MODELING SUSTAINABILITY OF ENERGY ACCESS IN RURAL AREAS OF TANZANIA

MODELING SUSTAINABILITY OF ENERGY ACCESS IN RURAL AREAS OF TANZANIA

By

Michael Mangula

A Thesis Submitted in Fulfilment of the Requirements for Award of the Degree of Doctor of Philosophy of Mzumbe University.

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CERTIFICATION

We, the undersigned, certify that we have read and hereby recommend for acceptance by the Mzumbe University, a thesis entitled **“Modeling Sustainability of Energy Access in Rural Areas of Tanzania”** in fulfilment of the requirements for award of the degree of Doctor of Philosophy of Mzumbe University.

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I, **Michael Mangula,** declare that this thesis is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

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DEDICATION

This thesis is dedicated to my late father Shadrack Jeremia Mangula, my mother, Janemery Kihegulo, to my wife Lena Amoni Lyama and to my children, Junior Michael Mangula, Shadrack Michael Mangula and Twilumba Michael Mangula.

I Love you all

ABBREVIATION AND ACRONYMS

AMOS	-	Analysis Moment Of Structures
CFA	-	Confirmatory Factor Analysis
CFI	-	Comparative Fit Index
DED	-	District Executive Director
DRPS	-	Directorate of Research and Postgraduate Studies
EA	-	Energy Access
EDI	-	Energy Development Index
EFA	-	Exploratory Factor Analysis
ESI	-	Energy Sustainability Index
GFI	-	Goodness Fit Index
GNP	-	Gross National Product
GOF	-	Goodness Of Fit
IIAA	-	Independence Irrelevant Alternative Assumption
IIA	-	Independence Irrelevant Alternative
IEA	-	International Energy Agency
IFI	-	Incremental Fit Index
KMO	-	Keiser Meyer Olkin
LPG	-	Liquefied Petroleum Gas
MLE	-	Maximum Likelihood Estimation
MLM	-	Multinomial Logit Model
MLR	-	Multinomial Logit Regression
MNP	-	Multi-Nomial Probit
MPM	-	Multinomial Probit Model
NBS	-	National Bureau of Statistics
OR	-	Odd Ratio
PCA	-	Principal Components Analysis
RAS	-	Regional Administrative Secretariat
RMSEA	-	Root Mean Square Error Approximation
SEA	-	Sustainability of Energy Access

SEM	-	Structural Equation Modelling
TLI	-	Tucker Lewis Index
UNECA	-	United Nations Energy Commission Africa
URT	-	United Republic of Tanzania
VEO	-	Village Executive Officer
VIF	-	Variance Inflation Factor
WEO	-	Ward Executive Officer
WSSD	-	World Summit on Sustainable Development

ABSTRACT

Lack of access to sustainable energy is an enduring problem facing rural households in Tanzania. This problem is caused by lack of model for measuring its sustainability. This study developed a model for measuring sustainability of energy access in rural areas of Tanzania. Positivism philosophy with deductive approach and cross-sectional survey design was used in this study. Data from rural Njombe and Iringa regions in Tanzania were collected using questionnaires. Districts and Villages were sampled using Multistage Cluster Sampling technique while rural households were randomly selected using Fishbowl draw method. Multinomial Logistic Regression, Exploratory Factor Analysis and Structural Equation Modeling were used to analyse data.

The study revealed that, indicators of energy access were availability, affordability, durability, efficiency, non-emission of smokes, easiness to use and the ability to keep cooking facilities clean. Moreover, it was revealed that, the indicators of sustainability of energy access involved social, economic, environmental, technical and institutional. Furthermore, the study revealed that education level, age, occupation, household size, and income determine the choice of energy sources. Lastly, a model for measuring sustainability of energy access in rural areas of Tanzania should consider social, economic, environmental, technical, and Institutional indicators.

The study concludes that the revealed indicators of energy access and its sustainability are useful in improving standard of living of rural households. Moreover, the study concludes that, apart from level of income, other factors such as age, household size, occupation, and education level determine the choices of energy sources. Lastly, the study concludes that apart from social, economic and environmental indicators, the model for measuring sustainability of energy access in rural areas of Tanzania should also take into consideration technical and institutional indicators.

The study recommends that, the identified indicators and its model to be used by energy experts, rural households, and government to ensure sustainable provision of energy. Moreover, apart from improving the income of rural households, training of rural households on sustainable use of energy sources, promoting reforestation and the use of modern cooking facilities should be done to ensure energy sources are being provided in a sustainable way in rural areas of Tanzania.

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CHAPTER ONE
RESEARCH PROBLEM SETTING

1.1 Introduction

In recent years, Sustainability of Energy Access (SEA) has gained importance and more importantly it has captured the attentions of many researchers due to its role of improving the livelihood of people in developed and developing nations, Tanzania inclusive. As Kandpal (2010) indicates, the provision of sustainable energy access improves social, environmental, and economic development of people in rural areas of developing nations. The social and economic development realized through the provision of sustainable energy access include among others improvement of quality of life of people, an increase of number of employments, improvement of income levels, and the reduction of environmental problems such as soil erosion and air pollution. Besides, the provision of sustainable energy helps in alleviating the existing developmental challenges such as poverty, health issues and poor education which face many developing nations (Ram & Bhaskar, 2019). Furthermore, sustainable energy access, according to Bhattacharyya (2015), improves human health and enhances the standard of living of rural households of the current generation without causing harm to livelihood of future generation.

The provision of sustainable energy access has also been emphasized in the National Energy Policy of the United Republic of Tanzania. The policy, among other issues, emphasizes on the provision of adequate, reliable, and affordable energy services in a sustainable way in order to attain the desired social, environmental and economic development of the people in Tanzania (URT, 2015). This policy aims at achieving the Sustainable Development Goal (SDG) number seven which emphasizes on the provision of sustainable energy services to all people by year 2030. In order to conceptualize well sustainability of energy access issues in developing countries and Tanzania in particular, the key terms such as energy access and sustainability of energy access need to be well explained in this section. Several empirical studies conducted globally explain the two concepts differently. Thus, there has been no consensus regarding the objective definitions of these two concepts. The differences in geographical locations, levels of income, affordability and availability of sustainable energy access to households in a particular area are among the reasons for lacking consensus on the definitions of energy access and sustainability among scholars globally (Bhattacharyya, 2012).

On the one hand, Sudhakara (2015) defines energy access as the provision of reliable, available, and affordable energy in the form of electricity generated from various sources such as coal, diesel and hydro power and cooking facilities such as firewood, charcoal, and Liquefied Petroleum Gas (LPG). On the other hand, Pachauri (2012) defines energy access as the provision and use of modern and clean fuel including energy for various activities such as cooking and lighting at a household level. Moreover, Yohannes (2012) defines energy access as the availability of modern energy sources to households for domestic and other uses. This implies that energy access should be available at a household level for various uses such as cooking, heating, and lighting and for other uses in productive activities such as farming and agriculture.

These varied definitions of energy access imply that there is no agreement by scholars on the common definition of energy access. Therefore, in the rural context of Tanzania, energy access in this study is defined as the provision of reliable, affordable, available and convenient energy in the form of electricity (generated from various sources such as fossils, coal or hydropower), charcoal, firewood and liquefied petroleum gas for cooking or lighting purposes. Thus, the energy sources included in this study were firewood, charcoal, Liquefied Petroleum Gas (LPG), kerosene, solar power, and electricity. These energy sources were included in this study because they are the ones being used by the majority of people living in rural areas of Tanzania for either cooking or lighting purposes. This is also supported by Fathiya *et al. (*2015) who revealed that although Tanzania is rich in terms of energy resources, biomass which is in the form of firewood and charcoal is the main source of energy for cooking by people in rural Tanzania followed by other forms of energy such as electricity and Liquefied Petroleum Gas (LPG). In order to ensure that social, environmental, and economic development of people in the rural areas of developing countries including Tanzania is realized, these energy sources should not only be accessible but also sustainable. In this regard, it is worth to explain also the concept of sustainability of energy access.

Sustainability of energy access is defined as the provision of energy access to households for the aim of bringing social, environmental, and economic impact on the livelihood of people of the existing generation without jeopardizing the future generation in acquiring their own needs (Marga *et al.*, 2019). This implies that energy sources such as firewood, charcoal, or electricity should be reliable, affordable, and should not only be available and safely but also it should not cause harm to human health and to the environment. Consistent to this, Mainali (2014) defines sustainability of energy access as the provision of energy which is reliable, affordable, and capable of meeting the economic, social and environmental needs within the overall development context and with equitable distribution in meeting these needs for the whole population. This definition of sustainability of energy access emphasis on the need of the provision of energy sources for cooking which is not only available, affordable and safe but also which represents people's interest socially, environmentally, and economically.

As pointed out earlier, sustainable energy sources in the form of electricity and modern cooking fuels play a great role in improving social, environmental, and economic development of rural households in developing nations and Tanzania in particular. Energy sources are widely used for various activities such as cooking, lighting and agricultural activities. However, provision of sustainable energy access for more than a decade has revealed to be a major problem in rural areas of the developing countries including Tanzania (Mainali, 2014; IEA, 2016). The increased problem of sustainability of energy access among other reasons has been attributed by inadequate evidence on the existence of a model for measuring its sustainability. To date, little is known on the existence of studies on developing a model for addressing sustainability of energy access in rural areas of Tanzania. The inadequate evidence on existence of information on the available models for measuring sustainability of energy access in rural areas of Tanzania has consequently led to an ad-hoc measurement of sustainability of energy access in rural areas. Ad-hoc measurement means provision of energy sources to people without being guided by any known indicators of sustainable energy. Continuing to address sustainability of energy access problems on ad-hoc basis has resulted into continued reliance on traditional and unsustainable sources of energy such as firewood and charcoal among people in rural areas of Tanzania. Such reliance on traditional energy sources can result into lung cancer caused by smokes destroy environment due to deforestation. In order to address this problem of sustainability of energy access, this study was meant to establish a model for measuring sustainability of energy access in rural areas of Tanzania and fill the knowledge gap in the existing literature on this aspect.

1.2 Background of the Problem

One of the most enduring problems facing people in rural areas of developing nations and Tanzania inclusive is lack of access to sustainable energy for social, environmental, and economic development. The problem of access to sustainable energy has made over 1.3 billion people globally to have no access to electricity, and about 2.7 billion people to continue relying on tradition sources of energy for various domestic activities such as cooking, lighting, or heating (IEA, 2017). The energy report by IEA (2016) also indicates that the problem of access to sustainable energy has made approximately 633 million people from Sub-Saharan African to have no access to electricity, while 792 million people continue relying on traditions sources of energy such as firewood and charcoal for cooking, lighting, or heating activities. Although the problem of access to sustainable energy is reported to affect majority of the developing countries, the problem is more serious and critical in rural areas of Sub-Saharan African countries, Tanzania inclusive. As Ranjit *et al.* (2013) observe, the problem of access to sustainable energy is more critical in rural areas of Sub-Saharan African countries than in the developed countries of Europe and America. Additionally, Mainali (2014) and IEA (2017) reveal further that majority of the people in rural areas of Sub-Saharan African countries are using traditional sources of energy such as firewood and charcoal for domestic activities such as cooking, heating, or lighting. This trend causes problems to human health including problems of lungs, prolonged coughing as well as problems to the environment such as soil erosion and environmental pollution.

Researches and scholarly works indicate that the provision of sustainable energy is the problem which has also seriously affected most of the people in rural areas of the developing countries, including rural areas of the East African nations. The United Nations Economic Commissions for Africa Report (UNECA, 2014) indicates that East African nations, such as Kenya and Uganda, have the problem of access to sustainable energy. The statistics from UNECA (2014) show that the problem of the provision of sustainable energy has made only 12% of the population in Uganda to have access to energy sources in the form of electricity leaving more than 88% of people to continue relying on biomass in the form of firewood and charcoal. The statistics indicate further that only about 16.1% of the populations in Kenya have access to Electricity while more than 85% of the people rely on tradition sources of energy for domestic uses such as cooking, heating, or lighting.

In Tanzania, the problem of provision of sustainable energy for various domestic uses in rural areas is also very critical because majority of people are still using traditional sources of energy which have been reported as obstacles in realizing the social, environmental, and economic development. For example, Mwakapugi *et al.* (2010) revealed that although Tanzania has a variety of energy sources such as biomass, gas, hydro, coal, geothermal and solar energy, 95% of her rural population depended on firewood and charcoal which besides being tradition they cause health problems to human beings and cause harm to the environment. Moreover, Swai (2014) reveals that the provision of sustainable energy is a problem in Tanzania as more than 37 million Tanzanians do not have access to sustainable energy. The URT National Panel Survey Wave 4(URT, 2015) indicates further that the provision of sustainable energy is a problem in rural areas of Tanzania because the percentages of households relying on traditional sources of energy for domestic use have remained largely unchanged. The statistics indicate that about 92% of the people in rural areas of Tanzania are still relying on traditional sources of energy for various domestic activities such as cooking, heating, and lighting.

Over several years, many empirical studies have been conducted globally in order to ascertain the major causes of sustainability of energy access problem in the developing nations and Tanzania in particular. On one hand, a study by Pachauri (2012) indicates that the problem of the provision of sustainable energy in Sub-Saharan African countries has been constantly increasing especially in rural areas due to various reasons but the most common ones include lack of harmony and agreement among researchers and other practitioners in the existing literature on what constitute energy access, and the way in which sustainability of energy access can be measured. Therefore, what constitutes energy access, sustainability of energy access, and the model for ensuring energy sources are provided in a sustainable way vary from one nation or community to another. The levels of income, differences in geographical location, availability, and the types of energy sources are among the factors that cause lack of the said harmony and common understanding (Bhattacharyya, 2015). On the other hand, the International Energy Agency report (2017) revealed that, inadequate literature from developing countries, Tanzania inclusive, on how energy sources can be provided in a sustainable way in order to improve the standard of living of people has to a large extent contributed to lack of access to sustainable energy access in rural areas of the developing countries. Thus, there is inadequate information in literature on the existence of a mechanism or a framework on how energy can be provided in a sustainable way so as to improve the social, environmental and economic development of people in rural areas. Consequently, in most of the rural areas of developing countries, including Tanzania, the provision of energy sources for domestic uses has been done in an ad-hoc basis making majority of the people continue to rely on traditional sources of energy. Besides, IEA (2016) reveals further that, various energy stakeholders such as policy makers, private institutions, and the Government need to have clear and well-defined model for ensuring that energy sources are provided in a sustainable way so as to improve the standard of living of people. Unfortunately, there is no sufficient evidence on the presence of these models for measuring sustainability of energy access especially in rural areas of Tanzania.

Inadequate information in the literature on how to measure sustainability of energy access has also been an obstacle to policy makers, government, and energy experts in establishing guidelines, strategies, and programmes for ensuring that energy sources are provided in a sustainable way in rural areas developing nations and Tanzania in particular. Furthermore, Takama *et al.* (2012) indicated that, more than 85% of the people living in rural areas of developing countries continue to rely on traditional sources of energy for domestic uses due to lack of a model for guiding them on how to use energy sources in a sustainable way in order to improve the standard of living of the people in a given nation or country. Similarly, a study by Mainali (2014) also suggests that there is a need of establishing a model in rural areas of developing countries for ensuring that energy sources are provided in such a way that they meet the needs of the existing generation without causing problems to the livelihood of future generations.

The foregoing observations indicate that there is inadequate information in literature on the model for measuring sustainability of energy access especially in rural areas of Tanzania. In this regard, the World Energy Outlook (WEO, 2012) established two models called Energy Development Index (EDI) and Energy Sustainability Index (ESI) in order to assist policy makers in establishing strategies and programmes of ensuring energy sources are provided in sustainable way to people living in any nation. However, the two models developed by WEO (2012) focused on addressing sustainability of energy access problem of the country as a whole without customizing the model for rural areas knowingly that rural areas have different characteristics that need special attention. The EDI and ESI models were also criticized by Doukas *et al.* (2012) who pointed out that these models address sustainability of energy access problem at country level but they do not actually explain specifically how sustainability of energy access in rural areas can be measured using a model to ensure there is social, environmental and economic development of people in rural areas of developing countries.

Moreover, the study conducted by Heap *at al.* (2002) and Bhattacharyya (2012) revealed the existence of energy models such as Energy Accounting Model, Energy

Optimization Model and Simulation Model. However, these models explain how energy can be used in optimal way as well they explain on the energy use status in a country; but, they do not address sustainability of energy access problem in rural areas of the developing countries and Tanzania inclusive. Furthermore, the study conducted by Ilskog (2008) established a model for ensuring that energy sources are provided in a sustainable way to people in a country. This study revealed that, in order to improve the standard of living of people, the model for provision of sustainable energy should consider three important aspects namely social, economic, and environmental indicators. Thus, the provision of energy should aim at fostering social, environmental, and economic development the people in a country.

However, the energy model developed by Ilskog (2008) has got a weakness as it covers only social, economic and environmental indicators ignoring technical and institutional indicators which are very important in assessing sustainability of energy access in rural areas as recommended by Mainali (2014). In this study, Mainali (2014) pointed out that apart from social, economic, and environmental aspects, a model for ensuring energy sources for cooking or lighting in rural areas of developing nations are provided in a sustainable way has to take into considerations technical and institutional indicators. The inclusion of technical and institutional indicators in a model for measuring sustainability of energy access in rural areas is crucial in the sense that these indicators explain how energy system can be maintained and become reliable and efficient, and that there is an availability of skilled labour at local level, and the ability of the energy system to be monitored locally as well as the ability to protect the interests of investor and that of the energy users in particular areas.

Therefore, lack of sufficient studies on models for ensuring the provision of sustainable energy in rural areas of Tanzania calls for a need of conducting this study. While on the one hand, the existing researchers and scholarly works have not covered models for measuring sustainability of energy access in rural areas, on the other hand, the efforts and initiatives devoted in mitigating the problem have not been well successful. The examples of the efforts made to ensure the provision of sustainable energy to people include the commitment of the United Nations General Assembly for a global partnership. This effort focused on achieving the then millennium development goals by the year 2015. The convening of the United Nations Climate Change conference held in Rio de Jeneiro in year 1992, and the World Summit on Sustainable Development (WSSD) in Johannesburg in 2012 were other initiatives aimed at mitigating a problem of lack of access to sustainable energy. However, the problem still persists in rural areas of the developing countries and Tanzania inclusive. Thus, despite the fact that the conference proposed other practices such as installation of generators powered by diesel engines to ensure provision of sustainable energy, yet people dwelling in rural areas of developing nation do not have access to sustainable energy sources for cooking or lighting.

The aforementioned practices and programmes did not work and neither did they survive due to high running and maintenance costs. In this regard, the USAID report (2006) revealed that installed generators in Afghanistan for rural electrification were not sustainable because the programmes focused on helping in terms of subsidies or technical assistance only. Thus, empirical studies and practices reveal that there is inadequate evidence in rural areas of the developing countries including Tanzania on the existence of model for ensuring energy sources are provided in a sustainable way. This study filled this research knowledge gap by establishing a model of measuring sustainability of energy access in rural areas of Tanzania. The developed model would ensure the provision of energy sources in a sustainable way for social, environmental and economic development of people in rural areas of Tanzania.

1.3 Statement of Research Problem

Despite the important role played by energy sources for cooking, heating or lighting purposes, lack of access to sustainable energy is reported to be a major problem endured by people in rural areas of developing nations, Tanzania inclusive. There have been many efforts made to address this problem, which include development of Energy Sustainability Index (ESI) and Energy development index by WEO (2012), energy accounting and optimization models by Heap (2002) and Bhattacharyya (2012), as well as installation of generators powered with diesel engines for electrification in rural areas developing countries. Despite these efforts, still more than 85% of people living in rural areas of Tanzania except in Dar es Salaam region continue to rely on traditional and un-sustainable sources of energy for cooking, heating, or lighting purpose (Swai, 2014; URT, 2012).

The increased problem of access to sustainable energy in Tanzania, among other reasons, is attributed by the existence of inadequate information in the existing literature regarding models for measuring sustainability of energy access in order to enhance social, environmental and economic development of people (Mainali, 2014; Bhattacharyya, 2015). Consequently, the provision of energy sources in rural areas nowadays is done on an ad-hoc basis where by energy sources are provided without having pre-defined indicators for ensuring energy are provided in a sustainable way. Provision of energy sources on ad-hoc basis cause health problems such as lung cancer due to smokes and environmental problems such as soil erosion caused by prolonged deforestation. Additionally, the problem of the provision of sustainable energy to rural households in developing nations and Tanzania inclusive is mainly caused by lack of common understanding and consensus among researchers and practitioners on what actually constitute indicators of energy access, factors determining the choices of energy sources, indicators of sustainability of energy access and the model for measuring its sustainability in rural areas (Bhattacharyya, 2015; Pachauri, 2012; Daukas *et al*., 2012).

Scholarly works (e.g. Ilskog, 2008; WEO, 2012; Mainali, 2014) indicate that some of the available models address sustainability of energy issues at country level and more specifically in urban areas leaving the rural areas uncovered although rural areas suffer the most from critical sustainability energy access problem. Moreover, other empirical studies indicate that the existing model covers only social, economic, and environmental indicators leaving aside technical and institutional indicators, which are very important in ensuring energy sources are provided in a sustainable way in rural areas (Ilskog, 2008; Mainali, 2014).

The lack of a model for measuring sustainability of energy access in rural areas of Tanzania has left several questions unanswered. For instance, what will be the future of people living in rural areas of Tanzania if energy is not provided in a sustainable way? What are the indicators of energy access? What are the indicators of sustainability of energy access? What are factors determining the choice of energy sources for cooking or lighting? What model should be developed to ensure that there is the provision of sustainable energy to people dwelling in rural areas Tanzania. All these questions indicate that there are scant literatures on modeling sustainability of energy access issues despite the existence of the problem of the provision of sustainable energy to people living in rural areas of Tanzania. Again, there is insufficient evidence in literature on whether the findings from studies conducted outside Tanzania on the model for measuring sustainability of energy access can be generalized to the selected study areas of rural areas of Njombe and Iringa regions and other rural areas having similar characteristics as that of study areas Tanzania. This study therefore looks at modeling sustainability of energy access focusing on the determining indicators of energy access, factors determining choices of energy sources for cooking; and identifying the indicators of sustainability of energy access and lastly establishes a model for measuring sustainability of energy access in rural areas of Tanzania.

1.4 General Research Objective

This study aimed at modeling sustainability of energy access through the establishment of a model for measuring Sustainability of Energy Access in Rural Areas of Tanzania.

1.4.1 Specific Research Objectives

To achieve the general research objective, this study was guided by the following specific research objectives

i. To determine the indicators of Energy Access in Rural areas of Tanzania
ii. To identify factors determining the choices of energy sources for cooking or lighting in Rural areas of Tanzania

iii. To identify the indicators of Sustainability of Energy Access in Rural areas of Tanzania

iv. To develop a model for measuring Sustainability of Energy Access in Rural areas of Tanzania using measurable indicators

1.5 General Research Question

In modeling sustainability of energy access in rural of Tanzania, this study was guided by the following general research question “How can Sustainability of Energy Access be measured in rural areas of Tanzania?

1.5.1 Specific Research Questions

This study was guided by the following specific research questions:

i. What are the indicators of Energy Access in Rural Areas of Tanzania?

ii. What are the factors determining the choices of energy sources for cooking or lighting in Rural Areas of Tanzania?

iii. What are the indicators of Sustainability of Energy Access in Rural Areas of Tanzania?

iv. How can Sustainability of Energy Access be measured using measured indicators in Rural Areas of Tanzania?

1.6 Scope of the Study

This study aimed at modeling Sustainability of Energy Access in Rural areas of Tanzania. The study was confined itself to heads of households living in rural areas of Njombe and Iringa regions in Tanzania. The areas covered from Njombe region were Njombe districts and the rural areas of Makambako Township Authority. From Iringa region, the study covered Iringa district, Mufindi district, and the rural areas of Mafinga Township Authority.

Moreover, the study covered energy access and sustainability of energy sources such as firewood, Charcoal, electricity and Liquefied Petroleum Gas (LPG), solar power, and kerosene for either Cooking/heating or lighting purposes at household level only. In identifying factors determining the choices of energy sources for cooking or lighting in the selected study areas, the study used demographic factors such as level of education, age , occupation, household size, and average monthly income as independent variables and energy sources such as firewood, charcoal, Liquefied Petroleum Gas (LPG) and electricity for cooking purposes and energy sources such as electricity, kerosene, solar power and solar Torch for lighting were used as dependent variables

1.7 Organization of PhD Thesis

This PhD thesis consists of six chapters. The first chapter sets the research problem, and this covers the general introduction, background, and statement of the research problem. It also covers the objectives, research questions, and the scope of the study.

The Second chapter consists of literature review, which covers theoretical and empirical review, synthesis of literature and the conceptual framework which guides the study. Theoretical literature review covers the definition of key terms and the theories guiding the study. Empirical literature review covers the review of indicators of energy access, the factors determining the choices of energy access, indicators of sustainability of energy access, and the models relating to sustainability of energy access.

The Third chapter presents the research methodology used in this study. The methodology components include research philosophy, research design, unit of analysis, study area, population of the study, sample size, sampling techniques, data collection methods, data analysis techniques, reliability and validity of data, and research ethics considered during conducting this study.

Chapter Four presents the research findings of the study and analysis. The findings include preliminary data analysis such as Outlier, Independence of Irrelevant Alternatives Assumption (IIAA) and Multicollinearity tests of data, followed by the research findings of the descriptive analysis. Thereafter, the chapter presents the research findings of inferential data analysis on the indicators of energy access in rural areas, factors determining the choices of energy sources for cooking or lighting, indicators of sustainability of energy access, and the model for measuring sustainability of energy access in rural areas of Tanzania.

The Fifth chapter presents the discussion of research findings. The discussion is on the findings of the demographic characteristics of the respondents, the indicators of energy access, factors determining the choices on energy sources for cooking or lighting, indicators of sustainability of energy access in rural areas, and the developed model for measuring sustainability of energy access in rural areas of Tanzania. The Sixth chapter presents the summary, conclusion, recommendation, policy implication of the study, contribution, limitations of the study as well as areas for further researches.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents both theoretical and empirical literature review guiding this study. Theoretically, the study has defined some of the concepts used in this study and explained the theory guiding this study. Empirically, this section has presented the reviewed literature on indicators of energy access, factors determining the choices of energy sources for cooking or lighting purposes at household level, indicators of sustainability of energy access and the review of various models related to sustainability of energy access. The conceptual framework is grounded on the theory guiding this study as well as on the reviewed literature on sustainability of energy access.

2.2 Definition of key Concepts used in this study

The key concepts defined in this section include, modeling, energy models and rural areas. Other key concepts such as Energy Access (EA) and Sustainability of Energy Access (SEA) have been well defined in the introductory section of chapter one of this thesis

2.2.1 Modeling

The concept of modeling has different meanings to different researchers. Bhattacharyya (2012) defines modeling as a process of presenting particular phenomena or any real system or problem using various approaches such as figure, number, flow charts, tables, or in the form of a text. Moreover, Andriano *et al.* (2012) look at modeling as a process of representing any reality in any form such as mathematical, physical, symbolic, graphical or descriptive form to present a certain aspect of that reality for the purpose of answering the question being studied. In this respect, modeling aims at answering the problem under study or act as a medium of communication by various actors. As stated by Andriano *et al.* (2012), the process of modeling provides a mechanism for answering a set of questions or addressing a particular problem. In this regard, this study aimed at modeling sustainability of energy access in rural areas of Tanzania by answering the main question of how can sustainability of energy access be measured using measurable indicators? To answer this question, a model for measuring sustainability of energy access in rural areas of Tanzania using was developed. Therefore, in this study, the term modeling implies addressing the sustainable energy problem by developing a model for measuring sustainability of energy access in rural areas of Tanzania using Structural Equation Modeling method and presents it using measurable indicators.

2.2.2 Energy Model

A model is the simplification of the real world representing the real phenomenon expressed in terms of figures, mathematics, a flow diagram, or through the use of words (Heaps, 2002). Thus, a model aims at presenting an abstract of anything such as system, concept, problem or phenomena. Moreover, Bhattacharyya (2010) defines a model as an abstraction of reality or one's conception that is used as an aid in answering a set of questions or to aid communication. Elsewhere, Bhattacharyya (2010) looks at a model as a representation of real things using various methods such as mathematical programming, econometric and other approaches depending on the data requirement, technology, and skills required as well as the computing demand. These definitions reveal that a model is not objective rather it is a subjective concept with different meanings to different professions because of different methods and approaches used to develop and present it. With this regard, energy model can be in different forms such as flow chart, mathematics, indicators as well as econometric approaches. Accordingly, a model can be developed using different methods and also presented using different ways or forms. The model for measuring sustainability of energy access in this study was established using Structural Equation Modeling (SEM) method and presented in the form of measurable indicators.

2.2.3 Rural areas

For more than a decade, academia and practitioners have been defining the term rural areas differently in various scholarly works. Tanzania Rural Development Strategy Report (2001) defines rural areas as area including villages and small towns nearby urban centres. This implies that any area outside the cities and towns with thin population and confronted with social, economic, political and moral problems. Among these social, economic and moral problems include lower per capita income, lower educational level, fewer employment opportunities, limited educational and cultural facilities, out-migration, less developed health and transport services, fewer commercial facilities, declining small towns, and less confidence in the future prospects. The United Republic of Tanzania human settlement development policy (2002) defines rural as all areas including villages with a population of less than 10,000 people having social services such as retail shops, market place, primary school, dispensary as well as post office. Although the process of establishing a universal and agreed definition of rural areas as a concept creates many challenges, rural areas have some common characteristics such as poor infrastructure, poor education, poor health and poor access to clean, modern and sustainable energy sources. Based on these observations, rural areas in this study are therefore defined as those areas including the selected villages and small towns near the urban centre in Njombe and Iringa regions.

2.3 Theory Guiding the Study

The concept of sustainability of energy access and energy sources for cooking or lighting have been explained by various academic and practitioners using various theories. However, the major dominant and mostly used theory in guiding sustainability of energy access is called Energy Ladder Theory or is sometimes called Energy Transition Theory. This study therefore was guided by Energy Ladder Theory proposed by Schlossberg's in 1984 and revised in year 1989 and year 1995.

2.3.1 Energy Ladder (Energy Transition Theory)

The Energy Ladder (Energy Transition Theory) emanated from the Transition Theory which was pioneered by Schlossberg's in 1984 and revised in year 1989 and year 1995. This theory explains the behaviour of households in shifting from traditional use of energy sources for cooking or lighting or any other uses to more sophisticated, modern and sustainable sources of energy in order to improve the social, environmental and economic development of people in a particular nation or community. Based on this theory, a household tends to abandon traditional sources of energy and shift to modern and clean sources of energy as the level of income increases. Being grounded on Energy Ladder Theory Van der Kroon *et al*. (2013) observe that poor people use traditional sources such as firewood, charcoal, kerosene for cooking and lighting purposes; however, as their income improves they shift to modern and clean sources of energy such as electricity and Liquefied Petroleum Gas (LPG).

The Energy Ladder Theory hypothesizes that poor people are found at the bottom of the ladder while those households with higher levels of income and can afford to procure modern and clean sources of energy are found at the top of the ladder. This implies that in Energy Ladder Theory, income is the factor influencing the choice of energy sources for domestic uses such as cooking, heating or lighting in any nation or community. Thus, based on the improvement of the level of income of households, Energy Ladder Theory follows three steps on climbing the Ladder. Firstly, there is universal reliance on traditional sources of energy such as firewood, cow dung and agricultural products remains for cooking, heating or lighting. Secondly, the level of income starts to improves a household gradually starts shifting from using traditional sources to transition energy sources such as kerosene or coal and thirdly, an individual shift to the modern, clean and sustainable energy sources such as electricity and Liquefied petroleum Gas (LPG) due to higher level of income as shown in Figure 2.1

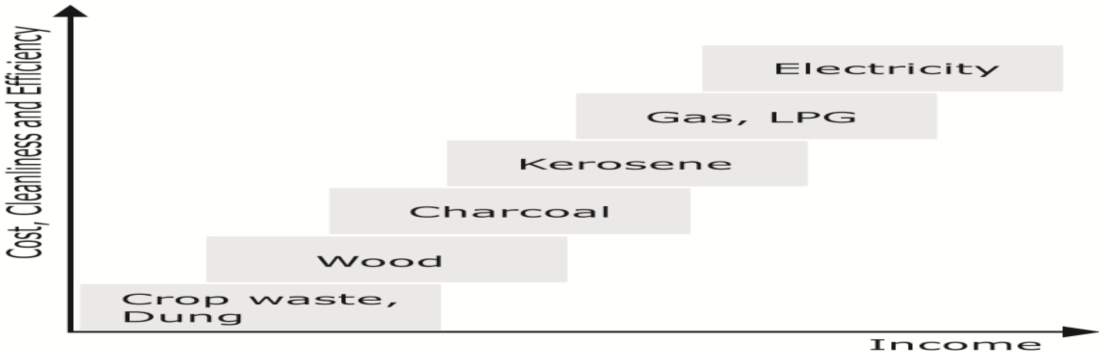

Figure 2.1: Energy Ladder Theory

Source: Van der Kroon *et al*. (2013

Theoretically, the process of shifting from using traditional sources of energy to modern, clean energy sources as the level of income increases is said to be linear. However, the practice is not the case. The tendency that the shifting process is not linear has been evidenced by the study conducted by Masera *et al. (2013)* which revealed that apart from following energy ladder, households sometimes continue using traditional sources of energy despite an increased level of income. This type of behaviour is called energy swifting behaviour or energy staking behaviour. Energy staking behaviour holds that an individual can still rely on both traditional and modern sources of energy as the level of income changes. This implies that household members do not only apply single – fuel substitution but rather a variety of fuel both traditions and modern as their sources of energy for cooking, heating or lighting purposes in a particular nation or community. Although households are free and can decide to use a variety of energy sources in time, the focus should be on ensuring that these energy sources are used in a sustainable way such that they meet their present needs without causing harm to the livelihood of future generation.

The use of energy sources for cooking, heating or lighting in a sustainable way was also indicated by Pachauri (2011) who observe that a variety of energy sources for cooking, heating or lighting in rural areas should be used in a sustainable way by focusing on bringing positive effect on social, economic, technical, environmental and institutional aspects of development. In this respect, the Energy Ladder theory deems to be useful in guiding this study. The theory provides useful guidance in discussing the findings regarding the indicators of energy access, factors determining the choices of energy sources for cooking or lighting purposes, the indicators of sustainability of energy access in rural areas as well as the model for measuring sustainability of energy access in rural areas of Tanzania.

2.4 Empirical Literature Review

The subsequent sections provide detailed empirical literature review under each subsection. The reviewed empirical literature focused on specific objectives guiding this study. The focus is meant to have deeper understanding on what other researchers and practitioners have done in similar or related studies.

