BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE & ENGINEERING

GEOSCIENCES DEPARTMENT

THE ADOPTION OF OFF-GRID SOLAR ENERGY TECHNOLOGY AS AN INTERVENTION FOR RURAL ENERGY POVERTY ALLEVIATION: A CASE OF SHAMVA DISTRICT: MASHONALAND CENTRAL PROVINCE, ZIMBABWE

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

MAY 2024

APPROVAL FORM

DEPARTMENT OF GEOSCIENCES

The undersigned certify that they have read and recommend to Bindura University of Science Education for acceptance of this dissertation entitled "THE ADOPTION OF OFF GRID SOLAR ENERGY TECHNOLOGY AS AN INTERVENTION FOR THE ALLEVIATION OF RURAL ENERGY POVERTY, A CASE OF SHAMVA DISTRICT, MASHONALAND CENTRAL PROVINCE, ZIMBABWE' submitted to the Geosciences Department in partial fulfilment of Master of Science Degree in Climate Change and Sustainable Development

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DECLARATION

I, **Stephen Mazongonda, Registration number B226349A** hereby declare that this Thesis entitled**:**

THE ADOPTION OF OFF GRID SOLAR ENERGY TECHNOLOGY AS AN INTERVENTION FOR RURAL ENERGY POVERTY ALLEVIATION: A CASE OF SHAMVA DISTRICT; MASHONALAND CENTRAL PROVINCE; ZIMBABWE

Is my own original unaided work. All citations, references and borrowed ideas have been duly acknowledged .I confirm that external editor was not used. It is being submitted to the Faculty of Science and Engineering, Department of Geoscience, Bindura University of Science Education for the fulfilment of a Master of Science Degree in Climate Change and Sustainable Development.

STEPHEN MAZONGONDA (Candidate) 27 May 2024

DEDICATION

To my lovely wife Patience and sons Tinotenda, Tinokudzaishe and Akudzweishe Mazongonda, this is the academic legacy which I have contributed to this world.

ACKNOWLEDGEMENTS

The abundant life and well-being which prevailed during this rigorous academic milestone should not pass unnoticed. This was made possible through the almighty. Thus with God, everything is possible. My gratitude goes to my thesis supervisor Dr A. Manyani who had been a pillar to reckon with through this thesis journey. His unwavering support in mentoring me culminated into this masterpiece thesis which can contribute significantly in the transition to sustainable energy sources. I cherish insightful discussions we had during the progression of the thesis. May God continue to bless. Furthermore, I would like to acknowledge the contributions of many others who acted in the background and made this thesis a success. My gratitude to all is immeasurable**.**

ABSTRACT

The global energy landscape has seen a revolutionary transition in recent years towards sustainable and renewable energy sources. This is in line with ensuring universal access to smart, affordable and sustainable energy for all as espoused in Sustainable Development Goal (SDG 7). Thus, no one and no place should be left behind in this sustainable energy trajectory. However, rural areas in developing countries remain marginalized in access to energy, thus the prevalence of rural energy poverty. Hence, the study sought to examine the adoption of off grid solar energy technology as an intervention in alleviating rural energy poverty in Shamva District, Mashonaland Central Province, Zimbabwe. Consistent with this, the study examined the key determinants in the adoption of off grid solar energy technology by households in Shamva District. Additionally, the study also assessed factors influencing household's perception in the adoption of off grid solar energy technology. Furthermore, the study evaluated barriers in the adoption of off grid solar energy technology which were critical success factors in the transition to solar energy in Shamva District. The study used concurrent mixed research design. In the same regard, multi-stage random sampling technique was adopted and administrative wards of Shamva District were divided into three clusters comprising of Madziwa Communal lands, Chakonda Communal Lands and A1 and A2 Resettlement Areas. Besides this, random sampling procedure was also used in the selection of clusters and research participants from the clusters. In the same vein purposive sampling was used in the selection of key informants. Quantitative data was collected from eighty-five (85) household respondents and qualitative data from four (4) key informants, thus culminating into a sample of eighty-nine (89) respondents. In line with data analysis, descriptive statistics, Statistical Package for Social Science (SPSS) version 21, regression analysis and thematic analysis were employed in data presentation and analysis. The study established that the following factors were key determinants in the adoption of households to off grid solar energy technology:-level of wealth, gender,level of education, size of herd of cattle owned and typology of solar energy technology. However, the study established a lack of association between age and adoption of off grid solar energy technology in Shamva District. In the same regard, quality of solar energy equipment, knowledge and awareness, and community participation in off grid solar energy projects were found key in influencing household perception towards the adoption of solar energy technology. Thus, these were key in framing interventions to address rural energy poverty in Shamva District. Furthermore, the research examined factors which were inhibiting households in the adoption of solar energy technology. Consistent with this, the following factors were found critical in the adoption of off grid solar energy technology: high upfront costs, extreme poverty, impacts of Covid 19 pandemic and vandalism and theft of solar energy equipment. Given the foregoing, the study recommended the introduction of measures to address gender disparities, Climate Smart Livestock Management and increased access to education. In addition the study also recommended the need to uphold quality control in off grid solar energy technology sector, dissemination of knowledge and awareness of off grid solar energy technology and enhancing community participation in off grid solar energy technology. Furthermore, the study recommended the need for financial incentives to offset upfront costs of off grid solar energy technology, introduction of poverty reduction strategies, post Covid 19 pandemic financial recovery package in the solar energy technology sector and enhancing security protocols on installed solar energy equipments' . Thus, multi-faceted and inclusive approach were proffered as interventions in fostering a sustainable transition to solar energy in Shamva District.

Key Words

Sustainable Development Goal (7)**, Off Grid Solar Energy Technology, Energy Poverty, Sustainable and renewable energy, Knowledge and awareness, sustainable transition**

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ACRONYMS

AD	Anaerobic Digestion
HHH	Household Head
HHs	Households
IRENA	International Renewable Energy Agency
MG	Mini- Grids
MLR	Multi- Linear Regression
OGSET	Off Grid Solar Energy Technologies
PV	Photovoltaic
REP	Rural Energy Poverty
SAT	Stakeholder Acceptance Theory
SDGs	Sustainable Development Goals
SSA	Sub Saharan Africa
TAM	Technology Acceptance Model
TAM	Technology Acceptance Model
TDT	Technology Diffusion Theory

CHAPTER 1

INTRODUCTION

1.1. Introduction

Off-grid solar energy systems have become the alternative option in meeting sustainable energy by rural communities (Asuamah et al; 2021). Stand-alone solar energy technologies are among the contemporary solutions that have rapidly proliferated throughout the developing world, replacing unsustainable sources of energy (; Scott and Miller, 2016; Chaurey et al., 2012; Lighting Africa, 2011).Thus off grid solar energy technology can be a better option to combat rural energy poverty, (Bensch et al., 2017). The research explored how the adoption of solar energy technology can be an intervention in addressing rural energy poverty in Shamva District.

1.2. Background of the study

Photovoltaic energy is the most ubiquitous form of energy (Yu et al; 2024 and Gohri et al, 2024).Notwithstanding this, the current global utilization of solar energy is still very low (Pourasl et al 2023). Globally, the deployment of solar energy is still limited (Sayigh ;2020).Hence it remains an inadequately tapped energy resource. The emergency of climate change and an increase in energy poverty are the major twin drivers towards the adoption of solar energy (Yerudkar et al 2024).Hence solar energy can address twin goals of climate and also energy. Given this, G-20 countries are on the forefront in the uptake of sustainable energy. In line with this, Richardson (2017) posits that German has switched a significant proportion of its energy needs to sustainable energy. Solar energy is key in the sustainable energy trajectory (Hassan et al; 2024). In light of this, smart energy is critical for rural development (Atuguba and Tuokuu;2020).

Rural energy poverty (REP**)** is highly becoming a global phenomenon. In Poland, a greater percentage of rural households rely on unsustainable sources of energy as compared to the urban households (Kaya ,et al 2019).In line with this, a significant proportion of rural polish households use fossil fuel for their households energy needs,(Kerimray et al ;2017).Consequently, availability of energy is linked with sustainability (Halkos and Aslanidis; 2023). As such, the utilization of coal is deemed energy poverty as it is in divergence to the dictates of sustainable energy. Hence, the need for the adoption of solar energy technologies to address the rural energy poverty.

Similarly, in the marginalized regions of the developed world photovoltaic energy technology have the potential to address energy deficit (Kaya et al., 2019).

In the developing world, lack of energy infrastructure in rural communities limits the extension of the central grid in rural areas, (Sosnovsky et al,.2023).Consistent with such a scenario, the expansion of sustainable energy technologies becomes the optional strategy to ensure access to energy in remote rural communities (Boamah; 2020).Thus the need for the diffusion of solar energy technology to rural communities. High upfront costs of solar energy technology is limiting the growth of sustainable energy uptake in African rural communities, However, due to high capital costs required in the migration to smart energy sources, (Ahmed et al 2022 and Aboagye et al ;2021).

In comparison to other forms of sustainable energy, solar energy has proven to be the dominant source of energy (Nasser and Hassan; 2024).In this regard, some forms of renewable energy have negative environmental impacts. For instance, energy generated from palm oil is a crucial energy source yet is the subject of controversy at the international level (Umayah et al ;2021).In spite of the economic benefits of palm oil energy to producing countries such as Indonesia and Malaysia, concern has been raised over its sustainability due to biodiversity loss , tropical deforestation and labour exploitation ,(Purnomo et al 2020 and Xim et al, 2022).In such a development, Ariel et al (2020) highlights the imposition of renewable energy laws aimed to regulate the palm oil industry in Indonesia. This signifies the critical role sustainable energy plays in addressing rural energy poverty.

Energy deficit is a key obstacle in the social economic transformation of rural areas of third world countries (Wassie and Adaramola, 2021). Consistent with this, a number of countries in the developing world are adopting renewable energy technological innovations. For instance, Bangladesh Solar Home System (SHS) is the world's solar energy technology model, (Hellqvist and Haubaum, 2023). This is notwithstanding the lack of end user support and installation which is negatively impacting Bangladesh from attaining sustainable energy security. Relatedly, Shandong Province of China, is one of the provinces with high energy poverty (Chen et al., 2023). In Nepal energy poverty is extremely high as rural access to electricity accounts for twenty-five percent (25%) (Lohani et al., 2023). Resultantly, there is slow uptake of solar energy technology due to low disposable income of the rural populace. Thus the high prevalence of energy deficit in rural communities.

Africa still lags behind in the distribution and access to energy (Mbanda and Simiyu ; 2021) . Ten percent of the world's population and particularly in the Sub-Saharan Africa still lack electricity access (Baker, 2023). In this regard, half a million of these are domiciled in rural areas of Africa (Babayomi et al., 2023). In light of this background of rural energy poverty, there is limited progress in the growth of smart energy (Alder et al; 2023) . Resultantly,a significant number of households live in rural areas where they are not linked to the central grid (Mugisha et al ; 2021).This exacerbate energy poverty in the region. Thus, the need for urgency in the development and expansion of other energy sources which are climate proof.

Paradoxically, despite the high energy poverty, Africa has the capacity to fill the energy deficit gap utilizing sustainable energy (Doorga, et al 2022). The continent receives a significant proportion of solar radiation (Baurzhan and Jenkins, 2016).Hence with high solar irradiance, investment in solar energy generation projects in African countries have the capacity to substantially alleviate the continent's energy poverty (Moussa et al., 2023). Thus, the tapping of the abundance sunlight would increase availability of energy. In the background of energy deficit in the developing world, laterns, Solar Home System (SHS**)** and micro grid powered by solar has become key ways of addressing the energy deficit (Kumar et al 2019).Thus the significant role being played by solar energy technology in address the energy deficit gap. Availability of energy in rural areas results in the transformation of rural services, (Branca; 2023). Thus solar energy technologies are critical in rural economic development.

In Tanzania, a great percentage of rural households are vulnerable to energy (Edsand and Bangens; 2024 and The World Bank; 2023).In this vein tackling the challenge of rural access to energy is of significant importance. Given the high rate of energy poverty in rural areas the use of fuelwood and fossil fuel becomes the alternative sources of energy ,(Bede-Ojimandu and Orisakwe,2020).Consequently, this results in reduction of carbon sinks and simultaneously acceleration of climate change risks.Thus,off grid solar energy technology becomes the best option in addressing rural energy challenges (Ojong; 2022) . Thus contributing to energy justice in the in the energy transition discourse.

Uganda had made remarkable progress in addressing energy poverty by expanding the country 's electrification rate (IEA et al ;2023).However, despite such a positive standing, the country is still in the energy poverty category . The utilization of smart energy technologies in Uganda has resulted in significant improvements of rural health services (Bhamidipati et al ;2019).Furthermore, Bahaj et al (2020) highlights that the deployment of off grid solar energy technology has a multiple roles from enhancing education and health provisions to improvement of rural commercial services. Thus improving the access to health facilities by rural households which is line with the attainment of sustainable goal on health and wellbeing. Thus, solar energy is no longer an alternative, it is now the driving force behind a strong energy transition (IRENA ,2023).

In Rwanda, the growth of the solar energy technology industry has contributed significantly to the country's rural energy needs (Bisaga, 2022).Consistent with this, in 2021, a great proportion of Rwandans have access to electricity with solar energy constituting 18 % .In line with this, a variety of solar energy solutions have been integrated into Rwanda's National Electrification Plan. Sustainable energy sources is key for SubSaharan African (SSA) countries in achieving development objectives Kawthar and Waldermar (2023). In the same regard, Ghana is falling short of its goal of accelerating the adoption of renewable energy (Amuzu-Sefordzi; 2020).Despite the formulation of policies and regulation to expand the smart energy sector the adoption of sustainable energy technology in Ghana is at a low pace, (Mahama et al ;2021).

In Southern Africa, most inhabitants of rural communities lack access to electricity from the central grid (Ayodele et al., 2021). Given the financial challenges in line with grid extension, photovoltaic energy technology becomes significant in the development of solar energy (Tafula et al., 2023) .

In Southern Africa, there is exponential rise in the sales of solar energy equipments between 2018 and 2022 (Munro et al., 2023; Tafula and Justo; 2023). For instance in Zambia, the plummeting costs of photovoltaic (PV) installations made rural electrification ideal (Mulenga et al 2023). Solar energy equipment has experienced rapid sales growth in urban centres of developing countries (Munro and Samarakoon, 2023). In the same vein, there is a marked uptake of photovoltaic hybrid energy system in the Chilubi district of northern rural Zambia (Mulenga et al; 2023).

In light of the foregoing, Zimbabwe is also struggling with energy security. Photovoltaic energy technology is one of the pathways in closing the gap of energy deficit (Njenda et al., 2021). In the departure from conventional energy sources which are highly carbonized renewable energy becomes the pathway in the attainment of energy security . Energy poverty in Zimbabwe is universally acknowledged in the public domain (Chipango; 2021). A study of Zingondi Rural Resettlement of Zimbabwe attributes energy poverty to lack of technical resources (Chipangano et al., 2022). The study attributed the energy poverty to multiple factors which include gender relations and marginalization of different geographical areas. Disproportionate access to electricity has negatively impacted rural households in Zimbabwe (Chipango, 2018).In this regard, ZimStat 2022 Report of Zimbabwe National Census indicates high prevalence of **Rural Energy Poverty**. Thus, limited access to electricity in rural areas as highlighted by **Figure 1.1** below:

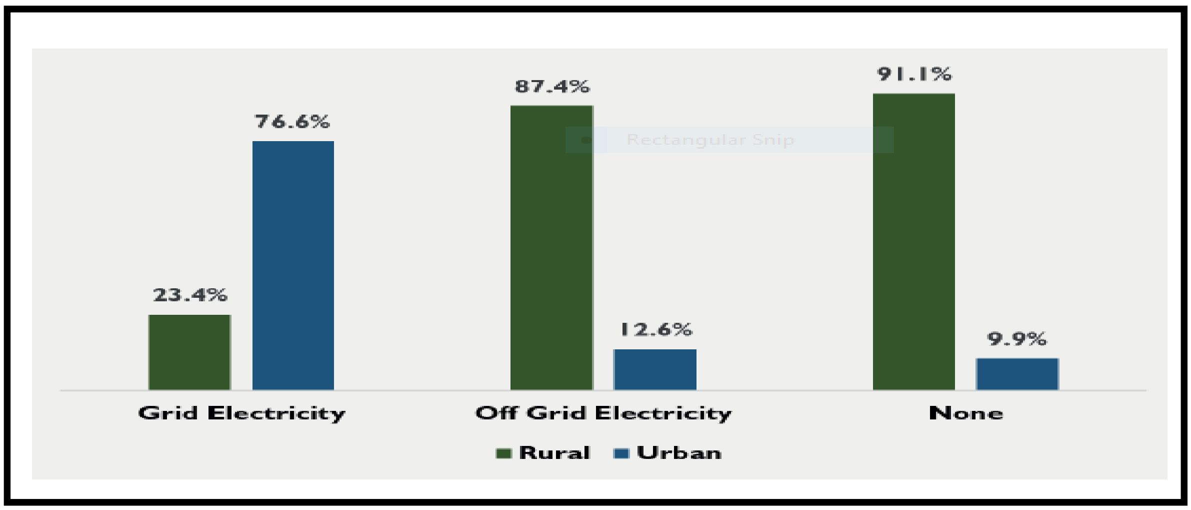

Figure 1.1 Rural Energy Poverty Adapted from (Zimstat, 2022 National Census Report)

For household that utilize electricity in Zimbabwe, 76,6 percent were in the urban areas compared to 23,4 percent in rural areas. In the same vein, 91.1% of rural households lacked access to either grid or solar energy technology and on the same note 9.9 percent are in urban areas. Thus, this clearly portray the state of energy deficit in rural areas of Zimbabwe.

In light of high energy deficit in rural areas, there is a paucity of studies which had been undertaken in the renewable energy sector particularly focusing on the deployment of photovoltaic energy technology in Zimbabwe's rural settlements. To this end, there is no empirical studies which had been under taken particularly in Shamva District yet the energy poverty is ubiquitous in the district. Hence the current research focused on solar energy technology as an option in filling the energy gap.

1.3. Statement of the problem

Energy poverty is a widespread phenomenon among households in Shamva District. In the same regard, the extension of power lines to increase availability of energy for marginalized rural communities is still a challenge in Zimbabwe (Mhandu, 2020). Lack of government interventions to spur rural electrification in remote and off grid rural areas has exacerbated rural energy poverty (Abdoulganiour ;2024)There is wide gap in Zimbabwe between Urban areas and Rural Communities in regards to access to energy, (Zimbabwe Statistics Agent Report : 2022 National Census).Consistent with the 2022 National Census Report , indicates that ninety-one percent (91 %) of Zimbabwe's rural households have limited access to energy. Consistent with this, in Shamva District the energy poverty is exacerbated by the existence of rugged terrain which limit the extension of central grid to the dispersed rural households. In addition, the sparse distribution of rural households of Shamva District increases the cost of central grid connection. Economically, rural households has low incomes which reduces the affordability of grid connection. Hence the vulnerability of Shamva rural households to energy poverty. With the drawing closer to the 2030 target of widespread availability of clean and smart energy, Zimbabwe is fast falling short of achieving the goal. Developing of off grid solar energy technology contributes to growth of rural service, expanding rural development and promoting sustainability and environmental quality (Hostettler; 2015). In this regard, the key energy source for the low income Shamva District households is non-renewable energy which is inconsistent with the Paris Agreement of 2015 which is premised on the development low emission pathways. In light of this, the adoption and deployment of sustainable energy technology in Shamva District becomes one of the best intervention in the decarbonization of rural energy. Given high energy poverty in communal areas, photovoltaic energy technology can significantly contribute to energy poverty alleviation (Akter and Bagchi; 2021).Thus, the study interrogated the adoption of solar energy technology as an intervention for the alleviation of rural energy poverty in Shamva District.

