐ 2. No ☐

57. What are some of the challenges faced in storage of medical supplies?...............

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

58. Does the healthcare facility have medical equipment that supports intensive care and incubation for babies?

1. Yes ☐ 2.No ☐

59. If Yes to question 58, are these services readily available for patients?

1. Yes ☐ 2.No ☐

60. Do you offer laboratory services at the healthcare facility?

1. Yes ☐ 2.No ☐

61. If Yes to question 60, how readily available are these services when there is no electricity at the healthcare facility?..

…………………………………………………………………………………

…………………………………………………………………………………

62. In your view, does the healthcare facility have sufficient equipment for healthcare delivery?

1. Yes ☐ 2. No ☐

63. Give reasons for your answer……………………………………………………….

....

....

Appendix B2: Questionnaire for End-users

Questionnaire No: ………..

THE UNIVERSITY OF ZAMBIA

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF POLITICAL AND ADMINISTRATIVE STUDIES

Dear Respondent,

My name is Betty Mtonga, I am a postgraduate student at the University of Zambia. I am conducting a research on **the reliability of unconventional sources of energy in public healthcare delivery in rural Zambia: a case study of Mumbwa district**. This is an academic research and is a requirement for the fulfilment of a Master of Arts in Public Administration (MPA) at the University of Zambia.

You have been randomly selected to participate in this study. Be assured that the information collected from you will only be for academic purposes and will be treated with the required guaranteed confidentiality.

INSTRUCTIONS TO THE RESPONDENTS:

9. Do not write your name on the questionnaire
10. Read the questions carefully before answering
11. Where boxes are provided, tick the relevant option √
12. Write your answers where space is provided…………………..

THANK YOU FOR YOUR TIME AND CO-OPERATION!

Section A: Personal Information

1. Sex

1. Male ☐ 2. Female ☐

2. Age

1. 18-25 ☐ 2. 26-33 ☐ 3. 34-51 ☐ 4. 52-59 ☐

5. 60 and above ☐

3. What is your marital status?

1. Single ☐ 2. Married ☐ 3. Divorced ☐ 4. Widowed ☐

4. What is the size of your household?

1. Between 1-3 ☐ 2. 4-6 ☐ 3. 7-9 ☐ 4. 10 and above ☐

5. How often do you seek medical services from your local healthcare facility?

1. Very Often ☐ 2. Often ☐ 3. Rarely ☐ 4. Very rarely ☐

6. If response to question 5 is very often or often, do you or a member of your family have a condition that makes you visit the healthcare facility regularly?

1. Yes ☐ 2. No ☐

Section B: Efficiency

Cost

7. What are the operational hours of the healthcare facility?

1. Open 08:00-17:00/day ☐ 2. Open 24:00/day ☐ 3.Other, specify……………………………………………………………………….

8. Does the healthcare facility operate on weekends?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

9. If No to question 9, give reasons………………………………………………….. ………………………………………………………………………………………… …………………………………………………………………………………………

10. When you visit your healthcare facility, is it a requirement that you should pay user fees?

1. Yes ☐ 2.No ☐

11. If Yes to question 11, do you find the user fees affordable?

1. Yes ☐ 2.No ☐

12. Give reasons for your answer to question 12……………………………………

……………………………………………………………………………………

……………………………………………………………………………………

13. Is the source of energy used at the health-care facility reliable?

1. Yes ☐ 2. No ☐

14. Do you think that the energy source used by your healthcare facility is properly maintained?

1. Yes ☐ 2. No ☐ 3. Not Sure ☐

15. Give reasons for your answer to question 15……………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Time/Duration

16. How often does your healthcare facility operate without electricity?

1. Very often ☐ 2. Often ☐ 3. Not very often ☐ 4. Never ☐

17. Have you ever visited the healthcare facility at a time when there was no electricity?

1. Yes ☐ 2. No ☐

18. If Yes to question 18 did you manage to receive the healthcare services that you had visited the facility for?

1. Yes ☐ 2.No ☐ 3. Sometimes

19. If Yes to question 19, how timely was the healthcare received at the facility?

1. Very timely ☐ 2. Timely ☐ 3. Not very timely ☐

20. If your response to question 20 was not very timely give reasons……………..

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………

………………………………

21. How would you rate the healthcare services provided on a day when there is no electricity at the healthcare facility?

1. Good ☐ 2. Very good ☐ 3. Bad ☐ 4. Very bad ☐

5. I'm not sure ☐

22. Using the scale below, rate the statements below on how you feel the absence of energy at the healthcare facility has affected healthcare delivery. 6- Strongly agree 5- Agree 4- Strongly disagree 3- disagree 2- I don't know 1- Not sure

		6	**5**	**4**	**3**	**2**	**1**
23.1	Absence of energy prevents access to many healthcare services						
23.2	Time taken to receive treatment is affected by absence of energy at the healthcare facility						
23.3	Quality and capacity of night time healthcare delivery is affected						
24.4	The quality of healthcare services are affected						
25.5	Maternal healthcare delivery is affected						
26.6	Laboratory healthcare services are affected						

23. Have you ever been requested to come back another day for treatment because on the actual day you visited the healthcare facility there was no electricity?