2.4.1 The Indicators of Energy Access in Rural Areas

Global literatures show that, several studies have been conducted in both developed and developing countries to determine the indicators or what actually constitute energy access. However, up to date there has been no consensus on the indicators of energy access. Lack of agreement among researchers poses challenges in ensuring the provision of energy access in developing countries especially in rural areas of Tanzania (Bhattacharyya, 2012). Differences in Geographical location, level of income, and level of energy access are among the factors leading to the lack of agreement on what actually constitute energy access and its indicators.

In this regard, Mensah *et al.* (2014) define indicators of energy access as the quantitative or qualitative measures derived from a series of observed facts that explain the status of energy access of a country, community, or household members. This implies that energy access indicators have an important role of clarifying and also making aggregate information to assist policy makers, the government, and energy experts to make decisions regarding energy. Rational decisions made by policy makers, government and other energy actors will ensure that people are provided with energy which subsequently fosters social, environmental and economic development of the people in a nation or community. The cited study revealed further that the presence of energy access in particular areas is measured by considering the number of people with access to modern cooking fuel and electricity and also the amount of household income spent in order to have access to energy sources. This indicates that many people with access to electricity and modern cooking facilities imply higher access to energy sources.

Regarding how energy access can be measured or the indicators available in a particular area which has energy access, a study by Pachauri (2012), on access to modern energy; an assessment and outlook for the developing and emerging points which was conducted in Luxemburg, Austria using case study approach, revealed that, the indicators of energy access in the form of electricity or modern cooking facilities are measured by considering the number or percentage of households with access to electricity and those who rely on modern energy sources for cooking, heating, and lighting purposes. Moreover, other studies pointed out that among the indicators of the presence of energy access in terms of electricity or modern cooking facilities include its availability, accessibility, disparity, affordability, renewability, security of energy use and efficient use (Pachauri, 2012; Bhattacharyya, 2015).

Besides, a study by Sudhakara (2015), on access to modern energy services revealed that energy access is measured using mainly three indicators namely availability, affordability, and reliability. Thus, it was these indicators which assisted policy makers in making decisions whether or not there is energy access in the form of electricity or modern fuel. Availability of energy according to Sudhakara (2015) implies that energy services should be available at the time when it is needed. In other words, the energy facility should be available in the same geographical location where household members dwell. Again, in the same study, the indicator of affordability referred to as the purchasing power and ability to buy a particular energy sources by household members in a nation or community.

Similarly, reliability as an indicator of energy access in the form of electricity or modern cooking refers to continuous supply (no shut down, blackout, voltage fluctuation) as well as the quality of the end use appliances in a particular household. Additionally, the study by Mainali (2014) on rural energy sustainability in developing countries conducted in Sweden revealed that the indicators of energy access in the form of electricity or modern cooking facilities is measured by looking at its availability, reliability, number of people with access to electricity or modern cooking facilities or the amount of energy which is consumed by one country or another

Apart from the aforementioned literature, WEO (2012) established that energy access indicator is measured by considering the percentage of people who use liquid fuels, or gaseous fuels as their primary fuel to satisfy their cooking, heating and lighting needs. According to IEA (2014), in order for energy sources to be accessible it needs to be available, affordable, and technically easy to be maintained. Energy access in the form of electricity or modern cooking facilities should also be available at desired hour of the day and should be safe to use (convenience), its supply should be of the right quality (e.g. voltage level) and should be used for most of the time (reliability). This implies that convenience and reliability are also indicators of energy access. The facts from the reviewed literature reveal that there are no unified or common indicators of energy access which can be used globally. The literature indicates further that every researcher has different indicators of energy access.

Lack of common indicators to guide energy experts, policy makers, and the government to ensure that there is a provision of energy access for social, environmental, and economic development is among the enduring problem facing people in rural areas of Tanzania from attaining sustainable development goals. Therefore, determining the indicators of energy access in rural areas of Tanzania is deemed important in this study.

2.4.2 Factors Determining the Choices of Energy Sources for Cooking or Lighting in Rural Areas of Tanzania

The provision of affordable, reliable, and safe sources of energy for cooking or lighting is among the sustainable development goals of any modern society nowadays. The use of modern sources of energy such as electricity and modern cooking facilities including Liquefied Petroleum Gas (LPG) play a crucial role in improving social, environmental, and economic development of people in a nation.

Thus, in order to improve the livelihood of people in rural areas of developing nations and Tanzania in particular, the emphasis should be on the provision of adequate, affordable, reliable, quality, safe and environmentally friendly energy sources for either cooking or lighting activities (Assa *et al.*, 2015).

Similarly, Adeyemi and Adereleye (2016) observe that the choice of energy sources for cooking or lighting should focus on addressing human health and environmental problems so as to improve the social-economic development of people. Additionally, IEA (2014) emphasizes further that energy sources such as firewood, electricity, charcoal and Liquefied Petroleum Gas (LPG) should be provided in a sustainable way in order to improve social, environmental, and economic development of people in rural areas of developing nations.

Although studies indicate that the use of modern energy sources for cooking or lighting play a crucial role in improving the livelihood of people, majority of the people in the rural areas of developing nations rely on traditional sources of energy (Goswami & Giri, 2017; IEA, 2017). While Energy Ladder hypothesis reveals that an individual shift from using traditional sources of energy to modern sources of energy as the level of income improves, statistics reveal that more than 80% of people in rural areas of developing nations continue to rely on biomass in the form of firewood or charcoal which apart from being traditional they also cause harm to human health and to the environment (IEA, 2017; Mainali, 2015; Bhattacharyya, 2015).

Given the important of energy sources for cooking and lighting in life, to continue relying on traditional sources of energy by majority of rural households in developing nations attracted the attention of various researchers and practitioners who carried out studies to ascertain the factors that determine choices of energy sources for cooking or lighting in order to improve the standard of living of the people. A study conducted by Francis and Gemma (2014) in Uganda established that factors such as expenditure welfare of the people, location of household member, the household size, and education play a significant role in determining the type of energy sources to be used for cooking purposes or other domestic uses. Besides, the study by Justice and George (2013) on households' energy choices in Ghana indicated that the decision to use particular sources of energy for cooking is influenced by factors such as age, sex, education as well the level of income of households.

Moreover, Abubakar H, Rabiul I, and Shri Dewi A. (2015) conducted a study in Nigeria on the determinants of household choice and consumption pattern in developing counties and established that household size, age, and nature of employment determine the choices of energy sources for cooking in rural areas. However, this study pointed out that not all these factors are equally important in determining the household member's behaviours in different parts of the developing nation. This implies that important factors in making decision regarding choices of particular energy sources vary from one nation to another. The study conducted by Fidel, Uchechukwu and Gabriel (2014) on household energy use and its determinants revealed that firewood is the major source of energy for cooking while kerosene is used for lighting. The choice of using firewood for cooking and kerosene for lighting was found to be influenced by factors such as education level of a mother and a father, per capital expenditure, and the number of people in the household.

Moreover, a study by Getamesay, Getachew, and Workneh (2016) on the determinants of household energy demand in Ethiopia revealed that households' size, proportion of women in households, education, owning of dwelling and electric appliance are useful factors determining the choice of energy sources. However, this study was confined only on electricity as source of energy leaving other sources of energy such as charcoal or firewood un-explained. The reason is that, this study was conducted in urban areas of Ethiopia where electricity and other sources of energy such as Liquefied Petroleum Gas (LPG) are readily available and are the only sources for energy for cooking or lighting. The study by Assa, Gebremariam and Maonga (2015) which explored the key factors determining the choice of energy sources for cooking revealed that location of residence, the income of households and age contribute significantly to making choices of energy sources for domestic uses. It was further revealed that the probability of using firewood in rural areas is higher than that of electricity due to the availability and affordability firewood as a source of energy for coking.

Elsewhere a study by Nnaji, Ukwueze, and Chukwu (2012) on the determinants of household energy choices for cooking in rural areas also revealed that household size, age, occupation, and the existence of internal cooking facilities determine the choice of energy sources for cooking purposes. Consistent to this, a study by Adepoju *et al*. (2012) indicates that the factors influencing domestics' energy choices are sex, level of education and proximity of energy sources. Likewise, the study conducted by Rasmus (2013) on factors determining household's on fuel choices in Guatemala showed that education, opportunity cost of using firewood, ethnicity, electrification, price and region of residence play an important role in transition towards using modern sources of energy for cooking or lighting by rural households in a country.

Adding on pivotal role of using modern energy sources for cooking or lighting in improving social, environmental, and economic development of the people, a study by Paul *et al.* (2013) on the household energy choice in Ghana established that income, education, family size and employment determine the choices of energy sources. This study revealed further that choices of energy sources to be used in the household and the important factors of energy source choices vary across the areas or within members of the community.

Similarly, a study by Mekonen (2013) on the on the impacts of rural electrification in Sub-Sahara Africa using a case study of Ethiopia linking the determinants of energy demand with access to electrification revealed that household total expenditure, occupation of households and family size positively affected fire wood and charcoal consumption. The reviewed literature reveals that factors determining choices of energy sources for various uses such as cooking, lightings and other uses such as in agriculture or industrial production vary from one nation, region, or community to another. Thus, the ability to generalize the findings from other nations to the rural context of Tanzania is not well documented in literature. Thus, this study is deemed important in order to ensure that energy sources are used in rural areas without causing harmful effect to human health and to the environment

2.4.3 The Indicators of Sustainability of Energy Access in Rural areas

Indicators of Sustainability of energy access help government, policy makers, and energy experts to ensure that development goal of providing reliable, affordable and safe energy services to people living in a nation is sustainable. A study by Swati (2015) established that indicators of sustainability of energy access assist the government, energy experts, and other energy stakeholders to ensure that there is a provision of sustainable energy sources for cooking, heating, lighting or other uses such as industrial production in order to improve social, environmental, and economic development of the households dwelling in a particular nation or community. The contributions of indicators of sustainability of energy access in improving the social economic development and livelihood especially in the rural areas of developing countries in the past and in recent years have attracted the attention of researchers and practitioners globally. Thus, numerous studies have been conducted to determine indicators of sustainability of energy access.

The study conducted by Swati (2015) on Benchmarking sustainability in India established that in order to ensure that energy sources is provided to the households without causing harm to future generations, social, economic and environmental indicators should be taken into consideration. This study recommended that individuals should use energy sources such as firewood or charcoal for cooking or lighting without causing harm to human health and to the environment. Similarly, Andre *et al.* (2015) in a study on the selection of sustainability indicators for planning revealed that social, economic, and environmental aspects are important indicators of ensuring that there is reliable, affordable, environmentally health and safe energy sources for the development of the current generation without causing harm to the future one. However, this study researched the indicators of sustainability of energy access in urban areas only ignoring the rural areas which suffers the most from the problem of sustainability of energy access.

Besides, a study by Pachauri (2012) in Australia on access to modern energy indicates that sustainability of energy access is measured generally by considering Energy Development Index (ED1) and Energy Sustainability Index (ESI) which also take into considerations social, economic, and environmental issues. However, these indicators were meant to address sustainability of energy access problem at country level and more specific in urban areas of the country. The study also did not address indicators of sustainability of energy access in rural areas context. Similarly, a study by Mostafa and Jürgen (2017) revealed that social, economic, and environmental aspects are worth considering in order to improve livelihood of the people in a given nation or community.

Moreover, a study by Wang *et al.* (2009) in China on multi-criteria decision analysis aid in sustainable energy decision-making revealed that economic, social and environmental indicators are important in ensuring that there is a sustainable energy sources for improvement of livelihood and standards of living of people. The study by Ilskog (2008) covered only three categories of indicators namely social, economic, and environmental to address sustainability of energy access problems. This study covered only the urban areas of developing nations where technical and institutional indicators were not found to be important. The study by Ilskog (2008) recommended further study to be conducted in rural areas of developing countries to cover technical and institutional indicators of sustainability of energy access apart from social, economic, and environmental, which have been addressed by previous studies. Thus, technical and institutional indicators were found to be useful when addressing sustainability of energy access problem in rural areas of developing countries including Tanzania. A study by Mainali (2014) on the assessment of rural energy sustainability in developing countries suggested that Energy Technology Sustainability Index should be measured considering Technical aspects indicators apart from social, economic and environmental indicators; however technical indicator was not used due to shortage of fund and time limitation. The indicators proposed by Mainali were as shown in Table 2.1 herein.

Table 2.1: Indicator of sustainability of energy technology in developing nations

Dimension (construct) of sustainability of energy technology	Measure of indicators	Suggested Indicators code
Social indicators	% of population with access to electricity	SOI01
	% of population with access to clean energy sources	SOI02
Economic indicators	Per capital use,	ECOI01
	Affordability	ECOI02
	Renewability	ECOI03
	Security of supply	ECOI04
Technical indicators	Delivery time	TEI01
	End use efficiency	TEI02
Environmental Indicators	Local environmental impact	ENI01
	Global environmental impact	ENI02

Source: (Mainali, 2014)

The proposed indicators on Table 2.1 show that social sustainability of energy technology is measured by considering the number or percentages of population without electricity (S01) and the percentage or population without access to clean energy (S02. Economic sustainability of energy technology is measured based on the electricity use per capita **(**EC01), the share/percent of household income spent on fuel and electricity termed as affordability (EC02) and the share of renewable energy in electricity generation termed as renewability **(**EC03). Besides, the technical sustainability of energy technology is measured by assessing the energy conversion efficiency (TEC1), and transmission/distribution loses or termed as energy delivery (TEC2). Lastly, the environmental sustainability of energy technology is measured by taking into consideration local emissions from production or energy use (EN01) and the global impact of household air pollution from energy systems (EN02). While the study by Mainali (2014) proposed the use of four categories of indicators of sustainability of energy technology, only three categories namely social, economic and environmental indicators were dealt in his study. Therefore, the aforementioned reviewed literatures on indicators of sustainability of energy access reveal that every country or nation has different indicators of sustainability of energy access. Furthermore, the reviewed literature indicate that the existing studies focus only on social, economic, and environmental indicators, leaving aside technical and institutional indicators. This is particularly because majority of studies concentrated much on urban areas leaving rural areas unattended to despite having most of the problems of lack of access on sustainable sources of energy. Therefore, determining these indicators was deemed important in this study.

2.4.4 The Existing Sustainability and Energy Choices Models

Energy models are defined as planning tools for exploring the use of available energy in sustainable way. These models among other roles are developed in order to ensure the provision and use of energy sources are sustainably done so as to improve social, environmental, and economic development of people in a given nation or community. The importance of a model in ensuring energy sources are used without causing harm to human health and to the environment has attracted the attention of various researchers with a view of developing models which suit the needs of different people and environments.

As pointed out by Van der (2013), various energy models have been developed and documented in literatures depending on the scope of region, time, methodology and modeling approach in order to ensure energy sources are used for improving livelihood and standard of living of the people. Emphasizing this matter, Bhattacharyya (2010) observe that energy model can be developed and presented using various approaches such as mathematical programming, econometrics, table, flow chart, indicators, and other related methods of statistical analysis and network analysis depending on the data requirement, technology, skills as well as computing demand. Based on the argument that different approaches can be used to develop a model, the subsequent sections present the reviewed literature of some of the existing models with regards to sustainability of energy access.

2.4.4.1 Cobb-Douglas Production Models (Function)

The Cobb-Douglas Production function is the form of production function which is used to represent the technological relationship between the amounts of two or more inputs, in particular the physical capital and labour and the amount of output that can be produced by these inputs (Cobb, C & Douglas, 1928). The model assumes constant share of labour in the output. Mathematically, this production function is expressed using Equation 2.1:

$$Y = A L^{\beta} K^{\alpha} \quad (2.1)$$

Where: Y= total production, L= Labour input, K= Capital inputs, A= Total Factor productivity, while β and α are the output elasticity. For instance, if α = 0.45%, then this can be interpreted as 1% increase in capita usage would result into 0.45% increase in the output.

An increased need of other resources in production apart from capital and labour, materials, and energy as inputs, has led to the extension of the model to capture these resources, mathematically this can be presented using Equation 2.2

$$Y = A L^{\alpha 1} K^{\alpha 2} M^{\alpha 3} E^{\alpha 4} \quad (2.2)$$

Where: M= Material input and E= Energy Input.

The Generalized Cobb-Douglas Model is now being applied in various fields including agriculture, economic, industries, and in assessing the productivity and efficiency of the system. For example, Kibirige (2008) used the Cobb-Douglas production function to analyse the impact of agricultural productivity enhancement program on the technical and allocative efficiency of maize farmers at Masinde district in Uganda. The study assumed that maize production is dependent on human labour, fertilizers applied, the amount of seeds planted, the size of the land allocated, animal draught power, and the capital invested (expenses incurred purchasing Variable inputs). However, the researcher did not cover the aspect on sustainability in the model. The researcher assumed that allocative efficiency is estimated using physical production relationships derived from the Cobb – Douglas production function leading to the specific model estimated given by Equation 2.3:

$$Y = A X_1^{\alpha 1} X_2^{\alpha 2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots X_n^{\alpha n} v \quad (2.3)$$

Where: 'Y' is the amount of maize produced per farm households (Kg), X_1 is the human labour used by a given household in maize production (person days), X_2 is the animal power used by a given households in maize production (hours), X_3 is the amount of fertilizers (DAP and Urea) applied in maize by household, X_4 is the amount of seed planted (kg) by a household, X_5 is the land allocated to maize production (ha) by a given household, X_6 is the capital (estimated as amount of money invested in maize production, A is the constant and V is the random error term.

Apart from being used in manufacturing firms, Cobb Douglas production models have also been used in the service sector. For example, Vitality (2013) used the model as an approach for better resource allocation in Ukrainian armed forces to explore the relation between labour and capital as inputs for the development of the army in Ukraine. Although this model can consider energy as input in production, it has not addressed how energy can be used in a sustainable way.

2.4.4.2 Time Series Energy Models

Time Series Energy Models uses times series trend analysis to predict the future energy requirements of a particular country or nation. The model indicates the relationship between energy consumption and growth in a particular country. Energy consumption, production, and demand patterns from various countries including India, Spain, Turkey, and Israel have been determined using this type of model. For example, the time series model was used to predict the consumption of electricity in Sri-lanka using income and price elasticity variables (Deshmukh *et al*., 2008). The model is also used to forecast the future requirements of energy in a particular region. However, the researcher did not explain how the required energy should be provided in a manner in which it meets the needs of the current generation without causing harm to the future generation.

2.4.4.3 Econometric Energy Models

Econometric Energy Models are more advanced models compared to the time series models. Econometric models are used to establish correlation energy demand with other microeconomic variables, among other uses. Sunganthi and Samuel (2006) used econometric model energy models to predict commercial energy and substitution of renewable energy sources and found that energy consumption in a country or nation depends on the Gross National Product (GNP), energy price technology, and the size of population in the country. Mathematically, this econometric relationship is presented in equation 2.4.

Energy consumption= f (GNP, energy price, technology and population size) (2.4)

However, the main weakness of this model is that it heavily relies on huge amount of time series data to be able to generate the results. Again, previous researcher who employed econometric model did not address sustainability of energy access issues which are useful in improving social, environmental, and economic development of people in developing nations especially in rural areas of Tanzania

2.4.4.4 Energy Technology Sustainability Index Model

This model was developed by Mainali (2014) with the aim of evaluating the sustainability performance of energy technologies in developing countries. The model was established using the multivariate technique called principal component analysis. The model depicts that the sustainability performance of energy technologies is expressed in terms of index called Energy Sustainability Index (ESI). Mathematically, the model is expressed in equation 2.5

$$ETSI = \alpha + \beta_1 X_1 + \ldots\ldots\ldots\ldots\beta_k + X_k + \varepsilon \qquad (2.5)$$

Where: ESI is the Energy Technology Sustainability Index; X1 and Xk are the set of proposed indicators used to quantify sustainability of energy; β1 and βk are the corresponding vector parameters in each domain, and "e" is the error term.

The model assumes that variation in the index is composed of the variation of the set of indicators only if there will be no assumed error in the model. However, the model was developed with data based on the national covered without being confined itself in rural areas which have a critical problem of lack of sustainable energy sources for cooking, heating, or lighting purposes. This model has also some weakness as it did not include technical and institutional indicators which, according to Bhattacharyya

(2011) are important in ensuring that energy sources which are provided are used in a sustainable manner in rural areas of developing nation including Tanzania. This model also has its weaknesses as it used Principle Component Analysis approach to develop the indicators. Principle Component Analysis (PCA) is an extraction method in Exploratory Factor Analysis which is able to establish or develop and indicator but cannot validate the usefulness of these indicator using model fit indices, and therefore it becomes difficulties to generalize the findings to other areas having similar characteristics as that of the study areas. Thus, this study employed Structural Equation Modeling (SEM) which apart from performing Exploratory Factor Analysis, it has the power to confirm and validate the developed indicators in a model using model fit indices (Kline, 2011).

2.4.4.5 Energy Optimization Model

The Energy Optimization Model was first developed by Gurfel in 1979 for the purpose of ensuring energy sources are efficiently and effectively utilized for social and economic development in a nation. This energy model was developed as an attempt of establishing a possible least-cost solution of technology choices for energy system given the various organizational policies and market constraints in the country. Among the popular and applied models of this type are Market Allocation Model (MARKAL), Energy Simulation model, Residential end use energy planning system, energy modeling system and Prime energy system Model. Among other roles, energy models of these types attempt to provide a descriptive quantitative illustration of production and consumption of energy by a particular country/region. They also describe the behaviour of the end- user of energy in relation to his/her income, energy security, public policies and the endogenous energy policies. As Heap (2002) points out, energy accounting model also falls in the above category of energy model. Although much energy issues have been dealt with by researchers using energy optimization model, there is no empirical evidence of covering sustainability aspect in the model to ensure that energy source is used in a sustainable way in order to improve the standard of living of the people in developing countries especially the rural areas of Tanzania

2.4.4.6 Energy Source Choice Models

Energy source choices for a long time have been modelled using probabilistic choice models which are the extension of the standard linear models. The most widely used energy choice models are Multinomial Probit and Multinomial Logit Models. The two models are as result of the extension of binomial logistic regression model. Multinomial Logit and Multinomial Probit Models are mainly used when dependent variables have more than two nominal or un-ordered regression model (Tabachnick *et al*., 2001). According to Bayaga (2010), the two models are applied in the analysis of data if the categorical response variables have more than two outcomes while independent variables are continuous, categorical or nominal. These two choice models are almost similar and they actual performs the same thing. However, they differ in some aspects such as assumptions and preliminary test.

A study by Bayaga (2010) indicated this by pointing out that both Multinomial Logit Model and Multinomial Probit Model are almost similar but they differ in the sense that Multinomial Logit Model or commonly known as Multinomial Logistic Regression (MLR) assumes Independence of Irrelevant Alternative (IIA) while Multinomial Probit Model does not. The Independence of Irrelevant Alternative assumption states that the choice of one type or sources of energy for cooking, heating or lighting is not affected by the choice or use of other available energy sources. Thus, depending on various factors a researcher can decide to use either Multinomial Probit Model or Multinomial Logit Model. Tabachnick et al. (2001) pointed out that the choice of using either Multinomial Logit Model or Multinomial Probit Model depends on various factors, the most prominent being the precision of estimates, goodness of fit of the model, time taken before convergence is complete, accuracy of the predicted probability, the rate of correct signs for coefficient and the implication of Violating IIA assumption.

Based on these factors, a study conducted by Kelvin (2013) established that for as sample less than 1000 both models accurately estimated parameters in the systematic components, but produced weak random components when Multinomial Probit Model (MNP) was used because MNP requires larger sample size preferably more than 1000 to estimate correctly the covariance matrix parameter. Besides, Kropko (2014) recommended that MNP performs better than MNL by predicting more accurate probability when one alternative is added or removed. However, Kropko (2014) revealed that Multinomial Logit Model (MNL) is more robust than MNP even in the case where IIA assumption has been violated. Other studies (e.g. McFadden, 1984; Tabachnick et al., 2001) also confirmed that Multinomial Logit Model is more appropriate given more than three choices or alternatives are used. Kropko (2014) added further that if there is more than three alternatives using Multinomial Probit Model creates problems because MNP will involve `evaluation of high dimension multivariate normal integral for solving probability which increase time before reaching convergence and becomes challenging if the probability is close to zero.

Based on the requirement and situation favouring the two energy choice models, this study used Multinomial Logit Model to identify factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania. Multinomial Logit Model allows the Logit in the model to be estimated simultaneously. Estimating the Logit simultaneously enforces the logical relationship between the parameters and thus data in the model are used more efficiently. The choice of Multinomial Logit Model (MNL) over Multinomial Probit Model (MNP) in this study is also supported with a study by Tabachnick *et al.* (2001) and Kropko (2014) who revealed that Multinomial Logit Model is more advantageous than Multinomial Probit Model (MNP) because the former is more robust to any violation of assumptions of multivariate normality and equal-variances matrices across the group. Thus, MNL is almost similar to linear regression but more easily interpretable diagnostic statistics do not assume linear relationship between dependent and independent variables; independent variables need not be interval, they do not require independent variables to be unbound and also normally distributed error terms are not assumed.

The choice of MNL in this study is also supported by Hair *et al*. (2006) who revealed that using MNL simplify estimation and its interpretation is a straight forward manner regardless the number of parameters involved. Additionally, Tabachnick *et al.* (2012) supported this choice by observing that that Multinomial Logit model is more appropriate if there are more than three choices. In this study, four energy source choices namely electricity, firewood, charcoal and Liquefied Petroleum Gas (LPG) were used, and this favour the use of Multinomial Logit Model instead of Multinomial Probit Model (MNP).

However, the Multinomial Logit Model has one main weakness as it assumes Independence of Irrelevant Alternative (IIA) which assumes that all else being equal, a household choice on one energy sources cannot be affected if another choice is added or removed. This is to say in Multinomial Logit Model, the relative odds of one alternative energy source choice from being selected or chosen is independent of the presence or absence of the other energy source choices. However, McFadden (1984) observes that Independence of Irrelevant Alternatives (IIA) assumption cannot affect the goodness of fit of the model if more than three energy sources or alternatives have been used. Again, in this study households use a variety of energy sources even if their levels of income improve. Thus, as far as energy transition theory is concerned, even if the IIA assumption is not conforming to the requirement the goodness of fit of a model can be affected given the use of large number of energy source choices (Bayaga, 2010)

2.5 Synthesis of Empirical Literature Review

The reviewed literatures indicate that many scholars and practitioners have widely investigated energy access indictors, the sustainability of energy access issues, factors determining the choices of energy sources and energy models globally. Based on these reviewed literatures several conclusions have been made and which form the basis of the present study. Firstly, the reviewed literature on indicators of energy access revealed that there is variation on the set of indicators of energy access between one nation or community to another (Bhattacharyya, 2012; Mensah et al. 2014; Pachauri, 2012; Bhattacharyya, 2015; Mainali, 2014; IEA, 2014). The lack of common consensus on the unified set of indicators is mainly caused by differences in geographical location, the level of energy access, income and energy sources available. These differences in geographical location, the level of income and types of available energy sources in a nation or community have resulted into difficulties of generalizing research findings on indicators for all nations or communities

The reviewed literature on indicators of energy access also revealed that the majority of studies have been conducted outside Tanzania and that there is no sufficient empirical evidence as to whether the identified indicators by researchers outside Tanzania can be used in the context of rural Tanzania to ensure that energy sources are provided to improve the social, environmental, and economic development of people in rural areas of Tanzania given the fact that energy access differ between one nation and another (Bhattacharyya, 2015). As a result, there is no sufficient evidence to the best of the researcher's knowledge on the studies conducted in Tanzania to determine indicators of energy access in rural areas of Tanzania. Thus, determining indicators for energy access in rural areas of Tanzania was inevitable in this study.

Secondly, the reviewed literature on indicators of sustainability of energy access revealed that the majority of these studies focused on three indicators namely social, economic, and environmental aspects only (Swati, 2015; Andre *et al.*, 2015; Pachauri, 2012 & Wang *et al.,* 2009). These studies recommended that social, economic, and environmental indicators should take into consideration when providing energy sources such as firewood, charcoal and electricity. These studies emphasized on the provision of these energy sources to household members without causing human health problems such as lung cancer and environmental problems such soil erosion caused by prolonged deforestations

The reviewed Literatures on indicators of sustainability of energy access also indicate that there is no single approach which is used for measuring sustainability of energy access. Thus, every country or community has different indicators of sustainability of energy access. Besides, the reviewed literature covers country wide especially in urban areas leaving rural areas aside despite that these areas have severe problems on sustainability of energy access. The reviewed literatures show further that the existing studies have not included technical and institutional indicators which are important in measuring the sustainability of energy access to rural households (Bhattacharyya, 2015; Pachauri, 2012; Ilskog, 2008; Mainali, 2014).

To date there is no sufficient empirical evidences on whether the indicators developed by studies conducted outside Tanzania can be used in the rural context of Tanzania to ensure that there is a provision of sustainable energy sources for cooking to improve social, environmental and economic development of people in rural areas of Tanzania. Thus, to the best of the researcher's knowledge, little is known on the existence of conducted studies on the indicators of sustainability of energy access in rural areas of Tanzania, these indicators important in ensuring energy sources for cooking or lighting are provided in a sustainable way. Thus, this study filled this knowledge gap by identifying the indicators of sustainability of energy access in rural areas of Tanzania.

Thirdly, the reviewed literature indicates that the factors determining the choices of energy are not common or similar globally. The reviewed literatures indicate that the type of factors and its importance in making decisions on the choices of energy sources vary from one nation, region, or community to another. The justifications of using the findings from studies conducted outside Tanzania to the rural areas of Njombe and Iringa regions in Tanzania are not well documented in the literature to the best of the researcher's knowledge. Consequently, little is known on what factors actually determine the choice of energy sources for cooking or lighting in rural areas of Tanzania to the best of knowledge of the research. Thus, identifying factors determining the choices of energy sources for cooking or lighting is inevitable in this study in order to improve social, environmental, and economic development of rural households in Tanzania.

Fourthly, the reviewed literature on the existing energy models revealed that several models are available on energy access. Among the energy models reviewed are Cobb-Douglas Production Model, Time series energy models, econometric energy models, energy technology sustainability index model, energy optimization model and energy choices models. The reviewed literatures also indicate that various researchers have used these models to address energy challenges issues such as energy trend analysis, energy optimization, and energy technology sustainability and end energy use (Bhattacharyya, 2011; Samuel & Sunganthi, 2006; Deshmukh *et al.*, 2008; Vitality, 2013). However, the reviewed literature on energy models revealed that no sufficient empirical evidence indicating that researchers who used these models included sustainability of energy access issues in rural areas in their model. Therefore, establishing a model for measuring sustainability of energy access in rural areas of Tanzania deemed to be important in this study

Regarding the methodological approaches employed by previous studies, the reviewed literatures (e.g. Mainali, 2014; Bhattacharyya, 2015; Mensah *et al.,* 2014; Sudhakara, 2015; IEA, 2017) revealed that only descriptive analysis using Exploratory Factors Analysis were employed to energy access and sustainability studies. Besides, the reviewed literatures indicate that Multinomial Probit Model and Multinomial Logit Models are the most popular probabilistic choice models used to model energy sources choices. While both models are deemed to be useful, this study employed Multinomial Logit model because of its ability to produce good precision of estimates, goodness of fit of the model, takes a short time before convergence is complete, accuracy of the predicted probability, the rate of correct signs for coefficient, and the implication of Violating IIA assumption

The reviewed literatures revealed further that the majority of these studies were descriptive using case study design (Pachauri, 2010), which does not allow generalization of findings to other areas with similar problems. The reviewed literature (e.g. Mainali, 2014; Mostafa & Jürgen, 2017; Umaporn and Christian, 2017) also revealed that some studies used Principal Component Analysis to model sustainability of energy sources and technologies in developing countries. However, employing Exploratory Factor Analysis where by factors was extracted using Principal Component Analysis (PCA) as it was the case in the existing studies can establish a factor and its loading values in the model, however it cannot validate or test the usefulness of importance of the identified indicators or variables in the model using model fit indices as SEM does.

The use of Descriptive and Exploratory Factors Analysis using Principal Component Analysis (PCA) as an extraction method leave some questions unanswered. Among these questions include; are the indicators in the model established using PCA and descriptive analysis real important to ensure energy sources are provided in a sustainable way. The other question is, do these indicators play a significant role or do they have an impact on the model for measuring sustainability of energy access in rural areas. All these questions cannot be answered by developing a model descriptively or through exploratory Factor Analysis using PCA.

Therefore apart from using Multinomial Logistic Regression to model energy source choices, and using Exploratory Factors Analysis using PCA to determine indicators of energy access and sustainability, this study has further employed Structural Equation Modeling (SEM) through the use of Confirmatory Factor Analysis (CFA) to determine and confirm indicators of energy access, indicators of sustainability of energy access and to establish a model for measuring Sustainability of Energy Access in Rural areas of Tanzania. The use of SEM has more advantages than do other traditional multivariate techniques because apart from providing descriptive and exploratory analysis of indicators in the model, SEM has the ability of confirming and validating the identified indicators in the model. Other advantages of SEM as a method of modeling sustainability of energy access in rural areas of Tanzania have been captured well in the methodology section of this thesis.

2.6 Conceptual Framework of the study

The conceptual framework for this study is grounded on Energy Ladder theory or commonly known as Energy Transition theory and the reviewed empirical studies related to sustainability of energy access. The main focus of the study is on modeling sustainability of energy access in rural areas of Tanzania. This conceptual framework therefore explains how sustainability of energy access in rural areas is measured using a set of measurable indicators. Based on the reviewed literatures, this framework is adapted from the sustainability of energy sources and technology proposed by Ilskog (2008). The model by Ilskog (2008) is centred on three pillars of sustainability namely social, economic, and environmental indicators. However, the model by Ilskog (2008) captured sustainability of energy sources at country level and mainly focusing on urban areas of the country.

In order to address the problem of provision of sustainable energy in rural areas, studies by Mainali (2014) and Bhattacharyya (2015) recommend for further studies to establish a model for measuring sustainability of energy access in rural areas and which takes into consideration other indicators such as technical and institutional indicators in addition to considering social, economic and environmental indicators. Thus, addition institutional and technical indicators in the model will assist policy makers, government, energy experts and other stakeholders to ensure that among other things energy system is available at any time when it is needed. Energy sources such as LPG and electricity work for a long time without or with minimum failure, energy conversion is very efficient using fewer resources and without causing harm to environment and people, and using the available local skilled staff in rural areas to maintain energy system and to have ownership and the ability of monitoring and controlling the energy system locally. By so doing, the livelihood and standard of living of people will be improved in rural areas of Tanzania. In this regard, the conceptual framework of this study consists of five categories of indicators which measure the sustainability of energy access in rural areas of Tanzania as presented in Figure 2.2.