1.4. Aim

To examine the adoption of solar energy technology as an intervention in addressing Rural Energy Poverty in Shamva District, Mashonaland Central, Zimbabwe.

1.5. Objectives

i. To establish determinant factors in the adoption of households' to solar energy technology in Shamva District.

ii. To determine the factors influencing households'perception in the uptake of solar energy technology in Shamva District.

iii. To examine the barriers in the adoption of solar energy technology in Shamva District.

1.6. Research Questions

i. What are the determinant factors to households 'in the adoption of solar energy technology in Shamva District?

ii. What are the factors influencing households' perception in the uptake of solar energy technology in Shamva District?

iii. What are the barriers in the adoption of off grid solar energy technology in Shamva District?

1.7. Study Hypothesis

The study tested one hypothesis which held certain assumptions about the adopting of solar energy technology.

Null Hypothesis (H0): There is no association between households' perception of solar energy technology and the adoption of solar energy technology in Shamva District.

Alternative Hypothesis (H1): There is an association between households' perception of solar energy technology and the adoption of solar energy technology in Shamva District.

1.8. Significance of the study

1.8.1. Policy Implications

As an empirical study, the gathering of primary data may provide policy makers with useful information that informs strategies aimed at improving rural livelihoods in Shamva, Zimbabwe. The study results contribute to the voice of scholars in providing information to the government on the significant of sustainable energy sources in reducing energy deficit in rural Zimbabwe in general and Shamva District in particular. As such, as the policy maker, the government can make informed decisions in policies relating rural households energy access. In addition, insights from the study might be useful for the nation's budget allocations and financial support of the sustainable energy sector. Furthermore, the study can be key in informing the amendment of rural electrification thus, the development of photovoltaic technologies and minigrids.

1.8.2. Theoretical Implications

The study is significant in the sustainable energy discourse. It offers an insight of the opportunities and hurdles in the transition to smart energy sources. Thus the study enhances knowledge on factors influencing household's attitudes and intentions towards solar photovoltaic adoption.

1.8.3. Inhabitants of Shamva District

The study results can also be useful to the people of Shamva District who can tap into the recommendations that were proffered, for their consideration for implementation of some of those.

1.8.4. Non-governmental organizations

The findings of the study are critical to non-governmental organizations on the possible intervention measures that they can implement in their efforts to assist the society in improving the welfare of the people living in Shamva District, and Zimbabwe at large.

1.8.5. Academia

The research findings are key in expanding knowledge on sustainable energy. In addition, it provides critical literature in the sustainable energy domain for future researchers.

1.8.6. Researcher

Lastly, the study is important for the researcher, who gained research experience. Additionally, the successful completion of the study was key in enabling the researcher to graduate from the country's leading tertiary institution, the **Bindura University of Science Education**.

1.9. Delimitation of the Study/Limitations

Geographically, the area of the study was Shamva District, Mashonaland Central Province, Zimbabwe. Only the inhabitants of Shamva District were considered for the study. Conceptually, the study considered the concept of Off Grid Solar Energy Technologies (OGSET) and Rural Energy Poverty. The study was of cross-sectional nature rather than longitudinal. The target population of the study was rural households of Shamva District. The study was conducted over a period of six (6) beginning January 2024 till June 2024.The sparse distribution of households and rugged terrain of Shamva District imposed challenges in accessibility during data collection period. However, the researcher engaged all terrain high powered vehicle and managed to traverse the district during the fieldwork period.

1.10. Operational Definition of Terms

The following key terms are defined specifically for this study:

Off Grid Solar Energy technologies: - An assortment of equipments and devices which tap energy from the sun and convert it into electricity.

Rural Energy Poverty: It entails deficit of energy for consumption by rural households. It is a significant challenge faced by communities around the world particularly in developing countries.

Sustainable livelihood: Refers to the users' capacity to respond to and manage the shocks and strains brought on by changes in the natural world, which negatively affect people's material, interpersonal, and subjective aspects of life and leave them vulnerable. It also helps users improve their capacity to increase their access to and entitlements to a range of resources for subsistence.

Solar irradiance –Solar irradiance is the output of light that is received from the. It is critical in the generation of solar energy as low solar irradiance translate to low generation of solar energy and the vice versa.

1.11. Chapter Summary

The Chapter highlighted the study problem of rural energy poverty and the use of solar energy technology as a countermeasure in addressing the energy poverty. Consistent with this, the chapter looked at background of the study problem. Furthermore, the study looked at the delimitations and limitation of the study among other key variables addressed in the chapter.

1.12. Lay Out of the Thesis

In chapter one, the study outlined the background of the study and setting of the problem statement of the research. The research objectives, research questions and significance of the study were highlighted. The chapter also highlighted the delimitation/ limitations of the study and definition of operational terms. Consistent with this, chapter two presents literature in line with the research. Chapter three presents the methodology used to carry out the study. Chapter four presents the framework for the presentation, analysis and discussion of the results. Finally, chapter five concludes the thesis.

CHAPTER II

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

1.13. Introduction

The chapter is going to offer an outline of energy poverty from a global, regional and up to local level. In addition to this, the chapter also gives an insight on theories underpinning the deployment of solar energy technology which are the Technology Diffusion Theory (TDT) and the Stakeholder Participation Theory (SP) as they were analyzed in connection with rural energy deficit. Furthermore, the chapter explains the conceptual framework underpinning the research. .Scholarly literature in the field were analyzed and evaluated in line with the research objectives.

1.14. Theoretical Framework

In this study, the two primary theories that direct the accessibility of solar energy technology for reduction of rural energy poverty are the Technology Diffusion Theory and Stakeholder Acceptance Theory. The Technology Diffusion Theory is based on factors surrounding the uptake of new innovations. In the same regard, Stakeholder Acceptance Theory focuses on the participation of the diverse stakeholders including the local rural community in the diffusion of smart energy technology. In the context of the study , these theories offer a thorough framework for analyzing the factors militating against the uptake of clean energy. Thus the theories are critical in guiding interventions in the transition of Shamva Community to a more sustainable energy pathway.

1.14.1. Technology Diffusion Theory

The Technology Diffusion Theory was propounded by Everett Rogers in 1960 (Toshniwaal et al; 2024).The theory is key in creating awareness of factors which are critical in sustainable energy innovations, (Alrashoud and Tokimatsu ;2019).Consistent with this, the Technology Diffusion Theory is more ideal in the development of sustainable energy, (Sharma and Gandhi;2024). Thus offering a broader view of photovoltaic system uptake at the household level. However, despite being a pillar in influencing the development of new technology, it has some shortcomings (Aloulou et al; 2024). For instance, one of the drawback of theory is one way information flow, (Essien et al; 2024). Notwithstanding this, the theory continue to be used in different fields including the field of renewable energy technology; (Rogers et al, 2014and Faiers and Neame; 2006). Thus, the theory is most effective in the diffusion of new innovations.

1.14.2. Stakeholder Acceptance Theory

Stakeholders are critical in the roll out of new technology (Kadenic et al., 2024).Given such a criterion, factors influencing stakeholder acceptance becomes relevant. In this vein, the uptake of sustainable energy involves the participation of different players (Ocelik et al, 2021).Consistent with this, local communities are significant stakeholders in the transition to sustainable. Lack of community adoption of new technology at grassroots level can hinder the diffusion of renewable energy new technology (Enevoldsen, 2018) .Hence the theory becomes applicable in this discourse as it guides community participation in the deployment of sustainable energy technology.

1.15. Conceptual Framework

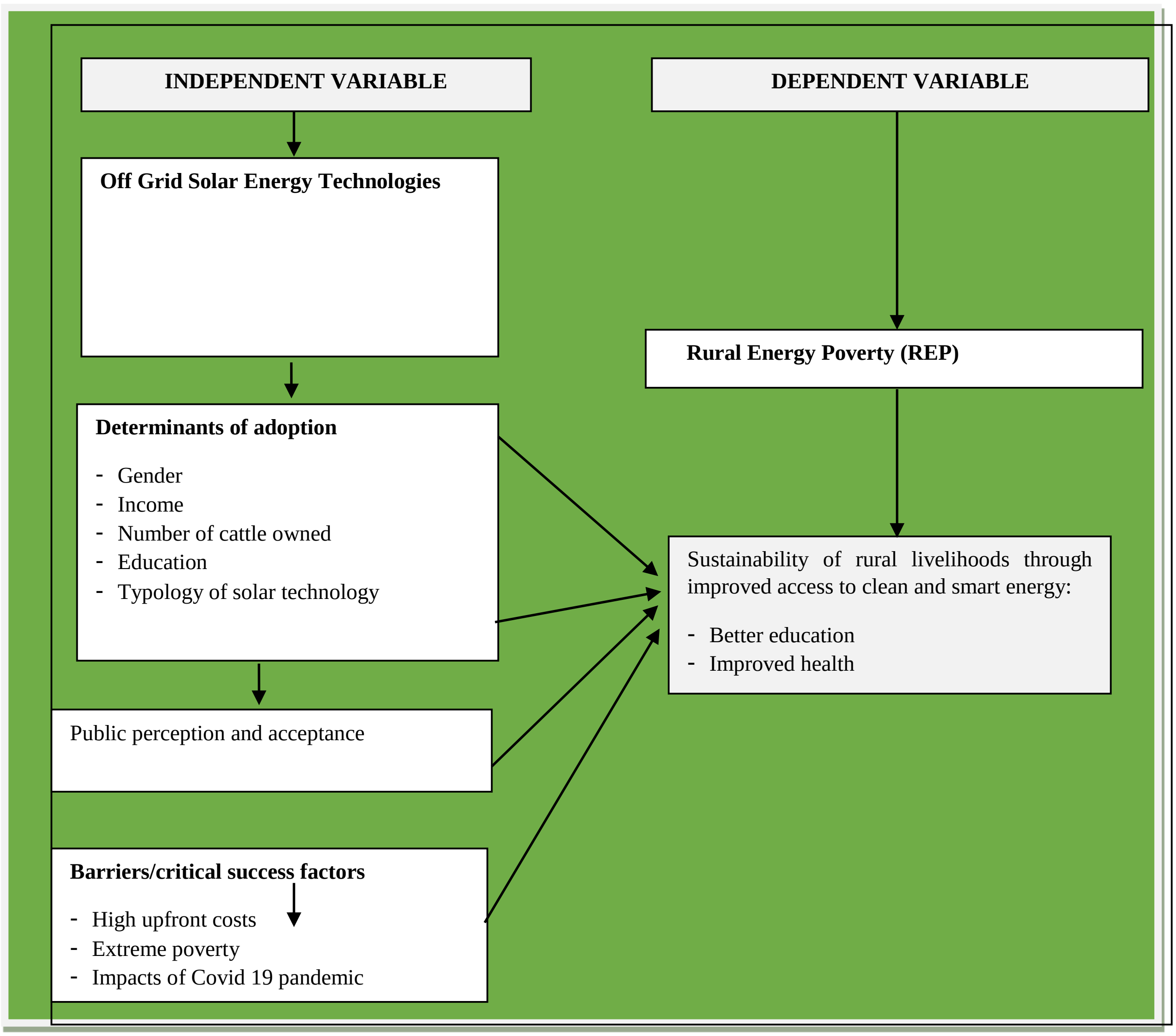

Figure 0.1: Conceptual framework that highlights the hypothesized relationship between Off Grid Solar Energy Technologies (OGSET) (Independent Variable) and Rural Energy Poverty (REP) (Dependent Variable)

Source: (Researcher 2024)

1.15.1. The Concept of Energy Poverty

Energy deficit is viewed as limited availability of sustainable energy services (Jones and Reyes; 2023). In the same viewpoint it is the consequence of failing to meet energy requirements human needs (Middlemiss et al 2019) .Consistent with this, individuals and communities exposed to energy poverty encounter hurdles in accessing sustainable energy (Manchanda; ;2017) . In this regard, energy poverty goes beyond mere measurements of energy access (Halkos and Aslanindis; 2023). The conceptualization of energy poverty has been a move from understanding energy poverty as not only having or not having energy but also understanding and analyzing conditions that shape energy vulnerability (Bouzarosvski ;2018).The energy poverty vulnerability perspective tend to have an insight of the person exposed to deficit (Middlemiss and Gillard;2015).Hence, offering a broader understanding of energy deficit. Despite the incompatibility of addressing energy deficit in rural areas using grid extension, clean energy is the ideal strategy (Cyrek and Cyrek; 2022). Attainment of energy security is crucial for multitudes of functions that are key in improving standard of living (Simcock et al; 2016).Thus the need for rural energy poverty reduction.

1.15.2. Defining Energy Access

Multidimensional Nature of energy Access.

Energy poverty, like economic poverty, has gone through unidimensionality and multidimensionality in terms of its measurements. However,Martin,et al (2023) argues that the modern construct of energy deficit refers not only to availability of electricity but also the quality of the energy and the equipment available to satisfy the various energy uses.In spite of this multidimensionality, a great proportion of the antecedents that empirically address energy poverty do so using a single indicator. In line with this household is perceived as energy poor if it allocates not less than 10% of its income to energy expenditure (Thomson ;2017).Consistent with this, the binary metric had been the dominant metric which has been used (Apergi et al ;2024). Consequently , the system viewed energy availability as obtaining energy from central power network irrespective of the reliability of the connection (Pal et al; 2024) .In line with the binary perception, households would be regarded electrified if a few are electrified (Tenenbaum ;2014).Thus, the defining of energy access in technical terms overshadows the critical social and cultural dimension of solar energy access (IKumar; 2018).Thus offering a limited view of electricity access.

Impliedly, this offers an inadequate view of electricity access as the dynamics and complexities are not adequately covered in such a perspective (Narlanka and Balachandra; 2024). Hence, the adoption of the Multi-Tier Framework (MTF) in calculating access to power which covers a broader spectrum in terms of energy access, (Muza; 2021). Thus including index such as adequacy, availability, reliability and also healthy and safety in the use of energy. Thus a household is perceived to have access to energy if the source of energy meets the foregoing variables. Thus, the multi-dimensional definition to access to energy is in sync the global aspiration of sustainable energy.

1.15.3. Global perspective of energy poverty

At a global scale there are a number of energy poverty determinants (Dunphy et al; 2023)). Consistent with this, Velasco- Herrejon et al; (2023) posits that geopolitics and the continued impacts of Covid 19 pandemic have led to the rise of energy deficit. In light of this, Barrella and Romero (2023) highlights that corona virus had a severe effects on household power access. Consequently, exacerbating energy poverty at global level. In the same regard, global energy deficit is perceived as a complex issue intersecting society,(Termeer, et al;2019). In this regard, according to geospatial research conducted in Finland rural areas were susceptible to energy poverty (Lehtonen et al ;(2024. Hence, this signifying the skewness in energy poverty distribution.

With the onset of the Russian-Ukraine War, the energy debates on energy transitions have taken on an another dimension (IRENA;2023).Notwithstanding pledges made by developed countries in pursuit of the sustainable energy trajectory, the Russian –Ukraine war coupled by the impacts of Covid 19 pandemic are having a negative effect on the global energy landscape. For instance, the European Union reopened some coal fired plants and in the same vein Germany is importing coal from South Africa (Zainab et al, 2021).Thus, reversing significant gains in the attainment of smart energy.

1.15.4. Energy Poverty in Sub-Saharan Africa.

In the Africa, rural households constitute the highest percentage of population marginalized in the provision of energy (Babayomi et al; 2023). Consequently, energy deficit is militating against development goals as access to energy is pivotal (Warner and Jones; 2018). Energy poverty in the African context is underpinned with political, social and institutional problems (Byaro et al;2024). Additionally, insufficient energy generation capacity and an over-reliance on fossil fuel is worsening Sub Saharan Africa energy dilemma (Desne', 2023).Given such a background, the uptake of sustainable energy innovations becomes the alternative to fill the electricity deficit gap in rural areas(Murshed and Ozturk; 2023) .Thus, solar energy technology offers a window of opportunity for Sub Saharan Africa to transit to smart and sustainable energy.

Overview of energy poverty in Zimbabwe

Access to smart energy sources has been difficult in Zimbabwe (Madobi; 2016).In this energy discourse, women and poor households are disproportionately impacted (Mupinga and Mawere; 2018).Poor governance and lack of funding in the energy sector were highlighted as key factors militating the development of the industry (Gandidzanwa et al; 2024).Given such a development, Zimbabwe has formulated several policy instruments consistent with addressing the energy challenges (Mushosho and Qutieshat; 2024). Inaddition to this, Zimbabwe has incorporated private players to contribute in the energy sector (Timisela; 2017).However, despite such a milestone, fluctuations in policy formulation processes had been highlighted as a key issue affecting renewable energy investment (Makoni; 2021).Notwithstanding this, Zimbabwe is in a low emission development pathway. Thus resonating with the sustainable energy trajectory.

1.15.5. Limitation of Central Grid Electricity in the provision of sustainable energy.

The traditional method of electrification is by grid extension (Bhattacharyya and Palit; 2021). Grid based electrification is the accessibility by households to a larger transmission network (Louie; 2018; Zeyringer et al 2015).The expansion of the traditional grid offers an opportunity for energy access to underprivileged remote rural communities (Ohiare ;2015). However, low population densities and less revenue accrued from grid expansion in rural areas limit the viability of further extension of central powerlines to poor rural communities (Buluswar et al ;2014). Furthermore, other challenges in grid expansion are topographical issues which can make the extension of grid electricity less favorable as compared to off grid solutions (International Energy Agency; 2017).For instance, a number of power companies within Africa countries registered losses following grid extension to rural areas (Franz et al; 2014).Hence, it is less economically viable to extend central grid to rural areas(Blimpo and Cosgrove-Davies; 2019). In the light of this, sustainable energy technologies becomes the optimum option for rural energy needs (Davies et al; 2017)

1.15.6. The Evolution of Solar Energy Technologies

The first prototype of photovoltaic (PV) technology were developed in the 19^{th} century (Fartash and Ghorbani; 2023).Following this, United States of America army funded research and development to use solar energy in spacecraft. Subsequently, photovoltaic energy was adopted in major western countries. Thus the developments put solar energy on the global energy agenda (Payel et al; 2023). In line with this, the discoveries of the scientific community indicates the significance of smart energy, (Ali et al; 2023). Solar energy is being regarded as the best option in the transition from fossil fuel which increase climate risks to clean and sustainable energy,(Ramachandran et al;2022).

1.15.7. Unconnected to the grid solar energy technology.

Unconnected to the grid solar energy technology can be viewed as standalone energy system that is not connected to an electrical grid (Desideri et al; 2013). Relatedly, off grid solar systems are mainly utilized where there is limited central grid access (Mandelli et al ;2016) .The off grid solar energy technologies are found in different assortments (Richardson ;2017) .In line with this, the widely adopted off grid solar technology is in the family of , Solar Home System (SHS) (Kumar et al ;2019). Another popular off grid solar energy technology is the Pico solar system (Hirmer and Cruickshank ; 2014). This solar power system has a multiple of roles at at household level from lighting to charging power appliances. Thus the potential to transform millions of off grid communities (Keane ;2014).Furthermore, mini grids which are also standalone networks are the other category of solar energy technology (Peters et al 2019). Mini –grids can be powered by either solar or wind and are designed to supply power to a small locality (Chaurey and Kandal ,2010).In light of this, sustainable energy is key in the decentralization of energy to the last mile users who are domiciled in poor rural communities.