1. Yes ☐ 2.No ☐

24. When you visit the healthcare facility, do you manage to have access to the medical services that you seek when electricity is available?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

25. If No to question 25, give reasons for your answer……………..........................

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

26. How would you rate the healthcare services provided on a day when electricity is available at the healthcare facility?

1. Good ☐ 2. Very good ☐ 3. Bad ☐ 4. Very bad ☐

5. I'm not sure ☐

Accuracy

27. When you visit the healthcare facility, are you able to access all the healthcare services that you seek when there is no electricity?

1. Yes ☐ 2. No ☐ 3. Sometimes ☐

28. If No to question 28, which services are you unable to receive?..........................

………………………………………………………………………………

………………………………………………………………………………

29. Do you think the healthcare facility would provide better services if it had a different source of energy?

1. Yes ☐ 2.No ☐

30. If yes, which source of energy would you recommend to be used?

	Yes	No
1. Hydroelectricity	☐	☐
2. Solar	☐	☐
3. Generator	☐	☐
4. Wind	☐	☐
5. Biomass	☐	☐
6. Geothermal	☐	☐

<u>Section C: Effectiveness</u>

31. Which of the following services does your healthcare facility provide?

	Yes	No
1. Specialized healthcare	☐	☐
2. Curative healthcare	☐	☐
3. Primary healthcare	☐	☐

4. Preventive healthcare ☐ ☐

32. Mark some of the services that you have found readily available at the facility

	Yes	No
1. Immunization	☐	☐
2. Vaccination	☐	☐
3. Outpatient services	☐	☐
4. Health sensitization services	☐	☐
5. Maternal healthcare	☐	☐

33. Do you receive the required medical services at your healthcare facility?

1. Yes ☐ 2. No ☐ 3. Sometimes

34. If No to question 34, which services don't you receive?....................................

……………………………………………………………………………………

……………………………………………………………………………………

35. If No to question 35, is it due to

	Yes	No
1. Poorly qualified healthcare personnel	☐	☐
2. Inadequate medical equipment at the facility	☐	☐
3. Electricity shortage	☐	☐

36. How would you rate the quality of healthcare provide by your local healthcare facility?

1. Very good ☐ 2. Good ☐ 3. Poor ☐ 4. Very poor ☐

37. If the rating to Q36 is very poor or poor, give reasons…………………………..

……………………………………………………………………………………

……………………………………………………………………………………

38. Do you think the healthcare facility has sufficient energy equipment to provide healthcare services to you?

1. Yes ☐ 2. No ☐

39. Has there ever been a time you could not access a service because there was no electricity?

1. Yes ☐ 2. No ☐

40. If Yes to question 40, describe what happened…………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

41. How often has this happened to you?

1. Very often ☐ 2. Often ☐ 3. Not very often ☐ 4. Never ☐

42. 17. What advice would you give to the healthcare facility on how to improve energy supply for healthcare delivery?...

……………………………………………………………………………………

……………………………………………………………………………………

Section D: Challenges

43. Does the healthcare facility provide night time services?

1. Yes☐ 2. No ☐ 3. Sometimes ☐

44. Does the healthcare facility offer emergency services?

1. Yes☐ 2. No ☐ 3. Sometimes ☐

45. How would you rate the efficiency of services provision mentioned in question 44 and 45 during peak hours of operation at the healthcare facility?

1. Very efficient☐ 2. Efficient ☐ 3. Very inefficient ☐ 4. Inefficient ☐

46. What type of services are referred to other healthcare facilities?..................................……………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

47. Why are such services referred to other healthcare facilities?...……………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

48. How would you describe the night time services provided at the healthcare facility?

1. Very good ☐ 2. Good ☐ 3. Bad ☐ 4. Very bad ☐

49. Does the healthcare facility have well maintained equipment to store vaccine and medication that requires refrigeration?