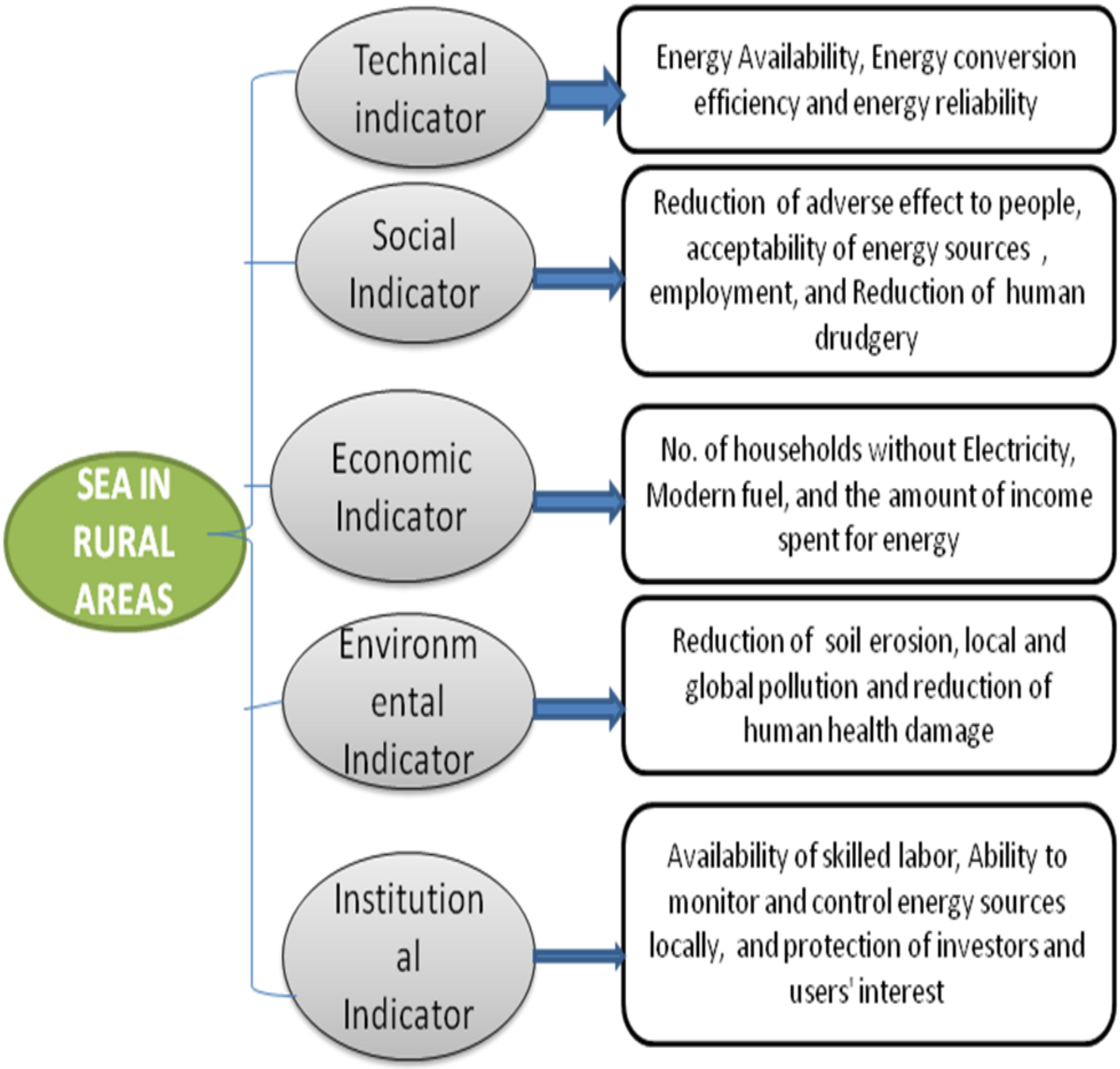

Figure 2.2: A Conceptual Framework for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

The conceptual framework provided in Figure 2.2 indicates that in order to ensure energy sources are provided in a sustainable way in improving livelihood and standard of living of the people in rural areas of Tanzania, its provision should take into consideration social, economic, environmental, technical, and institutional indicators. In this framework, each construct has been well explained on how it can be measured.

As it can be seen from Figure 2.2, the social indicator of sustainability of energy access in rural areas is measured in terms of the ability of the energy source/system to reduce human drudgery, to reduce adverse effects among women and children, as well as acceptability of the energy system by the society and the ability of the system to generate employment to the local people. Economically, sustainability of energy access is measured in terms of percentage or number of rural households with electricity, the percentage of rural households without modern cooking facilities as well as the percentage of rural households' incomes which are spent on procuring modern cooking facilities and electricity.

Besides, the environmental indicators of sustainability of energy access is measured by considering the effect resulting from using energy sources for cooking or lighting to the local environment, global environment, the reduction of human health damage and the reduction of environmental degradation. Moreover, technical indicators of sustainability of energy access are measured by identifying the cooking, heating conversion efficiency, energy availability as well as energy reliability. Lastly, the conceptual framework indicates that institutional sustainability of energy access in rural areas of Tanzania is determined by considering the availability of skilled staff, the ability of the energy system/source to protect the investors and consumers as well as the ability to monitor and control the energy system locally.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the research methodology used in this study. The chapter begins with the presentation of research philosophy and the approach used in this study. Thereafter, the chapter presents research design, the area of study, unit of analysis, sample size and sampling procedures, operationalization of research variables, types of data, and data collection methods. Others include data analysis techniques used, validity and reliability of the data as well as modeling process, and ethical issues which adhered during conducting of this study.

3.1 Research Philosophy and Approach

This study employed positivism philosophy using deductive approach. The positivism research approach was deemed a relevant approach for this study because this philosophy assumes that any social phenomena in research can be approached with scientific method. This philosophy establishes that the focus of science is to confirm on a certain phenomenon based not only on what an individual can observe, but also on what an individual is able to measure (Ndunguru, 2007).

In addition, Creswell (2009) reveals that positivism philosophy is more applicable in quantitative researches because the philosophy assumes that there is one true reality that can be discovered by means of rigorous empirical study. With positivism philosophy, researchers view themselves as neutral observers; whereby the outcomes of their researches are not influenced by their values, beliefs, and biases. Thus, researchers are expected to distance themselves from the research subject in order to ensure objectivity in the whole process of research.

Moreover, as Mugenda and Mugenda (2003) observe, positivism philosophy has a direct relationship with deductive approach. In deductive approach, the researcher conducts intensive review of the existing theories and empirical studies related to the existing study, establish concepts and operationalize them into variables. It is from these variables that a researcher is able to collect data and analyse them. Thus, this study employed Positivism theory to research approach and from general to specific approach (Deductive approach).

Being grounded on positivism philosophy and deductive approach, the researcher conducted intensive literature review on energy theory and on empirical studies related to sustainability of energy access in rural areas. The reviewed literature helped the researcher to identify various research concepts which were operationalize into research variables. The collected data for this study were based on the research variables captured in the conceptual framework and those variables which were found to be useful in the theory guiding the study.

3.2 Research Design

This study employed cross sectional survey research design. Using cross sectional survey research design allowed a researcher to visit the study areas only once in time. This type of research design is recommended for use when a study adopted positivism research philosophy with deductive approach. Cross sectional survey research design was used in this study for several reasons. Firstly, this research design enabled the researcher to collect large amount of data about the study at one point in time in an efficient way and thus minimizing cost and time (Ndunguru, 2007). Secondly, the results analysed from data collected using this design has the ability of being generalized to a larger population with similar characteristics as that of the study population in Tanzania or elsewhere.

The use of this research design is supported by Nsubili (2012) who points out that cross sectional survey research design is more appropriate when conducting research in which an individual or a person is studied as the unit of analysis, which is also the focus of this study. Nchimbi (2002) observes further that the use of cross-sectional survey research design provides quick, efficient, and accurate means of assessing the information about the population and is more appropriate when there is lack of secondary data. This study used cross sectional survey research design because of lack of or unreliability of secondary data database regarding sustainability of energy access in rural areas of Tanzania.

3.3 Study Areas

This study was conducted in rural areas of Njombe and Iringa regions in the southern part of Tanzania. Njombe District and the rural areas of Makambako Township Authority were selected from Njombe Region, while Iringa District, Mufindi District and Mafinga Township Authority were selected from Iringa Region.

3.3.1 Justification of selection of study area

Njombe and Iringa regions were selected for this study because the majority of people in rural areas of these regions have limited access to modern energy sources for cooking or lighting purposes. Only 12% of the people in rural areas of these regions have access to electricity and more than 92% of these people in rural areas rely on firewood as major sources of energy for cooking purposes (URT, 2012; URT, 2016). The choice of the two regions in this study is also supported by the ENRICH Project report (2014) on Energy Access and Collaborative Network in East Africa which revealed that rural areas of Iringa and Njombe regions are among the most challenged areas on matters of access to modern and sustainable energy sources for cooking and lighting. The Enrich report established that people in the rural areas of Njombe and Iringa regions use firewood as the major sources for cooking. The collection and use of firewood for cooking goes hand in hand with deforestation cause soil erosion and air pollution.

Besides, the choice of Iringa and Njombe regions is further supported by Household Budget survey report (URT, 2012) conducted by the National Bureau of Statistics which revealed that more than 95% of rural areas from other regions except Dar es Salaam have sustainable energy access problems. The Household Budget Survey (URT, 2012) showed that more than 85% of the people in the rural areas of these regions do not have access to modern energy sources. Moreover, the choice of the two regions with energy access problem focused also at ensuring that higher validity of the findings is achieved. In view of the reality that the concept of rural areas is not objective to ensure validity of the findings it is recommended that one chooses study areas that share common characters in terms of social, economic status, culture, agricultural, and farming activities (Creswell, 2009; Ndunguru, 2007). In achieving validity (social validity), rural areas of Iringa and Njombe were chosen for this study because they share common social, economic, cultural and belief as they were formerly in the same region named Iringa.

3.3.2 Selected Study Areas for this study

From Njombe District, the study covered the following villages from rural areas: Kichiwa, and Ibumila from Kichiwa ward; Tagamenda and Itipingi from Igongolo ward; Matiganjola from Ikuna ward; Ilunda, Welela, Itunduma, Lunguya, and Sovi from Mtwango ward. Makambako Township Authority covered the following villages: Ikwete, Kiumba, Mawande, Ikelu, and Lyamkena villages. In Iringa Region, the study covered Iringa District, Mafinga Township Authority, and Mufindi District. Villages covered from Iringa District include: Ifunda, Tanangozi, Kibena, Tosamaganga, and Ihemi. Villages covered from Mufindi District were Ndolezi, Luganga, Sao Hill, Nzivi, Kasanga, Ibatu, and Rungemba. Figure 3.1 shows the study areas covered in this study.

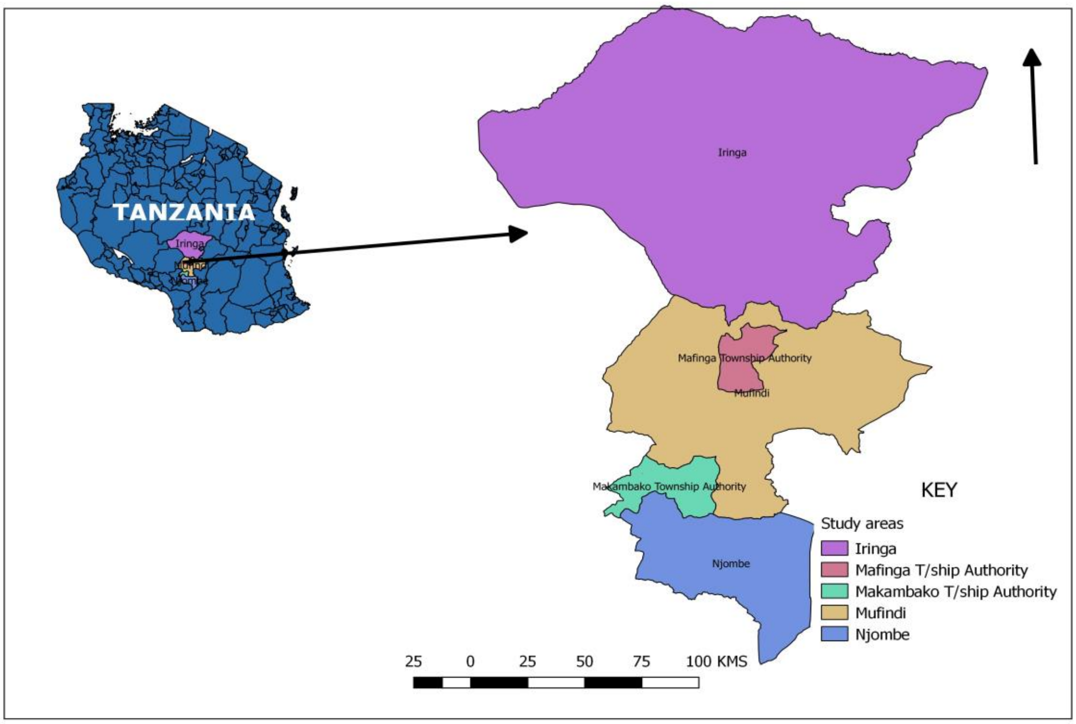

Figure 3.1: Map showing study areas

Source: (NBS)

3.4 Unity of Analysis

The Unit of Analysis comprises of person, collective or objects where the data about a study would be collected. The Unit of analysis consists of “what” or “who” is being studied in your research. A unit of analysis used in this study therefore was the head of households living in rural areas of Njombe and Iringa regions in Tanzania. The heads of households in this study comprised a mother, a father or any other person on behalf of a mother or a father who was available at the time when the study was conducted. In case of polygamous family, this study used the most senior wives due to their wealth of information on the types and use of energy sources for cooking or lighting in rural areas of Tanzania.

3.5 Sampling Technique

Probability sampling technique called Multistage-Stage Cluster was employed in this study. Multistage Cluster sampling is a sampling plan where the sampling is carried out in stages using smaller and smaller sampling units in each stage. This type of sampling technique is used or is convenient to be used when studying large and geographically dispersed populations (Kothari, 2010; Mugenda and Mugenda, 2003). In Multistage Cluster Sampling, a large number of units can be sampled for a given financial and time resources allocated and flexibility of utilizing several sampling methods at different stages. The objective of this method is to choose a limited number of smaller geographic areas in order to conduct simple random sampling technique.

Therefore, using Multi stage cluster sampling technique, Mufindi District, Iringa District, and Mafinga Township, Njombe Districts and Makambako Township were selected as study areas from Iringa and Njombe regions. After the selection of the districts from each region, villages with problems of energy access and reliance on traditional sources of energy were selected from each district. Lastly, the rural households from each village were chosen randomly within each cluster using fishbowl draw method.

Using fishbowl draw method, the researcher obtained the names of members of households in each selected village. Each name of the household member was written in a piece of paper. The pieces of paper were put in a bowl and shuffled. Finally, the shuffled pieces of papers were picked out from the bowl one by one without looking at them so as to avoid biasness until the required numbers of pieces selected was equal to the sample size needed at a particular village. The use of fishbowl draw method in sampling rural households is also supported by Gitawaty (2010) who pointed out that fishbowl draw method or commonly known as Lottery methods is a common method used in sampling households in villages with small populations.

3.6 Sample size used in this study

Sample size determination is an important aspect when conducting any research. In determining the sample size used in this study, factors such as representativeness of the sample size itself, the ability to generalize the research findings and the data analysis techniques used were taken into consideration. With regards to data analysis technique, this study employed a variety of techniques such as Factor Analysis, Multinomial Logit Model, and Confirmatory Factor Analysis techniques. The use of these methods of data analysis requires larger sample size preferably at least 100 respondents in order to increase the ability of generalizing the findings to other areas with similar characteristics as that of the sampled population (Hair *et al.*, 2006).

Based on the above factors, several methods can be used to determine the sample size. The most popular and prominent methods is the use of standard formula when the population is either known or not known, the use of table of numbers, and through reviewing and adopting the sample size of the previous similar studies. Similar views are reported by Masuku (2012) who reveal that Sample size can be determined using a census, for small population, imitating a sample size of similar studies, using published tables and also applying formulas to calculate the sample size. Although all these methods provide representative sample size, this study adapted the approach of using the sample sizes used by previous studies. The use of sample size from previous studies provides several advantages including allowing generalization of research findings to other areas with similar characteristics as that of the sampled population and increase the reliability of data.

Empirical literature indicates that similar previous conducted studies on sustainability of energy access used sample size ranging from 100 to 400 respondents. For instance, a study by Ognen *et al.* (2017) on rural energy access through solar home system employed a sample size of 500 early adopters of home system in two off-grid market in Africa. In addition, a study by Simon (2007) on rural electrification in Ghana: issue of photovoltaic energy technology utilization used a sample size of 117 households. Likewise, a study by Said (2016) on Sustainability in Kenya's energy and development employed a sample size of 232 respondents from both rural and urban areas. Furthermore, a study by Felix (2010) employed a sample size of 100 respondents to assess the barriers to the development and deployment of renewable energy technologies in Kenya. Additionally, a study by Blum *et al*. (2013) on cost effectiveness of the isolated renewable energy technologies in rural areas of Indonesia used a sample size of 350 respondents. In the light of various sample sizes used by the reviewed similar studies, this study employed a sample size of 384 respondents from Njombe and Iringa Regions of Tanzania. The distribution of sample size from Njombe and Iringa regions are as shown in Table 3.1.

Table 3.1: Sample size distribution from Njombe and Iringa regions

Region	District/Town	Villages	Household (N)	Percent (%)
Njombe Region	Njombe district	Kichiwa	10	02.60
		Ibumila	10	02.60
		Tangamenda	07	01.82
		Itipingi	11	02.86
		Matiganjola	09	02.34
		Ilunda	25	06.51
		Welela	15	03.91
	Makambako Township Authority	Itunduma	25	06.51
		Lunguya	15	03.91
		Sovi	12	03.13
		Ikwete	08	02.08
		Kiumba	15	03.91
		Mawande	10	02.60
		Ikelu	10	02.60
Iringa Region	Iringa district	Lyamkena	10	02.60
		Ifunda	16	04.17
		Tanangozi	25	06.51
		Tosamaganga	10	02.60
		Ihemi	11	02.86
	Mufindi district and Mafinga Township	Ndolezi	20	05.21
		Luganga	25	06.51
		Sao hill	10	02.60
		Nzivi	22	05.73
		Kasanga	10	02.60
		Ibatu	23	05.60
		Rungemba	20	05.21
Total			**384**	**100.00**

Source: Research Data (2017)

3.7 Data Type and Data Collection Method

Only primary data were used in this study and structured questionnaire was used as a survey instrument. Primary data were mainly used in this study due to the absence of reliable and accurate secondary database on energy access, sustainability of energy access and energy sources for cooking or lighting in rural areas of Tanzania. The use of primary data in areas with problem of secondary database in Tanzania is also supported by Nchimbi (2002) and Nsubili (2012) who pointed out that the challenge of having reliable and up-dated information on rural areas necessitate the use of primary data in the majority of the studies conducted in rural areas of Tanzania.

Regarding the survey instrument, questionnaire was used as a major tool for data collection in this study because it is among the efficient ways of collecting large amount of data for quantitative study analysis, which is also the focus of this study. The use of questionnaire as a tool for data collection has also been supported by Hair *et al.* (2006) who pointed out that questionnaire is an appropriate tool for data collection when the study has employed cross sectional survey research design. Therefore, questionnaire was employed to gather data for all specific objectives of this study.

3.7.1 Data Collection Tool Design

The design of this questionnaire was achieved through conducting rigorous literature review on empirical studies related to sustainability of energy access. During the designing process, all research variables under study from the conceptual framework were considered. This questionnaire consists of five parts: the first part covers the demographic factors of the respondents. The demographic factors of the respondents which were included in this study were age, sex, education level, marital status, occupation, average monthly income, and the household size.

The second part of the questionnaires covers the questions on types of energy sources used for cooking or lighting in rural areas of Tanzania as well as factors determining the choices of energy sources for cooking or lighting in rural areas of Njombe and Iringa regions in Tanzania. The third part of this questionnaire covers several questions on indicators of energy access in rural areas while the fourth part consists of questions on indicators of sustainability of energy access in rural areas of Tanzania. The last section consists of additional questions which aimed at providing insights on energy access and the challenges in attaining sustainability on energy access in rural areas of Tanzania.

The majority of questions from part one to four were close-ended questions while very few were open. In determining the indicators of energy access and indicators of sustainability of energy access, the respondents were required to indicate their extent of agreement or disagreement with particular indicators using five-point Likert scales. The Likert scale used ranged from Strongly Disagree (SD) to Strongly Agree (SA) whereby 5 is for Strongly Agree, 4 for Agree, 3 for Neutral, 2 for Disagree, and of 1= Strongly Disagree. Similarly, the Likert scale used in determining the indicators of sustainability of energy access in rural areas ranged from 1= Strongly Insignificant (SI) to 5 =Strongly Significant (SS).

The use of Likert scale in capturing the opinions from the respondents has several advantages. Firstly, Likert scale is widely used in both marketing and social science researches; secondly, it provides the likelihood of responses which represent the actual respondents' opinions and thirdly, it increases the spread of variance of responses which provides strong measure of association (Sungau, 2014). To increase efficiency and save time during data collection, a research assistant was used. The research assistant had a bachelor degree qualification which made easy for him to be trained on how to administer the questionnaires efficiently and effectively to the respondents.

3.7.2 Pilot study

Conducting a pilot study is among the requirement of any social or scientific research. As Sungau (2014) observes, a pilot study should be done prior to the commencement of actual data collection in order to assess the reliability and validity of the designed tool as well as to assess the reliability of research findings. Baker (2003) emphasizes further that validity of data collection instrument should be tested through conducting a pilot study. In this regard, the current study conducted a pilot study to thirty (30) respondents in order to assess if the designed questionnaire measures what was intended to be measured. The pilot study enabled the researcher to establish the time to be used in filling each questionnaire as well as the total time to be spent to collect data from 384 respondents in rural areas of Njombe and Iringa in Tanzania.

After conducting a pilot study, several improvements were made to the questionnaires so as to meet the purpose of the study. Firstly, open ended questions were also included in the questionnaire in order to allow the respondents to freely express their views about sustainability of energy access issues and the emerged challenges regarding energy sources for cooking or lighting in rural areas of Tanzania. Secondly, the rural household information on the average monthly income and the household size were added in the final version as during pilot study they were also found to have influence on energy sources choices in rural areas of Tanzania. Lastly, the questions on the indicators of energy access in rural areas of Tanzania were changed into Likert scale in order to easily capture the opinions from the respondents. The final version of the questionnaire was checked for grammar and ultimately it was used to collect data from 384 respondents residing in rural areas of Tanzania.

3.8 Operationalization of Research Variables

Prior to data collection, the research variables used in the present study was operationalized. According to Ndunguru (2007), operationalization of research variables helps in describing, defining, and explaining how each research variable is measured. Therefore, Table 3.2 provides explanation on how various research variables were operationalized for the purpose of collecting data of this study.

Table 3.2: Operationalization of research variables used in this study

Research variables	**Descriptions of the Research variable**	**Measurement**	**Measurement scale**
Education level	The maximum level of education attained by the heads of household in rural areas of Njombe and Iringa Regions	1 =No Formal Education, 2 = Primary Education, 3 =Secondary Education, 4 = College Education	Ordinal
Age	The number of years of the heads of households in rural areas of Tanzania	1 =Below 25 Years 2 =25 to 60 Years 3 =Above 60 Years	Continuous
Marital status	An indication whether the heads of household are married or not	1 =Single, 2= Married,3=Widowed, 4 =Divorced	Categorical
Sex	Whether the head of the household in rural areas of Tanzania is a male or a female	1 = Male, 2 = Female	Categorical
Occupation	The main economic activities done by heads of households in rural areas of Tanzania	1 =Farming, 2 = Livestock keeping, 3= Business, 4 = Wage Employment	Categorical
Income	Average monthly earning of heads of households in rural areas of Tanzania	1 = Less than 100,000/= 2 =100,000/= to 500,000/= 3 =More than 500,000/=	continuous
Household size	A number of children possessed by the heads of household in rural areas of Tanzania	Number of children in a household	continuous
Energy source choices for cooking in Rural areas of Tanzania	The available energy sources choices for cooking in rural areas such as Electricity, charcoal, firewood, and Liquefied Petroleum Gas (LPG)	1 = Electricity, 2= charcoal, 3= Firewood, 4 = Liquefied Petroleum Gas (LPG)	Categorical
Energy Sources Choices for Lighting in Rural areas of Tanzania	The available energy sources used for Lighting in rural areas of Tanzania such as Electricity, kerosene, Solar power and Rechargeable Solar Torch	1 = Electricity, 2 =Kerosene, 3 = Solar Power, 4= Rechargeable Solar Torch	Categorical
Indicators of Energy Access	Affordability (purchasing power and its ability to buy a particular energy sources) , Efficient(use few resources to product large amount of energy), Availability(energy sources to be available at time when it is needed or being present in the same geographical location), Easy to use(Does not need much skills and	A Five Point Likert scale: 1 = Strongly Disagree, 2 = Agree, 3 = Neutral, 4 = Agree, 5 = Strongly: I =Strongly Disagree, 5= Strongly Agree	Interval scale

Research variables	Descriptions of the Research variable	Measurement	Measurement scale
	knowledge to use), reliability(continuous supply of energy with no shutdown, blackout or any voltage fluctuation) Convenient(available at a desired hour of the day and safe to use), Does not produce smoke(does not cause harm to human health and environment, durability(stay and use for a long time before it fail), keep the cooking pots clean(Does not cause dirtiness to cooking utensils		
Indicators for sustainability of energy access in rural areas			
Research variables	**Descriptions of research variable**	**Measurement**	**Measurement scale**
Technical Indicators of sustainability of energy access in rural areas of Tanzania	Technical sustainability is assessed by taking into consideration the ability of a system to meet the present and future needs of rural household reliably, efficiently and by using clean and renewable sources. Thus, technical indicators of sustainability of energy access in rural areas of Tanzania is determined by looking the energy availability (amount of energy provided from the energy system), reliability (measure of constant services) and the energy conversion efficiency (ability to convert from the energy source to end user)	A five-point Likert scale: 1= Very insignificant, 2=Insignificant, 3 =Neutral, 4 = Significant, 4 = Very significant	Interval
Social indicator of sustainability of energy access in rural areas in rural areas of Tanzania	Social sustainability is measured by the assessing the ability of energy sources for cooking or lighting to reduce or remove human drudgery, acceptability of the system to the society, ability to generate employment, reduction of adverse effects to women and children	A five-point Likert scale: 1= Very insignificant, 2=Insignificant, 3 =Neutral, 4 = Significant, 4 = Very significant	Interval

Research variables	Descriptions of the Research variable	Measurement	Measurement scale
Economic indicator of sustainability of energy access in rural areas of Tanzania	The economic indicator of sustainability of energy access which is determined by identifying the percentage of rural population without electricity, without modern cooking facilities as well as the percentage of household income spent on modern cooking and electricity.	A five-point Likert scale: 1= Very insignificant, 2=Insignificant, 3 =Neutral, 4 = Significant, 4 = Very significant	Interval
Environmental indicator of sustainability of energy access in rural areas of Tanzania	Environmental sustainability is measured by assessing the ability of energy sources used for cooking or lighting to reduce the environmental impacts on the users and the society, its ability to reduce local environmental pollution, ability to reduce global environmental pollution, and its ability to reduce damage to human health and environment	A five-point Likert scale: 1= Very insignificant, 2=Insignificant, 3 =Neutral, 4 = Significant, 4 = Very significant	Interval
Institutional indicator of sustainability of energy access in rural areas of Tanzania	The institutional indicator of sustainability of energy access in rural areas of Tanzania is assessed by the ability of energy sources or system to managed and controlled by local people in a particular area, the availability of local skilled staff in rural areas, ability to protect the interest of consumers and investors	A five-point Likert scale: 1= Very insignificant, 2=Insignificant, 3 =Neutral, 4 = Significant, 4 = Very significant	Interval

3.9 Reliability and Validity of Data

Assessing reliability and validity of data and the research findings is among the requirements in conducting science or social science research. Hair *et al.* (2006) and Sungau (2014) also share the views on checking validity and reliability of the collected data and research findings. Therefore, on the one hand, validity of data in this study was tested in order to assess if the data collection instrument measure what it intended to measure. On the other hand, reliability of data was tested in order to assess if data are consistent over time and if they have the ability of producing similar results if repeatedly used to measure the same object. In the light of the stated role of validity and reliability testing in research, this study employed various approaches to ensure that the data for this study were valid and reliable. Firstly, the questionnaires for this study were pre-tested during pilot study to thirty (30) respondents from rural areas of Njombe and Iringa regions in Tanzania. During the pilot study, improvements were made to the questionnaires by adding questions so as to meet the purpose of the current study. Secondly, the constructs from each specific objective were measured using several questions instead of a single question. Multiple items were also used to measure a particular construct. Moreover, many of the variables used in this study were adapted from the previous studies and were tested and proved to be reliable. Thus, adapting previous data collection instrument enabled to increase reliability. Besides, in this study, careful selection of study population and the areas covered was done to ensure external or social validity of data and research findings are achieved. To achieve this external or sometimes called social validity, this study was conducted to rural areas of Njombe and Iringa regions. The two regions were selected and used for this study because they have similar economic, cultural and social values since they previously belonged in one region called Iringa.

Besides, the internal reliability of data in this study was tested using a common measure called internal consistency. The internal consistent of data in this study was tested using Cronbach's Alpha and Bartlett's test of sphericity. The research findings revealed that the tested Cronbach's Alpha had a value greater than 0.8, implying that data are reliable and guarantee for any inferential data analysis technique to be used. Accepting high value of Cronbach's Alpha is supported by the study by George and Mallery (2003) which established that a Cronbach's Alpha greater than 0.8 indicates that the reliability of data is excellent. The Bartlett's test of sphericity was found to be highly significant ($P = 0.000<0.05$) indicating that the collected data can be analysed using various inferential statistics such as Exploratory Factor Analysis, Confirmatory Factor Analysis, and probabilistic energy choices models such as Multinomial Logistic Regressions.

3.10 Data Analysis Process

Data analysis process in this study involved three stages namely preliminary, descriptive, and inferential data analysis as detailed in the subsequent sections.

3.10.1 Preliminary Data Analysis

At this stage, the administered questionnaires were then coded in order to assign numeric value to the data. Sungau (2014) established that the process of assigning numeric value to data in quantitative studies enables the researcher to speedup data processing and at the same time reducing errors which could have risen if data were entered without coding. The coded data were cleaned and screened in order to identify any errors which might have occurred during the filling in of the questionnaires and at the time of entering the data into SPSS Computer software. Thereafter, assumptions such as, outlier, Independence of Irrelevant Alternative (IIA), and Multicollinearity of data were checked. The outlier of data was tested using box plot score. The Independence of Irrelevance Alternative Assumption (IIAA) was tested using McFadden test. The Multicollinearity of data was tested using Variance Inflation Factor (VIF). The VIF quantify how much the variance of data is inflated. The minimum accepted values of VIF were 3.

3.10.2 Descriptive Data Analysis

Descriptive data analysis was done in order to describe the general characteristics of the study sample. Descriptive analysis involved computation of basic statistics such as mean, standard deviation frequencies, percentage distribution and the cross tabulation to the demographic characteristics of the heads of household from the selected rural areas of Tanzania. Among the demographic factors used in this study are: the level of education, age, sex, marital status, the occupation, the average monthly income, and the family size of rural households living in the rural areas of Njombe and Iringa regions of Tanzania.

3.10.3 Inferential Data Analysis

Inferential data analysis was performed in order to make inferences about the population using data established from the sample. The inferential data analysis approaches employed in this study include Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) which were employed to determine the indicators of energy access and the indicators of sustainability of energy access in rural areas of Tanzania. Multinomial Logit Model (MLM) was employed to identify factors determining the choices of energy sources for cooking and lighting by rural households in Njombe and Iringa regions of Tanzania. Structural Equation Modeling (SEM) was used to establish and confirm the model for measuring sustainability of energy access in rural areas of Tanzania as detailed in the subsequent sections

3.10.3.1 Exploratory Factor Analysis Technique

This study employed Exploratory Factor Analysis technique to determine indicators of energy access and indicators of sustainability of energy access in rural areas of Tanzania. Exploratory Factor Analysis in this study aimed at analysing the interrelationship among large number of variables in terms of their common underlying dimension. This was achieved through the reduction of a number of variables for each indicator (summated scale) without affecting the original meaning of these factors.

In determining the indicators of energy access, research variables such as affordability, efficient, availability, easy to use, economic, convenience, durability and the ability to produce less or no smoke at all were used. Likewise, in determining the indicators of sustainability of energy access in rural areas of Tanzania, sixteen variables categorized into social, technical, economic, environmental, and institutional indicators were employed in this study. The respondents were required to express the extent of agreement/disagreement using five-point Likert scales on different statements used this study. The five Likert scale of 1 representing Strongly Disagree and 5 representing Strongly Agree with the indicators was used in this study.

Prior to employing EFA, several assumptions under each of the technique used for data analysis were tested. The tested assumptions were found to meet the condition. The first assumption is that EFA requires large number of sample size ranging from 100 to 400. This study used a sample size of 384 respondents from rural areas of Njombe and Iringa regions. Therefore, the condition of using large sample size in this study was met by the researcher. The second assumption of EFA is that the analysed data must have at least the correlations of r= 0.3 or greater and the Bartlett's test for sphericity should be statistically significant at p<0.05 and Keiser Meyer Olkin (KMO) should be 0.6 or above. Based on the aforementioned assumptions, the analysed data in this study was found to have Cronbach's alpha value of 0.82 indicating that the data collection instrument was reliable and guarantees for EFA to be conducted. Additionally, the Bartlett‘s test was found to be statistically significant (P-Value <0.05), hence the collected data were accepted and guaranteed for EFA to be carried out.

3.10.3.2 Multinomial Logistic Regression Analysis Technique

Multinomial Logistic Regression or commonly called Multinomial Logit Model (MLM) data analysis technique was employed in this study in order to identify the factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania. This technique is employed when the dependent variables are measured at nominal level and have more than one independent variable that can be continuous, ordinal or nominal. As Hosmer and Lemoshow (2000) observe, Multinomial Logistic Regression is used when the dependent variable is nominal for which the number of categories is more than two and one or more continuous level (interval or ratio scale) independent variables. Besides, the use of MLR is also supported by Garson (2011) who established that MLR is used to predict categorical placement in or the probability of category membership on a dependent variable based on multiple independent variables which can be dichotomous or continuous (interval or ratio scale).