1.15.8. Determinant factors in the adoption of off grid solar energy technologies.

Household level of wealth

Household level of wealth is critical in the uptake of sustainable energy technologies (Guta; 2018;Akter and Bagchi ; 2021 ; Yadav et al ; 2019). High capital needed in the acquisition of solar energy technology prohibits poor households from adopting to sustainable energy, (Aarakit et al; 2021). Relatedly , wealth families have collateral security which is major criteria for financial institution to offer loans for off grid solar energy technology, (Island et al; 2022). Thus the system is skewed towards the wealth households.

In the farming realm, level of wealth of a farmer influences the uptake of clean energy (Kindeya ; 2019). Wealth farmers have higher access to credits and this influences their adoption rate (Ahmed et al; 2022).Level of wealth signifies the typologies of sustainable energy technology adopted (Barrie and Cruickshank; 2017).In rural Tanzania solar home system remained unaffordable by poor households (Grimm et al; 2020) .Thus, income levels is key in framing the typology of off grid solar energy technology adopted. Apart from income status of households, size and tenure of land ownership in rural areas are key in this energy discourse (Wade and Rudolph; 2024).In line with this, household's average farm size corresponds with ability to adopt to off grid solar energy technology (Warkaw and Chawla ;2016).

Within the Zimbabwe context, Zongoro and Zimucha (2022) investigated the factors which influenced the uptake of clean energy in Bloomingdale, Harare. In this regard, financial and economic capacity of consumers were key determinants in the uptake of sustainable energy in Harare. Financial and economic capacity are considered in the perspective of wealth metric(McLaughlin et al ; 2024).In this regard, the research was based in the urban setting of Harare and this is in sharp contrast with the current study which focused on Shamva District which is a rural set-up. Thus, creating a necessity to establish the association between wealth and the adoption capacity.

Gender of the household head (HH) as a key factor influencing adoption

Gender shapes the access and distribution of off grid solar energy technology (Lazoroska et al; 2021). In Africa men have more opportunity to photovoltaic energy technology as compared to women (Ojong; 2021; Winter et al; 2018; Guta, 2018). Consistent with this, social and cultural factors shape this energy distribution. In the same regard, gender dimensions have a critical impact in the uptake of smart energy (Clark, 2021).Hence, this define the system in resource allocation at micro-level. Thus having implications on renewable energy access. However, Wiehl et al, (2022) offered contrasting findings by highlighting lack of association between gender and adoption of sustainable energy technology . Thus highlighting a different perspective.

In the Southern African region, gender is rarely considered in the energy domain (Zeru et al; 2020) .In this regard, such neglect is detrimental in the roll out of sustainable energy. The energy problem is compounded by gendered energy access in marginalized communities. For instance, according (Fathallah and Pyakurel 2020), solar energy technology expansion resulted in more energy access to men than women in Zambia. Thus limiting access to smart and clean energy on women. Consistent with this, developing feminist energy jurisprudence can be a pathway in addressing the link between gender and energy access. Similarly, there is disproportional opportunity to solar power technologies on gender lines in the Mpanta rural district of northern Zambia (Johnson et al; 2019). Thus, traditional practices shaped women's access to solar energy technology in northern Zambia. Thus, energy poverty is uniquely linked to social and cultural issue (Lesala, et al; 2023).Hence, interventions targeted to address energy poverty can consider addressing underlying social and cultural factors.

The literature domain had underscored the significance of gender sensitivity in sustainable energy innovations (Nelson & Kuriakose; 2017; Clancy et al 2019) . However household head's innovation is also key in addressing the energy poverty gap (Wang et al; 2023). Innovative households were associated with potential in adoption of smart energy (Sovacool et al 2022; Strielkowski et al 2019).Thus its not gender alone which shape rural households' adoption capacity.

Zimbabwe has an inclusive renewable energy policy which is key in charting the low emission development pathway (Zimbabwe National Renewable Energy Policy; 2019).However, despite the existence of such a gender cross-cutting renewable energy blue-print, there is lack of empirical interrogation on the impact of gender in the uptake of sustainable energy.Consistent with this, Chanakira and Dzapasi (2021) examined evidence of gender difference on energy access in the peri-urban areas of Zimbabwe. Peri urban areas are areas within the urban continuum (Cattivelli;

2021). This implies that there is lack of interrogation of rural women of Zimbabwe in the renewable energy discourse. Hence, the study addressed the void.

1.15.9. Size of herd of cattle

Rural household's size of cattle herd has significant impact in the uptake of sustainable energy (Wu et al ;2023; Anteneh ;2019 ;Walekhwa et al ;2009). Thus, there is an association between the number of cattle of a household and the uptake of smart energy. For instance, in the Kasangazi rural district of Malawi, possession of cattle by households framed photovoltaic energy adoption trajectory (Nkhoma et al;2024).Despite low levels of education of the rural community in Kasangazi District, households with a large herd have an inclination towards smart energy uptake. Thus education is not the sole enabler of off grid solar energy technology adoption (Karet al ; 2024).

In the Zimbabwean perspective existing studies linked to livestock and renewable energy focused on the provision of cattle manure in the generation of biogas (Shonhiwa et al 2024 ; Mapenzauswa et al ;2024).Therefore, there is dearth on literature based on analyzing the influence of cattle ownership and photovoltaic energy adoption in rural areas in Zimbabwe. It is in this regards that this current study addressed such a critical issue in the renewable energy sector.

2.3.10 Education of the House Hold head as a critical factor in solar energy adoption.

Several studies have established an association between level of education and adoption of photovoltaic energy There is empirical evidence which highlights the link between education and smart energy uptake (Zeru et al 2020;Shallo et; 2020;Anteneh; 2019 and Bahadur et al 2017).Consistent with this, increase in the level of education corresponds with increased adoption to solar energy technologies. Impliedly, low level of education signifies decline in the rate of adoption. Education is informative in regards to decisions in the acquisition of photovoltaic energy technology (Mwalule and Mzuza ; 2022; Naomi ; 2014).Educated household heads were found to be highly knowledgeable of photovoltaic energy technologies, hence an increase in the adoption rate of educated households heads(Irene ;2013; Gichuhi ;2016) . On a divergent viewpoint, while accepting the critical role of education in regards to the uptake of photovoltaic energy technology, family size is also critical (Antena ;2019).Relatedly, contrasting findings emerged from a study by Marambanyika et al (2020) in Domboshava rural area of Zimbabwe focusing on biogas. The research highlighted that education attained was not a critical issue in the uptake of biogas.Given such a scenario ,a further study was key in this regard to collaborate or contradict the finding. Hence, the current study filled the niche by evaluating the effects of education on the uptake of photovoltaic electricity.

2.3.11 Age of the household head

Age is a critical factor in characterizing adoption of photovoltaic energy (Jayaweera et al;2018;Porter; 2011). There is a strong relationship between age and desire to consider the adoption of photovoltaic energy technology, (Maciaszczyk et al ;2022)Young age household head had high adoption propensity than older age household head (Walekhwa et al ;2009 ;Zander et al 2019).The major drive of adoption within the young age sub group was found to be centred on increased awareness of solar energy technology (Yuan et al ;2021). In the same vein, household head in the advanced age category had low adoption capacity (Warkaw and Chawla ;2016). However,Etongo and Naidu;(2022) offered a contrasting perspective on the link between age and inclination to adoption of photovoltaic technology within the context of Seychelles.In this regard there was weak correlation between age and uptake of off grid solar energy technology. Consistent with this, there was need to examine the effect of age on the adoption capacity to smart energy by households in Shamva District,

2.3.12 Typology of off grid solar energy technology

The nature of the photovoltaic energy equipment is key determinant in the energy uptake matrix (Grimm et al; 2020). In light of this, Akter and Bagchi (2021) in a study of solar power adoption of rural India established that there is high rate of adoption of solar latern uptake in comparison to Solar Home System (SHS). In the same regard, a similar study by Fenandez-Fuentes et al (2021) in Latin American countries reveals accelerated uptake of Third Generation Solar Home System (3G-SHSs). Thus, there is spatial variation in the adoption of typologies of photovoltaic energy technology from place to place. In this regard the solar latern enjoys the highest rate of adoption owing to low costs.

Consistent with this, in rural households of West Africa solar home system (SHS) and mini grids enjoys the highest uptake rates as compared to other off grid solar energy technologies (Antonanzas-Torres et al ;2021). This might have been linked to universal acceptance of the renewable energy technology (Boamah,2020 ;Pedersen ,2016) . In light of this more than three hundred (300) mini grids are operating in West African (Atuguba et al ; 2020). In contrast, to Rwanda, sustainable energy equipments in the family of Solar Home System (SHS) dominate in possession as compared to mini-grid solar energy technology (Bienvenue; (2021). However, despite such a dominance, rural households in Rwanda are skeptical about their reliability. In light of this, Bhattacharyya and Palit (2014) reveals that Solar Home System (SHS) provides intermittency services to consumers, thus affecting their adoption. Despite the existence of such a deficiency in Solar Home System, the technology still enjoys widespread appeal in terms of adoption owing to public perception and awareness ((Narayan et al ;2020). According to, Josi and Yenneti (2020) in the developed world smart energy is perceived consistent with conservation and sustainability. Furthermore, the accelerated expansion of the sustainable energy sector has made photovoltaic an attractive technology in addressing energy poverty (Timilsina et al;2012).Hence, it’s not all about the typology of photovoltaic energy technology but they is a host of other variable at interplay in terms of adoption.

Within the Zimbabwe perspective, studies undertaken on the effects of typology of photovoltaic energy technology largely focused on how Small and Medium Enterprise in rural areas could leverage solar energy through the deployment of minigrids (Kavu et al 2020; Kavu et al 2022; Kavu et al; 2022).In this regard, the studies were narrowed on the impact of minigrids at enterprise level neglecting the household level which is the grassroots level in energy utilization. Besides this, there is little coverage of other typologies of photovoltaic energy technologies. Thus, the current study explored how typologies of photovoltaic energy technologies influences the adoption of solar energy technologies under a household setting.

2.4 Factors influencing public perception in the uptake of off grid solar energy technology.

2.4.1 The influence of quality and durability of solar energy technology on public perception

Knowledge by photovoltaic users on the capacity and limitation of photovoltaic technology is fundamental in gaining public positive perception towards off grid solar energy technologies in rural areas (Bahaj et al; 2020).In this regard, solar energy equipment characteristics are critical in the adoption of the clean energy. Forinstance,Groenewoudt (2022) in study highlighted that more than 74 % of households in Uganda experienced problems with newly acquired Solar Home Systems (SHS).Consistent with this, lights were not lasting for the whole 12 hour night, batteries were depleting fasting affecting power supply to television. There is a link between the efficiency of photovoltaic energy technologies and the drive to adopt the technology (Aboagye et al;2021). Conversely, in spite of the drawback of quality and durability of solar energy technology, in Rwanda there is accelerated uptake ((Bisaga; 2022).Hence, quality of photovoltaic energy technology is not key in other jurisdiction in terms of adoption. The quality and durability of solar energy technologies in Shamva district have not been fully explored. Thus, the need to explore how the quality and durability of photovoltaic energy technologies are affecting public perception.

2.4.2 The influence of knowledge and awareness on public perception

Community awareness of sustainable energy is critical in the advancement of photovoltaic energy technologies (Bisaga, 2022). Consistent with this, the dissemination of sustainable energy innovations in Tanzania was slow due to low awareness (Edsand and Bangens ; 2024) . Hence the significance of awareness in the dissemination of photovoltaic energy innovations. Furthermore, a multitude of studies had demonstrated knowledge gap in terms of off grid solar energy innovations ,(Chodhowska-Miszczuk et al; 2022; Bhamidipati et al; 2019 and Chatterjee et al; 2019) .Consequently, knowledge and awareness on technical aspects of photovoltaic energy technologies is vital in influencing public perception (Akram et al; 2020). For instance, knowledge on sizing sustainable energy equipments during installation is critical in influencing public perception (Sayani et al ; 2022) In line with this, lack of knowledge on demand side management DSM) of off grid solar energy technologies decrease the generation of energy from minigrids (Gelchu et al; 2023). Thus the need to disseminate knowledge on the impact of deficiency in Demand Side Management (DSM) of off grid solar energy technologies (Abada et al 2021). Thus fostering positive attitudes towards smart energy could impact the uptake rate.

In the same regard, knowledge on the proper functioning of the battery is key (Manoharan et al ; 2024) .Batteries are key components of off grid solar energy technologies (Sowe et al; 2020) .However, many households lack knowledge on factors influencing the proper functionality of photovoltaic energy technologies,(Few et al; 2019).Thus increased knowledge and awareness of photovoltaic operations is a critical factor in smart energy discourse , (Schimpe et al; 2022).

2.4.3 The influence of size of off grid solar energy technology on public perception

Photovoltaic energy technologies is the prevalent sustainable energy system (Sutterlin and Siegrist ; 2017 and Kaenzig et al 2013). However, despite such an acceptance, there is a variation of households' attitude on solar energy technologies based on the size of sustainable energy equipment installed, (Cousse ;2021). Thus, the size of renewable energy technologies is a determinant factor towards public acceptance (Jobin et al; 2019).In regard to energy generated from wind, there is a decrease in public acceptance with the increase in size of the installation of the technology (Rand and Hoen ;2017 and Firestone et al ;2018). In the same regard, the installation of bulky photovoltaic equipment decreased public acceptance of sustainable energy in the United States of America, (Carlisle et al ;2015) .

However, (Aly et al; 2019) in assessing impediments to large scale roll out of solar energy in Tanzania established institutional barriers as key variable influencing public perception on the implementation of large solar projects. Hence, institutional factors are key in informing public perception in this regard. In the Zimbabwe context studies had centred on the scalability and feasibility of minigrids (Kavu et al 2020, Kavu et al 2022 and Azimoh et al; 2017).Consistent with the development of these large scale off grid technologies there is lack of comprehensive evaluation of public perception of these technologies within a Zimbabwean setting, hence influencing adoption.

2.4.4 Sensitization of the co-benefits of off grid solar energy technology.

Educating communities on the rewards of adopting sustainable energy is critical in nurturing positive perception (Njeru and Ndunda ; 2024; Kristofova et al ; 2022). In such a scenario, Stober et al ;(2021) posits that the acceleration in the growth of photovoltaic energy technologies can be enhanced through upscaling in the dissemination of the knowledge of accrued co-benefits to the local rural communities. Similarly, Hanger et al (2016) established a universal acceptance of large scale solar projects in rural Morocco. This universal acceptance was hinged on the awareness of environmental friendliness of solar energy (Leonard et al ; 2024) Thus the awareness of the co-benefits can foster positive attitude which can enhance the adoption of photovoltaic energy technologies.

2.4.5 The impact of seasonal variation of temperature on perception of off grid solar energy technology.

Spatial and temporal variation of temperature has a significant influence on public perception of photovoltaic energy technologies (Mardani et al; 2024). There is interruptions in the generation of photovoltaic energy (Kim et al 2018) .Thus knowledge on the energy output of photovoltaic plants is critical in influencing public perception. This is attributed by the fact that the daily atmospheric conditions have an important impact in the generation of photovoltaic energy (Xia; 2021).Thus the state of the weather system has a bearing on the photovoltaic output power,(Kang et al; 2018).

Global solar distribution and intensity level affects the output of solar energy technologies (Pravalie et al ; 2019).This entails the variation of insolation at global level. In high latitudes region, seasonality of solar radiation impacts the generation of photovoltaic energy (Vuichard et al ; 2021) .In this regard, the potential of photovoltaic energy technologies is frequently limited due to snow conditions (Ruan et al ; 2024;Chen et al ;2020).This signifies the need for the optimization of photovoltaic technology installation . In contrast, Africa has high solar irradiance, however there is lack of utilization of this abundant solar energy resource (Santos et al; 2023).In South Africa, Overen and Meyer (2022) in a study to explore solar resources of South Africa established abundant solar resources potential of the country.Djurisic et al (2024) in a public analysis of attitudes towards renewable energy indicates that high energy output from off grid solar energy technologies boost public perception. Hence seasonality affects public perception of solar energy technologies since it has effect on the generation of photovoltaic energy owing to variation in temperature.

The association between high solar irradiance in Zimbabwe and perception of off grid solar energy technologies had not been fully expored (Ghussain et al; 2020 ; Chahuruva and Dei; 2017). A number studies on photovoltaic energy focused in chacterisation of the technology (Ngwenya and Hull; 2024, Mutume; 2023).Thus the need to ascertain the impact of seasonal variation on households' perception of solar energy technology in Shamva District.

2.4.6 Community participation in the off grid solar energy technology.

Local communities play a significant role in rural development (Ozimek ; 2021).For instance, in Ecuador and Peru, there was unsustainability on the expansion of clean energy technology on account of lack of community participation, ((Feron et al; 2017).

Consistent with this, lack of public participation was found to be a hurdle in the expansion of sustainable energy in rural communities of South Africa (Jarbandhan et al; 2018). Successful roll out of solar energy technologies to the last mile users is anchored on the participation of the local rural communities (Tan et al ; 2022) .In line with this, there was marked growth in the diffusion of sustainable energy in the United States of America anchored on community participation (Aldarsi and Signh ; 2024) . In the context of the Southern Africa region, Ehimen et al (2023) highlights that a solar village concept in energy poverty rural Malawi registered success due local ownership and participation of in the project.In the Zimbabwean perspective the literature domain attest to studies on technical challenges of off grid solar energy technologies (Njenda et al 2021 and Samu,and Fahrioglu,;2017)..This, therefore cast an empirical gap on community participation in off grid solar energy diffusion in Zimbabwe.

2.5 Barriers in the adoption of off-grid solar energy technology

2.5.1 High upfront costs

Exorbitant initial costs inherent in photovoltaic technologies is a hindrance in the growth of the clean energy sector (Castro et al;2024).In Saudi Arabia,installation costs of Residential Solar Photovoltaic System (RSPS) has stalled the transition to small scale solar system expansion(Alrashoud and Tokimatsu ;2019) . Thus affecting the development of clean and sustainable energy. Similarly, Brazil had made significant investment in small scale solar energy energy technologhy (Rigo et al ;2019).In light of this, the deployment of photovoltaic energy technologies in Southern Region of Rural Brazil had been hampered by high costs of initial investments,(Garlet et al ;2019) . In another jurisdiction, high capital expenditure was found to be the stumbling block in the implementation of photovoltaic technologies in Lithuania (Streimikeine et al; 2022). Hence, the need to deal with the hurdle of substantial initial costs of solar energy technologies and this can translate into increased access to smart energy in rural areas ,(Lv; 2023;Waldau; 2023) . Thus the need for optimization of costs in the solar energy sector (Nyarko et al; 2023).

African manufacturing industries still lags behind in the output of photovoltaic technologies,(Adenle ; 2020). The absence of locally manufactured off grid solar energy technologies increases the prices of solar to the local consumers as players in the industry depends on importation (Jadhav et al; 2017). In Nigeria, high operational costs of solar energy technologies had been highlighted as the impediment for rural household uptake of photovoltaic technologies, (Osunmuyiwa and Kalfagianni ;2017) .Thus, the need for the growth of local solar sector to upscale the affordability of sustainable energy technologies to grassroots customers. Consistent with this , the Covid 19 pandemic increased the costs of photovoltaic technologies due to lockdowns which restricted importation (Shen and Ayele;2020). In addition to the halting of importation of solar panels, the pandemic also affected income levels of consumers of solar energy technologies (Gebreslassie; 2022).Thus impacting on the initial cost of acquiring sustainable energy technologies.