1. Yes ☐ 2. No ☐

50. Are you able to access laboratory services at the healthcare facility?

1. Yes ☐ 2. No ☐

51. Do you think the available sources of energy at the facility are sufficient?

1. Yes ☐ 2. No ☐

52. If No to question 52, how has this affected healthcare delivery at the facility, give reasons for your answer………………………………………………………………………….
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Appendix C1: List of Healthcare Facilities in Mumbwa District

	Name of Healthcare facility
1.	Chunga

2.	Kaindu
3.	Kalenda
4.	Kafwikamo
5.	Luili
6.	Lutale
7.	Naluvwi
8.	Mooye
9.	Shakumbila
10.	Lungobe
11.	Nalubanda
12.	Nangoma
13.	Nakanjoli
14.	Chiwena
15.	Bulungu
16.	Lubanda
17.	Shimbizhi
18.	Nalusanga
19.	Kashinka
20.	ZafHc
21.	Muchabi
22.	Nambala
23.	Mulungushi
24.	Maimweene
25.	Keezwa
26.	Kabwanga
27.	Mpusu
28.	Kamilambo
29.	Kapepe
30.	Mumbwa Correctional
31.	Namabanga
32.	Mumbwa District Hospital
33.	Nangoma Mission Hospital

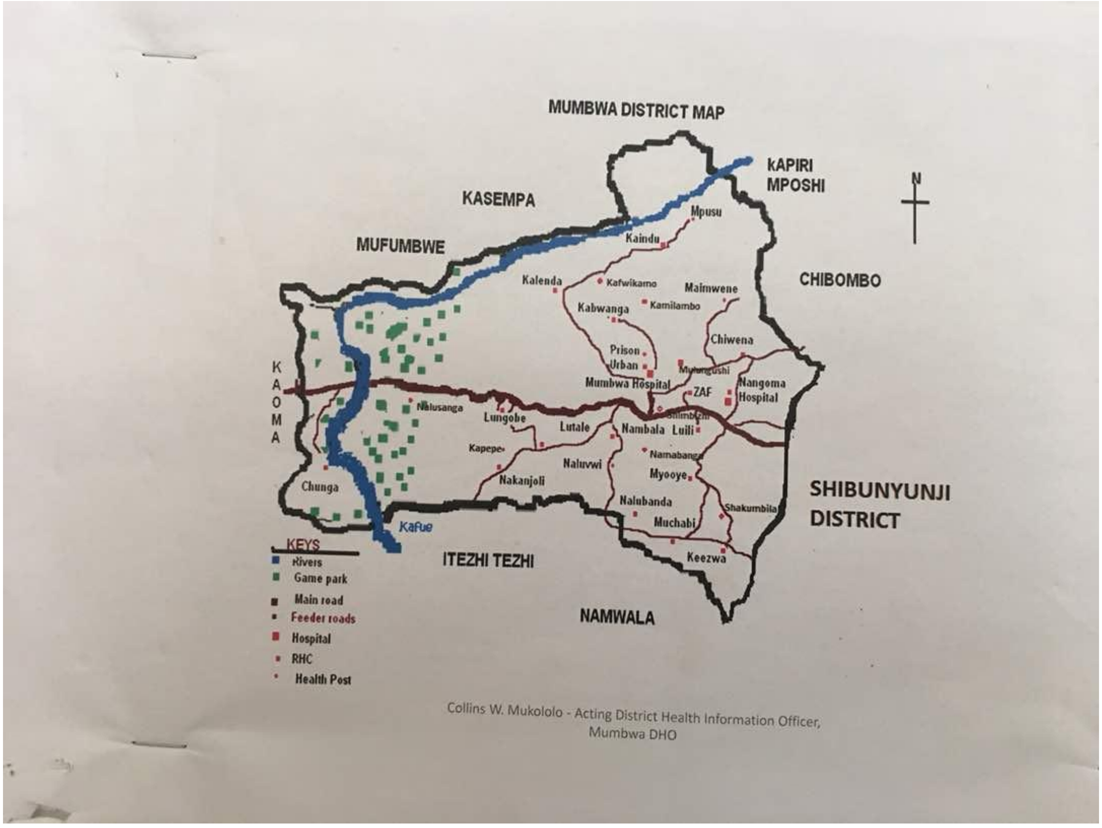
Source: Mumbwa District Medical Office (February, 2018)

Appendix C2: List of Healthcare Facilities not Connected to Hydroelectricity in Mumbwa District.

	Name of Healthcare facility

1.	Kafwikamo
2.	Lutale
3.	Naluvwi
4.	Lungobe
5.	Nalubanda
6.	Nakanjoli
7.	Chiwena
8.	Nalusanga
9.	Muchabi
10	Nambala
11	Keezwa

Appendix D: Map of Healthcare Facilities in Mumbwa District



Source: Mumbwa District Medical Office, 2018

Appendix E: Car battery Installed on Solar PV System as Deep-cycle Battery Substitutes in a Rural Healthcare Facility in Mumbwa District

Source: Field Photograph, 2018

Appendix F1: Refrigerator Directly Connected to Solar PV System at Nalusanga Rural Healthcare Facility

Sour

Appendix F2: Nalusanga Rural Healthcare Facility

Source: Field Photograph, 2018

Appendix G: Deep-cycle Batteries

Source: Field Photograph, 2018