Considering the nature and type of scale of research variables used in this study, MLR data analysis method was deemed to be an appropriate technique in identifying factors determining the choices of energy sources of cooking and lighting in rural areas of Tanzania. MLR in this study was considered as an appropriate analysis method because it does not assume normality, linearity, and homoscedasticity. The usefulness of this method is also evidenced by Starkweather (2011) who points out that MLR is a good technique in modeling choices because it does not necessarily obey the assumptions such as normality, linearity or homoscedasticity. Additionally, Multinomial Logit Model was found to be more appropriate in this study over Multinomial Probit Model (MNP) due to these reasons: Firstly, Multinomial Logit Model (MNL) is more robust than Multinomial Probit Model even in the case where Independence of Irrelevant Alternative Assumption has been violated. Moreover, according to scholars (e.g. McFadden, 1984; Tabachnick *et al.*, 2001; Kevin, 2013), Multinomial Logit Model is more appropriate given more than three choices or alternatives which is also the focus of this study whereby four energy source choices have been used

In this study, the dependent variable used was energy source choices which were nominal variables with four categories namely electricity, charcoal, firewood, and Liquefied Petroleum Gas (LPG) whereby electricity was used as a reference category. The independent variables employed in this study were education, age, the average monthly income, occupation, household size, and marital status of the respondents living in rural areas of Njombe and Iringa regions in Tanzania. These independent variables were continuous, ordinal or even nominal in nature. In employing Multinomial Logit Model (MNL), a rural head of household has as a set of alternative energy sources "i" which he/she may choose from for cooking or lighting purposes. The available energy source choices were said to vary among heads of household dwelling in rural areas because of various assumed factors "j". The Multinomial Logistic Regression model bases on the assumption that a rational rural head of household makes a choice of the energy sources that maximize their utility among the available alternatives as expressed mathematically in equation 3.1

$$\Pr[Yi = j) = \frac{\exp(\beta j \chi i)}{\sum_{j=0}^{J} \exp(\beta j \chi i)}, \quad (3.1)$$

Where: $\Pr[Yi = j) =$ is the probability of choosing firewood, charcoal, or Liquefied Petroleum Gas (LPG), and electricity which in this study was considered as a reference category; “j” is the number of energy source choice in the choice set, “j=0” is the reference category namely electricity; “χi” Is the vector of the predictor (exogenous) household factor (variable). On the other hand, “βj” Is a vector of the estimated parameter of the variables. When the Multinomial Logit Model above is re-arranged using algebraic express, it follows in equation 3.2 as

$$Pi = \frac{e^{(bo+b1x1)+........bvXv}}{1+e^{((bo+b1x1)+........bvXv}}, \quad (3.2)$$

The equation which has been used in estimating the coefficient of the research variables is as presented in equation 3.3

$$\ln[\frac{pi}{1-pi}] = bo + biXi + ...bvXv. \quad (3.3)$$

The Multinomial Logistic Regression Model employed in this study was estimated using maximum likelihood method. Using Maximum Likelihood method, positive estimated coefficient implies an increase in the likelihood that the head of a household dwelling in rural areas will choose a particular source of energy, while negative estimated coefficient indicates that there is less likelihood a household will choose particular energy source for cooking or lighting in rural areas of Tanzania given the available alternatives of energy sources.

3.10.3.3 Structural Equation Modeling (SEM) Technique

Structural Equation Modeling (SEM) was employed in order to establish and confirm the model expressed in the form of measurable indicators or factors for measuring sustainability of energy access in rural areas of Tanzania. Under SEM, the model was established and confirmed using Confirmatory Factor Analysis (CFA). The

Confirmatory Factor Analysis establishes the Measurement Model which specifies the number of factors, how the various indicators are related to the factors and the relationship among the indicators error. The use of CFA under SEM also establishes the relationship between the observed measures called indicators and the latent variables in the model. The goal is to establish the number and nature of factors that account for variation and co-variation within the set of indicators. The use of SEM in establishing a measurement Model for measuring sustainability of energy access in rural areas of Tanzania has several advantages. Firstly, SEM technique guarantees precise estimation of the indirect of the exogenous variables on all endogenous variables. Secondly, SEM is useful when the study has multiple constructs and each construct is presented by multiple indicators (Hair *et al.,* 2006).

Similar observations are reported by Jihye (2015) that SEM enables the analysis of latent variables and their relationship, and offers opportunity of analysing the dependencies of psychological constructs without measurement error. SEM also includes measurement errors and structural errors in the analysis. Besides, SEM has the ability of establishing the direct, indirect, and the total effects of research variables. SEM also applies multiple of statistical methods in one model and has the ability of showing reciprocal relationship between latent variables.

Additionally, the use of SEM technique in this study is also supported by Paul and James (2014) who depicted that SEM is a powerful data analysis and modeling technique as it jointly assesses measurement and theory, it allows holistic testing of multistage models, avoids fixed scale construction and it also better tests moderators. Betsy (2003) reveals further that SEM allows a researcher to estimate the effects of theoretical or hypothetical constructs commonly called latent variables; the number of variables can be used to estimate the effects of latent variables. It also accounts for the potential error of measurement and allows the researcher to account for measurement error explicitly and finally allows researchers to model the direct, indirect, and the total effects of system variables in the model.

3.10.3.4 Measurement Model for Sustainability of Energy access in rural areas of Tanzania

The type of model developed for the purposes of measuring sustainability of energy access in rural areas of Tanzania is called Measurement Model. Measurement model refers to the implicit or explicit model that relates the latent variables to its indicators. Kline (2011) pointed out that measurement model defines the relationship between latent (unobserved variables) and observed indicators.

In the Structural Equation Modeling, the measurement model is sometimes called Confirmatory Factory Analysis (CFA) model. Sungau (2014) observes that measurement in SEM helps to evaluate how well the observed variables combine to identify the underlying constructs or latent variables. In the measurement model, the latent (unobserved variables) are presented by the measured variables called indicators. In this study the model for measuring sustainability of energy access in rural areas of Tanzania was established using measurable indicators. Since the focus of the study is on developing measurable indicators of sustainability of energy access, Confirmatory factor Analysis under Structural equation Modeling (SEM) was employed. The Confirmatory Factor Analysis allows the researcher to determine and confirm through testing the indicators for measuring a particular phenomenon (Kline, 2011). In establishing a model for measuring sustainability of energy access in rural areas using SEM, the modeling process as shown in Figure 3. 2 were followed.

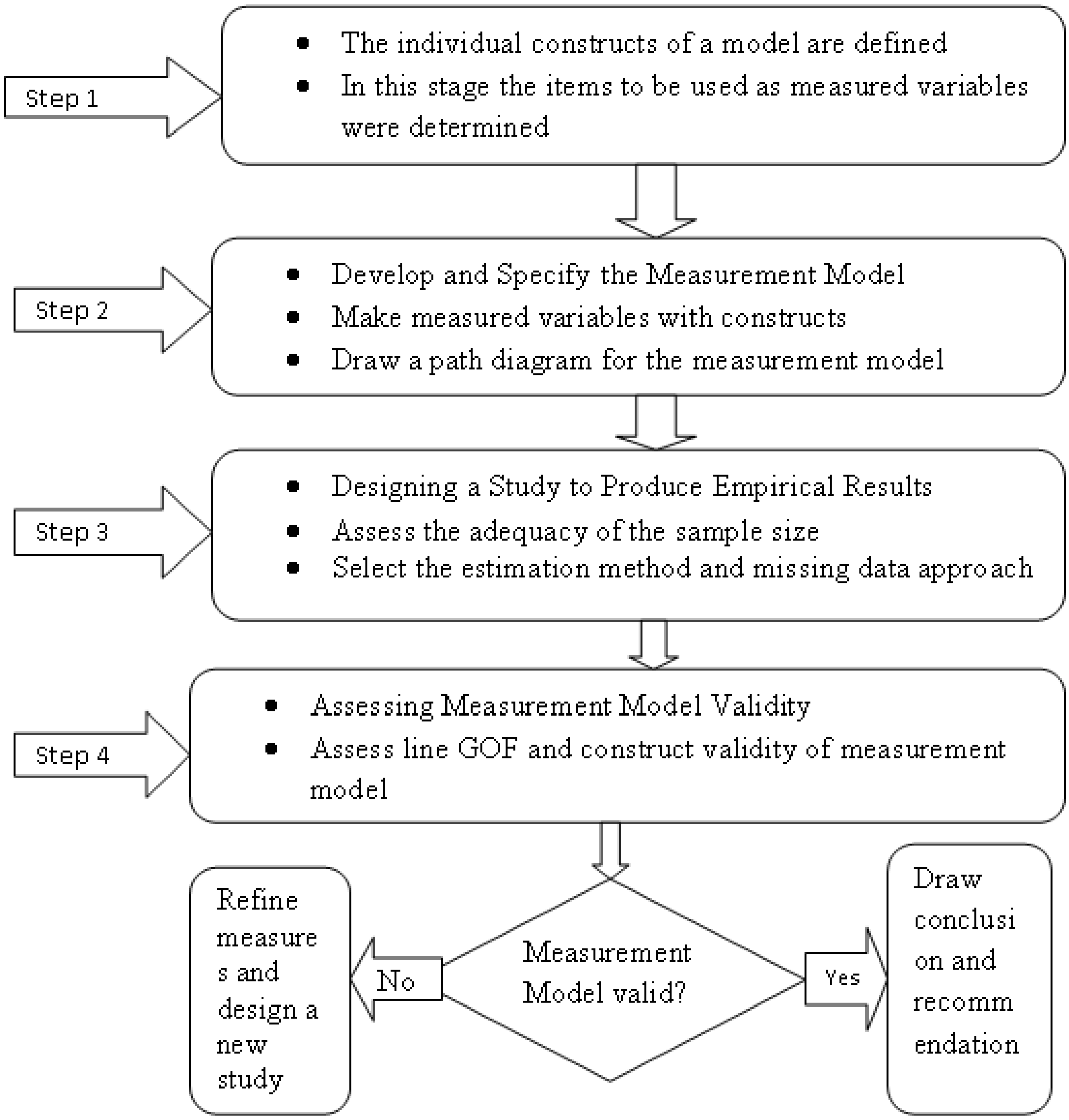

Figure 3.2: Modeling process using Structural Equation Modeling (SEM)

Source: (Hair *et al,* 2014)

From Figure 3.2, the first step of establishing the model using SEM is called definition of individul constructs to be used in the model. The establishment of constructs of a model in this study was achieved by reviewing theories and conducting literature review from previous related studies to assertain the reliable constructs to be used in the model. Based on reviewed literature, five constructs of the model for measuring sustainability of energy access in rural areas were develpoed. These identified constructs were social, economic, environemental, technical and institutional. These constructs are well explained in the conceptual framework presented in Chapter Two of this thesis.

The second step of the model development using SEM involves development and specification of a measurement model. In this stage, each latent (unobsrved) construct to be included in the model is identified together with its measured (observed) indicator variables. The observed variable is assigned to the latent construct. In this study, the variables of each construct have been presented in the operationalization of research variables shown in Chapter Three of the research methodology. The assignment of each observed variable to the latent construct in this study is presented using a flow diagram drawn with the aid of AMOS software version 18. The oval shape represents the latent varibales while the rectangle shape represents the observed or measured indicator.

The third step in modeling using SEM invloves designing a study in order to produce empirical results. In this step, the researher has to take into consideration all important aspects of research designs and assumptions. Among the important issues taken into consideration was the effects of sample size in the model and the model estimation technique. SEM requires large sample of ranging from 100 to 400 respondents. Based on this condition, this study used a sample size of 384 respondents from rural areas of Njombe and Iringa regions. The sample size used was within the recommended range. Maximum Likelihood Estimation (MLE) methods was used to estimate the variables in the model in this study. MLE was chosen because it provides valid and stable results with even small sample size.

The last step in establishing mesurement model is to assess its validity. In assessing measurement model validity, the Goodness Of Fit of the model and its construct validity were used. The messure of Goodness Of Fit(GOF) of the model used in this study were Comparative Fit Index (CFI), Tucker Lewis Index (TLI), Incremental Fit Index (IFI) and Root Mean Square Error of Approximation (RMSEA) and their recommended values are presented in Chapter Four of this thesis.

3.11 Research Ethical Issues

Ethic refers to the code of conduct or expected societal norms of behaviours which a researcher needs to adhere to while conducting a research. As a requirement of any scientific research, this study observed and adhered to all research ethical issues during conducting the study. In complying with research ethics, firstly a researcher obtained data collection letter after being granted a permission to proceed with data collection from the Directorate of Research Postgraduate Studies (DRPS) of Mzumbe University. Secondly, prior to the commencement of data collection process to the heads of households in the rural areas of Njombe and Iringa regions, the researcher obtained permission letters from the Regional Administrative Secretaries (RAS) of these regions. The letters directed the Districts Executive Directives (DED) to inform the Villages Executive Officers (VEO) as well Ward Executive officer (WEO) to appoint person who would assist the researchers during data collection processes. Thirdly, the study also maintained privacy of the participants, allowed voluntary participation and for the consent of participants in disclosing any information relating to the study. Fourthly, the respondents were also informed that the researcher collects data which were to be used only for academic purposes and not otherwise. Lastly, all academic sources used in this study were acknowledged.

CHAPTER FOUR

PRESENTATION OF RESEARCH FINDINGS

4.1 Introduction

The chapter presents the research findings on modeling sustainability of energy access in rural areas of Tanzania. The chapter begins with the presentation of preliminary research findings, followed by descriptive research findings and lastly, the inferential research findings. Preliminary, the research findings of outlier, IIA assumption and Multicollinearity of data were presented, while descriptive research findings covered demographic factors of the respondents, indicators of energy access, factors determining the choices of energy sources for cooking or lighting, and the indicators of sustainability of energy access in rural areas of Tanzania. Lastly this chapter presents the inferential research findings based on the research objectives used in this study.

4.2 Preliminary Research Findings

This section presents research findings of various assumptions tested in this study. The tested assumptions in this study include: Outlier of data, Multicollinearity, and Independence of Irrelevant Alternative assumption. Assumptions such as Linearity, Homoscedasticity, and Normality have not been tested because Multinomial Logistic Regression analysis technique does not require these assumptions. The results of the tested assumptions are presented herein.

4.2.1 Outliers

Prior to conducting any actual data analysis, the outlier of data should be tested. In research, Outlier consists of any value in the data set which is, to a certain extent, different from the rest of the other values that are related to a particular variable. The presence of outlier in any data set can affect the quality of the output of a model. Therefore, in this study, the outlier of data was tested in order to identify any data which were out of range so that substantive corrections could be made. Based on the said facts about outlier, in this study the outlier was tested using box plot score. The research findings on the box plot score showed that some data were found to have higher value than others due to wrong entry of these values in the data set. The identified outliers were corrected by cross-checking the entered data in the questionnaires as well as in the data. Editing and corrections were made to ensure that all entered data were free from outlier.

4.2.2 Multicollinearity of Data

Prior to conducting any inferential data analysis, Multicollinearity of data must be tested. The Multicollinearity should be tested in order to assess if there is high but perfect correlation between two or more predictors (Independent Variables). Therefore, in this study, the Multicollinearity of data was tested to all factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania through the use of Variance Inflation Factors (VIF) method. The role of Variance Inflation Factors is to quantify how much the variance of data is inflated. The rule of thumb is that; the larger the values of Variance Inflation Factor, the higher the Multicollinearity of data. The minimum recommended values of the VIF indicating the presence of Multicollinearity is three (3). The Multicollinearity results of the factors determining the choices of energy sources for cooking or lighting in rural areas are as presented in Table 4.1.

Table 4.1: Multicollinearity Test Results

Model	Unstandardized Coefficients		Standardized Coefficients	Collinearity Statistics	
	B	Std. Error	Beta	Tolerance	VIF
(Constant)	2.266	0.204			
Education level of a respondent	0.071	0.042	0.120	0.491	2.04
Age of the respondent	0.176	0.063	0.161	0.761	1.31
Marital status of respondent	0.034	0.049	0.042	0.727	1.38
Sex of a respondent	-0.014	0.066	-0.011	0.976	1.03
Occupation of respondent	0.039	0.041	0.078	0.376	2.66
Average monthly income of a respondent	0.011	0.074	0.011	0.507	1.97
Household size	0.008	0.037	0.011	0.943	1.06
The Recommended value of Variance Inflation Factor = ≤ 3					

Source: Research Data (2017)

The research findings from Table 4.1 show that the value of the Variance Inflation Factor for each predictor is as follows: Level of education (VIF= 2.038), Age of the respondent (VIF=1.31), Marital status (VIF=1.38), Sex (VIF =1.03), Occupation (VIF=2.66), Average monthly income of heads of household (VIF =1.97) and the household size (VIF=1.06). Generally, the research findings in Table 4.1 indicate that all factors have VIF value less than 3. This implies that Multicollinearity does not exist in all tested variables. Therefore, Multinomial Logistic Regression analysis is guaranteed to be conducted. However, the Variance Inflation Factor value of more than 10 indicates serious Multicollinearity.

4.2.3 Independence of Irrelevant Alternative Assumption Test (IIA)

Multinomial Logistic Regression has an assumption of independence among the dependent variables. This assumption states that the choice or membership in one category is not related to the choice or membership of another category. To ensure goodness of the model, this study tested the Independence of Irrelevant Alternative assumption using McFadden test which showed that the chi-square value of the research variables used in the model was positive indicating that Independence of Irrelevant Alternative (IIA) assumption was not violated and guaranteed for Multinomial Logistic Regression analysis technique to be employed.

4.3 Descriptive Research Findings

The descriptive research findings of the demographic characteristics of the respondents, indicators of energy access in rural areas of Tanzania, factors determining the choices of energy sources for cooking or lighting in rural areas, and the indicators of sustainability of energy access in rural areas of Tanzania are presented in the following sections.

4.3.1 Demographic Characteristics of the Respondents

This section presents the research findings on demographic characteristics of the respondents in rural areas of Njombe and Iringa Regions in Tanzania. The demographic characteristics of the respondents included in this study were education level, age, marital status, sex, occupation, average monthly income, and the household size of the respondents. These demographic characteristics were found to be useful in making the analysis on the factors determining the choice of energy source for cooking or lighting in rural areas of Tanzania. The research results of these demographic characteristics are presented in Table 4.2.

Table 4.2: Demographic characteristics of Respondents

Demographic Characteristics of respondent	**Category**	**Frequency (N)**	**Percent (%)**
Education Level of respondent	No formal education	65	16.9
	Primary education	173	45.1
	Secondary education	90	23.4
	College education	56	14.6
	Total	**384**	**100**
Age of respondent	Less than 25 years	34	8.9
	25 but below 60 years	286	74.5
	60 and Above years	64	16.7
	Total	**384**	**100**
Marital status of respondent	Single	62	16.1
	Married	246	64.1
	Widowed	65	16.9
	Divorced	11	2.9
	Total	**384**	**100**
Sex of a respondent	Male	89	23.2
	Female	295	76.8
	Total	**384**	**100**
Occupation of respondent	Farming activities	296	77.1
	Livestock keeping	5	1.3
	Business	33	8.6
	Wage employment	49	12.8
	Total	**384**	**100**
Average monthly income of respondent	Less than 100,000/=	277	72.1
	100,000/=to 500,000/=	95	24.7
	More than 500,000/=	12	03.2
	Total	**357**	**100**
Household size	Less than 5 members	179	46.6
	5 to 8 members	154	40.1
	More than 8 members	51	13.3
	Total	**376**	**100**

Source: Research Data (2017)

It is apparent from Table 4.2 that the majority (45.1%) of the respondents had acquired primary education while the remaining 23.4% of the respondents attained secondary education, 16.9% had no formal education and 14.6% attained college education. In terms of age, the research findings indicate that the majority (74.5%) of the respondents were of the age category ranging from 25 to 60 years. The findings reveal further that many (64.1%) respondents were married. The remaining respondents were either single or widowed. While we sampled rural heads of households in Iringa and Njombe regions, the study findings revealed that the majority (76.8%) of the respondents were female while the remaining respondents were male.

Besides, the findings in Table 4.2 show that large numbers (77.10%) of the respondents are engaging in farming activities. Few of them are employed and others deal with business and livestock keeping activities. The study findings show that majority (72.10%) of the people living in rural areas of Njombe and Iringa regions in Tanzania have an average monthly income of less than Tshs 100,000/=, followed by those with an average monthly income of between 100,000/= and 500,000/=. The study findings also show that more than 89% of the rural households in Tanzania had a family size ranging from 1 to 8 children.

4.3.2 Indicators of Energy Access in Rural areas of Tanzania

This section sought to determine the indicators of energy access in rural areas of Tanzania. In order to achieve this objective, nine research variables named affordability, efficient, availability, easy to use, economical, convenience, durability, non-emission of smoke, and the ability to keep the cooking pot were used. A five Likert scale was used to solicit options from the respondent whereby a Likert of I implied Strong Disagree (SD), 2 = Disagree (DA), 3 = Neutral (N), 4 = Agree (A) and 5 = Strong Agree (SA). Using Five Point Likert Scale, respondents were required to express their extent to which they agree or disagree with each of the indicator of energy access. The descriptive research results on the indicators of energy access in rural areas of Tanzania are as presented in Table 4.3.

Table 4.3: Indicators of Energy Access in Rural Areas of Tanzania

Indicator of Energy access	N	Mean response	Percent (%)
Convenience	384	3.63	72.00
Keep the cooking pot clean	384	4.24	84.80
Non-production of smoke	384	4.32	86.40
Economical	384	4.39	87.80
Durability	384	4.42	88.40
Efficient	384	4.46	89.20
Affordability	384	4.53	90.60
Easy to use	384	4.58	91.60
Availability	384	4.61	92.20

Source: Research Data (2017)

The study findings in Table 4.3 indicate that the indicators of energy access based on its importance are: Availability (92.20%), Easy to use (91.60%), Affordability (90.60%), Efficient (89.20%), Durability (88.40%), Economical (87.80%), Non-production of smokes (86.4%), Ability to keep the cooking pots clean (84.80%) and Convenience (72.00%) of energy sources for cooking or lighting purposes in rural areas of Tanzania.

4.3.3 Energy Sources used for Cooking in Rural areas of Tanzania

This section sought to determine the types of energy sources used for cooking in rural areas of Tanzania. The study results are presented in Table 4.4.

Table 4.4: Energy source used for cooking by households in rural areas of Tanzania

Type of energy source for cooking	Frequency (N)	Percent (%)
Electricity	07	01.80
Charcoal	47	12.20
Firewood	289	75.30
Liquefied Petroleum Gas (LPG)	41	10.70
Total	**384**	**100.00**

Source: Research Data (2017)

The study findings in Table 4.4 show that firewood is the main source of energy used for cooking by majority (75.30%) of the people living in rural areas of Tanzania followed by charcoal (12.20%). Other sources of energy used for cooking in rural areas although in small amount include Liquefied Petroleum Gas (10.70%) and electricity (01.80%).

4.3.4 Energy Sources used for Lighting in Rural Areas of Tanzania.

This section sought to identify the type of energy sources used for lighting purposes by people in rural areas of Tanzania. To achieve this objective, the respondents were required to choose the type of energy sources used for lighting purpose given the available alternatives such as electricity, kerosene, solar power, and solar torch. The study results on the energy sources used for lighting in rural areas of Tanzania are presented in Table 4.5.

Table 4.5: Energy sources used for lighting by households in rural areas of Tanzania

Energy source	**Frequency (N)**	**Percent (%)**
Electricity	95	24.70
Kerosene	88	22.90
Solar power	165	43.00
Solar torch	35	09.40
Total	**384**	**100.00**

Source: Research Data (2017)

The study findings in Table 4.5 show that solar power (43.00%) is highly used by people in rural areas of Tanzania for lighting purposes followed by electricity (24.70%) and kerosene (22.90%). The study findings indicate further that solar torch (9.40%) is the least used source of energy for lighting purposes by rural households in Tanzania.

4.4 Cross Tabulation between the Demographic Characteristics of Respondents and the types of Energy Source used for cooking by rural households

This study employed cross tabulation approach in order to assess if there is an association between various demographic characteristics of the respondents and the choices of energy sources for cooking or lighting in rural areas of Tanzania. The demographic factors employed in this study were the level of education, age, sex, marital status, occupation, household family size and the average monthly income of the respondents. The available energy sources choices used in this study were electricity, charcoal, firewood, and Liquefied Petroleum Gas (LPG).

4.4.1 Relationship between Education Level and the Choice of Energy Sources for Cooking in Rural Areas of Tanzania

This section sought to determine if there is any relationship between the level of education attained by the respondents and the choice of energy sources for cooking in rural areas of Tanzania. The research results on the relationship between education level and the choices of energy sources for cooking are presented in Table 4.6.

Table 4.6: Cross Tabulation between Education Level and Choices of energy sources for cooking in Rural Areas of Tanzania

Maximum Education Level	**Unit**	**Energy sources for cooking in rural areas of Tanzania**				
		Electricity	**Charcoal**	**Firewood**	**LPG**	**Total**
Informal Education	Count	0	1	63	1	65
	% within	0.00	1.50	96.90	1.50	100.00
Primary Education	Count	4	22	142	5	173
	% Within	2.30	12.70	82.10	2.90	100.00
Secondary Education	Count	2	13	61	14	90
	% within	2.20	14.40	67.80	15.60	100.00
College Education	Count	1	11	23	21	56
	% within	1.80	19.60	41.10	37.50	100.00
Total	Count	7	47	289	41	384
	% within	1.80	12.20	75.30	10.70	100.00
Chi-Square test:	Pearson Chi-square value = 76.61; df=9; P-Value = 0.000					

Source: Research Data (2017)

The study findings in Table 4.6 indicate that large number (96.90 %) of the respondents who have not acquired any formal education use firewood as the major source of energy for cooking in the rural areas of Tanzania. Besides, the study findings show that the extent of using modern sources of energy such as Liquefied Petroleum Gas (LPG for cooking and electricity in rural areas of Tanzania is high among household members with secondary and college education than those with primary and those who have not acquired any formal education. The Chi-Square value results on the association between education level and the choices of energy sources was found to be 76.61with 9 Degree of Freedom (DF) and significant (P-value =0.000<0.05) which is less than P- value of 0.05. This indicates that, there is an association between the level of education of the respondents and the type of energy sources they use for cooking in rural areas of Tanzania.

4.4.2 Relationship between Age of Respondents and the Choices of Energy sources for cooking in Rural Areas of Tanzania

The study findings in Table 4.7 indicate the relationship between the age of the respondents and the choices of energy sources for cooking in rural areas of Tanzania.

Table 4.7: Cross Tabulation between age and the choices of energy used for cooking in Rural Areas of Tanzania

Age of respondent	Unit	Energy sources for Cooking in Rural areas				Total
		Electricity	Charcoal	Firewood	LPG	
Less than 25 years	Count	3	8	21	2	34
	%within	08.80	23.50	61.80	05.90	100.00
25 but below 60 yrs	Count	4	38	20	39	286
	%within	01.40	13.30	71.70	13.60	100.00
60 and above yrs	Count	0	1	63	0	64
	%within	00.00	01.60	98.40	00.00	100.00
Total	Count	7	47	289	41	384
	% within	01.80	12.20	75.30	10.70	100.00
Chi-Square test:	Pearson Chi-square value = 36.14; df=6; P-Value = 0.000					

Source: Research Data (2017)

The findings in Table 4.7 indicate that about 71.70% of the respondents belonged to the age group ranging from 25 to 59 years use fire as the main source of energy for cooking in rural areas of Tanzania. The findings also indicate that 61.80% of the respondents with fewer than 25 years also use firewood followed by charcoal for cooking purposes in rural areas of Tanzania. Additionally, the findings reveal that electricity and LPG are used to a less extent by the respondents in all age categories. The Chi-Square value for the association between the choices of energy sources and the age was found to be 36.14 with 6 Degree of Freedom and significant (P-value=0.000), indicating that there is the association between the age of the respondents and the choices of energy sources for cooking in rural areas of Tanzania.

4.4.3 Relationship between Marital status and the Choices of Energy Sources for Cooking in Rural areas of Tanzania

This section sought to assess the relationship between marital status of the respondents and the choices of energy sources for cooking among rural households in Tanzania. The results are presented in Table 4.8

Table 4.8: Cross tabulation between Marital Status and the Choices of Energy Sources for Cooking by Rural Households in Tanzania

Marital status	Unit	Energy sources for Cooking in Rural Areas				Total
		Electricity	Charcoal	Firewood	LPG	
	Count	4	14	22	22	62
Single	%within	6.50	22.60	35.50	35.50	100.00
Married	Count	3	32	197	14	246
	%within	1.20	13.00	80.10	5.70	100.00
Divorced	Count	0	0	61	4	65
	%within	.00	.00	93.80	6.20	100.00
Total	Count	0	1	9	1	11
	Within	.00	9.10	81.80	9.10	100.00
Chi-Square test:	Pearson Chi-square value = 82.32; df=9; P-Value = 0.000					

Source: Research Data (2017)

The findings in Table 4.8 show that 80.10% of the married respondents use fire as a source of energy for cooking, while 93.80% of the divorced respondents also use firewood for cooking purposes. The findings show further that the respondents who are not married prefer to use LPG for cooking purposes in rural areas of Tanzania. Moreover, the Chi-Square value for the association between energy sources choices and marital status was found to be 82.14 with 9 Degree of Freedom and significant (P-value =0.000), indicating that there is a relationship between Marital status of the respondents and the choices of energy sources for cooking in rural areas of Tanzania.

4.4.4 Relationship between Sex of Respondent and the Choices of Energy Source for Cooking in Rural Areas of Tanzania

The findings on the relationship between the sex of the respondents and the choice of energy sources for cooking by rural households are presented in Table 4.9.

Table 4.9: Cross tabulation between Sex of respondents and energy sources for cooking by rural households in Tanzania

Sex of the respondent	Unit	Energy sources for cooking in rural areas				
		Electricity	**Charcoal**	**Firewood**	**Gas**	**Total**
Male	Count	1	10	69	9	89
	% within	1.10	11.2	77.50	10.10	100.00
Female	Count	6	37	220	32	295
	%within	2.00	12.50	74.60	10.80	100.00
Total	Count	7	47	289	41	384
	%within	1.80	12.20	75.30	10.70	100.00
Chi-Square test:	Pearson Chi-square value = 0.50; df 3; P-Value = 0.91					

Source: Research Data (2017)

The findings in Table 4.9 indicate that 77.50% of the male respondents use firewood as their source of energy for cooking, while the remaining respondents use electricity, charcoal or gas for cooking in rural areas. Moreover, the findings in Table 4.9 reveal that about 74.60% of female respondents use firewood as a major source of energy for cooking. Furthermore, the findings show a Chi-square value of 0.50 with 3 degree of freedom and not significant (P-value = 0.91) indicating that there is no any relationship between sex of the respondents and the types of energy sources used for cooking purposes in rural areas of Tanzania. Therefore, this variable was not used during the analysis because it was not found to be statistically significant.

4.4.5 Relationship between Occupation of respondents and the Choices of Energy Sources for Cooking in Rural Areas of Tanzania

This section aimed at determining the relationship between the occupation of the respondents and the choices of energy sources for cooking in rural areas of Tanzania. To achieve this objective, descriptive analysis using cross tabulation was performed. The findings are presented in Table 4.10.

Table 4.10: Cross tabulation on the relationship between the occupation of respondents and the choice of energy sources for cooking by rural households in Tanzania.

Occupation of respondent	**Unit**	**Energy sources for Cooking in Rural Areas**				
		Electricity	**Charcoal**	**Firewood**	**LPG**	**Total**
Farming activities	Count	3	28	254	11	296
	%within	1.00	9.50	85.80	3.70	100.00
Livestock keeping	Count	0	0	5	0	5
	%within	0.00	0.00	100.00	0.00	100.00
Small businesses	Count	3	10	10	10	33
	%Within	9.10	30.30	30.30	30.3	100.00
Wage employment	Count	1	9	19	20	49
	%Within	2.00	18.40	38.80	40.80	100.00
Total	Count	7	47	289	41	384
	%Within	1.80	12.20	75.30	10.7	100.00
Chi-Square test:	Pearson Chi-square value = 113.71; df=12; P-Value = 0.000					

Source: Research Data (2017)

The findings in Table 4.10 show that 85.58% of the respondents who engage in farming activities use firewood as a major source of energy for cooking. The findings also show that out of 384 respondents, only 1.8% use electricity for cooking purposes. The findings indicate further that there is a relationship between the occupation of the respondents and the choices of energy sources for cooking in Rural areas of Tanzania (Pearson Chi-square value = 113.71; df =12; P-Value = 0.000)

4.4.6 Relationship between Average Monthly income of Respondents and the Choices of Energy sources for Cooking in Rural Areas of Tanzania

The existence or nonexistence of the association between the average monthly income of the respondents and the choices of energy sources for cooking in rural areas of Tanzania was determined descriptively using cross tabulation analysis method. The results on this association are presented in Table 4.11.

Table 4.11: Cross Tabulation on the relationship between average monthly income of the respondents and the choices of energy sources for Cooking in Rural areas of Tanzania

			Energy sources for Cooking in in rural areas				
		Unit	**Electricity**	**Charcoal**	**Firewood**	**LPG**	**Total**
Average Monthly income of Respondents	Less than 100,000	Count	3	29	234	11	277
		% within Average monthly income	1.10	10.50	84.50	4.00	100.00
	100,000/= to 500,000/=	Count	3	16	50	26	95
		% within the average monthly income	3.20	16.80	52.60	27.40	100.00
	More than 500,000/=	Count	1	2	5	4	12
		% within the average monthly income	8.30	16.70	41.70	33.30	100.00
Total		Count	7	47	289	41	384
		% within the average monthly income	1.80%	12.20	75.30	10.70	100.00
Chi-Square Test		Pearson Chi- Square Value =60.71, df=6; P –Value = 0.000					

Source: Research Data (2017)

The findings in Table 4.11 indicate that firewood is mostly used for cooking purposes by the respondents with an average monthly income of less than 100,000/= People with low level of income prefer using firewood because they cannot afford to buy modern sources of energy such as electricity and LPG. Besides, the findings also indicate that there is a relationship between the average monthly income and the choices of energy sources for cooking activities in rural areas of Tanzania (Pearson Chi- Square Value =60.71, DF=6; P-Value= 0.000)

4.4.7 Relationship between Household Family size and the Choices of Energy Sources for Cooking in Rural Areas of Tanzania

The relationship between the size of household's family size and the choices of energy sources for cooking in rural areas of Tanzania was established descriptively using cross tabulation approach. The results regarding this relationship are as presented in Table 4.12.

Table 4.12: Cross tabulation on the relationship between household family size and the choices of energy sources for Cooking in Rural areas of Tanzania

	Unit	Energy sources for Cooking in Rural Areas				
Household size		**Electricity**	**Charcoal**	**Firewood**	**Gas**	**Total**
Less than 5 members	Count	6	32	107	34	179
	%within	3.40	17.90	59.80	19.00	100.00
5 to 8 Members	Count	0	14	134	7	155
	%within	0.00	9.00	86.50	4.50	100.00
9 and Above Members	Count	1	1	48	0	50
	%within	2.00	2.00	96.00	0.00	100.00
Total	Count	7	47	289	41	384
	%within	1.80	12.20	75.30	10.70	100.00
Pearson Chi-Square=48.949, df=6 and Value = 0.000						

Source: Research Data (2017)

The study findings in Table 4.12 show that 96.00% of the respondents with family size of 9 and above members use firewood as a major source of energy for cooking. The findings indicate further that the use of firewood increases as the size of the household increases (Pearson Chi-Square=48.949, DF=6 and Value = 0.000)

4.5 Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

This section sought to determine indicators of Sustainability of Energy Access (SEA) in rural areas of Tanzania. To achieve this objective, sixteen research variables measuring Sustainability of Energy Access were used to capture the opinions from the respondents regarding the importance of these indicators in ensuring the provision of sustainable energy sources for cooking, heating or lighting in rural areas of Tanzania. These research variables were categorized into social, technical, economic, environmental, and institutional indicators. The respondents were supposed to indicate their extent of agreement or disagreement with these indicators of sustainability of energy access as far as rural areas of Tanzania is concerned.