In the African setting, high upfront costs in the procurement of photovoltaic energy technologies can be exercabated by high levels of poverty. Rural households in the context of the African continent live on less than US$1, 5 per day (Mugisha et al ;2021).This symbolize extreme poverty on the continent, hence impose limitation in the uptake of smart energy. In the backdrop of poverty and high upfront costs in terms of photovoltaic technologies, rural households resort to bioenergy in the form of woodfuel and charcoal (Mohammed et al ;2015). In Nigeria, fuelwood is the major alternative in place of modern and smart energy (Okwanya et al; 2021; Wassie et al ;2021).Thus becomes key determinants which militate in the adoption of sustainable energy apart from high upfront costs. On the other hand, the existence of high forest biodiversity in rural Tanzania act as a stumbling block in the acquisition of clean energy technology , (Dokken and Angelsen ; 2015) .Thus, rural household have cheap alternative source of energy in the form of fuelwood. Hence, it’s not only high upfront cost alone, but a combination of interlinking factors in the energy matrix.

On the local context, installation costs were found to be a militating issue in the transition to solar energy by the small scale mining sector of Zimbabwe (Maronga et al ;2021). This exemplified the adoption of photovoltaic technology in the small mining realm, thus lack of exploration of adoption in rural setting. Hence, there is a void in the literature domain on the experiences of rural households in Shamva District in regards to initial costs in the acquisition of photovoltaic energy equipment.

2.5.2 Access to credit facilities and finance

Funding is a key enabler for rural household to access of photovoltaic energy technologies, (Isaac ;2014).In this regard, funding and financing of sustainable energy technologies is one of the major constraints in the expansion of smart energy industry in Africa,(Branca,2023).. Investors in photovoltaic technologies are skeptical in making significant funding to the sector due to uncertainties (Adewuyi et al; 2020). In light of this, financial institutions have more confidence in directing energy investment in fossil fuel than in sustainable energy (Schwerhoff and Sy; 2020). Information deficiency on photovoltaic industry by banking sector in Sub- Saharan Africa makes it hesitant in offering credits to consumers (Yang and Yang ;2017).Hence, there is lack of credit facilities for rural households to acquire solar equipment. Thus limiting rural household adoption to off grid solar energy technologies.

Insufficient funding had been identified as one of the stumbling block in the development of photovoltaic technologies in Zimbabwe (Mushosho and Qutieshat; 2024). Impliedly, lack of funding reduces credit facilities for rural households to access credits lines for the assimilation of sustainable energy. Hence, the significance of ascertaining whether household have access to credits in the current study.

2.5.3 Theft and Vandalism of Photovoltaic equipment.

In Africa, theft and vandalism of solar equipment has emerged as one of the impediments in the diffusion of photovoltaic energy technologies (Ikejemba and Schuur; 2018).Solar Home System (SHS) are highly susceptible to theft in rural communities of South Africa. In a bid to counteract solar panel theft, rural communities in Thlatlaganya rural area of Limpopo Province of South Africa have resorted to countermeasures to address theft and vandalism of solar energy equipment,(Azimoh et al; 2014).Consistent with this, there is need to establish whether households in Shamva District were vulnerable to theft and vandalism of solar energy technology.

2.5.4 Limited technical skills

Technical barrier is one of the drawback in the diffusion of rural solar projects (Abdullahi et al; 2022); Lo et al;2018). In this regard, lack of skilled personnel resulted in hazardous installations of solar equipment in Ntchisi village of Malawi (Ngonda et al;2023). Hence, there is need for solar education training at school level and in higher education to establish skills chain for installation, repair and maintenance of solar system at community level (Senger et al;2017).In the same vein, Mgonja and Saidi (2017) found an association between solar energy technology field maintenance and improved operations of installed solar system in rural Rukwa Region of Tanzania. Consequently, solar installation and maintenance increased solar energy output of the system (Naicker ;2018). In contrast, poor operation and maintenance practices of solar energy technology can result in decreased performance (Aboagye et al ;2022).Thus field maintenance of solar system results in the increased performance of rural solar energy system. Inadequate skills in the configuration and repairing of solar energy innovations were cited as key factors inhibiting the dissemination of sustainable power generation equipments in Zimbabwe (Clean Africa Energy;2021).Hence the need to establish the skills gap in the solar energy technologies.

2.6 Research Gap

The study notes that while there is evidence of researches on the uptake of smart energy against the backdrop of energy poverty in Zimbabwe little had been done to comprehensive address rural household energy poverty. For instance some of the studies focused on peripheral areas of Zimbabwean towns, (Zongoro and Zimucha; 2020).In addition to this, Chanakira and Dzapasi (2021) examined evidence of gender differences on energy access in the peri-urban areas of Zimbabwe. Thus neglecting rural areas in empirical investigation on energy needs. Furthermore, a similar study on renewable energy was carried out in Rural Domboshava, Zimbabwe focused on biogas technology (Marambanyika et al; 2020).Hence the deficiency of studies focusing on the nexus between solar energy technologies and rural energy poverty. Thus, this study was motivated by the existing knowledge gap and moved to close the gap by examining the factors determining the uptake smart energy in the face of household energy poverty in Shamva District, Mashonaland Central, Zimbabwe. Hence offering context specific interventions in the adoption of sustainable energy in ameliorating rural power deficit.

2.7 Chapter Summary

The chapter highlighted past studies related to the research starting with the theoretical framework underpinning the study. Following this was a discussion of the conceptual framework .The empirical literature underpinning the research was discussed. In the discussion of the related literature, research gaps which were to be filled by the current study were identified.

CHAPTER III

RESEARCHMETHODOLOGY

2.1. Introduction

The chapter zeroes on the actions which were taken in the investigation of the uptake of solar technology (OGSET) as an option in reducing rural energy deficit (REP) in Shamva District. This comprise the procedures that were utilized for the identification, selection, processing and analysis of data that was used for understanding the research problem. In addition to this, the chapter highlight detailed information on the methods which were used and the reasons for why the methods were chosen. Thus it sheds light on how the answers to the research questions were obtained using the methods selected.

3.2 Brief Description of the Study area

The empirical research was conducted in Shamva District that is 1,015, 6 km2 in size .It is an area of territorial administration and local governments with 29 political wards which are predominant area of agriculture and small scale mining activities. The area is sparsely populated with 70% of rural inhabitants which make up majority of the overall population. It borders with, Mupfure Rural District to North, Maramba-Pfungwe District to the East, Murewa District to the South and Bindura Rural District to the West. The majority of households in the rural area depend on fuelwood for their energy needs. Despite the fact that the households are dependent on fuelwood, it is ironic that the area is ideal for the implementation of sustainable energy technologies.

Brief Description of the study area

Map of the Study Area

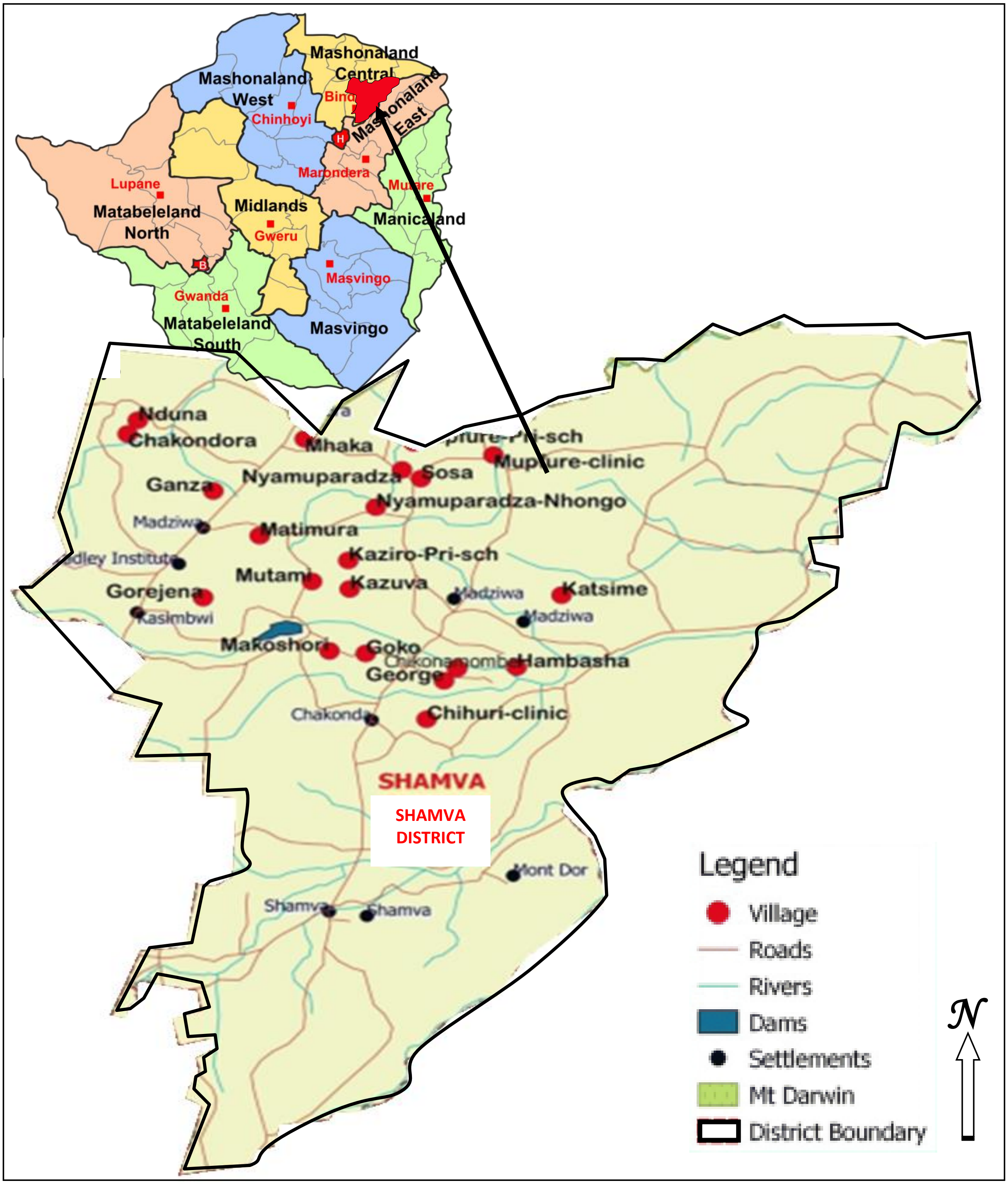

Figure 2.1: Shamva District Map

3.3 Research Design

The study adopted concurrent mixed method as the ideal design in exploring variables influencing the uptake smart energy technology in Shamva District. In line with this, concurrent mixed method research design entails the concurrent collection of qualitative and numerical data and this is followed by the comparisons of the collected data (Edmonds and Kennedy (2012). Thus, this approach involves the gathering of varied but complementary data on one issue. Hence, it is used for the integration and subsequently interpretation of quantitative and qualitative data. Energy poverty is a complex issue that involves social, economic and cultural factors (Schaube et al; 2022). By using concurrent mixed method design, the study was able to have a comprehensive understanding of energy poverty by collecting both qualitative and quantitative data.Thus, the design allows for a more holistic view of the research problem (Neuman; 2014).In addition to this, the concurrent mixed research design allows for triangulation, which is the process of comparing and contrasting different data sources or methods (McBride, MacMillan and Steiner; 2019). Thus, by combining both qualitative and quantitative data, the research was able to cross validate the results thus strengthening the overall conclusion.

In addition, qualitative methods facilitate a flexible process and allows the study to build in-depth knowledge of the phenomenon under investigation (Benard and Benard; 2013). Furthermore, qualitative methods are more appropriate for obtaining context specific information (Claudy et al : 2015).Thus, it offers the study the ability to proffer context specific interventions to address energy poverty in Shamva District. In the same regard, the quantitative methodology allows for systematic and standardized data collection which enhances the objectivity of the study (Johnson et al; 2003) Hence, allowing the research outcome to be generalized to the wider population. However, disregarding the strength of concurrent mixed method, it has some challenges complexity in designing and implementing concurrent mixed method is the frequently cited drawback (Creswell; 2013. This entails that the researcher needs knowledge in different forms of data processing and analysis. In light of this, the researcher possessed diverse expertise in different research methods, hence the ability to integrate both quantitative and qualitative data.

3.4 Sampling Procedure

The selection of research participants from a large group of population for research study is viewed as sampling (Bhardwaj;2019).Sampling allows researchers to collect and analyse data from a small subset of the population (Mujere; 2016).Thus sampling is feasible and cost effective than attempting to study the entire population. In light of the current study, multi stage random sampling technique was employed.Multi-stage random sampling method also known as multi stage cluster sampling is a sampling technique that is based on splitting a population into multi stages or cluster and selecting samples from the clusters (Fan and and Sun;2024). In this way, it allows for efficient sampling by reducing the number of observation required compared with sampling of the entire population. This sampling strategy was ideal for the current study as the study participants were spatially dispersed in different administrative wards within the district. In line with the multi-stage sampling technique, the classification of clusters for the study is based on geographical regions which are found within the study area (Zhang et al; 2024). Consistent with this, within the Shamva District the classification of clusters for the wards was based on geographical dispersion of the wards. Hence the study established three clusters Cluster 1 which is Madziwa Communal Lands, Cluster 2 which is Chakonda Communal Area and Cluster 3 which is A1 and A2 Resettlement Area. Inaddition to this, random sampling was used in the selection of the three wards from the three clusters. Each cluster was randomly sampled to come up with one ward, thus the three wards were selected, Ward 3 Goora, Ward 11 Gono and ward 17 Kifi.

However, the use of multi-stage random sampling technique is fraught with problems. There are potential biases and errors that can arise in multi-stage random sampling such as selection bias at each stage (Hejazi and Roozkhosh; 2019).However, the researcher ensured that all relevant clusters were included in the sampling frame to minimize the selection bias.

3.5 Sample Size Determination

The Roscoe (1975) set of guideline was adopted to establish the size of the sample to participate in the research. Roscoe suggests that a sample size greater than 30 and less than 500 is suitable for any Social Science Researches (Ghoreishi et al; 2024). Hence from each of the three wards 30 households participated in the study. The research employed simple random sampling to choose the 30 households from each ward selected to take part in the research. The total number of participants for the quantitative data was 90 and for the qualitative data were four (4) key informants, thus the study had a sample of 94 research participants.

Table 3.1 Sample Size Determination Guideline using Roscoe (1975) and calculations were based on Zimstat (2022) Households Census Data.

Ward	Area	Cluster	Household	Sample Size Determination
3	Goora	Madziwa Communal Lands	1,528	30
11	Gono	Chakonda Communal Lands	2,014	30
17	Kifi	A1 and A2 Resettlements Area	1,870	30
		Total Households		**90**

Source: (Researcher Calculation; 2024)

3.6 Methods of Data Gathering

3.6.1 Household Survey Questionnaire

The study employed a questionnaire in the gathering of quantitative data. A household questionnaire survey is a structured set of questions framed to elicit data about various aspects of a household (Strauss et al; 2016). It is normally adopted to collect data that can provide insights into the characteristics and needs of a household (Dillon and Mensah; 2024). The household survey was ideal in view of resource limitations of the study also insufficient time. Hence quantitative data was obtained from ninety households swiftly. Furthermore, household survey questionnaire enabled swiftly processing and analysis of data by SPSS version 21. However, five respondents did not return the questionnaire as they were not found during the follow up. In this regard, the household survey questionnaire (Appendix A) was the chief instrument used in data collection. The design catered for four sections. Consistent with this, **Section A** encompassed questions about respondents' basic background information such as **gender, age, and level of education of a household. Section B** of the questionnaire focused on the determinant factors in the assimilation of households of solar energy technology in Shamva District. These variables are key in informing adoption of household to sustainable energy. Following section B, the next section is Section C which focused on establishing factors which influenced household decision in the uptake of smart energy in Shamva District. These factors are key as they influence acceptance or rejection of the solar energy technology in Shamva District. Lastly**, Section C,** which is the last section of the questionnaire was framed to capture barriers to the uptake by households of solar energy technology .The instrument employed some statements or declaration which were supposed to be rated by the respondents. The use of SPSS version 21 made quantitative data capturing a swift accomplishment.

The household survey question was inclusive of structured and exploratory questions. Consistent with this, the close-ended questions constituted the predominant questions and this was key in the quantification of responses from the study. On the other hand, the few open- ended questions were crucial in capturing unique qualitative data in regards to the uptake of sustainable energy .Hence, giving a deep insight of the study.

The researcher catered for ethical issues which are key in data collection and an introductory consent note written in English was on the first part of the questionnaire (Appendix 1).The introductory note was informative of the aim of the research and also fostered anonymity of participants in whatever contribution they were going to make in respect of the research. At the same time, respondents were at libert to pull out from the study. In conformity to research ethical issues, authority to undertake the research was obtained from Shamva District administrator.

3.6.2 Key Informant Interview Guide

The study conducted key informant interviews in order to validate household questionnaire survey data**.** In this regard, key informant interview is a method of research which is based on a series of qualitative questions (Few et al,; 2019) .The participants were selected through purposive sampling criterion. Purposive sampling is a non-probabilistic sampling technique that involves deliberately selecting specific individuals or groups based on predetermined criteria (Rai and Thapa; 2015).The key informants were critical figures in community development programmes, hence had in-depth knowledge in the assimilation of photovoltaic energy in the district (Andrade; 2021).Hence, the approach managed to select individuals with relevant knowledge to the current study. Interview guide (Appendix 2) was designed to elicit data from key informants. In this regard, a total of four (4) key informants participated in the study, ward counsellor, traditional leader, school headmaster and solar energy equipment retailer. The Interview guide had six (6) exploratory questions which were centred on the three (3) research objectives which were to establish the determinant factors, perception and barriers in the assimilation of sustainable energy. The researcher took advantage of a district development meeting at Chakonda Business Centre which is a rural business centre in Shamva District .The four (4) key informants were in attendance of the district development meeting hence the interviews were conducted. The responses were recorded during the interview time.

3.6.3 Photo Videoing/ Observation Method

The observation method was another method which was employed by the study to augment the data collected from the Likert Scale Questionnaire and Key Informant Interviews. Observational method is a research technique employed in various scientific disciplines to gather data by systematically observing and recording the behavior and characteristics within their natural environment (Kumar; 2022). With the observational method, salient issues in line with the uptake of photovoltaic energy by the households were captured. Hence this enhanced the validity of the study as data collected from multiple sources enriched the study. The observation method focused on two key issues that is highlighting evidence of theft of solar equipment mounted at a school classroom block and also evidence of existence of Solar Home System (SHS) at household level. The researcher used a smart phone to take photographs of the highlighted solar equipments. Thus photographing these key solar installation was critical in enhancing valuable insights in the research study. The observation method instrument is illustrated **Appendix 3.**

3.7 Data presentation and analysis

Data analysis can be considered as the categorization of the responses obtained from the gathered data in line with the research design employed in a particular study (Sutton and Austin; 2015). In this regard, the numerical data was subjected to statistical analysis. In addition to the Likert scale, the numerical data was further underwent statistical test using SPSS version 21.In the same regard, Linear Regression and Pearson Correlation tests were used in confirming the statistical significant of variables. For the qualitative data, a summary of responses were recorded per question and also some direct quotations were also recorded from the four (4) Key Informants. In the same regard, thematic exploration was used following the coding of the exploratory data. Hence central themes emerging from key informant interviews were captured and analyzed. Consistent with this analysis, photos were presented to highlight significant phenomenon observed during the field work.