Each item from each of these categories of indicators was measured using five Likert scale of which 1 implied very insignificant, 2= insignificant, 3= neutral, 4= significant and 5= very significant. The results are as shown in Table 4.13.

Table 4.13: Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Indicators	Explanation of the indicators	N	Mean	Percent (%)
Technical Indicators of Sustainability of Energy Access in Rural areas of Tanzania	Energy availability (Amount of energy provided from a particular source of energy)	384	3.95	79.00
	Energy conversion efficiency (ability to convert from the energy source to end use)	384	3.95	79.00
	Reliability (Measure of constant service)	384	3.96	79.20
	Grand Mean		**3.95**	**79.00**
Social Indicators of Sustainability of Energy Access in Rural areas of Tanzania	Reduction of adverse effects to women and children	384	4.31	86.20
	Acceptability of the energy source by the society	384	4.32	86.40
	Employment generation	384	4.32	86.40
	Ensure reduction/removal of human drudgery	384	4.32	86.40
	Grand Mean		**4.32**	**86.40**
Economic Indicators of Sustainability of Energy Access in Rural areas of Tanzania	Number of rural households without electricity	384	4.13	82.60
	Amount of f household income spent energy	384	4.14	82.80
	Number of households without modern cooking fuel	384	4.14	82.80
	Grand mean		**4.14**	**82.80**
Environmental Indicators of Sustainability of Energy Access in Rural areas of Tanzania	Reduction in soil erosion (Environmental Degradation	384	4.62	92.40
	Reduction in local and global environmental pollution	384	4.63	92.60
	Reduction in human health damage	384	4.63	92.60
	Grand Mean		**4.63**	**92.60**
Institutional Indicators of Sustainability of Energy Access in Rural areas of Tanzania	Availability of skilled staff	384	4.73	94.60
	Ability to monitor and control the energy source locally	384	4.73	94.60
	Ability to protect the investors and energy consumers	384	4.73	94.60
	Grand mean		**4.73**	**94.60**

Source: Research Data (2017)

The findings in Table 4.13 indicate that five indicators named Technical (79.00 %), Social (86.40%), Economic (82.80), Environmental (92.60%), and Institutional (94.6%) indicators are very important and useful in measuring sustainability of energy access in rural areas of Tanzania. Based on its importance, the findings reveal that institutional indicator ranks first, followed by environmental, social, economic, and technical indicators. More specifically, the research findings show that technical sustainability of energy access requires energy source or production system to have the ability of being easily converted from the energy source to the end user (79%), be available at a time when it is needed at a particular geographical location (79%), and being reliable (79.20%). Social sustainability of energy access requires the energy sources being provided be able to generate employment to rural households (86.40%), ensure reduction/ removal of human drudgery (86.40%), reduces the adverse effects to women and children (86.40%), and being accepted by rural households in the study area (86.20%). Similarly, the findings indicate that the energy access should be environmentally sustainable if its provision reduces the human health damage (92.60%), reduces local and global environmental pollution (92.60%), and reduces soil erosion (92.40%).

The findings indicate further that the prevention of environmental degradation caused by soil erosion should be taken into consideration when measuring the sustainability of energy access under environmental indicators. Additionally, the findings establish that items such as percentage of rural household without electricity, percentage of households without modern cooking fuel, and the percentage of household income spent on energy should be taken into consideration in measuring the sustainability of rural energy access economically.

Furthermore, descriptive study findings indicate that in measuring sustainability of energy access using institutional indicators, items such as availability of skilled staff at a local level in rural areas (94.6%), ability to monitor and control the provision of energy source locally in the villages (94.6%) and the ability of the energy system to protect the rights of the rural households plus the investors (94.6%) should be taken into consideration in order to ensure the provision of sustainable energy access to households in rural areas of Tanzania.

4.6 Inferential Research Findings

This section sought to present the inferential research findings of this study. The section covers inferential research findings on indicators of energy access, factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania, and indicators of sustainability of energy access in rural areas of Tanzania. Lastly, this section provides the analysis and development of model for measuring Sustainability of Energy Access in Rural Areas of Tanzania (SEA).

4.6.1 Indicators of Energy Access in Rural Areas of Tanzania

This section sought to determine Indicators of Energy Access in rural areas of Tanzania. In determining the indicators of energy access in rural areas of Tanzania, Exploratory Factor Analysis (EFA) was employed using Principal Component Analysis (PCA) as an extraction method with Varimax rotation method. Only those factors with Eigen value greater than one were retained according to Kaiser Criterion. Factors with factor loadings (λ) values greater than +_0.33 were considered important and were found to meet a criterion of being important indicator of energy access in rural areas of Tanzania, (have met the practical importance). The findings the indicators of energy access in rural areas of Tanzania are presented in Table 4.14.

Table 4.14: Indicators of Energy Access in Rural Areas using Factors Analysis Method

Indicators of Energy Access in Rural Areas	Factor Loadings (λ)
Affordability	0.63
Efficient	0.68
Availability	0.72
Easy to use	0.55
Economical	0.51
Convenience	0.16
non-emission of smoke	0.66
Durability	0.74
Keep the cooking pot clean	0.83

Source: Research Data (2017)

The findings in Table 4.14 show that all indicators of energy access in rural areas of Tanzania, with the exception of convenience indicator, have loading factor values greater than 0.33 indicating that they are important and useful in measuring energy access in rural areas of Tanzania. Ranking them according to their importance, the findings in Table 4.14 reveal that indicators such as keeping the cooking pot clean (λ=0.83) ranked the highest, followed by other indicators such as durability (λ=0.74), availability (λ=0.72), efficient (λ=0.68), nonproduction of smokes (λ=0.66), affordability (λ=0.63), easy to use (λ=0.55), and being economically viable(λ=0.51). The total variances explained among the nine items are as shown in Table 4.15

Table 4.15: Total variance explained by Indicators of Energy Access in Rural Areas of Tanzania

Component	Initial Eigen Value			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% Var	Cum %	Total	% Var	Cum%	Total	% Var	Cum%
1	3.98	44.21	44.21	3.98	44.21	44.21	3.16	35.06	35.06
2	1.44	16.03	60.25	1.44	16.03	60.25	2.27	25.19	60.25
3	0.95	10.60	70.85						
4	0.70	7.77	78.62						
5	0.58	6.44	85.06						
6	0.45	4.94	90.00						
7	0.38	4.18	94.18						
8	0.33	3.67	97.85						
9	0.19	2.15	100.00						

Source: Research Data

The findings in Table 4.15 indicate that the first group of indictors accounted for 35.06% of the variance and the second group of indictors accounted for 25.19% of the variance. Thus, 60.25% of the variance is accounted for by the first two groups of indictors while the remaining 39.76% of the variance is accounted for by other indictors. The scree plot in Figure 4.1 shows the Eigen value of the extracted indicators.

Figure 4.1: Eigen value Screen plot

Source: Research Data (2017)

The identified indictors using exploratory Factor Analysis were then rotated using Varimax method. Indicators with factor loading values greater than 0.33 were accepted while those with loading factor greater than 0.33 were omitted. Therefore, in this study, the identified rotated groups of indicators were arbitrary named as Techno-Economic and financial indicators of energy access as presented in Table 4.16.

Table 4.16: Rotated components matrix of the indicators of energy access in rural areas

Indicators of energy access in rural areas	**Loading Factor Value** 1	2	**Name of the indicator**
			Techno-economic
Keeping the cooking pot clean	0.91**		Indicators
Durability	0.85**		
non-emission of smoke	0.81**		
Economical	0.63**	0.33	
Availability		0.86**	
Affordability		0.79**	
Easy to use		0.71**	
Efficient	0.47	0.64**	Financial indicators

** = Highly correlated and accepted loading factor.

Source: Research Data (2017)

The findings in Table 4.16 indicate that Techno-Economic indicators of energy access in rural areas of Tanzania include indicators such as are keeping the cooking pot clean (λ = 0.91), durability (λ = 0.85), non-emission of smoke (λ = 0.81), and economic indicator (λ = 0.63). Besides, the findings in Table 4.16 also revealed that

Financial indicators of energy access comprised indicators such as availability (λ = 0.86), affordability (λ = 0.79), easy to use (λ = 0.71= 0.71), and efficient as measures of energy access in rural areas of Tanzania (λ = 0.64).

4.6.2 Confirmatory Factor Analysis (CFA) on Indicators of Energy Access in Rural Areas of Tanzania

The identified factors using Exploratory Factor Analysis (EFA) were then subjected into Confirmatory Factor Analysis (CFA) for confirmation purposes. The findings of Confirmatory Factor Analysis is presented in Figure 4.2

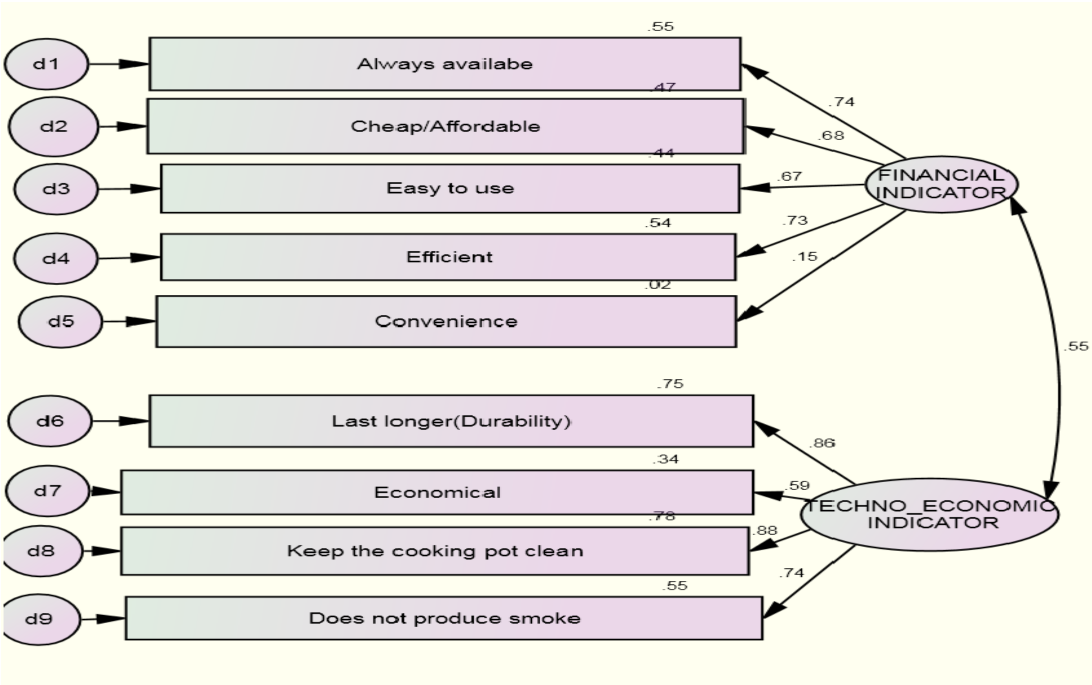

Figure 4.2: CFA Research findings on Indicators of Energy Access in Rural Areas.

Source: Research Data (2017)

The CFA findings esatablsihed using AMOS software presnted in Figure 4.2 show the Loading Factor value (λ) of each indiactor of which the higher the factor loading value the more important the indicator of energy access is. The findings in Figure 4.2 show further the Squared Multiple Correlation Coefficinet (R^2) values for each indicator which explains the amount of variance the common factor (Latent variable) account for the observed variables. Apparently, the findings in Figure 4.2 show that four indicators out of five financial indicators of energy access in rural areas have loading factors values of greater than the minimum required value of 0.33 indicating that they are important indicators for measuring energy access in rural areas of Tanzania. The findings depict that indicators such as availability (λ = 0.74), affordability (λ = 0.68), easy to use (λ = 0.67) and efficient (λ = 0.73 were found to be important indicators under the financial indicator category for measuring energy access in rural areas of Tanzania. It was also revealed that only one indicator under financial category named convenience had a loading factor value of less than 0.33 indicating that it not an important indicator in measuring energy access in rural areas of Tanzania

The findings revealed further that the squared multiple correlation coefficient (R^2) values for the financial category of indicators of energy access were availability (R^2 = 0.55), affordability (R^2 = 0.47), easy to use (R^2 = 0.44), and efficient (R^2 = 0.54). Based on the revealed values of R^2, the findings imply that 55% of the variance in financial category of indictors of energy access in rural areas of Tanzania is explained by availability while 47% of its variance is explained by affordability. Moreover, the findings also show that 44% and 54% of the variances in financial category of indicator of energy access in rural areas of Tanzania are explained by easy to use and efficiency of energy access respectively.

With regards to Techno-Economic category of indicators, the research findings indicate that all Techno-Economic indicators of energy access have loading factor values greater than 0.33 indicating that they are all important in measuring energy access in rural areas of Tanzania. These indicators are Durability (λ = 0.86), economic indicator (λ = 0.59), keeping the cooking pot clean (λ = 0.88) and non-emission of smoke (λ = 0.74). Regarding the squared multiple correlation coefficient, the research findings in Figure 4.2 show that 75% of the variance in Techno-economic category of indicators of energy access in rural areas of Tanzania is explained by durability as an indicator of energy access, while 34% of its variance is explained by economic aspect as an indicator of energy access in rural areas.

Similarly, the study findings in Figure 4.2 show that 78% and 55% of variances in Techno-Economic category of indicator of energy access is explained by indicators such as keeping the cooking pot clean and non-emission of smoke respectively when energy sources are used for cooking or lighting in rural areas of Tanzania.

4.6.3 Factors Determining the Choices of Energy Sources for Cooking in Rural Areas of Tanzania

This section sought to identify factors that determine the choices of energy sources for cooking in rural areas of Tanzania using Multinomial Logistic Regression method. To achieve this objective, the respondents were required to choose the energy sources being preferred mostly by them among the given available alternatives. The energy sources used in this study were electricity, firewood, charcoal and Liquefied Petroleum Gases (LPG). These energy source types were regressed against demographic factors such as education level, age, occupation, marital status, average monthly income and family size of respondents. The sex and the marital status of the respondents were not included in the analysis of this study because they were found to have no significant relationship with energy sources when it was cross tabulated. In this regard, subsequent sections provide an overall test of the relationship results, the strength of multinomial Logistic regression, relationship between each independent and dependent variable and the parameter estimates of the model.

4.6.3.1 Overall Test of Relationship of Variables in the Model

The first important aspect when using Multinomial Logistic Regression (MLR) analysis is to describe the overall test of relationship between independent and dependent variables used in the model when combined together. The relationship between the dependent and combination of independent variables is based on the statistical significance of the final Chi-Square model called Model fitting information presented in Table 4.17.

Table 4.17: Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	P-Value
Intercept only	354.563			
Final	209.125	145.438	15	0.000

Source: Research Data (2017)

The study findings in Table 4.17 reveal that the probability of the model Chi-Square (145.435) was 0.000 which is less than the level of significance of 0.05(i.e. $p<0.05$). These findings suggest that there is a relationship between the independent variables and the dependent variable used in this study

4.6.3.2 Strength of Multinomial Logistic Regression Relationship

This section aimed at establishing the strength of the relationship between independent and dependent variables used in this model. The strength of the relationship is established using Pseudo R square measures such as Cox &Snell R Square value, Nagelkerke R Square value and McFadden R Square value as presented in Table 4.18

Table 4.18: Pseudo R-Square Test

Step	Cox & Snell R^2	Nagelkerke R^2	McFadden R^2
	0.32	0.40	0.24

Source: Research Data (2017)

The study findings in Table 4.18 show that the values of Cox and Snell, Nagelkerke and McFadden were 0.32, 0.40 and 0.24 respectively suggesting that between 24% percent, 32% percent and 40% percent of the variations in the dependent variables are explained by this set of independent variables used in this model. In other words, the findings show that dependent variables define 40% of the variance in independent variables according to Nagelkerke R-Square value, 32 % according to Cox and Snell R square value, and 24% according to Mc Fadden R-Square value

4.6.3.3 Relationship of Independent and Dependent Variables

After establishing the overall relationship of variables in the model and its strength, this section sought to scrutiny further the relationship of each independent variable and dependent variable in the model. This relationship was achieved by performing likelihood ration test which evaluated the relationship between an independent variable and the dependent variables. The likelihood ratio test results are presented in Table 4.19

Table 4.19: Likelihood Ratio Tests

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	P-Value
Intercept	213.571	04.446	3	0.200
Household Family size	246.420	37.295	3	0.000**
Occupation of respondent	213.804	04.679	3	0.1000*
Education level of respondent	216.638	07.512	3	0.0570*
Age of respondent	222.865	13.740	3	0.003**
Average monthly income of respondent	212.992	03.867	3	0.2700

** Significant at 5%, * significant at 10%

Source: Research Data (2017)

The study findings in Table 4.19 show that there is a statistically significant relationship between the independent variables such as family size (P Value<0.05), age of the respondent (Value<0.05), education level of respondent (P- Value<0.1) occupation of the respondent (P- Value=0.1) and the dependent variable (Energy Source Choices).

4.6.3.4 Parameter Estimates of the Model

The parameters used in the model on factors determining the choices of energy sources for cooking in rural areas of Tanzania were estimated using Maximum Likelihood method. The independent variables used in this study were household family size, occupation, education level, age, and the average monthly income of the respondents. The independent variable is the cooking energy sources (Charcoal, firewood, liquefied Petroleum Gas (LPG) and electricity) with electricity being a reference category. The estimated coefficient in the model measures the estimated change in the Logit for one-unit change in the predictors' variable while other predictors are kept constant. During the estimation of the parameters, a positive estimated coefficient implies an increase in the likelihood that a household will choose the alternative energy source. Likewise, a negative estimated coefficient indicates that there is less likelihood that a household will choose a particular source of energy for cooking in rural areas of Tanzania. The findings of the estimated parameters are presented in Table 4.20

Table 4.20: Estimate Parameters results on factors determining the choices of energy sources for cooking in Rural Areas of Tanzania

	Energy sources for cooking in rural areas of Tanzania								
Explanatory Variables	**Charcoal**			**Firewood**			**Liquefied Petroleum Gas (LPG)**		
	β	**Std Error (S.E)**	**EXP(β)**	**β**	**Std Error (S.E)**	**EXP(β)**	**β**	**Std Error (S.E)**	**EXP(β)**
Household size	0.18	0.80	1.20	1.31	0.76	03.69	-0.62	0.86	0.54
Occupation	0.02	0.53	1.02	-0.29	0.51	00.75	0.21	0.54	1.24
Education level	0.74	0.67	2.09	-0.37	0.64	01.45	1.15	0.69	3.14
Age	1.31	0.87	3.72	2.31	0.85	10.04	2.00	0.93	7.39
Average income	-1.55	0.92	0.21	-1.66	0.86	00.19	-1.15	0.92	0.32

Reference Category = Electricity

Source: Research Data (2017)

Using odd ratio [EXP (β)], the study findings in Table 4.20 reveal that one unit increase in an explanatory variable household hold size as a predictor in choosing charcoal as a source of energy for cooking in rural areas of Tanzania over electricity is expected to increase by a factor of 1.20 (Odd ratio >1) while keeping all other predictors constant. Similarly, the findings in Table 4.20 show that one unit increase in the explanatory variable occupation of the respondent as a predictor in choosing charcoal as a source of energy for cooking by rural household in Tanzania over electricity is expected to increase by a factor of 1.02 (Odd ratios>1) while keeping all other predictors constant.

Consistent to that, the findings in Table 4.20 indicate that that one unit increase in the explanatory variable education and age of the respondents as predictors in choosing charcoal as a source of energy for cooking in rural areas of Tanzania over electricity are expected to increase by a factor of 2.09 and 3.72 each respectively (Odd ratio>1) while keeping all other predictors constant. However, the study findings in Table

4.20 show that one unit increase in the explanatory variable average monthly income as a predictor in choosing charcoal as a source of energy for cooking in rural areas of Tanzania over electricity is said to be decreased by a factor of 0.21 (Odd ratio<1) while keeping all other predictors constant.

Regarding the choices of firewood as a source of energy for cooking over electricity in rural areas of Tanzania, the findings in this study as shown in Table 4.20 reveal that one unit increase in the variable household size as predictors in choosing firewood as a source of energy for cooking in rural areas of Tanzania over electricity is expected to increase by a factor of 3.69 (Odd ratio>1) while keeping all other predictors used in the model constant. Furthermore, the study findings in Table 4.20 show that one unit increase in variables household size, education, and age of the respondent as predictors in choosing firewood as a source of energy for cooking over electricity in rural areas of Tanzania is expected to increase by a factor of 1.45 and 10.04 each respectively (Odd ratio>1) while keeping all other predictors constant. Contrary, the study findings in Table 4.20 show that one unit increase in explanatory variables occupation and average monthly income of the respondent as predictors in choosing firewood as a source of energy for cooking in rural areas of Tanzania over electricity decrease by a factor of 0.75 and 0.19 each respectively (Odd ratio<1) while keeping all other predictors constant.

As far as Liquefied Petroleum Gas (LPG) is concerned, the study findings show that one unit increase in explanatory variables occupation, education and age or the respondent as predictors in choosing Liquefied Petroleum Gas (LPG) as sources of energy for cooking over electricity in rural areas of Tanzania increased by a factor of 1.24, 3.14, and 7.39 each respectively (Odd ratio >1) while keeping other predictors constant. Besides, the findings reveal that one unit increase in variable household size and average monthly income as predictors of choosing energy sources called Liquefied Petroleum Gas (LPG) for cooking in rural areas of Tanzania over electricity decrease by a factor of 0.54 and 0.32 each respectively (Odd ratios<1) while keeping all other predictors used in the model constant

4.6.4 Factors Determining the Choices of Energy Sources for Lighting in Rural areas of Tanzania

This section sought to identify the factors determining the choices of energy sources for lighting in rural areas of Tanzania using Multinomial Logistics technique. The energy sources for lighting used in this study were electricity, kerosene, solar power and solar torch, while the demographic factors used were education level, age, occupation, average monthly income and household size of the respondents. In this study, torch is used as a reference category. The overall test of the relationship, the strength of Multinomial Logistic Regression, relationship between each independent, and dependent variable as well as the parameter estimates of the model are presented hereunder.

4.6.4.1 Overall Test of Relationship

The overall test of relationship of the variables used in the model when combined together is tested by assessing the statistical significance of the final Chi-Square model called model fitting information as presented in Table 4.21

Table 4.21: Model fitting Information

Model	-2 Log Likelihood	Chi-Square	df	P-Value
Intercept only	588.803			
Final	480.068	108.734	21	0.000

Source: Research Data (2017)

The study findings in Table 4.21 reveal that the probability of the model Chi-Square (108.734) was 0.000, which is less than the level of significance of 0.05(i.e. $p<0.05$). This suggests that there is a relationship between independent variables and dependent variables used in this study when considered together

4.6.4.2 Strength of Multinomial Logistic Regression Relationship

This section sought to assess the strength of the relationship between independent and dependent variables used in this model. The strength of the relationship is established using Pseudo R square measures such as Cox & Snell R Square value, Nagelkerke R Square value and McFadden R Square value as presented in Table 4.22.

Table 4.22: Pseudo R- Squares

Step	Cox & Snell R^2	Nagelkerke R^2	McFadden R^2
	0.25	0.27	0.12

Source: Research Data (2017)

The study findings in Table 4.22 show that the values of Cox and Snell, Nagelkerke and McFadden were 0.25, 0.27 and 0.12 respectively; suggesting that between 12% 35% and 27% of the variations in the dependent variables are explained by a set of independent variables used in the model. In other words, the findings show that dependent variables define 27% of the variance of the independent variables according to Nagelkerke R-Square value, 25% according to Cox and Snell R square value, and 12% according to Mc Fadden R-Square value

4.6.4.3 Relationship of Independent and Dependent Variables

This section aimed at ascertaining the relationship of each independent variable and dependent variable in the model using Likelihood ratio test. The likelihood ratio test results are presented in Table 4.23.

Table 4.23: Likelihood Ratio Tests

Factors determining energy source choices	-2 Log Likelihood of Reduced Model	Chi-Square	df	P-Value
Intercept	496.417	16.348	3	0.001
Education level	495.986	15.918	3	0.001**
Age	489.578	9.510	3	0.023**
Occupation	480.845	0.777	3	0.855
Household size	484.861	4.793	3	0.188
Marital Status	491.295	11.226	3	0.011**
Sex	492.517	12.448	3	0.006**
Average monthly income	481.266	1.198	3	0.754

Source: Research Data (2017)

The study findings in Table 4.23 indicate that factors such as the level of education (P =0.001), age (P = 0.023, marital status (P = 0.011) and sex (P = 0.006) of the respondents significantly determine the choices of energy sources for lighting purposes in rural areas of Tanzania (i.e. all have P-Values less than 0.05)

4.6.4.4 Parameter Estimates of factors determining the choices of Energy Sources for Lighting in rural areas

The parameters of the model on factors determining the choices of energy sources for lighting in rural areas of Tanzania were estimated also using maximum likelihood method. The study results of the estimated parameters explained using odd ratio are presented in Table 4.24.

Table 4.24: Parameters estimation on factors determining the choices of energy sources for lighting in rural areas of Tanzania

Explanatory Variables	Types of energy sources for Lighting in rural areas of Tanzania								
	Electricity			Kerosene			Solar Power		
	β	Std Error (S.E)	EXP(β)	β	Std Error (S.E)	EXP(β)	β	Std Error (S.E)	EXP(β)
Education level	0.83	0.33	2.29	0.07	0.34	1.07	0.79	0.31	2.21
Age	1.09	0.45	2.29	0.98	0.44	2.66	0.38	0.40	1.47
Occupation	0.28	0.35	1.32	0.21	0.38	1.23	0.16	0.34	1.18
Household size	0.18	0.32	1.20	0.58	0.31	1.78	0.38	0.29	1.46
Marital status	-0.35	0.37	0.71	0.64	0.36	1.90	0.02	0.33	1.02
Sex	0.69	0.46	2.00	1.27	0.52	3.57	0.07	0.41	1.07
Household income	0.49	0.60	1.63	0.40	0.63	1.49	0.19	0.58	1.20

Reference Category = Solar Torch

Source: Research Data (2017)

The study findings in Table 4.24 indicate that one unit increase in education level and age variables as predictors in choosing electricity over solar torch as a source of energy for lighting in rural areas of Tanzania is expected to increase by the factor of 2.29 each (Odd Ratio >1) while keeping other predictors constant. The same trend happens to variables such as household size, sex and household income. However, the study findings reveal that one unit increase in marital status as a predictor in choosing kerosene as source of lighting in rural areas over solar torch is expected to decrease by a factor of 0.70 (Odd Ratio<1) while keeping all other predictors constant.

Besides, the study findings in Table 4.24 show that one increase in the variables such as education level, age, occupation, household size, marital status, sex and household income as predictors of choices of using kerosene as source of energy for cooking increase by factors of 1.07, 2.66, 1.23, 1.78, 1.90, 3.57 and 1.49 each respectively (Odd ratio>1) while keeping all other predictors constant. Additionally, the study findings in Table 4.24 indicate that one unit increase in variables such as education level, age, occupation, household size, marital status, sex and household income as predictors of choices of using Solar power as source of energy for lighting over solar battery or torch increased by a factor of 2.21, 1.47, 1.18, 1.46, 1.02, 1.07, and 1.20 each respectively (Odd ratio >1) while keeping all other predictors constant.

4.6.5 Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

This section sought to determine the indicators of sustainability of energy access in rural areas of Tanzania. To achieve this objective, the respondents were provided with sixteen indicators categorized into social, economic, technical, environmental, and institutional indictors. The respondents were required to indicate their extent of agreement or disagreement with the indicators for measuring sustainability of energy access in rural areas of Tanzania. A five-point Likert scale of 1= strongly disagree, 2= disagree, 3= Neutral, 4 = Agree and 5 = strongly agree were used to solicit opinions from the rural households in Iringa and Njombe regions in Tanzania regarding the indicators of sustainability of energy access. Exploratory Factor Analysis Technique and thereafter Confirmatory Factor Analysis (CFA) techniques were employed to determine and confirm these indicators as presented in the subsequent sections of this chapter

4.6.5.1 Technical Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

This section sought to determine the technical indicators of sustainability of energy access in rural areas of Tanzania. To achieve this objective, the respondents were provided with three indicators from technical category which measure sustainability of energy access using a five-point Likert scale of 1 = strongly Disagree and 5 =

Strongly Agree. The indicators used under Technical category were such as Energy availability (TEC_1), Reliability (TEC_2) and Energy conversion efficiency (TEC_3).

Prior to employing Exploratory Factor Analysis on these indicators, the sampling adequacy was tested using KMO test. The tested KMO had a value of 0.76 which is between the range of good and excellent indicating that Factor analysis is appropriate to be conducted (Netemeyer *et al*, 2003; & Field, 2005). The Bartlett's test of sphericity which focused on measuring the internal consistency of the variables was found to have a Chi-square of 971.224 and statistically significant (P-Value<0.05) indicating that there is an internal consistency or relationship among indicators of technical sustainability of energy access in rural areas of Tanzania. Thereafter, Exploratory Factor Analysis (EFA) was employed using Principal Component Analysis method. The study results showing the loading factors are presented in Table 4.25

Table 4.25: Loading factors values on Technical Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Construct	**Variable code**	**Statement(s)**	**Loading Factor Values**
Technical indicators of sustainability of energy access in rural areas of Tanzania	TEC_1	Energy availability (Amount of energy provided by a particular source of energy)	0.95
	TEC_2	Reliability (measure of constant service)	0.94
	TEC_3	Energy conversion efficiency (Ability to convert from energy source to end use)	0.93

Source: Research Data (2017)

The study findings in Table 4.25 indicate that all three variables under technical indicator of sustainability of energy access namely energy availability, reliability and energy conversion efficiency have loading factor values greater than 0.30 indicating that they are important in measuring technical sustainability of energy access in rural areas of Tanzania. After conducting EFA, these indicators were subjected to Structural Equation Modeling (SEM) using Confirmatory Factor Analysis (CFA) in order to confirm those indictors which were extracted using Principal Component Analysis in Exploratory Factor Analysis. The CFA research results are presented in Figure 4.3.

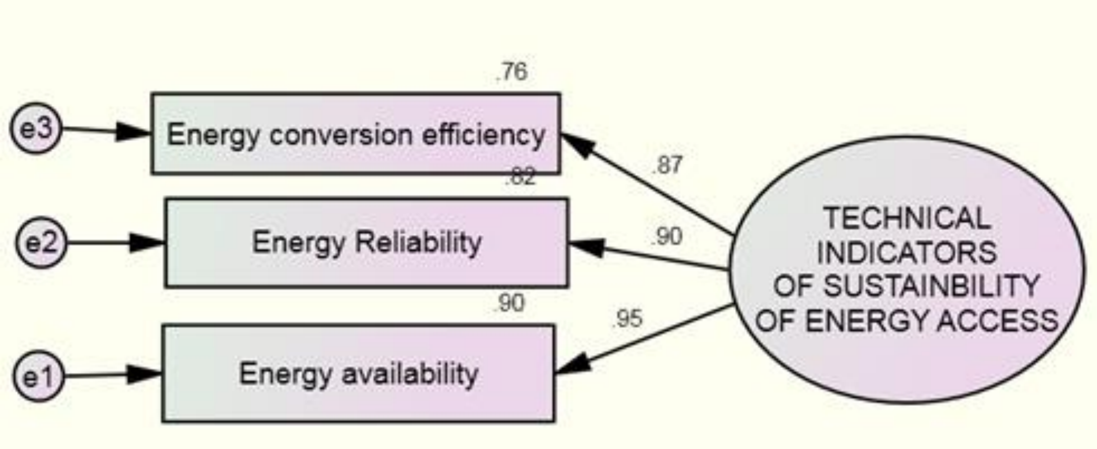

Figure 4.3: CFA Results on Technical Indicators of sustainability of Energy Access in Rural Areas of Tanzania

Source: Research Data (2017)

The CFA findings in Figure 4.3 indicate that all three indicators measuring technical sustainability of energy access in rural areas namely energy conversion efficiency, energy reliability, and energy availability have loading factor values of greater than the minimum recommended value of 0.30 indicating that these indicators are important in measuring sustainability of energy access in rural areas of Tanzania. Besides, the findings in Figure 4.3 indicate further that 76% of the technical sustainability of energy access is explained by energy conversion efficient indicator, 82% is explained by energy reliability indicator, and 90% is explained by energy availability indicator. Having higher value of Squared Multiple correlation coefficient, implies that these indicators under technical category are important and useful in measuring technical sustainability of energy access by rural households in Tanzania.

4.6.5.2 Social Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

The indicators used in soliciting opinions from the respondents regarding social category of indicators of sustainability of energy access in rural areas were: the reduction or removal of human drudgery (SOC_1), acceptability of the energy sources by the society (SOC_2), reduction of adverse effects to women and children (SOC_3), and employment generation (SOC_4).

Prior to conducting EFA, the KMO was tested and found to have a value of 0.84 which ranges from good to excellent, indicating high significant results and thus, Exploratory Factor Analysis becomes appropriate. The Bartlett's test of sphericity showed a Square value of = 1702.345) and highly significant at P- value < 0.05) indicating that all four variables are internally consistent and they all measure one category of indicators namely social indicator of sustainability of energy access in rural areas of Tanzania. The study results indicating the loading value of each indicator obtained by employing EFA using Principal Component Analysis (PCA) as an extraction method are presented in Table 4.26.

Table 4.26: Loadings factors on Social Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Construct	**Variable code**	**Statement(s)**	**Loading factor**
Social indicators of sustainability of energy access in rural areas of Tanzania	SOC_1	Ensure reduction/removal of human drudgery	0.93
	SOC_2	Acceptability of the energy source by the society	0.95
	SOC_3	Reduction of adverse effects to women and children	0.94
	SOC_4	Employment generation	0.94

Source: Research Data (2017)

The study findings in Table 4.26 show that all four variables under social indicators of sustainability of energy access namely the reduction or removal of human drudgery, acceptability of the energy sources by the society, the reduction of adverse effects to women and children, and generation of employment have loading factor values greater than the required minimum value of 0.30. This implies that these indicators are important in measuring social sustainability of energy access in rural areas of Tanzania. These findings which emanated from Exploratory Factor Analysis were subjected further to Factor analysis (CFA) using Amos software Version 18 for confirmation purpose of these social indicators. The study results are presented in Figure 4.4.