3.8 Pilot Study

A pilot study was conducted from **1 March 2024 to 7 March 2024** using Self –Administered Questionnaires. The pilot study was carried out on the households of Nyagande area of Uzumba District, of Mashonaland Central Province. This is an adjacent district to Shamva District and fifteen households took part in the Pilot Survey. The outcome of the survey indicated that there were about two questions which the respondents were failing to understand. In light of this, the researcher fine-tuned the questions being informed by the comments coming from households through the pilot study.

3.9 Conclusion

The chapter highlighted the various research methodologies adopted in the study. Mixed approach was used that allowed the employment of multiple data gathering tools. In the same regard, the justification for employing multiple research instruments was highlighted in line with the research design. The chapter also offered a general description of the study area which is Shamva District. Furthermore, it highlighted how data was collected, processed and analyzed.

CHAPTER IV

DATA PRESENTATION, ANALYSIS, AND DISCUSSION

3.1. Introduction

The chapter presents the findings of the research. The study response rate was presented first, followed by research instrument reliability test results. Next, the chapter presents the demographic data relating to the study participants focusing on gender, age and education. Additionally, the chapter presents data analysis and discussions made in line with the research's objectives. The chapter finally ended with the presentation of chapter summary.

3.2. Response Rate

This section provides the response rate which was achieved by the researcher during data collection phase.

Table 3.1: Study Response Rate

Form of Data	Target Sample	Responses	Non-response	Percentage Response Rate (%)
Quantitative	90	85	5	94
Qualitative	4	4	0	100
Aggregate Total	**95**	**89**	**5**	**95**

(Source: Primary Data, 2024)

The data illustrates a high response rate of 95% within the sample population of 95 participants, indicating a robust level of engagement with the study. In this regard, five (5) respondents failed to return the questionnaire despite spirited follow ups made. This high response rate is indicative of effective communication and engagement strategies employed throughout the research process. Thus, this demonstrated success in achieving a 95% response rate underscores the effectiveness of the research team's efforts in fostering participant involvement and cooperation.

3.3. Reliability Tests

Cronbach's Alpha Test was employed to determine the internal consistency and reliability of research instruments .The findings of the test is indicated in table 4.2

Table 3.2: Reliability Tests

Variable	quantity	Cronbach's Alpha
Determinant factors	**8**	**0.886**
Gender of household head	**4**	**0.746**
Knowledge and Awareness of off grid solar Energy Technologies	**7**	**0.911**
Typologies of off grid solar Energy technologies	**5**	**0.719**
Barrier to the adoption of Off grid solar energy technologies	**8**	**0.783**

Source: (Research Questionnaire 2024)

Table 4.2 above indicates the study instruments had reliability constants of 0.886, 0.911, 0.719, 0.783 and0.746 for the study variables. Pallant (2011) indicate that the threshold acceptable level of Alpha value is 0.7. Thus the study instruments were regarded reliable and consistent. In the same regard, reliability tests are essential to ensure the consistency and accuracy of the measurement scales used in the study.

3.4. Demographic characteristics of participants

This section of the research presents the demographic information of the study participants . The background information of the participants is key in informing the research problem. Table 4.3 below indicates the demographic information.

Table 3.3: **Demographic characteristics of participants**

n= 89

Demographic Variable	Frequency	Percentage
Gender		
Male	47	53 %
Female	42	47 %
Total	**89**	**100 %**
Age		
Below 24 years	2	2 %
25-34 years	48	54 %
35-45 years	25	28 %
46-54 years	7	8 %
Above 55 years	7	8 %
Total	**89**	**100 %**
Education Level		
"O" Level	2	2 %
Diploma	34	38 %
Undergraduate Degree	5	6 %
Professional Certificate	23	26 %
Master's Degree	22	24 %
Other Qualifications	3	4 %
Total	**89**	**100 %**

(Source: Primary Data, 2024)

3.4.1. Gender of the Respondents

Table 4.3 shows that the gender distribution of the participants is slightly skewed towards males, with fifty-three percent (53 %) males and forty- seven (47%) females. This distribution suggests a relatively balanced representation of both genders in the study, which was essential for capturing potential gender-specific perspectives and experiences related to the research problem.

3.4.2. Age of Respondents

Table 4.3 highlights the age distribution of the participants and the majority fifty-four percent (54%) fall within the 25-34 years age group, indicating a substantial representation of young adults in the sample. The next largest group was twenty-eighty percent (28%) in the category of 35-45 years age group, representing individuals in their middle stage. The age groups of 46-54 years and above 55 years each account for eight percent (8 %) respectively of the participants, suggesting a lesser representation of older individuals. Only two percent (2 %) of the participants were below 24 years of age. This age distribution suggests that the study captured a diverse range of age groups, with a focus on individuals who were likely to be key in the sustainable energy discourse.

3.4.3. Education Level of the Respondents

Table 4.3 indicates that in terms of education, a great proportion of the research participants thirty-eight percent (38 %) were diploma holders, followed closely by those with a professional certificate twenty-six percent (26 %) and a master's degree twenty-four percent (24%). A smaller proportion six percent (6 %) holds an undergraduate degree, while only two percent (2%) have an "O" level qualification. Additionally, four percent (4%) of the participants reported having other qualifications. This distribution indicates a relatively fair level of educational attainment among the participants, which can translate to well informed responses.

3.5. Determinants in the adoption of off grid solar energy technologies in Shamva District.

The research sought to establish the determinants to the uptake of sustainable energy in Shamva District. This section addressed Section B of the questionnaire and item number 1 to 2 of the key informant interview guide.**Table 4.4** presents the results of the questionnaire.

Table 3.4 Key determinants to the adoption of off grid solar energy technology in Shamva District.n=89

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Household level of wealth is a determinant in the uptake of clean energy	**1%**	**10%**	**7 %**	**37%**	**45 %**
The gender of a household head (HHH) is a key determinant factor in the adoption of solar energy technology.	**0%**	**0 %**	**4 %**	**42 %**	**54 %**
The size of head of cattle owned by a household is a determinant factor in the uptake sustainable energy	**6 %**	**4%**	**3 %**	**15 %**	**72 %**
Education is a key determinant in the adoption of solar energy technology.	**0**	**2%**	**10 %**	**38%**	**50%**
Typology of solar energy technology determine the adoption capacity of households.	**7%**	**7 %**	**7 %**	**22 %**	**57 %**
There is nexus between age and the capacity to adopt solar energy technology.	**54 %**	**26 %**	**10 %**	**6 %**	**4 %**

Source: Research Questionnaire

3.5.1. Household level of wealth

The statement sought to elicit opinions from the respondents whether household level of wealth has a bearing on the adoption of sustainable energy in Shamva District. The findings from the gathered data are as highlighted in **Table 4.4 above**.

Table 4.4 illustrates that the majority forty-five percent (45%) of sampled household strongly agreed that household level of wealth was a determinant factor in the adoption of smart energy , with a significant proportion thirty-seven percent (37 %) agreeing with the above opinion, while the minority one percent (1%) strongly disagreed to the notion that household level of wealth influences the uptake sustainable energy. A very few, ten percent (10%) were in disagreement with the above sentiment, while seven percent (7%) felt neutral to the idea. Thus, household level of wealth is a key determinant in the uptake of sustainable energy in Shamva District.

The results are in line with findings from key informant interviews, which revealed that household level of wealth is a significant factor in embracing smart energy in Shamva District. This is evidenced by the responses indicated below:-

> ***[Ward Councilor]*** *The households who have acquired solar energy technology are those who are relatively wealth. These are people with streams of income which is key in acquiring the solar energy technology.*
>
> ***[Solar Appliance Retailer]*** *The households who normally visits the shop for solar energy products are those who are engaged in income generating projects. Those who do not engage in income generating projects, for instance those who hang around the rural shopping centre fail to have finance for acquiring the solar energy technology.*
>
> ***[Traditional Leader]*** *Those who are wealth in this district are the majority of people who are able to acquire solar energy technology. The underprivileged households are not able to have disposable income for solar energy technology financing*
>
> ***[School Head]*** *Those engaged in gold mining activities have significant income to acquire solar energy technology. Thus, wealth is significant in the adoption of sustainable energy.*

In this regard there was convergence of views between quantitative and qualitative data on whether level of wealth influences households' ability to adopt sustainable energy. From the stated results it is evident that households' level of wealth is a key enabler in the uptake of off grid photovoltaic energy technology. The finding conform with results by Akter and Bagchi (2021) , Grimm et al ;(2020) and Yadav et al (2019) among others who established that wealth is a determinant factor in the uptake of off grid photovoltaic energy technology. In the Zimbabwean context, consistent findings were also confirmed by Zongoro and Zimucha (2022) in a study of factors influencing the uptake of photovoltaic energy technology in Bloomingdale, Harare. Thus, the adoption of off grid photovoltaic energy technologies is anchored on the household's level of wealth. Hence the need for gender disparity interventions.

3.5.2. Gender of the household head (HHH) .

The statement wanted to determine from the respondents the effects of gender on the uptake of off grid photovoltaic energy technology in Shamva District. The quantitative data gathered are as indicated on **Table 4.4** above.

The findings in **Table 4.4** reveal that a great proportion of respondents fifty –four percent (54 %) strongly agreed with the notion that gender of the household is a determinant variables in the uptake of smart energy technology in Shamva District, with forty-two (42 %) agreeing to the above viewpoint, while a minority four percent (4 %) felt neutral on the proposition that gender of household head is a determinant factor in the uptake of off grid photovoltaic energy .

The above results are consistent with the outcome from the interviews with key informants which expressed the same sentiments that gender has a bearing in the adoption of solar energy technology in Shamva District. This is indicated by sentiments from the Key Informants:-

> ***[Ward Councilor**] Male headed households are adopting solar energy technology than female headed households. This is because men participated in gold mining activities than women, hence men have more disposable income to purchase solar energy equipment as compared to women.*
>
> ***[Traditional Leader]** Most of the income in my area of jurisdiction is obtained from mining activities. In this regard, it is a taboo for women to be engaged in gold mining activities. This sidelining reduces the capacity of female headed households from acquiring solar energy technology.*
>
> ***[Solar energy products retailer]** More male costumers frequent my solar energy products retailer shop to acquire solar products. Women are not regular customers.*
>
> ***[School Head**] More men are involved in income generating projects as compared to women. Due to gender stereotype women are excluded in many economic activities, hence women have reduced capacity in adoption.*

The consensus from the gathered data was that gender influences the capacity of households in the uptake of photovoltaic energy in Shamva. The above finding implies that gender is a determinant factor in the adoption of photovoltaic energy in Shamva District. The finding resonates with Ojong (2021) who revealed that in Africa there is disparities in access to solar energy technology between men and women. In the same vein, similar findings by Winter et al (2018) in a research of gendered implications of sustainable energy in Kenya's rural district of Kitui.Furthermore,Gutra (2018) also confirms the same finding in rural Woliso of Ethiopia where it was found that males were likely to adopt to Solar Home System (SHS) as compared to their female counterparts. In addition to this, in Southern Africa, the finding in Shamva District is affirmed by Johnson et al (2019) who revealed disproportional distribution of benefits and services of smart energy in Mpanta rural District of Zambia. At a local level, the findings are in sync with Chanakira and Dzapasi (2021) who reveals a gendered access to solar energy technology in the peri-urban areas of Zimbabwe. However, on the same phenomena of the effect of gender in the adoption of photovoltaic energy technologies,Wiehl et al (2022) offered contrasting findings by establishing little evidence in support of the notion that gender of the household head influences the uptake of sustainable energy in rural Tanzania.Overally, the implication of the findings is that gender is a critical factor in the adoption of solar energy technologies in Shamva District. Hence, the need for interventions to address gender disparities in order to win rural energy poverty.

3.5.3. The size of herd of cattle owned by a household determines adoption capacity

The statement was set to establish whether the size of herd of cattle owned by a household determines the uptake capacity of smart energy. The field data gathered is indicated in **Table 4.4**

The majority seventy-two percent (72%) strongly agreed with the statement that the size of herd of cattle owned by a household is a determinant factor in the uptake of photovoltaic energy technology in Shamva District, with another fifteen percent (15 %) agreeing to the same viewpoint, while a minority of there percent (3 %) was neutral on the same issue. However, six percent (6%) of the research participants strongly disagreed that the size of herd of cattle owned by a household determine the off grid solar energy adoption capacity with four percent (4%) agreeing to the same notion. The above findings, therefore signifies that the size of herd of cattle owned is significant in the uptake of photovoltaic energy in Shamva District. The findings are consistence with earlier findings which indicates a positive correlation between the size of herd of cattle owned and the potential to adopt to solar energy technologies (Anteneh;2019;Wu et al; 2023, Walekhwa et al ;2009).In addition to these studies , the results are also consistence with Nkhoma et al; (2024) in Kasangazi rural district of Malawi which highlights that households with a large herd of cattle have a high adoption capacity of photovoltaic energy technology .From the foregoing, the capacity of Shamva District household to adopt to off grid solar energy technology is dependent on cattle ownership .This, therefore implies that cattle is a significant asset which enable household to have additional finance ,thus ability to acquire off grid solar energy technology. Hence the need to safeguard, the herd of cattle in the district in the background of climate change induced livestock diseases infestation.

3.5.4. The level of Education of household head

The statement was set to ascertain whether there is a correlation between education and the uptake of photovoltaic energy in Shamva District. The quantitative data which was collected to address the question is as indicated by **Table 4.4** above.

The majority fifty percent (50%) of the research participants strongly agreed that the level of education has a bearing with the ability of the household head to adopt to photovoltaic technologies in Shamva District, while thirty eight percent (38%) of the study participants agreed to the same viewpoint. Conversely, a minority two percent (2%) disagree with the notion that education is associated with the ability to adopt to off grid solar energy technology, with a ten percent (10%) of the sampled respondents expressing neutral opinion about the idea.

In this regard, the majority of the households fifty percent (50%) and thirty-eighty (38%) highlighted that level of education influences solar energy adoption capacity. This, therefore implies that the capacity of a household head to adopt to off grid solar energy technology is influenced by education. The finding is in congruency with multitudes of earlier studies on the renewable energy discourse which affirms to the notion that education is a determinant variable in the uptake of photovoltaic energy (Zeru et al ;2020; Shallo et al; 2020; Anteneh,2019 ; Bahadur et al ,2017).In addition to this,the same finding is also in sync with Mwalule and Mzuza (2022) who also affirmed to the notion that education influences household head's adoption capacity of photovoltaic technology in rural Malawi. Conversely, the finding is inconsistent with Marambanyika et al (2020) who established lack of association education and the capacity to adopt to biogas technology in Domboshava Communal Lands. In the context of Shamva District, the finding imply that level of education is a precipitating factor in off grid solar energy adoption. Thus, the need to expand education access in the district.

3.5.5. Typology of photovoltaic energy technology

The statement was earmarked to establish whether photovoltaic energy technology is a determinant factor in the capacity of Shamva District household heads to adopt to photovoltaic energy technology. **Table 4.4** above indicates the results of quantitative data which was gathered in this regard.

Table 4.4 above depicts the results of data collected and the results indicates that the major finding fifty –seven percent (57 %) of the research participants strongly agreed to the notion that typology of photovoltaic energy technology was a determinant factor in the adoption of sustainable energy in Shamva District, with twenty- two percent (22 %) agreeing with the same perception. However, seven (7%) of the respondents were neutral on whether typology of off grid solar energy technology influences household's adoption capacity. Contrary to this viewpoint, another seven percent (7 %) of the respondents disagreed to the perception with another seven percent (7%) strongly disagreeing. From the findings, it can be deduced that typology of photovoltaic energy technology has a bearing in the uptake of sustainable energy.

The current study findings are in line with Akter and Bagchi (2022) who established high rate of adoption of Solar Home System (SHS) among other types of photovoltaic technologies in rural India. Relatedly, the same findings were also collaborated by Bienvenue, (2021) who highlights that off grid solar energy innovation in the family of Solar Home System (SHS) dominated in installation as compared to mini-grids energy technology. However, in West Africa, Atuguba et al (2020) indicates that mini-grids are the types of photovoltaic energy innovations which have the highest adoption rate .Thus, this indicates spatial variation in regards to the adoption of different types of smart energy technology .Thus, in, line with the current finding, Solar Home System (SHS) is the dominant typology of sustainable energy technology in terms of adoption in Shamva District.

Image1.1 Photography of Solar Home System (SHS) observed at one of the homestead within the study area. This signifies the universality of this type of solar energy technology in Shamva District.

3.5.6. The nexus between age and the capacity to adopt to sustainable energy

The question was set to establish whether age has an impact on the capacity to switch to smart energy . Results below indicates the outcome of the gathered data on the issue**.**

Results in Table 4.4 above shows that a great proportion of study participants fifty- four percent (54%) strongly disagreed that there is an association between age and the uptake of sustainable energy in Shamva District, with twenty six percent (26%) of them disagreeing on the same statement. However, ten percent (10%) of the respondents were neutral on whether age has a correlation with the ability to adopt clean energy technologies. Besides this, six percent (6 %) of the respondents agreed that there is an association between age and the ability to adopt off grid solar energy technology, whilst a paltry four percent (4%) strongly agreed to the notion. The overall implications of the results was that age is not key factor in the adoption off grid solar energy technology by Shamva District households. Earlier findings in the renewable energy literature domain are in conformity with the findings of the current study. In this regard, Etongo and Naidu (2022)established a weak correlation between the ability of household head and the potential to adopt to solar energy technology.However,Maciaszczyk et al ;(2022) offered contrasting findings in which a correlation between the age of polish consumers and the willingness to adopt were highlighted. In addition to this, the same findings were in contradiction to Jayaweera et al (2018) who established an increase in the propensity to adopt to renewable energy in the old age owing to availability of pension benefits of adopters. However, in the context of the present study there was a lack of association between age and the capacity to adopt sustainable energy technologies. Therefore, age is not key in framing interventions to address rural energy poverty in Shamva District.

3.6. Statistical Test

The study went further to establish the statistical significance of four determinants in the uptake of households to sustainable solar energy. The five variables are gender, age, income level, education level and size of herd of cattle owned by a household. **Table 4.5** reveals the results of the statistical test.

Table 3.5 Chi-Square Test

Source of Variation	F-statistic	p-value	Significance Level
Gender	4.27	0.041	0.05
Age	1.61	0.178	0.05
Income Level	4.04	0.010	0.05
Education Level	3.24	0.009	0.05
Size of herd of cattle	2.52	0.046	0.05

(Source: SPSS Version 21, 2024)

The results indicate statistical significant of four determinants to household adoption to off grid solar energy technology that is gender, income level, education and size of herd of cattle owned by household. In this regard, the statistical significant of the variables; gender (p-value =0.041), income level (p-value=0.010), education level (p-value=0.009) and size of herd of cattle owned by a household (p-value=0.046). Thus, these four determinants are key in the assimilation of sustainable energy in Shamva District. This tallies with a multitude of studies which revealed the correlation between the four determinants and the adoption of smart energy technology (Ojong; 2021; Wu et al; 2023; Akter and Bagchi; 2021 and Zeru et al; 2023).Thus, the variables were found key in informing solar energy technology adoption strategies in Shamva District. However, a weak correlation between age and the potential to adopt to sustainable energy technology was established as the statistical significant of age was (p-value =0.178).Hence age was not a key determinant factor influencing adoption of photovoltaic energy technology in Shamva. The results were consistent with Etongo and Naido ;(2022) who established a lack of correlation between age and capacity to adopt to off grid solar energy technology. Thus age is not critical in framing interventions in addressing rural energy poverty in Shamva District.

4.6 Factors influencing public perception in the uptake of photovoltaic energy in Shamva District.

The study sought to determine factors influencing public perception on the uptake of off grid solar energy technology in Shamva District. Table 4.6 indicates the factors which influences households 'perception in the uptake of sustainable energy technologies.

Table 3.6: Factors influencing households' perception in the uptake of clean energy technology in Shamva District. n = (89)

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Quality of solar energy technology influences household perception on the uptake of smart energy.	**6%**	**5%**	**12 %**	**18 %**	**59 %**
Knowledge and awareness of solar energy technology influences household perception on the uptake of clean energy.	**6%**	**18 %**	**12 %**	**23 %**	**41 %**
Community participation in solar energy projects influences households' perception on the uptake of sustainable energy.	3 %	7 %	5 %	33 %	52 %
The size of solar energy equipment installed influences households' perception on the uptake of clean energy.	**7%**	**10 %**	**6 %**	**24 %**	**53 %**
Changings seasons influences households' perception on the uptake of sustainable energy technology.	**5%**	**7%**	**3%**	**15 %**	**70 %**
Sensitization of households' on the co-benefits of smart energy technology influences perception on the uptake smart energy.	**12 %**	**5 %**	**1 %**	**17 %**	**65 %**

(Source, Research Questionnaire, 2024)

3.6.1. Quality of smart energy equipment influences public perception

Findings in Table 4.6 reveals that a great proportion of the research participants fifty-nine percent (59 %) strongly agreed that quality of off grid solar energy technologies influences public perception of off grid solar energy, with eighteen percent (18 %) agreeing on the same viewpoint. However, twelve percent (12 %) of the respondents were neutral on the issue. In contrast, five percent (5 %) of the respondents disagreed to the contention that the quality of off grid solar energy technologies influences public perception with another six-percent (6 %) strongly disagreeing. It can be deduced from the overall findings that the quality of photovoltaic technology has an influence on public perception of the technology.

Consistent with the findings from the quantitative data from the household questionnaire which indicates that quality of off grid solar energy technology influences public perception of the technology the same findings was also supported by **Key informant:**

> **[*Ward Councilor]*** *Local households are not happy about the durability of the lighting system of the* ***Solar Home System (SHS).*** *The lighting system cannot withstand a single night. Household are spending part of the night in darkness as the system would have degraded thereby failing to light up. This makes the local people skeptical about the off grid solar energy technology.*

> *[**Traditional Leader]** I normally hear people in the community saying that the photovoltaic equipment are no longer functioning yet they would not have spent a longer period using the solar system. This indicates that there is something wrong with the quality of the equipment .This makes people wonder to continue using the technology.*

> ***[School Head]*** *Our school photovoltaic system has some intermittency in its functions .In terms of the function of the solar system for the local community some school children from the community are failing to write their homework as they indicate that there is poor lighting derived from photovoltaic technology. This attest to the low quality of the off grid solar energy technology.*

> ***[Solar energy appliance retailer]*** *The battery system of the photovoltaic technologies have a short life span. My shop is inundated with local customers who come with complaints in regard to the operations of the battery of the solar equipment. In this regard, the local*

people are becoming increasingly worried about the feasibility of clean energy technologies.

Both the gathered two types of data affirmed to the existence of low quality solar energy technology in Shamva District. The finding from the current study is consistent with a similar study by Groenewoudt (2022) in Uganda where it was established that seventy- four percent (74%) of rural household who installed Solar Home System (SHS) experienced problems with the efficiency of the technology. In this regard lights were not lasting the whole night as had been indicated by the Key Informants data. Additionally, the results were also supported by Aboagye et al (2021) in a study of degradation analysis of installed photovoltaic technologies in Ghana where it was discovered that less power output and short lifetime of the smart energy technology discourage the widespread adoption of Photovoltaic (PV) in Ghana. Thus, this influenced negative perception of off grid solar energy technology, thus low uptake of the technology. However, the same findings are inconsistency with an earlier similar study by Bahaj et al (2020) which offers a contrasting perspective on the same issue. Thus the quality and functionality of off grid solar energy technologies influences public perception of the technology. Hence, the need for quality control in the innovation of solar energy technology to boost positive public perception, hence increase in adoption of the technology.

3.6.2. Knowledge and awareness of photovoltaic energy influences public perception

Table 4.6 Exhibits that high percentage of the respondents forty – one percent (41 %) strongly agreed that knowledge and awareness of clean energy technologies influences public perception on the adoption of sustainable energy technology, with twenty-three percent (23 %) agreeing to the sentiment. In the same regard, twelve-percent (12 %) of the respondents were neutral on whether knowledge and awareness of off grid solar energy technologies influences public perception. In contrast, eighteen-percent (18 %) of the respondents disagreed with the notion that awareness and knowledge of off grid solar energy technologies influences public perception with a `minority of six percent (6 %) strongly disagreeing with the viewpoint. It can be deduced from the overall finding that knowledge and awareness of smart energy technology is key in influencing public perception in the uptake of sustainable energy. In the same regard the same viewpoint was supported by qualitative data which were gathered from key informant as indicated below:

[Local Councillor] *Knowledge and awareness is critical in the uptake of smart energy technology. However, the local community is not abreast with the latest information to do with off grid solar energy technology. This is due to ignorance of the local community as they seem to be occupied with their farming and mining activities .They do not have an urge to amass knowledge of these off grid solar energy technologies and this affects the adoption rate as you know the adage that knowledge is power.*

[Traditional Leader] *There was a certain year when personnel from a company from Harare came at my homestead seeking authority to education the local community about off grid solar energy technologies so that the local community would buy the off grid equipment. I doubt very much wether the sales people who were imparting information about off grid solar energy technology managed to reach all the areas due to the fact that they didn't have a vehicle .It therefore means the local community do not have information about smart energy technology .*

[School Head] *The issue of knowledge and awareness in terms of sustainable energy technologies is lacking within our community. Only a few enlightened household heads come here asking latest information in regards to clean energy, hence signifying the importance of knowledge and awareness in the adoption matrix.*

[Solar Appliances Retailer]*Knowledge and awareness is significant in the adoption of smart energy technology, however, the local communities are quite ignorant of information as far as off grid solar energy technology are concerned. They do not bother even to read the equipment manual as they say they do not understand what is written and also they say they do not have time for that as they want to engage in their illegal gold mining activities.*

The overall finding from the study indicates that knowledge and awareness of sustainable energy technology is key in influencing public perception in the uptake of clean energy technology. This is in line with Edsand and Bangens (2024) who established that lack of knowledge in Tanzania negatively affected the uptake of sustainable energy. Consistent with this, the same findings is in concurrence with Chodhowska-Miszczuk et al (2022) who reveals that limited awareness and knowledge of photovoltaic energy technology affected the diffusion of smart energy technology in Lipno, which is a rural area in Poland. This attests to the significance of awareness and knowledge of clean energy technology in influencing adoption as highlighted by (Chatterjee et al; 2019).Thus lack of awareness and knowledge of clean energy technology translate into low uptake of solar energy technology and vice versa .Hence, the need to enhance knowledge and awareness building as an intervention in addressing rural energy poverty.

3.6.3. The influence of community participation in solar energy projects on public perception

Table 4.6 illustrates that a great proportion of the respondents fifty two percent (52 %) strongly agreed that community involved in off grid smart energy projects influences public perception in the adoption of clean energy and this was also supported by a significant number of respondents thirty three (33 %) who agreed on same sentiment. At the same time , seven percent (7 %) of the participants had an alternative view as they disagreed that community participation in solar energy projects influences household perception on the uptake of solar energy and the same viewpoint was also shared by a minority three percent (3 %) who strongly disagreed. However, five percent (5 %) of the respondents were neutral on whether community participation in solar energy technology projects influence household perception towards the uptake of the technology. The overall results from the study highlighted that community participation in solar energy technology projects influences the perception of households towards the uptake of the energy technology.This is in conformity with a similar earlier study by Feron et al (2017) which indicates unsustainability of photovoltaic projects in rural Ecuador and Peru due lack of community participation. In the same vein, the same finding is further collaborated by Jarbandhanet et al (2018) who further confirmed the significance of public participation in fostering positive perception of sustainable energy technologies to the last mile user of smart energy technology who are remote rural communities .Furthermore, the validity of community participation in fostering positive perception of off grid solar energy technology can be drawn from a study by Aldarsi and Signh (2024) which highlights viable rural solar projects in United States of America through community participation. In addition to this, within the Southern African context a study by Ehimen et al (2023) serves to highlight another viable off grid solar projects in Malawi through community participation in village solar projects. Thus, signifying the importance of community participation in photovoltaic energy projects which foster positive attitude towards uptake of off grid solar energy technologies.

3.6.4. The impact of the size of solar energy equipment installed on public perception.

Table 4.6 above highlights that the majority fifty-three percent (53 %) of the respondents strongly agreed with the assertion that the size of photovoltaic energy technology installed has an effect on public perception of off grid solar energy technology , with twenty-four (24 %) also agreeing on the same viewpoint. In contrast, seven percent (7 %) strongly disagree with the notion that the size of solar energy technology installed has an influence on public perception of sustainable energy technology, with ten percent (10 %) disagreeing to the same view. In the same vein, six percent (6 %) of the participants were neutral on whether the magnitude of smart energy technology installed have an influence on public perception of clean energy. Thus, the findings indicates that the size of solar energy equipment installed have a bearing on public perception. The findings conforms with Carlisle et al (2015) who found out that there is a negative correlation between the increase of the size of solar energy technology installed and public perception. In the same vein, a subsequent study by Aly et al (2019) collaborated the same findings in Tanzania where it was revealed that the installation of large sized off grid solar energy technology draws negative public perception due to environmental and social-economic impacts of large solar projects. Similarly, the same findings are also affirmed by Jobin et al (2019) who highlighted that the size of smart energy technology is a determinant factor towards public acceptance .Hence, size of off grid solar energy technology installed is key in influencing public perception towards uptake of clean energy. Hence, intervention to address energy poverty should incorporate public perception.

3.6.5. Changing seasons influences public perception

The findings highlighted in **Table 4.6** indicates that a great number seventy percent (70 %) of households agreed with the notion that changing seasons affects public acceptance of off grid solar energy technology , with fifteen percent (15 %) agreeing to the same sentiment. In the same vein, three percent (3%)of the research participants were neutral on the subject. On the contrary, seven percent (7 %) of the respondents disagreed that changing seasons affect public perception of off grid solar energy technology with a minority of five percent (5 %) strongly disagreeing to the opinion. In this regard, the overwhelming response indicates that changing weather seasons have a bearing on public perception of photovoltaic energy in Shamva District.

The overall finding from the study was consistence with a study by Vuichard et al (2021) which attested to the notion that seasonality of solar radiation impacts the production of energy from solar radiation. This viewpoint is affirmed by Kang et al (2018) who established an association between sunshine duration and amount of electricity generated. Hence seasons with high amount of sunshine are consistent with high output of solar energy. Consistent with this, Djurisic et al (2020) reveals that high generation of photovoltaic bolster positive perception of clean energy. Thus the changing seasons impacts public perception on sustainable energy in Shamva District, hence signaling implications in the adoption of sustainable energy.

3.6.6. The influence of community sensitization on the co-benefits of smart energy

Table 4.6 Illustrates that a high number of research participants sixty-five percent (65 %) strongly agreed that increased awareness of the co-benefits of solar energy technologies on climate change mitigation and atmospheric pollution have an impact on the public perception of off grid solar energy technology, with another seventeen percent (17 %) agreeing to the same viewpoint. In contradiction to this, (12 %) of the respondents strongly disagreed that increased awareness of the co-benefits of photovoltaic energy technologies has an effect on public perception of the technology with another five percent (5 %) disagreeing. At the same time, one percent (1 %) of the respondents was neutral on whether off grid solar energy technology has an influence on public perception of the technology.

The research findings were consistence with earlier finding by Hanger et al (2016) which affirmed to the notion that awareness of the co-benefits of solar energy technology on carbon emission reduction resulted in positive public perception of clean energy in Morocco. In the same regard, the same findings were also collaborated by Njeru and Ndunda (2024) who found out that knowledge of the potential of smart energy in reducing carbon emissions in Embu County of Kenya influenced positive perception of clean energy, hence increased adoption. In line with this, the implication of the study is that deficit in information on the co-benefits of off grid photovoltaic energy technology creates negative perception of smart energy, thus reduced adoption.

3.7. Statistical Significance of the variables influencing public perception.

The study established the statistical significance of three key variables which influence public decision in the uptake of clean energy in Shamva District. Chi-square test was employed to ascertain statistical significance of quality of solar energy equipment, knowledge and awareness and community participation on public perception on the uptake of solar energy technology. The results are as indicated on **Table 4.7**

Table 4.7. Indicating cross tabulation results of variables influencing public perception of off grid solar energy technology.

Variable	Cross-tabulation	Chi-square Value	p-value
Quality of solar energy equipment	Quality and perception	28.57	0.00000
Knowledge and Awareness	Knowledge and Awareness and perception	16.67	0.00005
Community Participation	Community Participation and Perception	22.14	0.00000

Source (Primary Data; 2024)

Table 4.8.1 indicates that quality of solar energy equipment has a chi-square value of 28.57 and (p –value =0.0000), thus this entails that the state of solar energy technology has statistical significance on public perception of clean energy. Hence, there is a correlation between quality of solar energy equipment and public perception. The association between quality of solar energy technology and household perception is also supported in literature by Groenewoudt; (2022). Inaddition to this, knowledge and awareness of households on off grid solar energy technology has a chi-square value of 16.67 and a p-value of 0.00005, thus there is a statistical significant relationship between knowledge and perception of smart energy. Thus knowledge and awareness influences public perception of sustainable energy, hence adoption. In line with this, Edsand and Bangens ;(2024) established a significant association between knowledge and awareness of households and perception to adopt smart energy. Furthermore, the influence of community participation on solar energy projects was found to have chi square value 22.14 and a p-value of 0, 0000, thus community participation in solar energy projects has a bearing in fostering public perception of the technology. The same finding is consistent with Aldarsi and Signh; (2024) who established that community participation in solar energy technology was key in fostering positive perception of clean energy. Hence, the variables are critical in instilling public perception of smart energy, thus uptake of the technology.

3.8. Chi-square test

The test was employed to establish whether there was an association between household perception and the adoption of off grid solar energy technology.

Table 4. 8: Contingency table

Situational	Adopted	Not Adopted	Total
Positive Perception	65	35	100
Negative Perception	20	80	100
Total	85	115	200

Source :(Primary Data; 2024)

Null Hypothesis (H0): There is no association between households' perception of photovoltaic energy and the adoption of the solar energy system in Shamva District.

Alternative Hypothesis (H1): There is an association between households' perception of off-grid solar energy technologies and the adoption of off-grid solar energy technologies in Shamva District.

Since the p-value (0.00000) is less than the commonly used significance level of 0.05, we reject the null hypothesis and conclude that there is sufficient evidence to suggest an association between households' perception of smart energy and the adoption of these technology exists in Shamva District. Thus, based on the chi-square test outcome, we can conclude that there is a significant association between households' perception of clean energy technology and their uptake of these technology. Thus the uptake of smart energy in Shamva District is significantly driven by households' perception.

4.10 Section D: Barriers in the adoption of off grid solar energy technologies in Shamva District.

The research sought to establish the barriers in the adoption of off grid photovoltaic energy in Shamva District. **Table 4.4** indicates possible barriers in the uptake of smart energy.

Table 3.9: **Barriers in the adoption of sustainable energy in Shamva Distric**t

n = (89)

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
High upfront costs in the acquisition of solar energy technology is a barrier in the adoption of smart energy.	**7%**	**3%**	**5 %**	**30%**	**55 %**
Extreme poverty at household level erodes the potential of households to adopt to solar energy technology.	**12%**	**7%**	**10%**	**14 %**	**57 %**
The impacts of Covid 19 pandemic retard household capacity to adopt solar energy technology.	**4%**	**7 %**	**2 %**	**20%**	**67%**
There is rampant theft and vandalism of photovoltaic energy equipment.	**6%**	**6 %**	**4 %**	**22%**	**62 %**
There is lack of credit facilities for households to acquire solar energy technology.	**3%**	4 %	**7 %**	22 %	64 %
Limited technical skills act as a barrier in the sustainability of clean energy technology.	**3 %**	**7 %**	**5 %**	**33 %**	**52 %**

Source: Research Questionnaire

4.10.1 High upfront costs

The question was set to establish whether exorbitant initial costs in the procurement of smart energy technology were an impediment in the research participants desire to acquire the technology.

Table 4.9 reveals that majority fifty-five percent (55 %) of the respondents strongly agreed that high upfront costs in the acquisition of smart energy technology was the barrier in the acquisition of the renewable energy technology in Shamva District, with thirty percent (30%) of the respondents agreeing to the same viewpoint and with a few five percent (5 %) feeling neutral about the issue .However, three percent (3%) of the respondents disagreed with the notion that high upfront costs are limiting the expansion of off grid solar energy technology in Shamva District with seven percent (7 %) of the respondents strongly disagreeing to the same notion. The results were in line with Castro et al; (2024) who averred that exorbitant upfront costs in photovoltaic technology results in stunt growth of the renewable energy sector. Furthermore, the same findings were confirmed by Garlet et al ; (2019) in Southern Region of Brazil where the diffusion of small scale Distributed Generation technology were hampered by the initial costs of investment. In the Zimbabwean context, Maronga et al; (2021) acceded to the same findings. Thus exorbitant costs of clean energy technology diminished the capacity of Shamva District households in the adoption of sustainable energy .Thus the need for policy interventions to infuse incentives in the clean energy sector so as to cushion households from high initial costs in the adoption of solar energy equipment.

4.10.2 Extreme poverty at household level erodes the purchasing power of solar energy technology

The question was set to establish the association between poverty at household level and the ability to adopt off grid solar energy technology. Below are the answers which were gathered from the respondents**.**

From the findings in **Table 4.9** above, a great proportion of research participants fifty- seven percent (57 %) strongly agreed with the assertion that extreme poverty at household level degraded the potential of the participants to adopt to clean energy technology, with another (14 %) agreeing to the same viewpoint. However ten percent (10 %) of the respondents were neutral as to whether extreme poverty at household level has an impact on the uptake of off grid photovoltaic energy technologies .In contrast, twelve percent (12 %) of the respondents strongly disagreed that extreme poverty at household level has an impact on the ability of the household to acquire off grid solar energy technologies, with another (7 %) of the household disagreeing to the same issue**.**

It can be deduced from the above results that extreme poverty at household level in Shamva District was reducing the household's ability to adopt smart energy. The results were in sync with Mugisha et al ;(2021) who revealed that rural areas in the context of African communities live in extreme poverty. Hence, they lack disposable income for the adoption of sustainable energy. Consistent with this, rural areas in Nigeria were found resorting to fuelwood as they lacked financial capacity to adopt clean and sustainable energy due to poverty (Mohammed et al; 2015). Hence, poverty is a key inhibitor in the quest of rural households to adopt to clean energy. Thus interventions aimed at addressing energy poverty at household level should incorporate poverty reduction strategies.