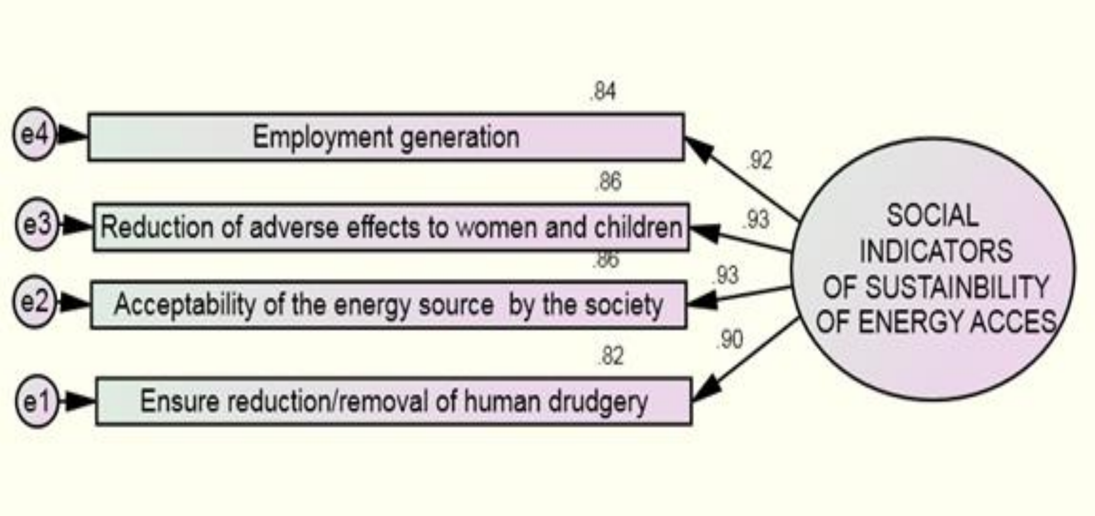

Figure 4.4: CFA Results on Social Indicators of Sustainability of Energy Access in Rural Areas of Tanzania
Source: Research Data (2017)

The study findings in Figure 4.4 indicate that all three indicators measuring the social sustainability of energy access in rural areas namely, reduction of human drudgery, acceptability of the energy sources by the households, the reduction of adverse effects to women and children and employment generations have loading factors values greater than the minimum recommended value of 0.30 indicating that these indicators are important in measuring the sustainability of energy access in rural areas of Tanzania.

Besides, the study findings indicate that 82% of the social sustainability of energy access is explained by the reduction of human drudgery indicator, 86% is explained by acceptability of the energy sources by the households and the reduction of adverse effects to women and children indicators each and 84% is explained by employment generation indicator. These findings imply that these indicators are useful in measuring social sustainability of energy access by rural households in developing countries including Tanzania.

4.6.5.3 Economic Indicators of Sustainability of Energy Access in Rural areas of Tanzania

The indicators used in determining the economic sustainability of energy access in rural areas of Tanzania were the percentage of rural households without electricity (ECO_1), the percentage of rural households without modern cooking facilities (ECO_2), and the percentage of rural household income spent on fuel/electricity (ECO_3). Prior to performing Exploratory Factor Analysis, the sampling adequacy was tested and found to have a KMO value of 0.77 which is ranged from good to excellent indicating that the data are appropriate for Factor Analysis.

The Bartlett's test of sphericity measuring internal consistency of variables was found to have a chi-square value = 1364.226, showing that they were highly significant at p-value <0.05. This indicates that all three statements were strongly relating to each other and they are all measuring economic indicators of sustainability of energy access. Thereafter, the loading factors values of these indicators were extracted using Principal Components Analysis (PCA) method. The study results are as presented in Table 4.27

Table 4.27: Loading factors values on Economic Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Construct	Variable code	Statements from questionnaire	Loading Factors Value
Economic indicator of sustainability of energy access	ECO_1	Percentage of rural households without electricity (%)	0.96
	ECO_2	Percentage of rural households without modern cooking facilities (%)	0.93
	ECO_3	Percentage of household income spent on fuel/ electricity	0.92

Source: Research Data (2017)

The study findings in Table 4.27 show that all three indicators under economic category have loading factor values of greater than the minimum accepted value of 0.30 indicating that they are useful indicators in measuring technical sustainability of energy access in rural areas of Tanzania. The identified indicators using Exploratory Factor Analysis were then subjected to Confirmatory Factor Analysis for further confirmation of these indicators. Figure 4.5 presents the study findings on these indicators.

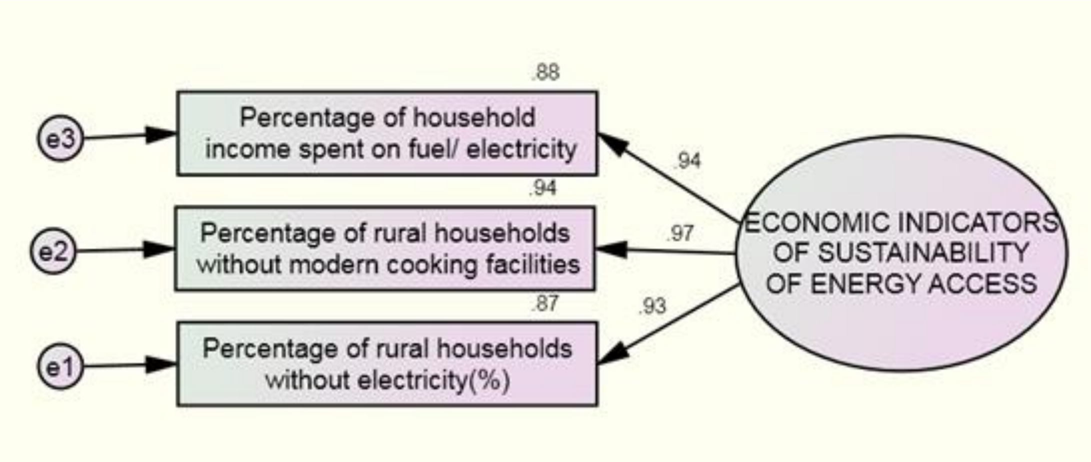

Figure 4.5: CFA Results on Economic Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Source: Research Data (2017)

The study findings in Figure 4.5 show that all three indicators measuring economic sustainability of energy access in rural areas of Tanzania have loading factors values of greater than the minimum recommended value of 0.30 indicating that these indicators are important in measuring economic sustainability of energy access in rural areas of the developing countries including Tanzania.

Besides, the study findings indicate that 87% of the economic sustainability of energy access is explained by an indicator named the percentage of rural households without electricity, 94% of the economic sustainability is explained by an indicator named the percentage of rural households without modern cooking facility and 88% of the economic sustainability of energy access is explained by an indicator named the percentage of household income spent on modern cooking facilities or electricity. These study findings imply that these indicators are useful in measuring the economic sustainability of energy access in rural areas of Tanzania.

4.6.5.4 Environmental Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

This section sought to determine the environmental indicators of sustainability of energy access in rural areas of Tanzania. To achieve this objective, three indicators under the environmental category named reduction in local and global environmental pollution (ENV_1), reduction in human health damage (ENV_2) and reduction in soil erosion/environmental degradation (ENV_3) were used in this study.

Prior to performing Exploratory Factor Analysis (EFA), a sampling adequacy of these variables was tested through the use of KMO test. The results revealed that a KMO value of 0.78 which indicates high correlation implying that these indicators are important and useful in measuring environmental sustainability of energy access in rural areas of Tanzania. Besides, the Bartlett's test of sphericity was also found to be statistically significant (Chi-square = 1288.012, DF= 3, P-Value< 0.05). This implies that all the indicators under environmental category have strong relations among themselves and they all measure one category of environmental indicator of sustainability of energy access in rural areas of Tanzania. Thereafter, Exploratory Factor Analysis (EFA) was performed using PCA as an extraction method and Varimax as rotation method. The study results showing the loading factor value for each indicator are presented in Table 4.28.

Table 4.28: Loading factor values on Environmental Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Construct	Variable code	Statements from questionnaire	Loading Factor Value
Environmental indicator of sustainability of energy access in rural areas of Tanzania	ENV_1	Reduction in local and global environmental pollution	0.96
	ENV_2	Reduction in human health damage	0.97
	ENV_3	Reduction in soil erosion	0.96

Source: Research Data (2017)

The study findings in Table 4.28 show that the indicators of sustainability of energy access under environmental category named the reduction of local and global environmental pollution, the reduction in human health damage, and the reduction in soil degradation have loading factor values greater than 0.30 indicating that they are useful and important in measuring environmental sustainability of energy access in rural areas of Tanzania. Besides, SEM using Confirmatory Factor Analysis (CFA) was performed in order to test and confirm the extracted indicators in Exploratory Factor analysis. The Confirmatory Factors Analysis results on the environmental category of indicators of sustainability of energy access are hereby presented in Figure 4.6.

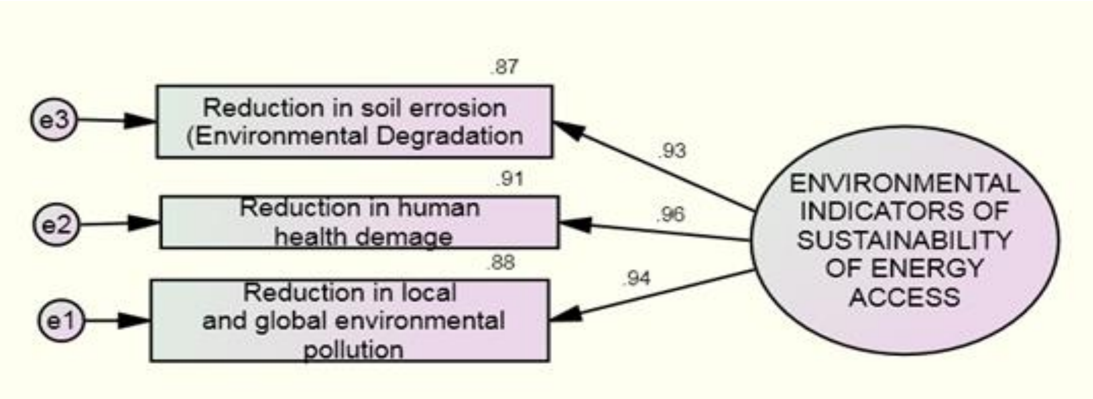

Figure 4.6: CFA Results on Environmental Indicators of Sustainability of Energy Access in Rural Areas of Tanzania.

Source: Research Data (2017)

The study findings presented in Figure 4.6 show that all indicators measuring the environmental sustainability of energy access by rural households have loading factors values of greater than the minimum recommended value of 0.30. These findings imply that these indicators are useful in measuring environmental sustainability of energy access in rural areas of Tanzania.

Moreover, the study findings establish that 88% of the environmental category of indicators on sustainability of energy access in rural areas of Tanzania is explained by an indicator named the reduction in local and global environmental pollution, 91% of the environmental sustainability is explained by the reduction in human health damage indicator, and 87% of environmental sustainability of energy access is explained by the reduction in soil erosion indicator. These findings imply that these indicators are useful in measuring environmental sustainability of energy access in rural areas of Tanzania.

4.6.5.5 Institutional Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

The focus of this section was on determining institutional indicators of sustainability of energy access in rural areas of Tanzania. In order to gather data on this aspect, three indicators under institutional category of indicators named availability of skilled staff (INST_1), the ability to protect investors and energy consumers (INST_2), and the ability to monitor and control the energy source/system locally (INST_3) were used in this study. Prior to employing Exploratory Factor Analysis, the Kaiser Meyer-Olkin (KMO) as a measure of sampling adequacy was tested and found to have a KMO statistic value of 0.761 which is above the minimum recommended value of 0.5 (Hair *et al*, 2006). Having higher value of KMO indicates that these data are suitable for EFA approach to be carried out. The three indicators under institutional category showed a strong relationship among themselves (Internal consistency with a Chi-square = 1180.252) and was statistically significant (P-Value<0.05). This implies that all three items measure the same construct of institutional indicator of sustainability of energy access in rural areas of Tanzania. After testing these assumptions, the EFA was performed using PCA as an extraction method. The study results on the extracted factors are presented in Table 4.29.

Table 4.29 Loading Factors values on Institutional Indicator of Sustainability of Energy Access in Rural Areas of Tanzania

Construct	Variable code	Statements	Loadings
Institutional indicator of sustainability of energy access in rural areas of Tanzania	INST_1	Availability of skilled staff	0.94
	INST_2	Ability to protect the investors and the consumers of the energy	0.96
	INST_3	Ability to monitor and control the energy source locally	0.96

Source: Research Data (2017)

The study findings in Table 4.29 show that the three indicators under institutional category of indicators of sustainability of energy access in rural areas named availability of skilled staff, the ability to protect investors and consumers of the energy and the ability to monitor and control the energy system/source locally have loading factor values greater than the recommended minimum value of 0.33 indicating that these indicators are important and useful in measuring institutional sustainability of energy access in rural areas of Tanzania. Thereafter, these indicators which were analysed using EFA were further subjected to Confirmatory Factor Analysis (CFA) using AMOS software version 18. The study results on these indicators are presented in Figure 4.7

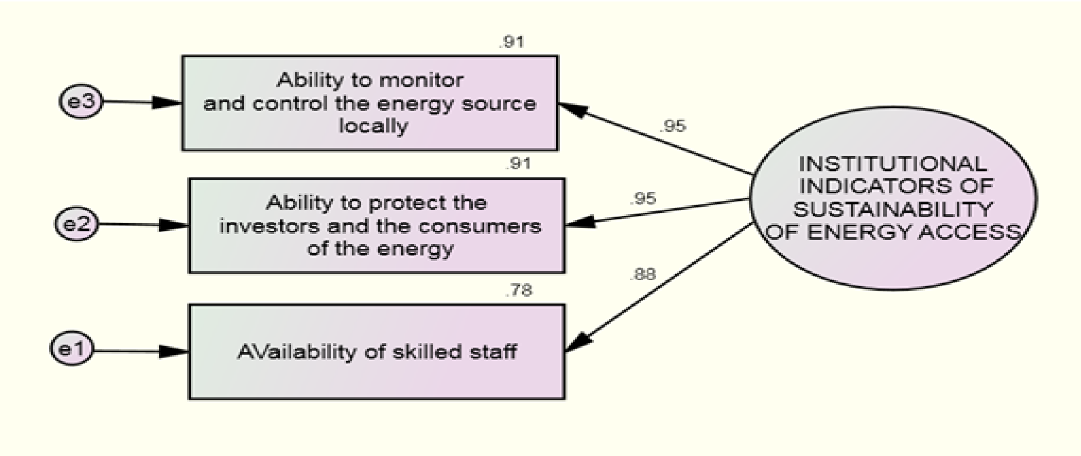

Figure 4.7: CFA Results on Institutional Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Source: Research Data (2017)

The study findings presented in Figure 4.7 indicate that the three indicators under institutional category of indicator of energy access in rural areas of Tanzania have loading factors value greater than the minimum recommended value of 0.30. These findings imply that the indicators are important in measuring institutional sustainability of energy access in rural areas of Tanzania. Besides, the findings establish that 78% of the institutional category of indicator of sustainability of energy access in rural areas of Tanzania is explained by availability of skilled labour, 91% of the institutional sustainability of energy access is explained by the ability to protect the interest of consumers and investors of energy sources and 91% of its sustainability is explained by the ability to monitor and control energy sources locally. These findings imply that these indicators are useful in measuring the institutional sustainability of energy access in rural areas of Tanzania.

4.6.6 Establishment of Model for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

This section sought to establish a model for measuring sustainability of energy access in rural areas of Tanzania using Structural Equation Modeling (SEM) technique. The use of SEM in establishing a model for measuring sustainability of energy access in rural areas of Tanzania is supported by Hair *et al.* (2006) who revealed that the role of SEM is to test or develop theoretical or an abstract model. The developed model aims at solving particular problem or as a means of communication among stakeholders. Therefore, in the context of this study, the model aimed at addressing the problem of provision of sustainable energy access in rural areas of Tanzania.

SEM consists of two types of models namely Measurement Model and Structural model. Measurement model defines the relationship between latent variables and observed indicators, while structural model defines the relationship among the latent variables and observed variables that are not the indicators of the latent variable (Kline, 2011) and Sungau (2014). When a SEM model comprises only Measurement Model it is sometimes called Confirmatory Factor Analysis Model while when it includes only structural model it is called Path Analysis Model. Considering the two types of models under SEM, this study focused on the development of Measurement Model for measuring sustainability of energy access in rural areas of Tanzania. Therefore, the use of SEM by employing Confirmatory Factor Analysis was deemed to be a useful technique in developing a model for measuring sustainability of energy access in rural areas of Tanzania.

The use of SEM was aided with Amos software version 18. The developed Measurement Model encompasses theory and specifies how the measured variables come together to represent latent variables. Using AMOS software, latent variables

(Un-observed) were presented using oval-shape while the Observed variables were presented using rectangle shape. The two–headed arrows shown in the developed model represent the covariance between the constructs while one headed connector indicates the causal path from the construct to an indicator. The developed model for measuring was then tested its fitness using various measures of Goodness of fit of model as explained herein.

4.6.6.1 Measures of Goodness of Fit of a Measurement Model

Various measures of goodness of fit of the model are used under Structural Equation Modeling (SEM) technique. Among these measures of Goodness of Fit model are Chi-square (χ^2) statistic, Degree of Freedom (DF), and significance level (p-value). The use of these measures is supported by Kline, (2011) who revealed that a goodness of fit of a model under SEM is evaluated using various tests such as Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), Goodness of Fit Index (GFI), Tucker Lewis Index (TLI), Incremental Fit Index (IFI), and Relative Chi-square ($\frac{\chi^2}{df}$). Besides, the study by Hair *et al.* (2006) also pointed out that the major tests which are sufficient to assess the fitness of the measurement model include but not limited to: Chi-square ($\frac{\chi^2}{df}$), *df*, Relative Chi-square ($\frac{\chi^2}{df}$), CFI, TLI, IFI and RMSEA. The recommended value of each measure is presented in Table 4.30.

Table 4.30: Measurement of Goodness of Fit and its recommended Values

Goodness of Fit Test (GOF)	Requirement
Chi-Square test (χ^2)	χ^2 <df
Df	>0
$\frac{\chi^2}{df}$	< 3
GFI	>0.90
TLI	>0.90
IFI	>0.90
CFI	>0.90
RMSEA	< 0.08
Factor Loading Value	>0.50

Source: Kline (2011)

Based on the above measure of goodness of fit model, this study developed a measurement model expressed in terms of indicators using five categories indicators namely, social, technical, economic, environmental, and institutional indicators. For the sake of simplicity, this study proposes the abbreviations as presented in Table 4.31.

Table 4.31: Abbreviations of Indicators used in a model for measuring Sustainability of Energy Access in Rural Areas of Tanzania

Indicators of sustainability of energy access in rural areas of Tanzania	Code
Social Indicators of Sustainability of Energy Access in Rural Areas of Tanzania	SOC_ISEA
Technical Indicators of Sustainability of Energy Access in Rural Areas of Tanzania	TEC_ISEA
Economic Indicators of Sustainability of Energy Access in Rural Areas of Tanzania	ECO_ISEA
Environmental Indicators of Sustainability of Energy Access in Rural Areas of Tanzania	ENV_ISEA
Institutional Indicators of Sustainability of Energy Access in Rural Areas of Tanzania	INST_ISEA

Source: Research Data (2017)

4.6.6.2 Measurement Model Analysis

The model for measuring Sustainability of Energy Access in rural areas of Tanzania was assessed by determining its convergent validity; internal reliability as well as goodness of fit. Prior to the development of the overall model, the individual model for each construct was analysed and evaluated by employing SEM. The results are presented in the subsequent sections.

4.6.6.2.1 Measurement Model Assessment for Technical Indicators of Sustainability of Energy Access in Rural Area of Tanzania

The focus of this section was on the assessment and evaluation of the fitness of indicators in the model under the category of technical indicators of measuring sustainability of energy access in rural areas of Tanzania. The indicators under the category of technical indicators are availability (the amount of energy provided from particular source of energy, reliability (measure of constant services), and the energy conversion efficiency (ability to convert from energy source to end use). Using SEM, the three indicators under this category were analysed using Confirmatory Factory Analysis (CFA) with the aid of AMOS software version 18. The research results of the model assessment of the goodness of fit are presented in Table 4.32.

Table 4.32: Assessment of Goodness of Fit Indices for Technical Indicators

				Goodness of Fit Indices							
Standard Regression (Loading Factor Values)			**Weight**	**GFI**	**AGFI**	**NFI**	**RFI**	**IFI**	**TLI**	**CFI**	**RMSEA**
TEC_3	<---	TEC_ISEA	0.87								
TEC_2	←-	TEC_ISEA	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.1
TEC_1	←-	TEC_ISEA	0.95								

Recommended Values and Ranges: GFI, AGFI, NFI, RFI, IFI, TLI and CFI close to 1, 0 ≤ RMSEA ≤ 0.1 (Field, 2013), (Hair et al. 2006), Loading Factor values ≥ 0.3 (Field, 2014)
KEY: TEC_ISEA = Technical Indicator of Sustainability of Energy Access in Rural Areas of Tanzania

Source: Research Data (2017)

The study findings in Table 4.32 show that the three indicators under technical indicators such as Energy conversion efficiency (ability to convert from energy source to end use (TEC_3), reliability (measure of constant services) (TEC_2), and energy availability (the amount of energy provided from particular source of energy (TEC_1) have Loading factor values of 0.87, 0.90 and 0.95 respectively which are greater than the minimum recommended value of 0.33. Having high value of loading factor imply that these indicators have good convergent validity and thus they are good measure of these indicators under the category of technical measure of sustainability of energy access in rural areas of Tanzania. The study findings in Table

4.32 also reveal that the model practically fits the data due to the fact all measures of goodness of fit indices are within the recommended values and ranges.

4.6.6.2.2 Measurement Model assessment for Social Indicators Sustainability of Energy Access in Rural Area of Tanzania

In order to assess the fitness of the model to indicators under the category of social measure of sustainability of energy access in rural areas of Tanzania, four indicators namely the reduction of human drudgery, acceptability of the energy sources by the indigenous rural households, the reduction of adverse effects to women and children, and the ability of the energy system to generate employment to people living in the rural areas of Tanzania were used. The study results on the model fitness of indicators under the category of social indicator which was established with the aid of AMOS software version 18 is presented in Table 4.33.

Table 4.33: The assessment of Convergent validity and goodness of fit for Social construct

Standard Regression Weight (Loading Factor Values)				Goodness of Fit Indices GFI	AGFI	NFI	RFI	IFI	TLI	CFI	RMSEA
SOC_4	<---	SOC_ISEA	0.92								
SOC_3	<---	SOC_ISEA	0.93	0.96	0.97	0.98	0.90	0.98	1.00	0.98	0.229
SOC_2	<---	SOC_ISEA	0.93								
SOC_1	<---	SOC_ISEA	0.90								

Accepted value and Ranges: GFI, AGFI, NFI, RFI, IFI, TLI and CFI close to 1, $0 \leq RMSEA \leq 0.1$ (Field, 2013), (Hair et al. 2006), Regression weights ≥ 0.3 (Field, 2014)
KEY: SOC_ISEA = Social Indicator of Sustainability of Energy Access

Source: Research Data (2017)

The study findings in Table 4.33 show that the four indicators under social indicator category namely the reduction or removal of human drudgery (SOC_1), acceptability of the energy source by the households in the society (SOC_2), the reduction of adverse effects to women and children (SOC_3), and the ability to generate employment (SOC_4) have loading factor values greater than the recommended minimum recommended value of 0.30 which indicate that these indicators are an important measure of social sustainability of energy access in rural areas of Tanzania. Additionally, the study findings under the social category of measuring sustainability of energy access in rural areas of Tanzania fit the data due to the fact that the majority of the model fit indices values are within the recommended value and range except RMSEA index which is out of range. However, in this study, the higher value of RMSEA is caused by large sample size which is used in this study and this is said to have no significant effect to the model fit (Kline, 2011).

4.6.6.2.3 Measurement Model assessment for Economic Indicators of Sustainability of Energy Access in Rural Area of Tanzania

The measurement model for economic indicators of sustainability of energy access in rural areas of Tanzania was measured using three indicators namely the percentage of rural households without electricity (ECO_1), the percentage of rural households without modern cooking facilities (ECO_2), and the percentage of rural household income spent on fuel/ electricity (ECO_3). These indicators under economic category measure of sustainability of energy access were assessed in terms of their fitness in SEM with the aid of AMOS software version 18. The study results of the assessment of the convergent validity and the goodness of fit of various indices are presented in Table 4.34.

Table 4.34: The Assessment of Convergent Validity and goodness of fit for Economic construct

Standard Regression (Loading Factor Values)			**Weight**	**Goodness of Fit Indices**							
				GFI	**AGFI**	**NFI**	**RFI**	**IFI**	**TLI**	**CFI**	**RMSEA**
ECO_3	<---	ECO_ISEA	0.94								
ECO_2	<---	ECO_ISEA	0.97	1.00	1.00	1.00	-	1.00	-	1.00	0.769
ECO_1	<---	ECO_ISEA	0.93								

Accepted value and Ranges: GFI, AGFI, NFI, RFI, IFI, TLI and CFI close to 1, $0 \leq RMSEA \leq 0.1$ (Field, 2013), (Hair et al. 2006), Regression weights ≥ 0.3 (Field, 2014)
KEY: ECO_ISEA = Economic Indicator of Sustainability of Energy Access

Source: Research Data (2017)

The results in Table 4.34 indicate that the percentage of rural households without electricity in rural areas (ECO_1) has a loading factor value of 0.93, the percentage of rural households without modern cooking facilities has a loading factor value of 0.97, and the percentage of household income spent on Modern cooking facilities or electricity has a loading factor value of 0.94. The three indicators under economic category of indicators have loading factor values greater than the minimum value of

0.30 indicating that these indicators are good measure of economic sustainability of energy access in rural areas of Tanzania because they also have good convergent validity. Additionally, the majority of the tested model fit indices as shown in Table 4.34 are within the recommended values and ranges except RMSEA which is out of range. RMSEA out of range due to the large sample size used in this study and the fewer items used to measure the construct. However, this has no significant effect to the model fit.

4.6.6.2.4 Measurement Model assessment for Environmental Indicators of Sustainability of Energy Access in Rural Area of Tanzania

The model for measuring the Environment Indicators of Sustainability of Energy Access in rural areas of Tanzania was assessed using three indicators namely the reduction in local and global environmental pollution (ENV_1), the reduction in human health damage (ENV_2) and the reduction in soil erosion (Environmental Degradation (ENV_3). The results on the convergent validity and the Goodness of fit indices for the three items under environmental indicators are indicated in Table 4.35.

Table 4.35: Assessment of convergent validity and Goodness of fit indices under environmental indicators

Standard Regression Weight (Loading Factor Values)				**Goodness of Fit Indices**							
				GFI	**AGFI**	**NFI**	**RFI**	**IFI**	**TLI**	**CFI**	**RMSEA**
ENV_3	<---	ENV_ISEA	0.93								
ENV_2	<---	ENV_ISEA	0.96	1.00	1.00	1.00	-	1.00	-	1.00	0.70
ENV_1	<---	ENV_ISEA	0.94								

Accepted value and Ranges: GFI, AGFI, NFI, RFI, IFI, TLI and CFI close to 1, $0 \leq$ RMSEA ≤ 0.1 (Field, 2013), (Hair et al. 2006), Regression weights ≥ 0.3 (Field, 2014)
KEY: ENV_ISEA = Environmental Indicator of Sustainability of Energy Access

Source: Research Data (2017)

The study findings in Table 4.35 establish that all indicators under the environmental category used for measuring environmental sustainability of energy access in rural areas of Tanzania were found to have good convergent validity and loading factor values greater than the minimum recommended value of 0.33 indicating that they are all good measure of environmental indicators of sustainability of energy access in rural areas of Tanzania. The Goodness of fit of these indicators under environmental categories was assessed using Goodness of fit indices presented in Table 4.35. The findings show that the model fit for environmental construct is good as all indices are within the recommended values and ranges with the exception of only one index called RMSEA which is out of range. The index is out of range because of fewer items used to measure the construct. However, this has no significant effect to the model fit.

4.6.6.2.5 Measurement Model assessment for Institutional Indicators of Sustainability of Energy Access in Rural Area of Tanzania

To assess the fitness of the model for measuring the institutional sustainability of energy access in rural areas, three indicators under institutional category named availability of skilled staff at local level (INST_1), the ability to protect investors and consumers of the energy source (INST_2) and the ability to control the energy source locally (INST_3) were used. The convergent validity and the goodness of fit of the model fit were tested using various indices are as presented in Table 4.36.

Table 4.36: Assessment of convergent validity and Goodness of fit indices under Institutional indicators

Standard Regression Weight (Loading Factor Values)				**Goodness of Fit Indices**							
				GFI	**AGFI**	**NFI**	**RFI**	**IFI**	**TLI**	**CFI**	**RMSEA**
INST_3	<---	INST_ISEA	0.95								
INST_2	<---	INST_ISEA	0.95	1.00	1.00	1.00	-	1.00	-	1.00	0.72
INST_1	<---	INST_ISEA	0.88								

Accepted value and Ranges: GFI, AGFI, NFI, RFI, IFI, TLI and CFI close to 1, $0 \leq RMSEA \leq 0.1$ (Field, 2013), (Hair et al. 2006), Regression weights ≥ 0.3 (Field, 2014)
KEY: INST_ISEA = Institutional Indicator of Sustainability of Energy Access

Source: Research Data (2017)

The study findings in Table 4.36 show that the three indicators under institutional indicators have loading factor values greater than the minimum recommended value of 0.33. The findings in Table 4.36 reveal further that indicators under institutional category of indicators measuring sustainability of energy access in rural areas of Tanzania fits the model because all the tested indices fall within the recommended values.

4.6.6.3 The Overall Model for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

The foregoing sections tested and assessed the individual measurement models fit from each of the five categories of indicators used in this study. In this section, the overall measurement model fit has been tested and assessed to ascertain the adequacy and fitness of a model in measuring sustainability of energy access in rural areas of Tanzania. The overall Measurement Model for measuring sustainability of energy access in rural areas of Tanzania comprised sixteen indicators. Out of sixteen indicators, four (04) indicators belong to social category; three (03) to the Technical category of indicators, three (03) to the economic category of indicators, three (03) to the environmental category of indicators, and three (03) indicators were to the institutional category.

Using the sixteen items, the overall model fit in this study was assessed using the common and widely used Model fit Indices such as CFI, TLI, IFI as well as RMSEA as recommended by Kline (2011) and Sungau (2014). The decision to use these e indices is also supported by Mcquitty (2004) who established that the common and mostly useful measure of goodness of fit indices include TLI, CFI and IFI, and RMSEA. Besides, the used indices in this study are also commonly used by other researchers due to their ability of being less sensitive to sample size. Although these indices are commonly used, it is not necessary for all indices to be within the recommended values and range for a model to be fit. If one or two of these indices fall within the recommended ranges then this guarantee for a model to be fit. Similar observation is reported by Kline (2011) who pointed out that it is unlikely to find all those fits measures, but a subset of sample of fit indices can be used to generalize the degree of the overall fitness of the developed model. The study results of fit indices of the measurement model for measuring sustainability of energy access in rural areas of Njombe and Iringa regions and other areas having similar characteristics as that of the study areas in Tanzania are presented in Table 4.37.

Table 4.37: Overall Results of model for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

Variable codes			Variable Description	Loading Factor Value	Composite reliability
SOC _4	<---	SOC-ISEA	Ability to generate employment	0.92	
SOC _3	<---	SOC-ISEA	Reduction of adverse effects to women and children	0.93	
SOC _2	<---	SOC-ISEA	Acceptability of the energy source by the society	0.93	
SOC _1	<---	SOC-ISEA	Ensure reduction/removal of human drudgery	0.90	0.96
TEC _3	<--	TEC_ISEA	Energy conversion efficiency (Ability to convert from energy source to end use	0.87	
TEC _2	<---	TEC_ISEA	Reliability (Measure of constant service)	0.90	
TEC _1	<---	TEC_ISEA	Energy availability (amount of energy provided from the available energy source	0.95	0.93
ECO _3	<---	ECO_ISEA	Amount of rural household's income spent in electricity and modern cooking facilities	0.94	
ECO _2	<---	ECO_ISEA	Number of rural households without modern cooking facilities	0.97	
ECO _1	<---	ECO_ISEA	Number of rural households without electricity	0.93	0.96
ENV _3	<---	ENV_ISEA	Reduction in soil erosion (environmental degradation)	0.93	
ENV _2	<---	ENV_ISEA	Reduction in human health damage	0.96	0.96
ENV _1	<---	ENV_ISEA	Reduction in local and global environmental pollution	0.94	
INST _3	<---	INST_ISEA	Ability to monitor and control energy source locally	0.96	
INST _2	<---	INST_ISEA	Ability to protect the consumer and investor of energy	0.95	
INST _1	<---	INST_ISEA	Availability of skilled staff	0.88	0.950

Achieved indices in the Measurement Model

CFI	**IFI**	**TLI**	**RMSEA**	**Loading Factor Value**
0.90	0.90	0.86	0.10	>0.70

Source: Research Data (2017)

The study findings in Table 4.37 show that the sixteen items categorized into social, technical, economic, environmental, and institutional indicators have the loading factor values greater than the minimum accepted value of 0.30 indicating that these indicators are important in measuring sustainability of energy access in rural areas. The study findings in Table 4.37 show further that the tested goodness of fits indices such as Comparative Fit Index (CFI), Tucker Lewis Coefficient (TLI), Incremental Fit Index (IFI) and the Root Mean Square Error of Approximation (RMSEA) were found to be:

$\chi^2 = 810, df = 94, (\chi^2/df) = 8.617, NFI = 0.89, CFI = 0.904, TLI = 0.860, IFI = 0.905 and RMSEA = 0.10$ which are within the recommended range and values. This indicates that the developed model is good for measuring sustainability of energy access in rural areas of Tanzania. Thus, the provision of sustainable energy sources for cooking or lighting in order to improve their standard of living in rural areas of Tanzania should take into consideration social, technical, economic, environmental, and institutional categories of indicators.

Following the completion of testing the overall goodness of the model fit indices and their convergent validity the overall model confirmed using CFA. This study also presents graphics developed with the aid of AMOS software Version 18 showing loading factor values of each indicator and the Squared Multiple Correlation Coefficinet (R^2) of each variables in a model. The developed model is presented in Figure 4.8.