4.10.3. The effects of Covid 19 pandemic on capacity of households to adopt clean energy

The question aimed to solicit information on the impacts of Covid 19 pandemic on household's ability to adopt off grid solar energy equipment in Shamva District. Below are the results of data gathered.

The findings highlighted in **Table 4.9** indicates that a great number sixty seven (67 %) of the research participants strongly agreed that the effects of Covid 19 pandemic retarded the development of photovoltaic energy in Shamva District with twenty percent (20 %) of the respondents agreeing to the same idea. Apart from that, a minority four (4 %) strongly disagreed with the above notion with seven percent (7 %) disagreeing to the same view point , while two percent (2%)of the respondents were neutral on whether the impacts of Covid 19 pandemic affected the capacity of rural household to possess off grid solar energy technology.

The above findings were supported by the revelations gathered through the interview with all the Key Informants who disclosed that the impacts of Covid 19 pandemic eroded the purchasing power of Shamva community in acquiring of smart energy technologies. Consistent with this, indicated below were responses from the key informants:

> ***[Ward Councillor]*** *Covid 19 pandemic was a game changer in the livelihoods of households. Imposed lockdowns means households were no long able to do their economic activities which are key source of income, hence there was no money to acquire solar energy products.*
>
> ***[Traditional Leader]*** *Covid 19 pandemic crippled all economic activities in this area. Most households are still to recover from financial shocks which were brought by the virus . It reduces the financial capacity of households.*
>
> ***[Solar products retailer]*** *Corana virus resulted in the closure of the solar energy products shop. Following the lifting of Covid pandemic protocols we are back in business however we still have challenges with the impacts of Covid 19.Households have low capacity to*

purchase solar energy products as their economic activities have not yet recovered from the shocks of Covid 19.

[School Head] *Household's capacity to adopt to solar energy technology was greatly affected by Covid 19.The emergency of the diseases paralyzed all the economic activity in the district. Households have not yet fully recovered from the impacts of Covid 19, hence reduced ability to acquire solar energy technology.*

The above findings are in congruency with Shen and Ayele; (2020) who posited that Covid 19 pandemic restrictions in the form of lockdowns reduced the importation of solar energy equipment. Hence there was reduction of solar products and accessories on the domestic markets. Furthermore, in addition to lockdowns which restrained the movements of goods and people, Covid 19 pandemic affected income levels of households (Gebreslassie ; 2022). Hence, the adoption of clean energy in Shamva District were significantly hampered by Covid 19 pandemic. Thus the need for past Covid 19 pandemic recovery packages which can act as a financial bale out in order to have sustainable energy solutions in rural areas.

4.10.4 Rampant theft and vandalism of solar energy equipment

The question was asked to establish whether there was theft and vandalism of solar equipment within Shamva District. Highlighted below were the responses which were gathered from the collected field data.

Findings in **Table 4.9** shows that a significant proportion of the research participants sixty-two percent (62 %) strongly agreed that there was rampant theft and vandalism of solar energy equipment in Shamva District and closely followed by another twenty- two percent (22 %) of the respondents who agreed to the same issue. However, four percent (4 %) of the respondents were neutral on the existence of theft and vandalism of off grid solar energy equipment in Shamva District. Apart from that , six percent (6 %) of the research participants disagreed that there was theft and vandalism of solar energy equipment in Shamva District with another six percent (6 %) strongly disagreeing to the same notion. The implication of the overall findings is that there was theft and vandalism of solar energy equipment in Shamva District.

The findings from the quantitative data were in line with the Key Informant sentiments as indicated below:

[Local Councillor] *There is now a growing trend on theft and vandalism of solar equipment in the villages. We have some criminals who are targeting these equipment and households are now putting the equipment inside houses during the night for fear of theft and vandalism.*

[Traditional Leader] *I have some cases of theft and vandalism of solar equipment which I am dealing with at my traditional courts. The criminal are youthful drug addicts who steal the equipment in order to resale so that they obtain money to purchase drugs.*

[Solar energy products retailer]*Household's complaints of solar equipment theft and vandalism. They normally come to the shop to replace stolen or vandalized equipment.*

[School Head] *Theft and vandalism of solar equipment is widespread. Even here at the school we have experienced theft of solar panels which were mounted on one of the classroom blocks.*

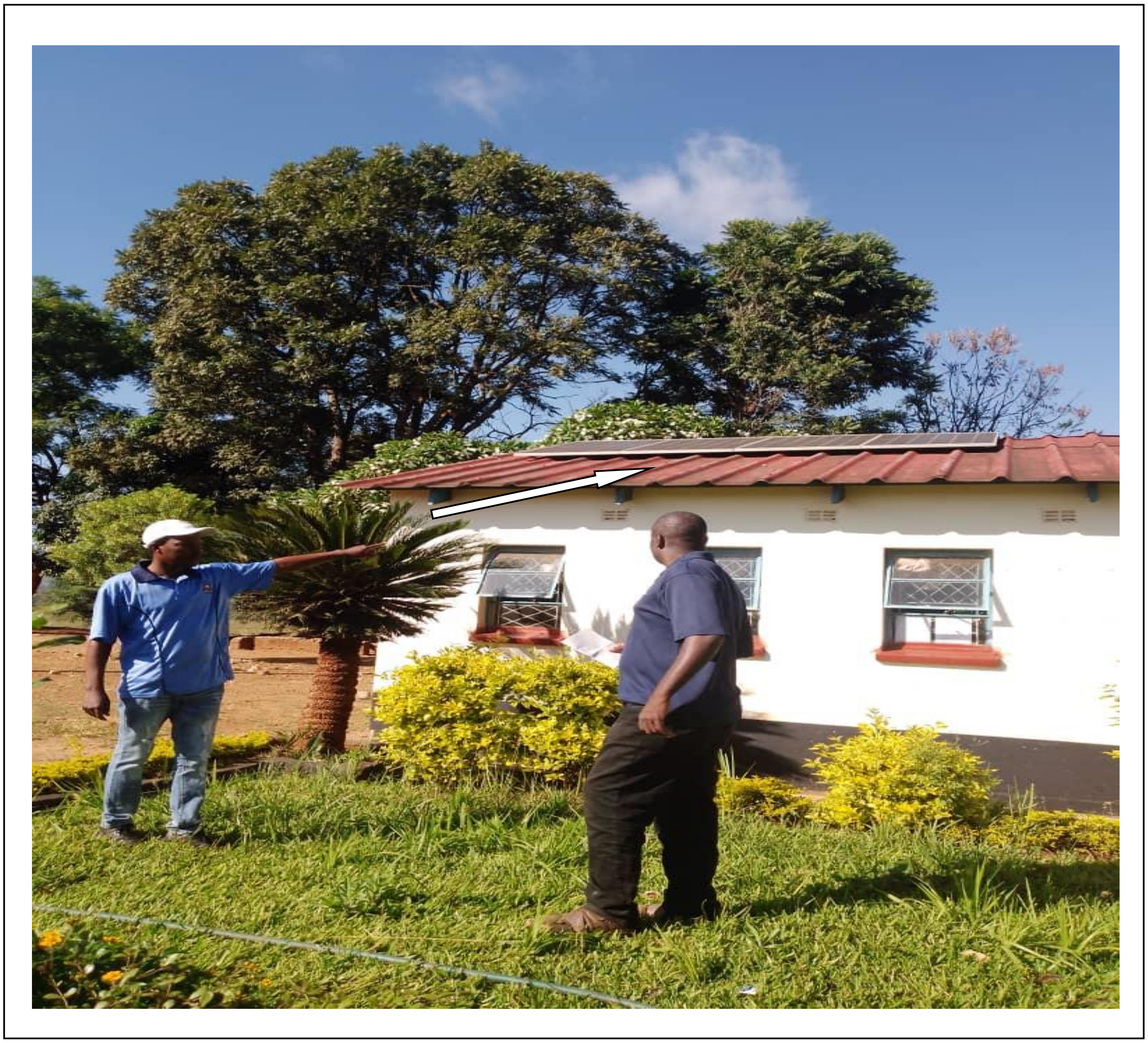

Image 1.2 highlights classroom block where a solar panel was stolen source field research 2024

The results indicated widespread theft and vandalism of solar energy equipment in Shamva District. The findings of the current study were confirmed by Ikejemba and Schuur ;(2018) who established rampant theft and vandalism of solar energy equipment within Sub Saharan Africa. Additionally, the same findings were confirmed by Azimoh et al; (2014) who reveals the widespread theft and vandalism of Solar Home System (SHS) was an impediment in the adoption of smart energy in Thlatlaganya Village within Limpopo Province of South Africa. This, therefore means theft and vandalism of solar energy equipment is retarding the sustainability of household uptake of photovoltaic energy in the Shamva District. Thus interventions focused on addressing rural energy poverty should consider security issues to guarantee smooth transition to sustainable energy systems in rural areas.

4.10.5 Lack of credit facilities for households to acquire off grid solar energy technology

The question was set to solicit information as to the existence of credit facilities to financially empower households in the acquiring of smart energy technology in Shamva District. Below are the results which were obtained following gathering of data.

From the findings in Table 4.14 above, a great proportion of the participants sixty-four (64 %) strongly agreed that absence of credit facilities to financially empower households in acquiring off grid solar energy technology act as an impediment in the adoption of sustainable energy in Shamva District, with twenty-two percent (22 %) of the respondents agreeing on the same assertion. However, seven (7%) of the respondents were neutral on the notion that lack of credit facilities for households to acquire off grid solar energy technology has a limitation on the uptake of photovoltaic energy technology. Conversely, four percent (4 %) of the respondents strongly disagreed that absence of credit facilities has a bearing on the uptake of photovoltaic energy technology, with three percent (3 %) of the respondents disagreeing on the same viewpoint.

The study established lack of credit facilities was a critical factor hindering the uptake of photovoltaic energy technology in Shamva District. In this regard, the study resonates with Branca; (2023) who asserted that the uptake of smart energy technology in African rural areas was being hampered by lack of credit facilities. Low investments in the smart energy sector by lending institutions contributes to reduced funding of the sector (Adewuyi et al;2020).Lack of confidence in the renewable energy sector by banks was found to be the contributor to less credit facilities (Schwerhoff and Sy; 2020).Subsequent findings by Mushosho and Qutieshat; (2024) corroborated the same findings within the Zimbabwean context. Thus, non-existence of credit facilities was found to be reducing the capacity of households to adopt to smart energy. Thus the need to upscale credit facilities towards sustainable and smart energy in rural areas.

4.10.6 Limited technical skills.

The question was posed to establish whether limited technical skills on installation and maintenance of solar energy equipment act as a barrier in the sustainability of clean energy in Shamva District. The findings of the data gathered is as highlighted below.

Table 4.8 exhibits that the majority of the respondents seventy- two percent (72 %) strongly agreed that there is limited technical skills in photovoltaic energy technology in Shamva District, with fourteen percent (14 %) agreeing on the same issue. However, three percent (3 %) of the respondents were neutral on whether there was adequate technical skills in solar energy technology in Shamva District. Contrary to this, four percent (4 %) of the respondents disagreed on non-availability of technical skills which are key in maintenance of solar energy equipment in Shamva District while seven percent (7%) strongly disagreed. Thus the results from the current study indicates that lack of technical skills for configuration and maintenance of photovoltaic equipment in Shamva District is one of the variables limiting the sustainability of photovoltaic energy technology expansion in the district. The findings of the current research were in line with earlier findings by Abdullahi et al; (2022) and Lo et al; (2018) who confirmed the longstanding notion on the existence of wide skills gaps on installation and maintenance of solar energy equipment in poor countries. In the same regard, the same viewpoint was substantially supported by Ngonda et al (2023) who highlighted the existence of hazardous installation of solar energy equipment in Ntchisi Village of Malawi. On the same perspective, the results were bolstered by Mgonja and Saidi (2017) who established a link between solar energy technology field maintenance practices and the performance of installed solar system. Hence, the study established skills deficiency in smart energy technology in Shamva District. Thus, the need for the introduction of training programmes to impart technical skills on key personnel about the operations of smart energy technology in Shamva District.

4.10.7 Regression Coefficient

Table 4.8 indicates regression analysis of variables which militates the roll out of smart energy technology in Shamva District. The variables were indicated in order of their statistical significance, hence indicating a model in the uptake of photovoltaic energy in alleviating rural energy poverty. Thus the introduction of countermeasures to address the variables would culminate in increased uptake of smart energy, thus reduction in rural energy poverty.

Table 3.10: **Regression Results**

Variable	Coefficient	Standard Error	t-statistic	p-value
Constant	2.145	0.375	5.721	0.000
High upfront costs	-0.324	0.092	-3.522	0.001
Extreme Poverty	-0.178	0.081	-2.198	0.030
Impacts of Covid 19 Pandemic	-0.105	0.068	-1.544	0.020
Theft and vandalism	-0.249	0.095	-2.622	0.010

(Source: SPSS Version 21, 2024)

The linear regression analysis aimed to identify the critical impediments in the uptake of photovoltaic energy technology. The model included four independent variables: high upfront costs, extreme poverty, Covid 19 Pandemic, theft and vandalism of solar energy equipment.

The outcome revealed that high upfront costs had a statistically significant negative impact on the adoption of off-grid solar energy technology (p-value = 0.001).Households or communities facing financial constraints have low capacity to adopt to smart energy which often require substantial upfront costs. Furthermore, the analysis indicated that poverty significantly influenced the uptake of smart energy (p-value = 0.030). Thus, poverty was found to be a statistically critical factor in the uptake of off grid solar energy technology, hence the need to address household poverty so that household are able to afford sustainable energy technology.

In the same regard, the impacts of Covid 19 pandemic was found to be statistically significant in the uptake of photovoltaic energy technology (p-value = 0.020).Thus, the emergency of Covid 19 pandemic crippled household financial capacity to acquire off grid solar energy technology. Furthermore, theft and vandalism of solar energy equipment was also established to be statistically significant in the uptake of solar energy technology (p-value= 0,010).Households were prone to theft and vandalism of solar equipment and is an obstacle in the adoption of smart energy. Therefore, the linear regression analysis provided valuable insights into the energy poverty of Shamva District. Thus stakeholders can potentially overcome these barriers and accelerate the adoption of these technology, ultimately contributing to the alleviation of rural energy poverty.

4.10.8 Pearson Correlation Test

The Pearson Correlation Test was conducted to interrogate the relationship between the uptake of off-grid solar energy technology (OGSET) and rural energy poverty (REP) in Shamva District. Knowledge of the relationship is quite key in informing policy and interventions. The table below indicates the outcome of the relationship.

Table 3.10.1 Pearson Correlation Test

Variable 1	Variable 2	Pearson Correlation Coefficient (r)	p-value
OGSET Adoption	Rural Energy Poverty	-0.712	0.000

(SPSS Version 21, 2024)

The results indicate a strong negative correlation between the two variables, with a Pearson correlation coefficient (r) of -0.712.The negative value of the correlation coefficient suggests an inverse relationship between off grid solar energy technology (OGSET) adoption and rural energy deficit. In this regard, as the adoption of off-grid solar energy technology increases, rural energy poverty tends to decrease, and vice versa. The coefficient value of -0.712 indicates a strong negative correlation. Access to clean energy by households and communities can potentially improve their living standards, enhance economic opportunities, and reduce their reliance on traditional, often polluting and unsustainable energy sources.

4.7 Chapter Summary

The chapter highlighted, analyzed and discussed the data collected from the research were concurrent mixed method research approach was employed. First to be presented was the study's response rate, which was followed by the presentation of the reliability test.Next the study presented the demographic. Following this, presentation of data, analysis and discussion was guided with objectives of the research.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

The study focused on examining the adoption of photovoltaic energy as an intervention in alleviating rural energy poverty. The examination was centered on the contribution of households to the research instruments which were formulated to elicit data. The research was guided by the research objectives.

5.1 Summary of the Key Findings

The study findings were based on critical issues in the transition of rural communities to smart and sustainable energy. In this regard, the results highlights factors shaping rural households energy vulnerability .Thus, the interplay of the factors in the sustainable rural energy matrix formed the central discussion and analysis of the research. Thus increasing access to smart and affordable energy, thus building sustainable and resilient energy sources for rural communities. Consistent with this, in the energy trajectory, rural areas remain marginalized, however by addressing key issues which makes rural households vulnerable to energy poverty, they would be widespread access to energy. The following summary of results highlights critical reviews which were key in addressing knowledge gap identified in this study.

5.2 Objective One: Determinant factors in the adoption solar energy technology.

The focus of this objective was to identify key variables in the adoption of sustainable energy against the backdrop of rural energy poverty. Consistent with this, some demographic characteristics of households were found to have an impact in the uptake of clean energy in Shamva District. In this regard, gender, educational level and wealth and size of herd of cattle of a household were demographic factors which were found to have an influence in the uptake of households to smart energy in Shamva District. However, age was not found to be a key variable in the uptake of clean energy. In the same vein, the findings were aligned to Yang et al ;(2021), Kyere et al;(2024), Akter and Bagchi (2021), Grimm et al; (2020), Yadav et al;(2019),Ojong (2021),Winter et al; (2018), Anteneh;(2019), Wu et al; (2023), Zeru et al; (2020) ,Etongo and Naidu (2022).

These determinant factors were key in framing interventions to addressing the nexus between off grid solar energy technology and rural energy poverty in Shamva District. With less access of households to smart, affordable and sustainable energy, interventions to address rural energy poverty should be anchored on addressing solar energy adoption determinant factors.

5.3 Objective Two: Factors influencing households' perception

This objective was set to establish factors which influences households' perception in the uptake of sustainable energy in Shamva District. The study delved into the factors influencing public perception in the uptake clean energy. These factors are key in the solar energy technology discourse, since by influencing public perception they determine the acceptance of sustainable energy.

In this regard, the size of solar energy technology has a bearing on public perception of smart energy. The installation of large solar equipment was found to draw negative perception of solar energy technologies in rural communities. Findings were in line with, Carlisle et al; (2015),Aly et al ;(2019) and Jobin et al ;(2019). Additionally, a great proportion of the participants highlighted that knowledge and awareness was crucial in influencing positive perception of off grid solar energy technology. Results of the research found were consistent with Edsand and Bangens (2024), and Chodhhowska—Miszczuk et al (2024).Hence interventions to increase uptake of photovoltaic energy should focus on diffusion of education on sustainable energy.

Community sensitization of the co-benefits of photovoltaic energy was established to be key in influencing public perception towards uptake of smart energy .The findings were found to be similar to Hanger et al (2016), and Njeru and Ndunda (2024) Consistent with this, changing seasons were also found to be influencing public perception of off grid solar energy technology This signifies the need for solar energy technology innovations which withstand all weather system, thus increasing adoption.

Community participation in solar energy projects were found to have a bearing on public perception of off grid solar energy technology .This was exemplified by Ehim et al (2023) where community participation on village solar projects in Malawi fostered positive attitudes towards uptake of off grid solar energy technology . Thus, the need to upscale community participation in solar energy projects, hence increased adoption. Conversely, the quality of photovoltaic energy equipment was found to be influencing public perception. Thus the need for quality assurance in the solar energy manufacturing industries.

Factors influencing public perception of sustainable energy are key in the uptake of clean energy. Thus, interventions should address issues influencing public perception of solar energy technology.

5.4 Objective Three: Barriers in the uptake of photovoltaic energy

In line with this, the barrier in the uptake of smart energy in Shamva District were , high upfront costs in the acquisition of clean energy products, the impacts of Covid 19 pandemic, extreme poverty of rural households, none existence of credit facilities. Furthermore, theft and vandalism of solar energy assets and inadequacy of technical skills in the installation were found to be impediments in the expansion of photovoltaic energy innovations in Shamva District.

Photovoltaic energy technology were found to be characterized by high upfront costs. The results indicates that high upfront costs were a setback in the adoption of smart energy in Shamva District. In the literature, the results were similar to Garlet et al; (2019), Castro et al; (2024) and Maronga et al; (2021).Household lacked the capacity to offset high initial costs in the acquisition of solar energy equipment in Shamva District.

The emergence of Covid 19 pandemic hampered the potential of household to adopt to solar energy technology. The emergence of Covid 19 pandemic brought with it cessation of importation of smart energy equipment, hence the reduction of clean energy equipment on the markets. Besides the cessation of importation of solar energy equipment, Covid 19 pandemic incapacitated income streams of households through lockdowns and travelling restrictions. Thus reducing the ability of household to adopt to smart energy.

Extreme poverty was also found to be an inhibiting factor in the adoption of household to clean energy. In light of this, poverty restrained households to have disposable income to acquire solar energy technology. Results were similar to earlier findings by Mugisha et al; (2021) and Mohammed et al; (2015). Besides this, inadequate credit facilities for households in the procurement of smart energy equipment exert financial burden to households in the acquisitionof solar energy technology. Thus, none existence of credit facilities for solar energy equipment in Shamva District was discovered to be a drawback in the uptake of smart energy.

Rampant theft and vandalism of solar energy equipment was also found to be a challenge in addressing energy poverty in Shamva District. The findings were consistent to Schuur, (2018) and Azimoh et al, (2024).Thus, household in the district were susceptible to theft and vandalism of solar energy equipments. Thus the need for enhancing security measures to safeguard solar energy equipment in the district.

Finally, lack of technical skills in the photovoltaic energy sector was found to be an impediment in the uptake of sustainable energy in Shamva District .Hence, the need to upskill local personnel in the district on solar energy installation and maintenance.

5.5 Recommendations

5.5.1 Reducing the adverse impacts of key determinant factors

In the background of poverty, there is need for income generating programmes to increase the income levels of poor households in Shamva District, thus enhancing the uptake of sustainable energy.In the same regard, cattle were found to be a natural capital which enhances household capacity to acquire solar energy technology. Consistent with this, there is need for the introduction of **Climate Smart livestock Management** in the backdrop of increasing livestock disease infestation. Thus safeguarding the natural asset which would enable Shamva District households to adopt to solar energy technologies.

Furthermore, there is need for the introduction of programmes which addresses gender disparities in Shamva District.Furthermore, there is need for increase in education access to Shamva District as there is a correlation between education and adoption of solar energy technology.

5.5.2 Fostering positive perception of households on off grid solar energy technology in Shamva District.

There is need to address knowledge gap of clean energy by upscaling the dissemination of information on photovoltaic energy, thus increasing positive perception of the technology. Hence would translate into increased adoption. Furthermore, there is need for community sensitization on the co-benefits of smart energy as they were found to be key in fostering positive public perception of smart energy in Shamva District. Hence, instilling positive perception which is key in the uptake of sustainable energy.

Smart energy innovations should be tailor made to address the impact of seasonal weather changes on the production of energy from solar radiation of weather variation.In the same regard, there is need to accelerate community participation in clean energy projects thereby instilling positive perception of sustainable energy, hence the acceleration of renewable energy adoption.

There is need for **Environmental Impact Assessment** of large scale solar energy projects so that negative impacts are addressed and this would demystify the negative perception held by households towards these large scale solar energy projects. Hence, this would influence the adoption of the technology.

5.5.3 Introduction of interventions which address barriers in the uptake of photovoltaic energy

In light of high upfront costs of solar energy equipment, there is need for government incentives which can offset initial costs. Besides this, there is need for the introduction of rural poverty reduction strategies through enhancing the viability of rural livelihoods projects. Thus culminating into increased adoption of off grid solar energy technology.

The impacts Covid 19 severely affected households' solar energy technology adoption capacity. There is need to introduce post Covid 19 pandemic financial recovery package in the solar energy sector, thus capacitating household in the uptake of smart energy against the negative effects of Covd 19. In the same regard, there is need for key players in the renewable energy sector to upscale lines of credit facilities towards smart and sustainable energy, thus enhancing adoption.

Rampant theft and vandalism of solar energy equipment were also found to be militating factors in the uptake of sustainable energy in Shamva District. In light of this, there is need to conscientise households on security measures which enhances the protection of solar energy equipment from theft and vandalism. In addition to this, there is also need to upskill key personnel in the district in terms of solar energy equipment installation and maintenance. Thus, paving way for accelerated uptake of clean energy in shamva District.

5.6 Recommendations for Further Study

From the outcome of the study there is need to carry out a similar study on sustainable pathways in addressing rural energy poverty. For instance, there is the development of a sustainable energy landscape for Zimbabwe through the empowering of **Independent Power Producers (IPP**) to be part of addressing the energy poverty. In this regard, rural areas have ideal sites for the location of photovoltaic energy projects as compared to urban areas due to vast tracts of land in rural areas for solar farms. By empowering rural households to be key plays in the solar energy matrix, a win win situation would be attained. This entails reduction of energy poverty and also financial capacitation from revenues obtained by selling excess solar energy. Therefore further research would generate data on how rural households could be incorporated in this novel energy development.

5.7 Conclusion

The research examined factors influencing household s' capacity to adopt to off grid solar energy technology in a bid to alleviate rural energy poverty in Shamva District. In line with this, the study identified key determinants in the uptake of smart energy and these were highlighted as key in framing the reduction of rural energy poverty. Furthermore, the study examined the factors which were critical in influencing household's perception towards the uptake of sustainable energy. These factors were identified as key in fostering positive public perception on the uptake of sustainable energy.

Furthermore, the study examined the barriers to the uptake of sustainable energy technology in Shamva District. Consistent with this, a host of factors were found to be obstacles in the implementation of clean energy to ameliorate electricity poverty in Shamva District.

The outcome of the study further highlights the multi-dimensional nature in terms of rural energy poverty. Consistent with this, household's level of income, level of education, size of herd of cattle owned and gender were found to be key in influencing the capacity of households in Shamva District in the uptake of sustainable energy.

Consistent with this, the research noted the necessity adapt interventions in order to increase household potential to adopt to solar energy technology in Shamva District, thus reducing household energy poverty. Interventions ranging from financial capacitation of households, community participation and dissemination of information about solar energy technology were identified as key interventions among others. In this vein, the implementation of these strategies would usher in sustainable solar energy technology adoption in Shamva District. Thus, the research is significant as it delves on grassroots issues which inhibit the adaptation of smart energy, hence offering context specific interventions in reducing rural energy poverty.

Lastly, the research is key in addressing the knowledge gap in line with lack of critical information and data on factors influencing rural households in the uptake of clean energy. Hence, it informs interventions in terms of sustainable pathways in addressing rural energy poverty. Thus, the research is an indicator to the need for collaboration and grassroots participation in sustainable energy projects. Thus, no one and no place would be left out in the attainment of smart and sustainable energy.

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APPENDIX 1

6.0QUESTIONNAIRE

Bindura University of Science Education

Dear Participant

Good morning/Afternoon. I am Stephen Mazongonda ,a **Master of Science in Climate Change and Sustainable Development** student at **Bindura University of Science Education** .I am undertaking a Thesis which is titled “ **The adoption of off grid solar energy technologies as an intervention in the alleviation of rural energy poverty: A case of Shamva District, Mashonaland Central, Zimbabwe**. As part of my study, I am required to gather data from households in Shamva rural District about the adoption of off grid solar energy technologies in addressing rural energy poverty. The research is going to contribute in formulating strategies and policies which are key in the diffusion of off grid solar energy technologies in rural communities .In addition to this, it is going to guide government in addressing energy deficit in rural areas. You are kindly requested to freely participate in this study and also you are free to withdraw at any time you feel the need to do so. The information which you are going to provide is strictly confidential and your personal details will remain anonymous and protected. However , you are free to withdraw your participation from the interview any time you wish so .

SECTION A: Demographic data

1. Please indicate your gender

Male ☐ Female ☐

2. What is your age group?

18–29 ☐ 30–39 ☐ 40–49 ☐ 50–59 ☐ 60+ ☐

3. What is the highest level of education you attained?

Primary school ☐ Secondary school ☐ Diploma ☐

At least an undergraduate degree ☐

Section B Determinants of households to the adoption of off grid solar energy technology by households in Shamva District.

The objective is premised on eliciting data on the determinants of households to the adoption of off grid solar energy technology in Shamva District.Please indicate how far do you Agree/Disagree with the following factors influencing the adoption of off grid solar energy technologies at household level.

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5= Strongly Agree

Statement	**Strongly Dis**	**Disagree**	**Neutral**	**Agree**	**Strongly Agr Disagree**
Household level of wealth is a key determinant in the adoption of solar energy technology.					
The gender of a household head (HHH) is a key determinant in the adoption of off grid solar energy technology.					
The size of head of cattle owned by a household is a key determinant in the adoption of off grid solar energy technology					

The level of education of a household head (HHH) is a key determinant in the adoption of solar energy technology.					
The typology of solar energy technology is a key determinant in the adoption of solar energy technology.					
There is a nexus between the age of a household head (HHH) and the adoption of solar energy technology.					

Describe how gender disparities affect households adoption of solar energy technology in Shamva District.

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Section C: Factors influencing household perception on the uptake of solar energy technology in Shamva District

The objective examines factors that influence households' perception on the uptake of solar energy technology in Shamva District. Please indicate how far do you Agree/Disagree with the following statements on public acceptance and awareness of off grid solar energy technologies.

1=Strongly Disagree 2= Disagree 3 =Neutral 4= Agree 5 =Strongly Agree

Statement	**Strongl Disgree**	**Disagree**	**Neutral**	**Agree**	**Strongl Agree**
Quality of solar energy technology influences household perception on the uptake of solar energy technology.					

Knowledge and awareness of solar energy technology influences household perception on the uptake of solar energy technology.					
Community participation in solar energy projects influences households' perception on the uptake of solar energy technology.					
The size of solar energy equipment installed influences households' perception on the uptake of solar energy technology.					
Changings seasons influences households' perception on the uptake of solar energy technology.					
Sensitization of households' on the co-benefits of solar energy technology influences perception on the uptake of solar energy technology.					

What are the activities being done to foster positive perception of off grid solar energy technology in Shamva District.

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Section D: Barriers which inhibit households in the adoption of off grid solar energy technology in Shamva District.

The objective focused on the barriers which inhibit households in the adoption of off grid solar energy technology in Shamva District. Please indicate how far do you Agree/Disagree with the following statements on barriers on the adoption of off grid solar energy technology in Shamva District.

1=Strongly Disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly Agree

	Strongly Disag	Disagree	Neutral	Agree	Strongly AgreeDi sagree
High upfront costs in the acquisition of solar energy technology is a barrier in the adoption of off grid solar energy technology.					
Extreme poverty at household level erodes the potential of households to adopt to solar energy technology.					
The impacts of Covid 19 pandemic retard household capacity to adopt solar energy technology.					
There is rampant theft and vandalism of solar energy equipment which limit the sustainability of solar energy adoption.					
Lack of credit facilities for households to acquire solar energy technology is a barrier in the adoption of solar energy technology.					
Limited technical skills in the installation and maintenance of solar energy equipment act as a barrier in the sustainability of solar energy technology.					

Comment on the best financial model to be implemented in order to capacitate households in the adoption of off grid solar energy technology.

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Thank You.

APPENDIX 2

7.0KEY INFORMANT INTERVIEW GUIDE

Bindura University of Science Education

Dear Participant

Good morning/Afternoon. I am Stephen Mazongonda ,a **Master of Science in Climate Change and Sustainable Development** student at **Bindura University of Science Education** .I am undertaking a Thesis which is titled " **The adoption of off grid solar energy technologies as an intervention in the alleviation of rural energy poverty: A case of Shamva District, Mashonaland Central, Zimbabwe**. As part of my study, I am required to gather data from households in Shamva rural District about the adoption of off grid solar energy technologies in addressing rural energy poverty. The research is going to contribute in formulating strategies and policies which are key in the diffusion of off grid solar energy technologies in rural communities .In addition to this, it is going to guide government in addressing energy deficit in rural areas. You are kindly requested to freely participate in this study and also you are free to withdraw at any time you feel the need to do so. The information which you are going to provide is strictly confidential and your personal details will remain anonymous and protected. However , you are free to withdraw your participation from the interview any time you wish so.

1. What is the impact of income level of a household on the adoption of off grid solar energy technology?
2. How does gender impacts the capacity of households to adopt off grid solar energy technology?
3. How does the quality of solar energy technology influence household perception to adopt solar energy technology?
4. Why is knowledge and awareness of solar energy technology influence household perception on uptake of solar energy technology?
5. How the impacts of Covid 19 pandemic does retards the adoption of solar energy technology by households?
6. How theft and vandalism of solar energy equipment does impacts the sustainability of the adoption of solar energy technology?

Thank You

Observational Guide/ Guide for Photography Visioning in Shamva District: The adoption of off grid solar energy technology as an intervention in alleviating rural energy poverty: A case of Shamva District, Mashonaland Central Province, Zimbabwe.

PENDIX 3

8.0OBSERVATION GUIDE/ GUIDE FOR PHOTOGRAPHY VISIONING

Introduction

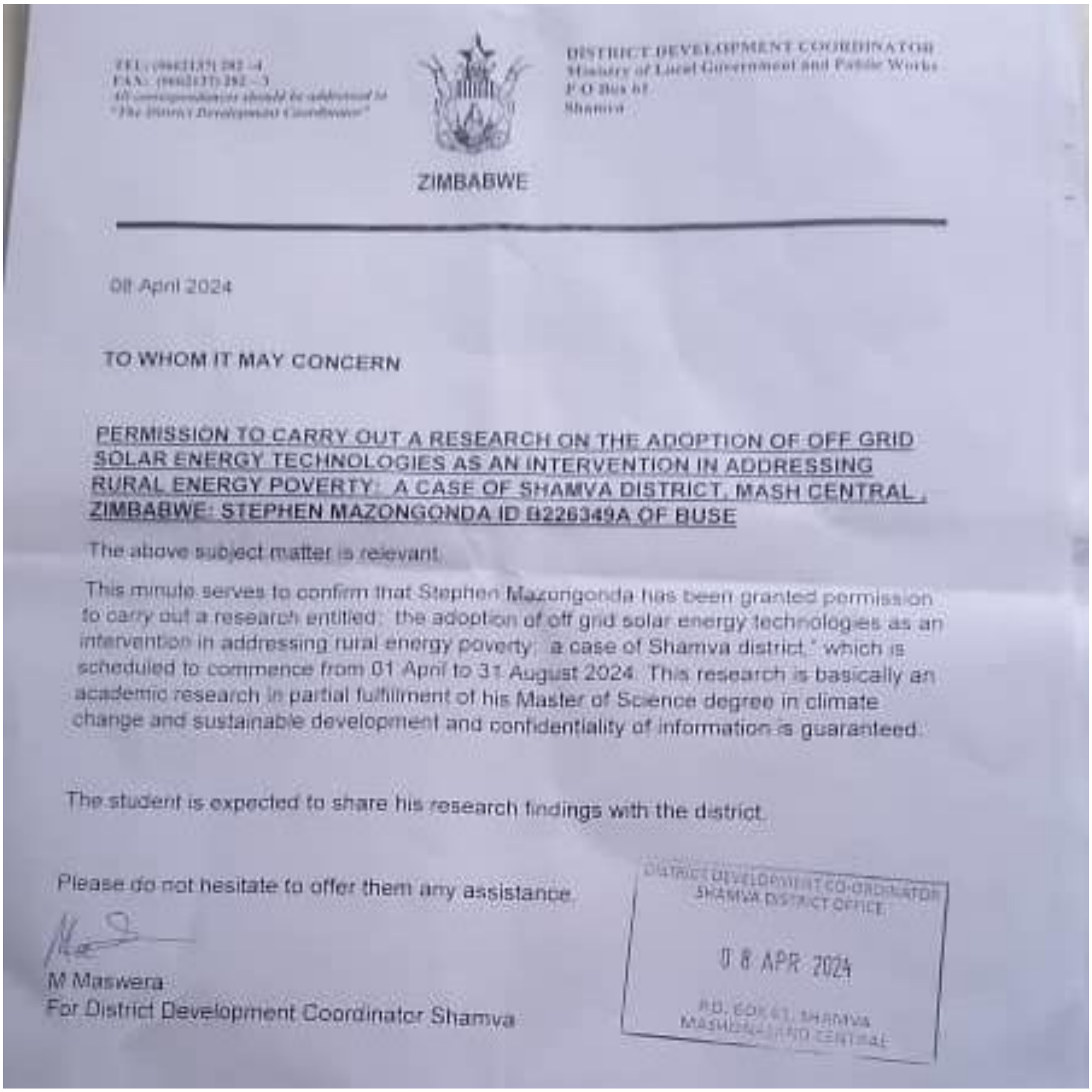
Good morning/Afternoon, I Stephen Mazongonda , a Masters student with Bindura University of Science Education (BUSE) and I am carrying a research study on The adoption of off grid solar energy technologies as an intervention in alleviating rural energy poverty in Shamva District. As part of my studies, I am required to gather data about factors influencing the adoption of off grid solar energy technologies by households in Shamva District. You are kindly asked to freely participate in this study. May I take some photographs of the activities you are doing if you would not mind. The information you provide shall serve as illustrations in the document. Your personal particulars will remain anonymous and protected. You are free to decide before I proceed with photographing .Thank you.

The researcher notes down the following observations in the field and was granted permission to take illustrative photographs.

1. Solar Home System is the widely adopted solar energy typology in Shamva District.
2. Indicate theft of solar panel from classroom block of a school within the study area.

APPENDIX 4

LETTER OF AUTHORITY



[illegible]
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All correspondence should be addressed to
"The District Development Coordinator"

DISTRICT DEVELOPMENT COORDINATOR
Ministry of Local Government and Public Works
P O Box 61
Shamva

ZIMBABWE

08 April 2024

TO WHOM IT MAY CONCERN

PERMISSION TO CARRY OUT A RESEARCH ON THE ADOPTION OF OFF GRID SOLAR ENERGY TECHNOLOGIES AS AN INTERVENTION IN ADDRESSING RURAL ENERGY POVERTY: A CASE OF SHAMVA DISTRICT, MASH CENTRAL, ZIMBABWE: STEPHEN MAZONGONDA ID B226349A OF BUSE

The above subject matter is relevant.

This minute serves to confirm that Stephen Mazongonda has been granted permission to carry out a research entitled: the adoption of off grid solar energy technologies as an intervention in addressing rural energy poverty: a case of Shamva district," which is scheduled to commence from 01 April to 31 August 2024. This research is basically an academic research in partial fulfilment of his Master of Science degree in climate change and sustainable development and confidentiality of information is guaranteed.

The student is expected to share his research findings with the district.

Please do not hesitate to offer them any assistance.

M Maswera
For District Development Coordinator Shamva

DISTRICT DEVELOPMENT CO-ORDINATOR
SHAMVA DISTRICT OFFICE
0 8 APR 2024
P.O. BOX 61, SHAMVA
MASHONALAND CENTRAL

Dissertation Stephen Mazongonda

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