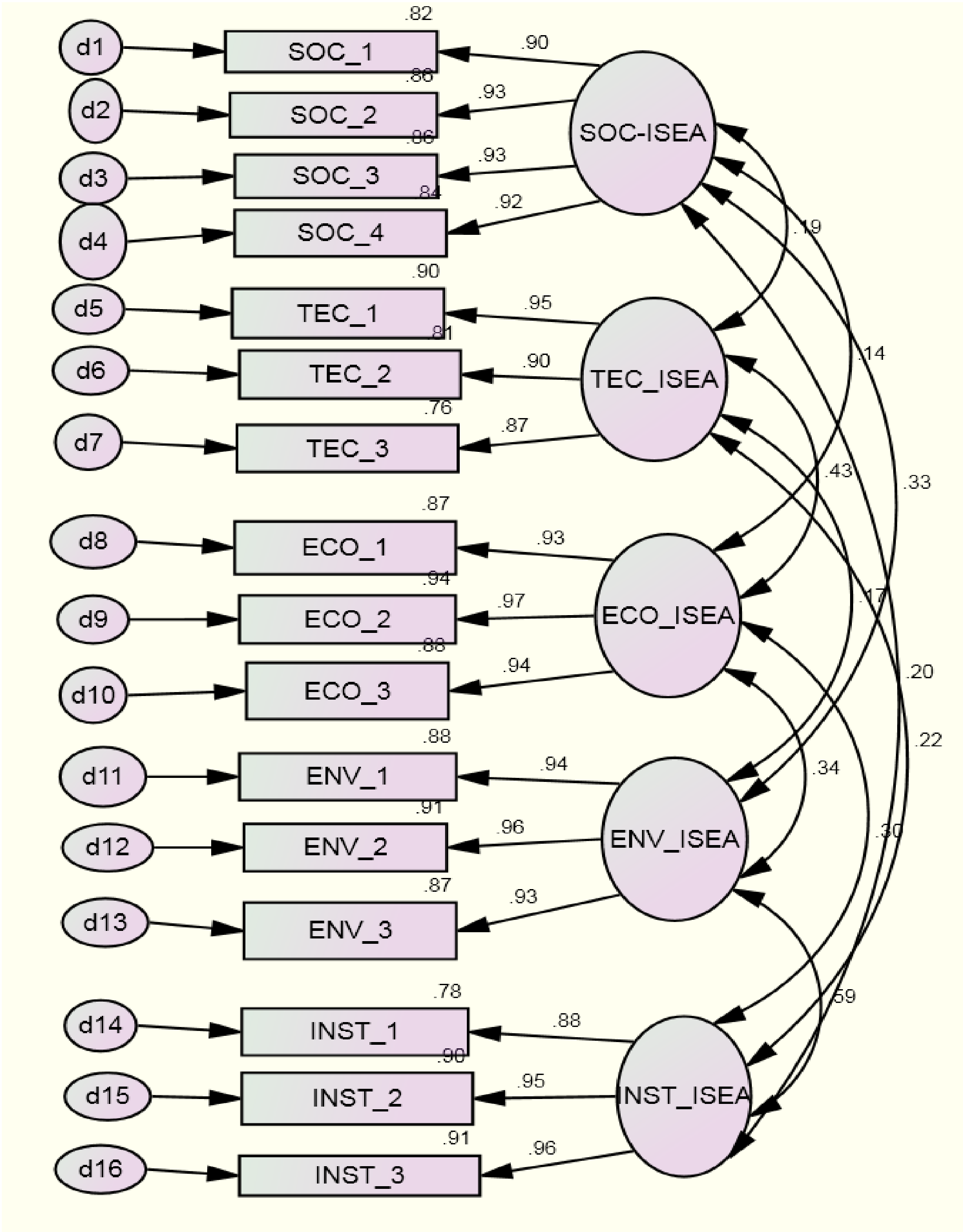

Figure 4.8: Model for measuring Sustainability of Energy Access in Rural Areas of Tanzania

Source: Research Data (2017)

The presented model in Figure 4.8 shows that the indicators under social category of measure of sustainability of energy access in rural areas of Tanzania namely the reduction or removal of human drudgery, acceptability of the energy source by the society, the reduction of adverse effects to women and children, and the ability to generate employment to households in the society have loading factor values greater than the minimum accepted value of 0.30. These results imply that these indicators are important and useful in measuring the social sustainability of energy access in rural areas of Tanzania.

Similarity, the findings in Figure 4.8 depict that the Squared multiple correlation coefficient (R^2) value of the four items namely the reduction or removal of human drudgery (SOC_1), acceptability of the energy source by the society (SOC_2), the reduction of adverse effects to women and children (SOC_3), and the ability to generate employment to households in the society (SOC_4) are 0.82, 0.86, 0.86 and 0.84 respectively. The value of R^2 under social category of indicators implies that 82% of the variance in social indicator is explained by the reduction or removal of human drudgery, while 86% of the variance in social indicator is explained by acceptability of the energy source by the society and the reduction of adverse effects to women and children each, and 84% of the variance in social indicator is explained by the ability to generate employment to people living in rural areas of Tanzania.

Furthermore, the study findings in Figure 4.8 show that the three indicators under technical category of indicators measuring sustainability of energy access in rural areas of Tanzania namely Energy availability (amount of energy provided from the available source of energy (TEC_1), reliability (Measure of constant service, and the energy conversion efficiency (ability to convert the energy source to end use) have loading factor values greater than the recommended minimum value of 0.30 indicating that these indicators are important measures of technical sustainability of energy access in the rural areas of Tanzania. Correspondingly, the squared Multiple correlation coefficient (R^2) for the three indicators named energy availability (amount of energy provided from the available source of energy, reliability (Measure of constant service), and the energy conversion efficiency are 0.9, 0.81 and 0.76

respectively. These findings indicate that 90% of the variance in technical indicator category is explained by availability (amount of energy provided from the available source of energy, 81% of the variance in technical indicator is explained by reliability (Measure of constant service, and 76% of the variance in technical indicator category is explained by energy conversion efficiency.

Besides, the study findings in Figure 4.8 establish that the three indicators under economic category namely the percentage of rural households with no electricity (ECO_1), the percentage of rural households without modern cooking facilities (ECO_2), and the percentage of household's income spent on fuel /electricity (ECO_3) have loading factor values greater than the minimum recommended values of 0.30. These findings imply that the abovementioned indicators are important in measuring economic sustainability of energy access in rural areas of Tanzania. Moreover, the study findings show that 88% of the variance in economic sustainability of energy access is explained by the percentage of rural households without electricity, 94% of the variance is explained by the percentage of rural households without modern cooking facilities, and 87% of the variance is explained by the percentage of household income spent by rural households.

Similarly, the study findings in Figure 4.8 show that the loading factors for the three indicators under environmental sustainability of energy access in rural areas is greater than the minimum recommended value of 0.30 indicating that they are important and useful in measuring the environmental sustainability of energy access in rural areas. Likewise, the findings in Figure 4.8 show that 88% of the variance in environmental sustainability of energy access is explained by the reduction in local and global environmental pollution, 91% of the variance in environmental sustainability is explained by the reduction in human health damage, and the reduction in soil erosion explains 87% of the variation in the environmental sustainability energy access in rural areas.

Regarding the institutional indicators of sustainability of energy access in rural areas, the results in Figure 4.8 establish that three indicators related to technical sustainability of energy access have loading factors greater than the minimum value of 0.3 indicating that they have significant contribution to the model and they are important in measuring the institutional sustainability of energy access in rural areas. Equally, the study findings in Figure 4.8 indicate further that 76% of the variance in the institutional sustainability of energy access is explained by availability of skilled staff, 90% of the variance is explained by the ability to protect consumers and investors of the available energy source, and 91% of the variance in the institutional indicator is explained by the ability to monitor and control the energy source locally. Generally, the findings in Figure 4.8 indicate that sustainability of energy access in rural areas is measured using technical, social, economic, environmental, and institutional indicators.

CHAPTER FIVE

DISCUSSION OF RESEARCH FINDINGS

5.1 Introduction

This chapter presents the discussions of the findings based on research objectives. The chapter begins by presenting the discussion on the demographic characteristics of the respondents. Thereafter, the discussions of study findings on the indicators of energy access, factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania, the indicators of sustainability of energy access in rural areas of Tanzania and finally the model for measuring sustainability of energy access in rural areas of Tanzania. The discussions of the study findings focus on answering the main question, “How can sustainability of energy access in rural areas of Tanzania be measured using measurable indicators.”

5.2 Demographic Characteristics of Respondents

The demographic characteristics of respondents used in this study were age, level of education, sex, marital status, occupation, household size and the average monthly income of people living in rural areas of Tanzania. In determining the level of education, the study findings revealed that majority of the respondents had primary education. This is primary because of the national educational policy of ensuring that universal ordinary education level is provided to all Tanzanian citizens. The research findings also revealed that few respondents had secondary and college education. Small number of rural households had higher level of education because educated people prefer living in urban areas than in rural areas. Only educated respondents who were employed as education officers teaching in primary schools and ward secondary schools were found in the rural areas of Tanzania.

Regarding the age of the respondents, the findings showed that many respondents were in age ranging from twenty-five to sixty years. A possible explanation for this may be because people of these ages are termed as working age group in Tanzania and more importantly, majority of people in this age category have already assumed the responsibility of taking care of the family. The working age is the major consumers of various sources of energy for cooking or lightings in rural areas of Tanzania. Regarding marital status, the study findings revealed that majority of the respondents were married while few of them were either widowed or not married. The presence of large number of married respondents indicates that majority of the respondents are mature and have families that are the major users of energy sources for cooking and lighting in rural areas of Tanzania.

Regarding sex of the respondents, the findings revealed that female heads of households were many when compared to male heads of households. These findings imply that females are the main users of energy sources for cooking or lighting than is the case with males in the rural areas of Tanzania. The other possible explanation for these findings is that the majority of the domestic activities such as cooking, collection of firewood or charcoal for domestic uses are done by women and children more than by males in many parts of rural areas of Tanzania. The presence of large number of females in this study is consistent with the findings reported in a study by of Adeyemi and Adereleye (2016) which also revealed that many females in the sample indicates that females are highly involved in using these sources of energy such as firewood, charcoal, or electricity for cooking or lighting in a particular nation or community.

Regarding occupation of the respondents, the findings revealed that majority of the people in rural areas of Njombe and Iringa regions of Tanzania deal mainly with agricultural activities. Few of them engage in livestock keeping business while few of them have been employed by the Government of the United Republic of Tanzania in various sectors such as education and health. Farming activities were found to be the dominant activities because Njombe and Iringa regions are the backbone of national economy of Tanzania. Concerning the average monthly income of the respondents, the study findings revealed that majority of the respondents have average low monthly income. These study findings imply that majority of the people in rural areas of Njombe and Iringa regions are relatively poor and thus they cannot afford to procure modern and sustainable sources of energy for cooking or lighting purposes and that is why they continue relying on traditional sources. These findings confirm the Energy Ladder theory guiding this study which stipulates that an average person tends to shift from traditional and unsustainable sources of energy to modern and sustainable sources of energy capable of bringing positive social, environmental and economic impact to livelihood of people as the level of income increases.

Regarding household size, the findings reveal that majority of the rural households in Tanzania had family members ranging from one to eight people. These findings imply that many of the respondents' households have large family sizes. Large family sizes by the majority of people living in rural areas of Tanzania imply an increased probability of the demand on the use of traditional sources of energy for cooking such as firewood or charcoal because of their availability and affordability.

5.3 The Indicators of Energy Access in Rural Areas of Tanzania

This section presents the discussions of the study findings on indicators of energy access in rural areas of Tanzania. In determining the indicators of energy access in rural areas of Tanzania, the study findings revealed that the indicators were affordability, easy to use, availability, durability, economical, non-emission of smoke, efficiency and the ability to keep the cooking pot clean. In the light of these findings, this study deduces that the determined indicators of energy access are of importance in measuring energy access in rural areas of Tanzania. Effective and efficient use of these indicators contributes to improving the standard of living as well as social, environmental, and economic development of the people dwelling in rural areas of Tanzania. For example, the respondents insisted on the importance of affordability as an indicator of energy access in rural areas by pointing out that energy sources should be affordable such that every household member in rural areas can be able to purchase such energy sources for cooking or lighting purposes. The respondents added that the price of solar power as a source of energy for lighting or installation costs for electricity should be cheap enough for any member of household with low income level to afford.

The durability of energy source or system has been reported in this study as an important indicator of energy access in rural areas of Tanzania. It was established in this study that the respondents required to be supplied with energy sources such as solar panel, solar battery or gases which were durable, capable of being used for a long period of time before they fail or break down. It was further established by the respondents that durability of energy sources improve efficiency and at the same time saves operating and maintenance costs. Saving costs therefore help in reducing the percentage of income rural households spend in acquiring modern cooking energy sources.

Apart from durability and affordability, the findings revealed that availability is also an indicator of energy access in rural areas of Tanzania. The study findings established further that for any energy source to be accessible it must first be available in the place and at the time when it is needed. The energy sources should be placed in the same geographical location of the customers. Household members from the study established that shops for selling electricity and gas should be near to their place of domicile and they should be available all the time as well. Energy access availability was found to reduce the cost in terms of money and time to seek for energy sources in distant places.

The study findings regarding indicators of energy access also indicated that easiness of use of particular energy source is an important indicator of energy access in rural areas of Iringa and Njombe regions of Tanzania. The most interestingly study findings regarding easiness to use was that the respondents required the energy system such as gas and electric devices to be made with simple technology such that even those people with low level of education can use them comfortably without any problem. Easiness to use as an indicator of energy access reduces problems such as accident or losses of energy and time. Another important finding of the current study on indicators of energy access was the cleanliness of energy sources for cooking and lighting. It was revealed that energy access must be able to keep the cooking utensils clean after being used. Additionally, the current study also found out that emission of smokes is also an indicator of energy access. In this aspect, the respondents required that the energy source should not produce smoke as these pollutants cause damage to human health and to the environment.

It is interesting to note that some of the findings in this study regarding indicators of energy access are also reflected in the previous studies. For example, a study by Sudhakara (2015) on access to modern energy service revealed that energy access is measured using various indicators such as availability, affordability and reliability of energy sources for either cooking or lighting purposes. Besides, the findings of the present study confirm further the study by Mensah (2014) on energy access trends in Ghana which revealed that affordability is an important indicator of energy access and it has a direct link with improved level of income. Thus, being able to afford to modern source of energy contributes to the improvement of the standard of living of rural household members. Moreover, the study findings of the present study are also in line with the findings of a study by Suan and Jose (2013) on energy access, a lesson from Brazil and perspectives for replication in other developing countries which reported that social and economic development of the people in a given nation or community is realized through the provision of affordable and reliable energy sources for cooking, heating or lighting purposes.

Surprisingly and interestingly is that some of the findings of the current study are not reflected in the previous studies. Although, the majority of previous studies revealed that availability, affordability, and reliability are the major indicators of energy access, the findings of the current study provide an insights on other indicators such as easiness to use, lasting longer, non-emission of smoke and the ability to keep the cooking pot clean. The absence of empirical evidence on these indicators in the previous studies is due to several reasons. Firstly, the majority of previous studies focused on energy access in urban areas, leaving the rural areas uncovered, but these areas have more energy access problems than is the case with uraban areas. Secondly, majority of the previous studies covered only electricity in assessing energy access leaving facilities such as firewood and charcoal for cooking and lighting unattended. The findings of the current study therefore confirm that apart from availability, affordability, and reliability, indicators such as no production of smokes, easiness to use and to keeping cooking pots clean should be taken into consideration in measuring energy access in rural areas of Tanzania for the purpose of improving the social economic development and livelihood of the people.

5.4 Factors Determining the Choices of Energy Sources for Cooking in Rural Areas of Tanzania

This section presents the discussions on the types of energy sources and factors determining the choices of energy sources for cooking in rural areas of Iringa and Njombe regions in Tanzania. In determining the energy sources used for cooking in rural areas of Tanzania, the findings revealed that people in rural areas of Tanzania use a mix of energy sources for cooking purposes ranging from firewood, charcoal, Liquefied Petroleum Gas (LPG) to electricity. More importantly, the study findings indicate that firewood is the dominating source of energy used for cooking by majority of people in rural areas of Njombe and Iringa regions followed by charcoal, Liquefied Petroleum Gas (LPG) and electricity.

The increased use of firewood as a source of energy for cooking in rural areas of Tanzania is influenced not only by its availability of forest, but also poverty among rural households which making majority of them to fail to afford to procure modern sources of energy such as electricity and Liquefied Petroleum Gas. The findings in this study correspond with the findings in a study by Abdullahi (2017) who found that continued use of solid fuels such as firewood for cooking by people in rural areas is influenced by availability and affordability of the energy as well as the prevalence of incidence of poverty among the people in rural areas of Tanzania. Conversely, the study findings revealed that Electricity and Liquefied Petroleum Gas are used by few people for cooking purposes not only because they are not available and also not affordable. The high cost of installation, operating costs and lack of training on how to use modern cooking stoves significantly contribute to low usage of electricity and Liquefied Petroleum Gas (LPG) in rural areas of Tanzania.

Regarding the factors determining the choices of energy sources for cooking in rural areas of Tanzania, the study findings indicate that age of the heads of households in rural areas of Tanzania has positive coefficient values for charcoal, firewood and Liquefied Petroleum Gas (LPG). These study findings imply that the use of charcoal, firewood, and Liquefied Petroleum Gas (LPG) as a source of energy for cooking over electricity in rural areas of Tanzania increase as the age of the respondents increase. Thus, the study findings imply that the use of charcoal, firewood, and Liquefied Petroleum Gas (LPG) over electricity for cooking purposes is highly preferred by adult heads of households as opposed to young heads of households in rural areas of Tanzania. Aged people prefer to use firewood and charcoal over electricity not only because of its affordability but also due to the availability of forest for firewood and charcoal making in rural areas of Tanzania.

These findings correspond with the findings in a study by Nnaji, Ukwueze and Chukwu (2012) who pointed out that older household members prefer to use charcoal or firewood than electricity because of its affordability and availability in rural areas of the country. Similarly, the affordability and availability of forests for firewood collections triggers individuals into using firewood or charcoal than electricity for cooking purposes. The increased use of traditional sources of energy such as firewood and charcoal for cooking purposes over electricity by rural heads of households in Tanzania in this study confirm the study conducted by Dil Bahadur *et al.* (2017) who revealed that an increase in the age of the respondents increases the likelihood of choosing sources of energy such as firewood as opposed to other commercial sources of energy such as electricity. Apart from corresponding with previous study, the study findings also concur with the theoretical expectation that increase in the age of the household forces these people into using firewood or charcoal for cooking purposes due to availability and affordability as opposed to electricity in rural areas.

However, the study findings contradict with the findings of a study by Assa, *et al.* (2015) which revealed that an increase in the age of the heads of household decreases the probability of using firewood or charcoal for cooking over electricity implying that as heads of household become older, their physical strength decreases and thus it becomes difficult for them to collect or gather firewood at distant places from their place of domicile. Again, the contrast in the findings between this study and that of Assa, *et al.* (2015) is because the later was conducted in the urban areas where traditional sources of energy for cooking are not available; as a result, heads of households are forced into using alternative sources of energy.

Regarding household size, the findings of this study show that household size has a positive coefficient for both charcoal and firewood but has a negative coefficient value for Liquefied Petroleum Gas (LPG). As it was theoretically expected, the study findings inform that the likelihood or the probability of using firewood and charcoal as opposed to electricity for cooking purposes increase as the household size increase in the rural areas of Tanzania. The possible explanation of this is that larger households prefer to use firewood or charcoal because it is comparatively cheaper for many people due to its low energy consumption per unit than Liquefied Petroleum Gas (LPG) or electricity. The other possible reason is that large family size implies larger man powers that are capable of collecting firewood in the place of their residence. Similarly, larger family size also may require large amounts of energy for cooking which has cost implication. Therefore, poor status of majority of household members in rural areas forces them to switch to firewood and move away from electricity and gas which are more expensive than firewood.

The study findings correspond with the findings of a study by Pundo and Fraser (2006) which revealed that it is cheap to use firewood for cooking when you have large family because the cost of acquiring other sources of energy such as electricity or Liquefied Petroleum Gas is higher compared to firewood or charcoal. These findings also confirm the theoretical expectation that larger family size would prefer to use firewood for cooking as it is somehow cheaper when cooking using firewood for many people due to affordability and availability of firewood in the places of their domicile. Conversely, the findings of the present study on household size are in contrast with the findings in a study done by Ouedraogo (2005) which showed that small size families unlike larger sized families prefer to use charcoal as a source of energy for cooking. The reason for this is because as a study by Ouedraogo (2005) indicates, charcoal was found to be preferred by households with fewer family members than those with larger size family members. The findings of this study also show that household size has a negative coefficient value on Liquefied Petroleum Gas (LPG) implying that the use of Liquefied Petroleum Gas (LPG) as a source of energy for cooking in rural areas of Tanzania decrease as household size increases.

Occupation of the respondent in this study was found to have a positive coefficient value for charcoal and Liquefied Petroleum Gas (LPG) and a negative coefficient value for firewood implying that the use of charcoal or Liquefied Petroleum Gas (LPG) changes with changes in the occupation of the respondents. Therefore, on the one hand, the study findings indicate that heads of households engaging in agricultural activities have low level of income and thus they rely on firewood as their sources of energy for cooking in rural areas of Tanzania. On the other hand, the study findings indicate that heads of households who are employed in the public sector prefer to use modern sources of energy such as electricity. Employed heads of households have higher earnings which help them to procure modern and sustainable sources of energy such as electricity and Liquefied Petroleum Gas (LPG) while heads of households who engage in farming activities continue to use traditional sources of energy. Therefore, these findings of the present study correspond with the findings in a study by Couture *et al* (2012) which established that self-employed heads of households dealing with farming and livestock keeping activities use traditional energy sources such as firewood and crop residue as their major energy sources for cooking because of having low and unstable sources of income. Rural heads of households y use firewood as a source of energy for cooking in Njombe because of availability, affordability, and convenience of obtaining planted and natural forests in rural areas of Tanzania. Consistently, the findings of the present study are consistent with the findings of a study by Adeyemi and Adereleye (2016) which indicate that rural households that are engaged in farming activities use traditional sources of energy while those working in the formal sectors use modern, cleaner and efficient source of energy for cooking such as Liquefied Petroleum Gas (LPG) and electricity.

The study findings on education level and the choices of energy sources revealed that education level of heads of households has a positive coefficient value for both Charcoal and Liquefied Petroleum Gas (LPG) but a negative coefficient value for firewood. These findings imply that the use of firewood as a source of energy for cooking over electricity in rural areas of Tanzania decrease as the level of education increase. The possible explanation of these findings is that educated people are aware on the effects of using traditional sources of energy such as firewood for cooking on the environment. In order to ensure that the environment and human health are well protected, educated heads of households opt for clean and sustainable sources of energy such as electricity or Liquefied Petroleum Gas (LPG) as sources of energy for cooking. These findings also suggest that educated heads of households are less likely to engage in using traditional source of energy, hence they reduce environmental degradation through deforestation in the process of searching for firewood.

These findings of the present study are also in line with the findings in a study by Johanna and Leonard (2017) which revealed that household members with the highest level of education are more likely to use clean fuels as their main cooking fuels than households without primary education or with only primary education. Similarly, the findings of the present study also comply with the findings of a study by Adeyemi and Adereleye (2016) who revealed that if all factors are held constant, heads of households with more education are likely to switch to modern sources of energy which also conform to the theoretical assumption that household with more education usually demand for modern sources of energy such as electricity.

Regarding the average monthly income, the study findings indicated negative coefficient values for charcoal, firewood, and Liquefied Petroleum Gas (LPG). These study findings indicate that the use charcoal, Liquefied Petroleum Gas (LPG), and firewood for cooking over electricity in rural areas of Tanzania decrease as the average monthly income of heads of households increase. These findings imply that heads of households in rural areas of Tanzania shift from traditional and un-sustainable sources of energy to modern, clean and sustainable sources of energy as their level of income increase. People from rural areas with higher level of income consider firewood as energy sources for poor people. These findings confirm the energy ladder theory guiding this study which states that an individual will shift from traditional, unclean sources of energy for cooking to modern, clean and sustainable sources of energy as the level of income increase.

Apart from confirming the theory, the research findings of the present study on income correspond with the findings by Nyembe (2011) who pointed out that people with low level of income prefer to use traditional sources of energy because apart from being available they are affordable. These findings concur with the findings in a study by Stephen (2011) who revealed that poor heads of households are the main users of firewood as opposed to other sources of energy, while rich heads of household switch from unclean to clean source of energy such as electricity or gas. a decrease in use of traditional sources of energy for cooking purposes also supports the existing national environmental policy which discourages cutting down of trees for the purpose of getting charcoal as has detrimental effects to the environment including soil erosion and environmental pollution.

However, the findings of the present study are in contrast with the findings in a study by Mekonen and Kohlin (2009) who established that the use of charcoal for cooking among people in rural areas decrease as their level of income increase. The contrast between the findings in this study and the previous study emanate because the previous study employed only two types of energy sources namely firewood and charcoal in their study. In a study by Mekonen and Kohlin (2009), charcoal was considered cleaner than firewood because the former cannot produce smokes and also leaves the cooking pot clean after use.

Additionally, a decrease in the use of Liquefied Petroleum Gas (LPG) over electricity as the level of income increases among rural household in Tanzania is attributed to shortages of gas cylinders in the rural areas and lack of training on how to use cooking gas. Heads of households from Iringa and Njombe regions reported that lack of training and non-availability of gas in the shops are among the factors hindering the usage of LPG for cooking in rural areas of Tanzania.

5.5 Factors Determining the Choices of Energy Sources for Lighting in Rural areas of Tanzania

This section presents the discussions on the types of energy sources used for lighting and factors determining its choices in rural areas of Tanzania. In determining the energy sources for lighting purposes in rural areas of Tanzania, the findings reveal that solar power is the major source of energy used by people for lighting in rural areas of Njombe and Iringa regions in Tanzania. The increase in the use of solar power as a source of energy for lighting over other sources such as kerosene or electricity is due to its affordability, availability, and not being able to produce smokes as well as people's inability to purchase and pay for other expensive sources of energy for lighting including electricity.

The increased use of solar power for lighting purposes in rural areas of Tanzania indicated in the current study correspond with the findings in a study by Irene (2013) which revealed that majority of the households living in rural areas of Kenya are not connected to national electricity grids and therefore they mainly rely on solar energy for lighting at their homes not only because it is affordable and safe but also because of solar does not produce smoke. The other possible reason is that solar power does not cause harmful effects to human health and to the environment. In this study, the respondents confirmed further that using solar power is cheaper than electricity as it requires only the initial installation costs as opposed to electricity which demands for monthly bill. The research findings in this study indicate less usage of electricity, kerosene and torch as sources of energy for lighting in rural areas of Njombe and Iringa regions in Tanzania. Majority of the people in the study areas have nowadays switched away from kerosene because of its high price, and the large amount of smokes it produces which ultimately cause harmful effects to human health and to the environment.

Regarding the factors determining the choices of energy sources for lighting in rural areas of Iringa and Njombe regions of Tanzania, the findings revealed that factors such as education level, age, occupation, household size, and household income have positive coefficient values for electricity, kerosene, and solar power. This implies that the choice of electricity or kerosene or solar power as a source of energy for lighting over solar torch increase as education level, age, income, occupational changes and household size of the respondents increase. These findings support the energy transition theory which states that an individual uses multiple sources of energy for lighting given various factors. The increased use of kerosene by older people implies that older heads of households cannot afford to pay bill for other modern sources of energy such as electricity for lighting in rural areas of Tanzania.

The findings of the present study are supported by the findings in a study by Ouedraogo (2006) which elaborated that the household with old age switches to traditional sources of energy instead of the modern energy sources for lighting. The occupations of the respondents were also found to influence the choice of energy source for lighting. Those heads of household who work in the highly paying sectors prefer to use modern sources of energy such as electricity and solar power while those working in farming sectors and with low earning use traditional source of energy such as kerosene for lighting despites its harmful effects to human health and to the environment.

The findings also revealed that the average monthly income of the heads of the household was also found to influence the choices of energy source for lighting in rural areas of Njombe and Iringa regions of Tanzania. The findings revealed further that heads of households with higher income prefer to use clean and efficient sources of energy such as solar power and electricity instead of kerosene for lighting. These study findings support the findings of the previous study by Samuel (2008) which showed that the likelihood of choosing the modern source of energy for lighting increases as the heads of household income increases. The findings also concur with the findings of Farsi *et al.* (2007) which showed that heads of household with high income level switches from traditional to modern source of energy because modern energy sources such as electricity and solar power for lighting. Electricity and solar power are perceived to be more superior, efficient, comfort and easy to use than kerosene.

5.6 The Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

This section presents a discussion on the indicators of sustainability of energy access in rural areas of Njombe and Iringa regions-Tanzania. In determining the indicators of sustainability of energy access in rural areas of Tanzania, descriptive study findings showed that institutional indicators ranked first followed by environmental indicators. The majority of the respondents from rural areas of Tanzania agreed or strongly agreed that institutional indicators are very crucial to policy maker, government, or energy stakeholders in ensuring that there are sustainable energy sources for cooking or lighting in rural areas of Tanzania. The findings also revealed that rural households in Iringa and Njombe regions of Tanzania agreed or strongly agreed on the inclusion of social aspects when measuring sustainability of energy access in rural areas of Tanzania. Other revealed indicators of sustainability of energy access in rural areas of Tanzania include; economic and technical indicators. In this regard, the findings imply that the indicators of sustainability of energy access in rural areas of Tanzania are social, institutional, environmental, economic and technical.

The findings of this study are also reflected in the previous studies. For example, Swati *et al.* (2015) in a study on Benchmarking sustainability indicators in India showed that social, economic, and environmental indicators are very important and useful in ensuring that there is the provision of sustainable energy access. Besides social, economic and environmental indicators, this study added two indicators namely technical and institutional which were not captured in previous studies including that of Swai *et al.* (2015). The inclusion of technical and institutional indicators in this study is proven to be useful in measuring the sustainability of energy access in rural areas as it was recommended by Mainali (2014).

The use of SEM through Confirmatory Factor Analysis (CFA) also revealed that all five indicators named, institutional, social, environmental, economic, and technical were found to be useful in ensuring energy sources are provided in a sustainable way. More specifically, the findings of this study showed that indicators such as the reduction or removal of human drudgery, acceptability of the energy source or system by the household in rural areas, the reduction of adverse effect to women and children, as well as the ability to generate employment to rural households are important components under social category of indicators measuring sustainability of energy access in rural areas of Tanzania.

In addition, social sustainability of energy access in rural areas of Tanzania requires energy sources for lighting to be able to provide maximum social benefits to rural households in Tanzania such as increased number of jobs and employment to household members. As a result, the introduction of energy source or system and the health benefit to the end user were among important aspects to household members when addressing the social sustainability of energy access in rural areas of Tanzania. The findings on social sustainability of energy access also implied that energy system for use in rural areas of Tanzania should be safe. The respondents argued that the energy system should not cause damage to human health and to the environment at the time when they are used for cooking or lighting purposes.

These findings are also consistent with findings reported in the previous scholarly works. For example, Mainali (2014) in a study on using sustainability index to assess energy technologies for rural electrification reported similar findings that the ability to generate employment to households, acceptability of the system to the society as well the reduction of harmful impact to women and children as important factors to be considered under social category of indicators measuring sustainability of energy technology for rural electrification. These findings imply that social consideration in the provision of sustainable energy access should focus on meeting the needs of the current generation without endangering the future generation.

Moreover, the findings of this study confirm the findings in a study by Insah and Bhattacharyya (2015) on Sustainable development index- A multi-dimensional indicators for measuring sustainable energy development which revealed that sustainability of energy access addresses the distribution and acceptability of energy supply as well equal distribution of the energy system among household members in the society. Accordingly, the study findings imply that generation of employment to rural households plays a crucial role in ensuring social sustainability of energy access in rural areas of developing countries including Tanzania.

Regarding the institutional indicators of sustainability of energy access in rural areas of Tanzania, the findings showed that all indicators such as availability of skilled labour at local level, the ability of the available energy system or source to protect the consumer and investors, and the ability of the energy source or system to be controlled by indigenous rural households were found to be important and were ranked high by the respondents in this study. These findings imply that the provision of sustainable energy access in rural areas should take into consideration the technical and skilled labour at local level instead of using the skills from external sources and thus reducing unnecessary shut down of the system, waiting time, and operating costs. These findings imply further that institutional sustainability of energy access requires the system to be owned locally and both investors and users of the system should have control over the system. In addition, members at household level in that society should be trained on how to operate the energy system in a sustainable way so as to improve the livelihoods of household members.

The findings of this study confirm the recommendation revealed in a study by Insah and Bhattacharyya (2015) and that of Ilskog (2008) that measuring sustainability of energy access in rural areas of Tanzania should include technical and institutional apart from social, economic, and environmental indicators when measuring sustainability of energy access. However, the inclusion of institution and technical indicators for assessing the sustainability of energy access in this study contradicts the findings of previous studies (see for example, Gosen *et al.*, 2013; Khalili and Duecker 2013) which revealed that sustainability of energy access is mainly measured by economic, social, and environmental indicators leaving technical and institutional indicators unaddressed. The possible explanation may be that the previous studies were not conducted in rural areas. The inclusion of technical and institutional indicators is very important in the present study because model fit indices in the model showed that these indicators have high contribution (high Goodness of Fit Indices values which are close to 1) in ensuring energy sources are provided in a sustainable way. The use of technical and institutional indicators in rural areas was also suggested by Mainali (2014) on assessing the sustainability of energy access in developing countries.

Regarding the technical indicators, the findings in this study show that technical indicators are useful in measuring the sustainability of energy access in rural areas of Tanzania of Njombe and Iringa regions. These findings imply that technical sustainability of the energy access requires the energy to be available for use by the household all the time, the energy system should be capable of providing the energy service with minimum or no failure at all. Additionally, the findings of this study imply that the energy system should be easily converted from the source to the end user for sustainable use.

These findings are consistent with findings of the previous study by Mainali and Silveira (2015) which showed that reliable and efficient energy supply are some of the important factors within the technical dimension in assessing the sustainability of any energy system. The study findings are also in line with the findings in a study by Bhattacharyya (2015) which insisted on the inclusion of technical indicator in assessing the sustainability of energy access. However, the study findings are in contrast with the findings in a study by Swati *et al.* (2015) which captured only social, economic and environmental aspects in assessing the sustainability of energy access. The possible explanation could be because the present study focused on the rural households whereby technical skills among the rural households are very important in enhancing the rural sustainability of energy access.

Apart from social, technical and institutional indictors, the study findings revealed that economic and environmental factors are important indicators in measuring sustainability of energy access in rural areas of Tanzania. Factors such as the reduction in local and global environmental pollution, the reduction in human health damage and the reduction in soil erosion are among the important variables to be captured under environmental indicators of sustainability of energy access. The findings revealed further that the percentage of household without electricity, fuel, or modern cooking facilities and the percentage of household income spent on fuel or electricity are also important aspects to be addressed under economic indicators of sustainability of energy access in rural areas of Tanzania.

These study findings imply that in order to ensure the provision of sustainable energy access among household members in the rural areas of Tanzania, the important economic factors to consider should be the reduction of cost of purchasing particular source of energy which is to be used for either cooking/heating or lighting. This has an implication also on the portion of income of household members which is to be used for buying either electricity or any other cooking fuel. The lower the amount of income spent on fuel/electricity consumption the higher the sustainability of the energy system. Thus, the energy system should be economically affordable to even household members with low incomes. Moreover, the findings revealed that economic indicators have a lot to do with the percentage of household without electricity and also those without modern cooking facilities. Implicitly, the energy access is said to be economically sustainable if the percentage of household members without electricity or cooking/lighting facilities is also low.

Similarly, the findings imply further that in order to enhance the provision of sustainable energy access in rural areas, environmental indicators should focus on preventing or reducing the local, global environmental pollution and reduce the human health damage among the household members dwelling in the rural areas. The other aspect to be considered under environmental dimension is the reduction of soil erosion and other environmental degradation during provision of energy among the household members.

The importance of economic and environmental indicators in assessing the sustainability of energy access in rural areas is also reflected in the previous research works. For example, Bhattacharyya (2012), Ilskog (2008), and Mainali et al. (2014) and Musango (2011) emphasized on the economic, environmental as well as social indicators in assessing the sustainability of energy access. according to these studies, in order to meet the needs of the current households without compromising the livelihood of the future generation, the available energy system should be economically, socially, environmentally, technically as well as institutionally sustainable for economic development.

The essence of incorporating economic and environmental indicators in assessing the sustainability of energy access as revealed in the findings of this study is also confirming the study done by Ivan and Kathleen (2005) on energy indicators to assess sustainable development at the national level in South Africa. The cited study emphasized that in order to ensure sustainable development; the energy access should be provided adequately and should consider the environmental aspects as well as social economic factors in improving the livelihood of household members in the society. Thus, the provision of energy to household members should be environmentally friendly and it should also conform to social and economic performance for sustainable development and improve the standard of living of household members in rural areas.

5.7 Model for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

The study findings regarding the model for measuring sustainability of energy access in rural areas of Tanzania show that loading factors for all sixteen items were found to be high ranging from 0.87 to 0.97. These findings imply that all indicators in the model are important measure of sustainability of energy access in rural areas of Tanzania. The findings of this study are consistent with those of Hair *et al.* (2006) who established that the loading factor values of 0.6 imply very good while 0.7 and above imply excellent. Apart from the loading factors, the fitness of the developed model was assessed using model fit indices such as Comparative Fit Index (CFI), Tucker Lewis Coefficient (TLI), Incremental Fit Index (IFI) as well as Root Mean Square Error of Approximation (RMSEA). The use of IFI, CFI, TLI and RMSEA fit indices in measuring the Goodness of model fit is in line with the findings in a study by Mcquitty (2004) which showed that the common and mostly used measures of goodness of fit indices are TLI, CFI, IFI and RMSEA.

The forgoing model fit indices are widely used by researchers because of its advantageous of being less sensitive to changes of the sample size used in the study. The tested model fit indices of the model in this study had the values of; CFI=0.90, TLI=0.86, IFI=0.91 and RMSEA= 0.1. This implies that the overall measurement model for measuring the sustainability of energy access in rural areas of Tanzania is good because all the tested indices fell within the recommended values and range. In this model the value of RMSEA was found to be out of range, but this had no significant effects on the fitness of the measurement model because the fitness of model does not necessarily require all indices to be within the acceptable range.

The acceptance of the measurement model of this study was good although RMSEA was somehow out of range. Similar finding is reported by Holmes-Smith *et al.* (2004) who argued that it is unlikely to find all those fits measures. In addition, Holmes-Smith *et al.* (2004) showed that a subset of a sample of fit indices can be used to generalize the degree of the overall fitness of the measurement model. In the light of the above facts the measurement model with sixteen items which were categorized into economic, social, technical, environmental and institutional indicators produce valid and reliable results that can be used in measuring the sustainability of energy access in rural s and other areas of Tanzania with similar characteristics. This model can be used by government, energy experts and other energy actors to plan and implement energy policies and strategies that can improve sustainability of energy access in rural areas of Tanzania. The study findings also showed that the measure of goodness of model fit are within the recommended values and ranges with the exception of RMSEA value which was found to have greater value than the recommended one (CFI=0.90), TLI=0.86, IFI=0.91 and RMSEA= 0.1).

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY IMPLICATION

6.1 Introduction

This chapter provides a summary of research findings, conclusion, and policy implication of the study. Others include contribution of the study, limitation and recommended areas for further studies.

6.2 Summary of Research Findings

This study aimed at Modeling Sustainability of Energy Access in Rural Areas of Tanzania. The specific objectives that guided this study were as follows: to determine the indicators of energy access in rural areas of Tanzania, to identify factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania, to identify the indicators of sustainability of energy access in rural areas of Tanzania, and lastly, and to establish a model for measuring sustainability of energy access in rural areas of Tanzania.

In determining the indicators of energy access in rural areas of Tanzania, the summary of research findings revealed that indicators such as: availability, affordability, easiness to use, efficient, economical, non-emission of smoke, durability and cleanliness are important in measuring energy access in rural areas of Tanzania for social, environmental and economic development of people. In determining the types of energy sources used for cooking, the findings indicate that firewood is the major source of energy used for cooking by many people living in rural areas of Njombe and Iringa regions in Tanzania followed by charcoal and Liquefied Petroleum Gas (LPG). The increased use of firewood for cooking purposes is due to its availability, affordability and that people do not have enough training on how to use modern sources of energy such as liquefied Petroleum Gas (LPG). The findings indicate that less use of electricity by household members is due to its high installation and operations costs and that majority of the villages in the study areas are not connected to the national electricity grid. Besides, the prevalence of poverty among people in rural areas of Njombe and Iringa regions contribute to the continued reliance on traditional sources of energy such as firewood and charcoal for cooking despite having detrimental effects to the environment such as pollution, soil erosion and damage to human health such as lung cancer resulting from the smoke produced.

In determining the types of energy sources used for lighting purposes in rural areas of Tanzania, the findings show that solar power is the widely used source of energy for lighting purposes by people in rural areas of Tanzania. The increased use of solar power as opposed to other sources such as kerosene, electricity or battery is due to its affordability, availability, easiness to use and that it does not produce smoke. Thus, solar power as a source of energy for lighting is environmentally friendly and does not cause health damage among household members in rural areas of Tanzania.

Regarding the factors determining the choices of energy sources for cooking or lighting in rural areas, the findings revealed that age, household size, occupation, household income and sex of the respondents significantly determine the choices of energy for cooking in rural areas of Tanzania. Additionally, the findings also indicate that education level, sex, age, occupation, household income and household size significantly determine the choice of energy sources for lighting in rural areas of Tanzania. On indicators of sustainability of energy access, the findings showed that social, economic, environmental, technical, and institutional aspects are important in ensuring that there is sustainable energy to people living in rural areas of Tanzania. Lastly, the findings revealed that the model for measuring sustainability of energy access in rural areas of Tanzania should take into consideration sixteen indicators categorized into social, economic, environmental, technical and institutional. The established model has also included technical and institutional indicators which are very important in improving the livelihood and standard of living of the people living in rural areas of Tanzania through the provision of sustainable energy sources for cooking or lighting.

6.3 Conclusions from Research Findings

The conclusions of the findings are presented in four sections as far as specific research objectives of this study are concerned. The first section (6.3.1) presents the conclusion of the study findings on the indicators of energy access in rural areas of Tanzania. The second section (6.3.2) presents the conclusion on factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania. The conclusion of the study findings on the indicators of sustainability of energy access in rural areas of Tanzania are presented in the third section (6.3.3). The last part in this section provides conclusion on a developed model for measuring sustainability of energy access in rural areas of Tanzania

6.3.1 Indicators of Energy Access in Rural Areas of Tanzania

Based on the empirical evidence obtained from Exploratory Factor Analysis (EFA) and SEM using Confirmatory Factor Analysis (CFA), this study concludes that the indicators of energy access in rural areas of Iringa and Njombe regions in Tanzania are availability, affordability, easiness to use, efficient, durability, keeping the cooking facilities clean, efficiency, and non-emission of smokes. These are important in measuring energy access in rural areas of Tanzania. The study conclude further that these indicators are very useful in improving social, environmental and economic development and the standard of living of people in rural areas of Tanzania.

6.3.2 Factors Determining the Choices of Energy Sources for Lighting or Cooking in Rural Areas of Tanzania

In the light of the findings and discussion on factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania, this study concludes that apart from income of rural households, other factors such as education level of respondent, age of respondent, occupation of the respondent, household size of the respondent, marital and sex of the respondents determine the choices of energy sources for cooking or lighting in rural areas of Tanzania.

6.3.3 Indicators of Sustainability of Energy Access in Rural Areas of Tanzania

Based on the research findings and its discussions, this study concludes that, social, economic, environmental, technical, and institutional are important indicators in measuring sustainability of energy access in rural areas of Tanzania. The study concludes further that apart from social, economic and environment, other indicators such as technical and institutional should be taken into consideration in ensuring sustainability of energy access so as to enhance social, environmental and economic development of people in rural areas of Tanzania.

6.3.4 Model for Measuring Sustainability of Energy Access in Rural Areas of Tanzania

Based on the analysis made using Structural Equation Modelling (SEM) technique and its discussion, this study concludes that a model for measuring sustainability of energy access in rural areas of Tanzania should be developed using sixteen variables categorized into social, economic, environmental, technical and institutional indicators. The study concludes further that apart from economic, social, and environmental, the model for measuring sustainability of energy access in rural areas of Tanzania should take into consideration technical and institutional indicators.

6.4 Policy Implication of Research Findings

In the light of the conclusions made, the findings of this study provide several policy implications. Firstly, the study revealed that apart from income, the other dominant factors such as education level, family size, and age influence the choices of energy sources for cooking in rural areas of Tanzania. In this regard, it is recommended that apart from improving the income of rural households, training should be provided in order to educate people on how to use sources of energy in a sustainable way without causing harm to people and to the environment.

Secondly, the findings of this study revealed that firewood is the major sources of energy for cooking by majority of people in rural areas of Njombe and Iringa regions in Tanzania. The study findings also revealed that people in rural areas of Tanzania use other sources of energy such as charcoal, liquefied petroleum gas and electricity. Thus, people in rural areas of Tanzania use multiples of sources of energy and switching from traditional to modern sources of energy is not a one-day process. These findings therefore call for policy intervention especially in reforestation and harvesting programmes of trees such as wood plants so that when harvested they provide economic, environmental and social benefits to people by being able to preserve the environment by avoiding environmental problems such as soil erosion and air pollution.

Thirdly, the findings of this study also revealed that sustainability of energy access in rural areas of Tanzania is measured using sixteen indicators categorized into social, economic, environmental, technical and institutional. These findings have policy implication as it requires policy intervention from either government, energy experts, policy makers, agencies and all stakeholders to formulate, develop and promote policies and strategies in order to enhance the sustainability of energy access in rural areas. Thus, the provision of energy sources for cooking or lighting to people living in rural areas should take into consideration social, economic, environmental, technical and institutional needs of the current generation without causing harm to the livelihood of the future generation. Among the mechanisms of enhancing sustainability of energy access in rural areas of Njombe and Iringa and other rural areas with similar characteristics include promoting the use of modern and clean technologies which do not cause harm to human health and to the environment. Lastly, this study recommends an intervention to ensure that there is promotion of using modern, clean and sustainable cooking stoves which consume less firewood so as to balance the production and consumption of trees by people living in rural areas of Njombe and Iringa regions and in other rural areas with similar characteristics.

6.5 The Contribution of the Study

The research findings of this study provide empirical, methodological and practical contributions.

6.5.1 Empirical Contribution of the Study

Based on the study findings and its discussion, this study provides several contributions to the existing body of knowledge. Firstly, the findings of this study contributed to and documented in the existing literature a model for measuring sustainability of energy access in rural of Tanzania which was not well documented by previous researchers. Secondly, the documented model has included technical and institutional indicators which were not included in the models of the previous researchers. The inclusion of technical and institutional indicators in the model is very important in ensuring that there is a provisional of sustainable energy sources for cooking or lighting in order to improve social, environment and economic development of people in the study areas. Thirdly, the findings of this study have contributed to the body of knowledge regarding other factors of determining the choices of energy sources for cooking or lighting in the study areas apart from income. Lastly, the study has contributed in the existing body of knowledge on the indicators of energy access and the indicators of sustainability of energy access in the study areas which were not well documented in the previous literatures.

6.5.2 Methodological Contribution of the Study

Methodologically, this study provides several contributions Firstly; this study has employed Structural Equation Modeling (SEM) technique to establish a model for measuring sustainability of energy access in rural areas of Tanzania. SEM was not used in the previous studies relating to sustainability of energy access. The indicators of energy access, sustainability of energy access and the measurable indicators of the model were confirmed by SEM through the use of Confirmatory Factor Analysis (CFA). Using Confirmatory Factor Analysis provides a chance of testing and confirming the indicators in the model and thus only important and reliable factors are being retained in the model. Secondly, the study has used cross sectional survey research design which provides room for generalization of the findings in other areas with similar characteristics as that of the studied areas, while majority of the previous studies used case studies which were not possible to generalize the findings.

6.5.3 Practical Contribution of the Study

Practically, the study has also several contributions. Firstly, the findings of this study help various energy stakeholders such as government, energy sectors, rural households to establish or make plans, strategies, and programmes of ensuring sustainable provision of energy sources for domestic used such as cooking and lighting. Secondly, the research findings of this study help rural areas in the study areas to make good choices of energy sources for cooking or lighting in order to reduce the negative impacts such as air pollution and soil erosion. The knowledge on indicators of energy access and indicators of sustainability of energy access helps in ensuring that rural people in the study areas have access to energy

6.6 Limitation of the Study and Recommended Areas for Further Research

This study aimed at modeling sustainability of energy access in rural areas of Tanzania. More specifically, this study focused on identifying factors determining the choices of energy sources for cooking or lighting in rural areas of Tanzania, to determine the indicators of energy access in rural areas of Tanzania, to identify the indicators of sustainability of energy access in rural areas, and finally, do propose a model for measuring sustainability of energy access in rural areas of Tanzania. However, execution of this study was confronted by several limitations. Firstly, the subjectivity of the concept of rural areas as it is used in Tanzania’s context. Thus, there is no uniformity among the people living in rural areas in terms of level of income and the extent of energy access. For example, rural people in the northern part of Tanzania including Moshi and Arusha are more developed than the people living in the southern part Tanzania such as Njombe, Iringa, and Ruvuma. Thus, this study was likely to suffer from social validity. This limitation was addressed by selecting the unit of analysis from the regions with similar origin, culture, and level of income. This was done in order to enhance the external validity of the collected data and research findings.

Secondly, this study used only primary data which emanated directly from the respondents. It was not possible to use secondary data due to the absence of secondary database regarding energy access and its sustainability to rural households in Tanzania.

Thirdly, this study used cross sectional survey research design which enabled researchers to visit the study areas only once. The use of larger sample size helped to address the limitation of using cross sectional survey design. The study recommends the use of other research designs such as longitudinal in order to add knowledge on methodology.

Fourthly, this study used only quantitative approach in analysing data leaving the qualitative part unaddressed. The researcher recommends the use of mixed strategy covering both qualitative and quantitative approach. Fifthly, this study covered energy access use at a household level. The study did not cover energy access for production and other industrial activities. Therefore, future studies may consider sustainability of energy access in SMES.

Additionally, this study developed an abstract model for measuring sustainability of energy access in rural areas of Tanzanian and which is measured in the form of indicators. The aim of the model was to mitigate the sustainability of energy access problem facing people living in rural areas of Tanzania. The indicators included in the model were tested and validated using the data collected from rural areas of Njombe and Iringa region using commended measures of goodness of fit of the model.

The indicators tested were found to fit the model implying that the indicators in the model are important in ensuring the provision of sustainable energy access to people living in rural areas of Tanzania. However, based on the scope of this study and time limitation, it was not possible to conduct studies in other areas of the country apart from Iringa and Njombe regions to test the repeatability of these results. Future studies may use the developed indicators in the model to measure sustainability of energy access in other rural areas of Tanzania and assess whether or not these variables are reliable. Being reliable will increase the possibility of generalizing the results in other areas in Tanzania or elsewhere with similar characteristics as that of selected rural areas from Njombe and Iringa Regions.

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Appendix 1: Questionnaires

QUESTIONNAIRE TO RURAL HOUSEHOLDS ON: MODELING SUSTAINBAILITY OF ENERGY ACCESSS IN RURAL AREAS OF TANZANIA.

Dear Respondent,

My name is Michael Shadrack Mangula, a PhD Candidate in the Faculty of Science and Technology - Mzumbe University. Currently I am conducting a research tiled: "**MODELING SUSTAINABILITY OF ENERGY ACCESS IN RURAL AREAS OF TANZANIA.** Being among the stakeholders in improving the sustainability of energy access in rural areas, you are humbly requested to participate in this study. Your response is very essential for accomplishment of the study. Please feel free to respond to the questions provided. All information provided will be treated with the strictest confidence and will be used for academic purposes and not otherwise. It is my sincere hope that you will assist me in filling this questionnaire.

PART ONE: HEAD OF HOUSEHOLD INFORMATION

A. **Maximum level of education attained by head of household**
   1. No formal education [ ]
   2. Primary education [ ]
   3. Secondary education [ ]
   4. College Education [ ]

B. **Age of the head of household**
   1. Below 25 years [ ]
   2. 25 to 60 years [ ]
   3. Above 60 Years [ ]

C. **Marital status**
   1. Single [ ]
   2. Married [ ]
   3. Widowed [ ]
   4. Divorced [ ]

D. **Sex of the head of household**:
   1. Male [ ]
   2. Female [ ]

E. **The occupation of the head of the households**
   1. Farming [ ]
   2. Livestock keeping [ ]
   3. Business [ ]
   4. Wage employment [ ]
   5. Others (specify) ____

F. **What is the total average monthly income of the household**
a) Less than 100,000/= [ ]
b) 100,000 to 500,000/= [ ]
c) More than 500,000/= **[ ]**

G. **How many household members do you have in your house? ___________________________________**

PART TWO: ENERGY SOURCE CHOICES BY HOUSEHOLD IN RURAL AREAS

H. **What are the energy sources used by households for cooking?(Tick where appropriate)**
1. Electricity [ ]
2. Charcoal [ ]
3. Firewood [ ]
4. Gas [ ]
5. Others
…………………………………………………………………………

Why do you use this type of fuel (let the respondent answer)…………………….

I. **What are the energy sources used by households for lighting?**
1. Electricity [ ]
2. kerosene [ ]
3. Solar power [ ]
4. Solar Battery [ ]

J. **What are the reasons for using a particular source of energy for both cooking and lighting? (Tick as many as you can).**

Reasons	**Tick(√)**
Fuel price	
Convenience to use	
Cost of the stove(technology)	
Low smoke level	
Effects of health and environment	
Safety	

Others____

K. **Is the amount of energy your household had less adequate, just adequate or more than adequate for your household needs?**
1. It is not adequate for household needs [ ]
2. It is just adequate for household needs [ ]
3. It is more than adequate for household need s [ ]

L. **What is the main reason why you feel that the amount of energy is inadequate to meet your household needs?(tick as many as possible)**
1. No enough money to pay for the energy we need [ ]
2. There are many electricity power cut in my areas [ ]
3. The supply of electricity to my household is limited [ ]

4. Firewood is very scarce [ ]
5. Gas not available in the shop [ ]
6. Others (specify)………………………………………………………….

M. Would you like to change the type of source of fuel you are using currently?

a) Yes
b) No

N. If yes why?(Select more than one)

a) Too costly fuel [ ]
b) High level of smoke [ ]
c) Safety risk for children [ ]
d) Collecting fuel takes long time [ ]
e) Cannot cook typical food [ ]

Others……………………………………………………………………
…

PART THREE: INDICATORS OF ENERGY ACCESS IN RURAL AREAS

O. Please show the extent of agreement/disagreement with the following indictors of energy access in rural areas. (*Use this scale below to assign the weight of each indicator)*

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

INDICATOR OF ENERGY ACCESS TO HOUSEHOLD IN RURAL AREAS	**WEIGHT OF THE INDICATOR**
Affordability	
Efficient	
availability	
Easy to use	
Economical	
Convenient	
Does not smoke	
Durability	
Keep the cooking pots clean	

PART FOUR: INDICATORS OF SUSTAINABILITY OF ENERGY ACCESS IN RURAL AREAS

P. Please rank the following indicators of sustainability of energy access according to its importance *(Use this Likert scale)*

1	2	3	4	5
Very insignificant	**Insignificant**	**Neutral**	**Significant**	**Very significant**

Indicators	Description of variables	Weight
TECHNICAL INDICATOR	Energy availability(amount of energy provided from the energy system	
	Reliability (measure of constant service	
	Energy conversion efficiency(ability to convert from the energy source to end use)	
SOCIAL INDICATOR	Ensure reduction/removal of human drudgery	
	Acceptability of the system by the society	
	Reduction of adverse effects to women and children	
	Employment generation	
ECONOMIC INDICATOR	Percentage of rural population without electricity	
	Percentage of rural population without modern cooking facilities	
	Percentage of household income spent on fuel and electricity	
ENVIRONMENTAL INDICATOR	Reduction in local and global environmental pollution	
	Reduction in human health damage	
	Other environmental degradation	
INSTITUTIONAL INDICATORS	Availability of skilled staff	
	Ability to protect the investors and the consumers	
	Ability to monitor and control the energy system locally	

PART FIVE: ADDITIONAL QUESTIONS ON INDICATORS OF SUSTAINABILITY OF ENERGY ACCESS IN RURAL AREAS

A. TECHNICAL INDICATOR OF SUSTAINABILITY OF ENERGY ACCESS					
I.	Are the energy sources capable of meeting the requirement of house hold?	**Yes [ ]**	**No [ ]**		
II.	On averages how many times do users face unscheduled supply interruption from the energy source in a week?	**Once[ ]**	**Twice [ ]**	**3 times [ ]**	**More than 3 times [ ]**
III.	On averages how long is each unscheduled energy supply interruption takes?	**> hr[ ]**	**1 hr [ ]**	**2 hrs [ ]**	**More 2hrs [ ]**
IV.	Frequency of maintenance of the energy system	**High [ ]**	**Medium [ ]**	**Low [ ]**	
B. ECONOMIC INDICATORS OF SUSTAINABILITY OF ENERGY ACCESS					
I.	Initial cost of acquiring energy source	**Low [ ]**	**High [ ]**		
II.	Operational and maintenance costs	**Low [ ]**	**High [ ]**		
III.	Share of household income spent on fuel and electricity (%)	**Less than 10%**	**10%**	**More than 10%**	
C. SOCIAL INDICATORS OF SUSTAINABILITY OF ENERGY ACCESS					
I.	Share of population without electricity to the total population (%)	**High [ ]**	**Medium [ ]**	**Low [ ]**	
II.	Share of population without clean energy	**High [ ]**	**Medium [ ]**	**Low [ ]**	
III.	Reduction in human drudgery	**High [ ]**	**Medium [ ]**	**Low [ ]**	
IV.	Reduction in adverse effects on women and children	**High [ ]**	**Medium [ ]**	**Low [ ]**	
D. ENVIRONMENTAL INDICATORS OF SUSTAINABILITY OF ENERGY ACCESS					
I.	% reduction in indoor emissions due to use of efficient cooking and lighting facilities	**High [ ]**	**Medium [ ]**	**Low [ ]**	
II.	Improvement in human health	**High [ ]**	**Medium [ ]**	**Low [ ]**	
E. INSTITUTIONAL INDICATORS OF SUSTAINABILITY OF ENERGY					

ACCESS					
I.	percentage share of skilled staff	**High [ ]**	**Medium[ ]**	**Low [ ]**	
II.	Availability of maintenance services at local level	**Available [ ]**	**Not available [ ]**		
III.	Capacity of local maintenance services	**Very poor [ ]**	**Poor [ ]**	**Satisfactory [ ]**	**Good [ ]**
IV.	Ability to protect the consumer and investors: involvement of local user representatives in management and techno-economic expertise	**High [ ]**	**Medium[ ]**	**Low [ ]**	

PART SIX: What Challenges do you face in attaining sustainable energy access in rural areas?

____

____

____

Thank you very much

Appendix 2: Results

Appendix 2.1: The SPSS Output on demographic characteristics of respondents, indicators of energy access and indicators of sustainability of energy access in rural areas of Tanzania

A. DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Maximum level of education of head of household

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No formal education	65	16.9	16.9	16.9
	Primary education	173	45.1	45.1	62.0
	Secondary education	90	23.4	23.4	85.4
	College education	56	14.6	14.6	100.0
	Total	384	100.0	100.0	

Age of the participant

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 25 years	34	8.9	8.9	8.9
	25 but below 60 years	282	73.4	73.4	82.3
	60 and above years	68	17.7	17.7	100.0
	Total	384	100.0	100.0	

Marital status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Single	62	16.1	16.1	16.1
	Married	246	64.1	64.1	80.2
	Widowed	65	16.9	16.9	97.1
	Divorced	11	2.9	2.9	100.0
	Total	384	100.0	100.0	

Sex of the Participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	89	23.2	23.2	23.2
	Female	295	76.8	76.8	100.0
	Total	384	100.0	100.0	

The occupation of the participant

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1	.3	.3	.3
	Farming activities	296	77.1	77.1	77.3
	Livestock keeping	5	1.3	1.3	78.6
	Business	33	8.6	8.6	87.2
	Wage employment	49	12.8	12.8	100.0
	Total	384	100.0	100.0	

The average monthly income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 100,000	252	65.6	70.6	70.6
	100,000/= to 500,000/=	93	24.2	26.1	96.6
	More than 500,000/=	12	3.1	3.4	100.0
	Total	357	93.0	100.0	
Missing	System	27	7.0		
Total		384	100.0		

he numbers of household members in the house

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5 members	179	46.6	47.6	47.6
	5 to 8 members	154	40.1	41.0	88.6
	9 and above members	42	10.9	11.2	99.7
	8	1	.3	.3	100.0
	Total	376	97.9	100.0	
Missing	System	8	2.1		
Total		384	100.0		

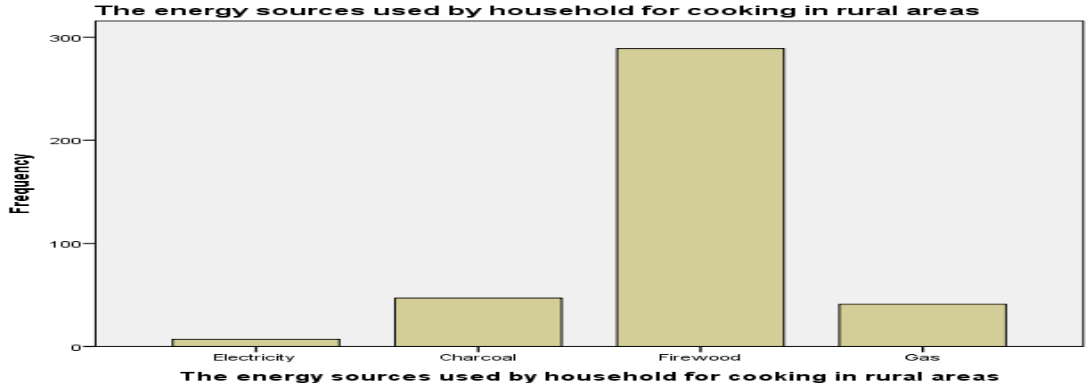
The energy source choices in rural areas

B. The energy sources used by household for cooking in rural areas

Statistics		
The energy sources used by household for cooking in rural areas		
N	Valid	384
	Missing	0
Mean		2.95
Median		3.00
Skewness		-.702
Std. Error of Skewness		.125
Kurtosis		2.539
Std. Error of Kurtosis		.248

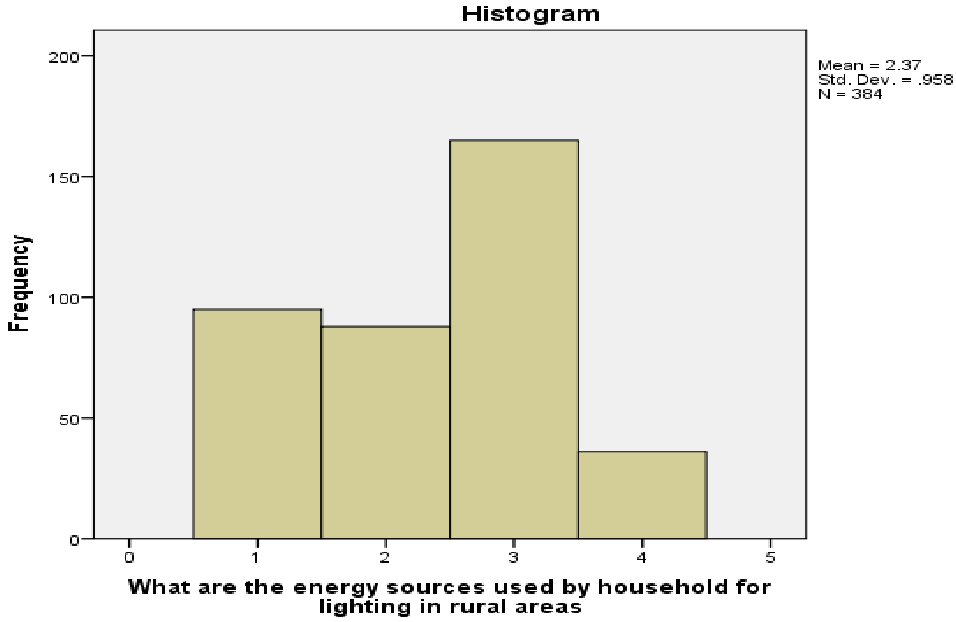
The energy sources used by household for cooking in rural areas

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Electricity	7	1.8	1.8	1.8
	Charcoal	47	12.2	12.2	14.1
	Firewood	289	75.3	75.3	89.3
	Gas	41	10.7	10.7	100.0
	Total	384	100.0	100.0	



What are the energy sources used by household for lighting in rural areas

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Electricity	95	24.7	24.7	24.7
	Kerosene/Paraffin	88	22.9	22.9	47.7
	Solar Power	165	43.0	43.0	90.6
	Solar Battery and Torch	36	9.4	9.4	100.0
	Total	384	100.0	100.0	



Reasons for using particular sources of energy

Statistics

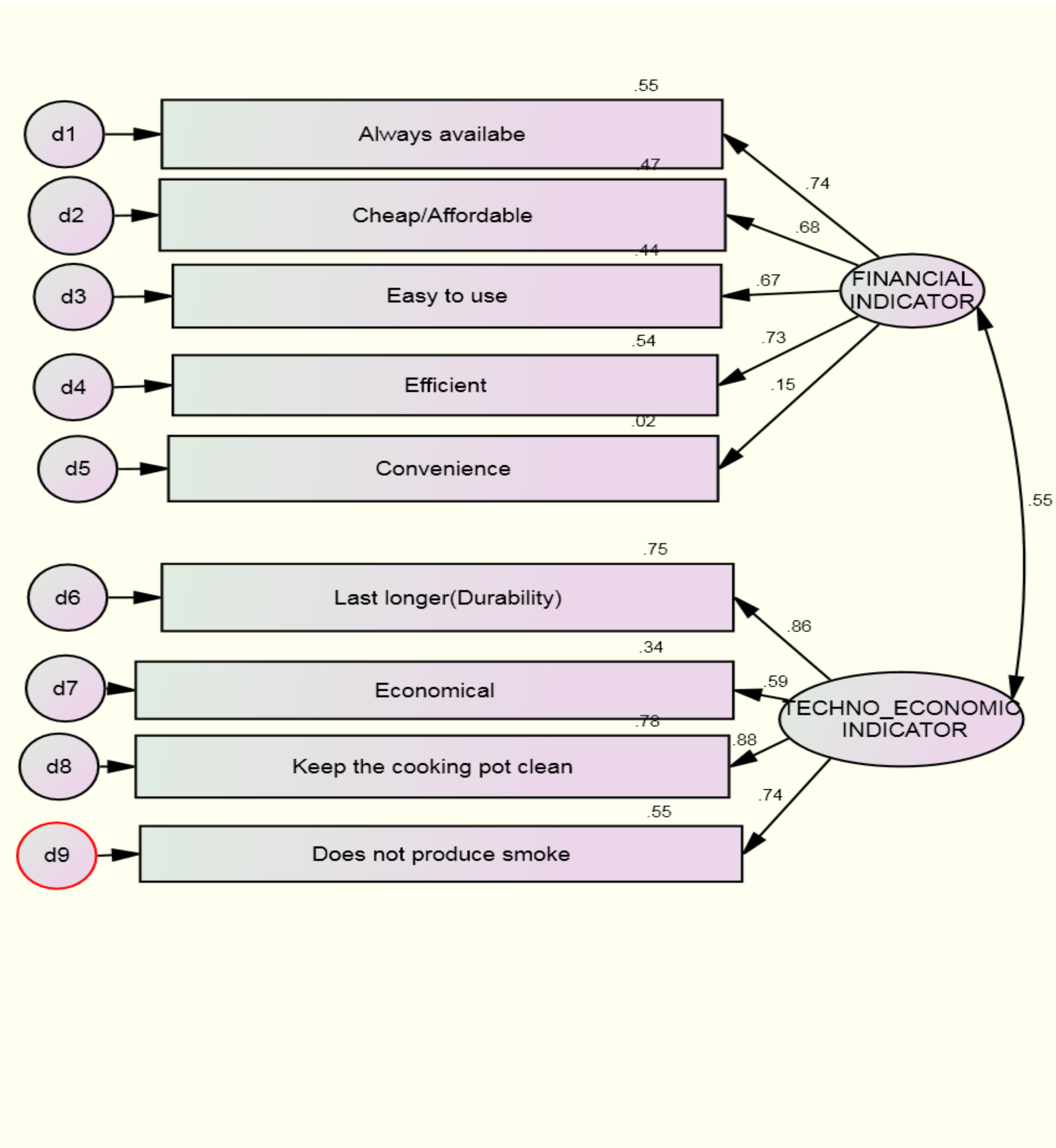
		Fuel price	Convenience to use	Cost of stove (Technology)	Low smoke level	Effects of human health and environment	Safety
N	Valid	384	384	384	384	383	384
	Missing	0	0	0	0	1	0
Mean		.98	.99	.77	.40	.50	.90
Median		1.00	1.00	1.00	.00	.00	1.00
Skewness		-6.325	-13.802	-1.294	.417	.016	-2.602
Std. Error of Skewness		.125	.125	.125	.125	.125	.125
Kurtosis		38.202	189.479	-.328	-1.836	-2.010	4.794
Std. Error of Kurtosis		.248	.248	.248	.248	.249	.248

C. INDICATORS OF ENERGY ACCESS

Statistics

		Indicators of energy access								
		Cheap/ Affordable	Efficient	Always available	Easy to use	Economical	Convenience	Does not produce smoke	Last longer(Durability)	Keep the cooking pot clean
N	Valid	383	383	383	383	383	383	383	383	383
	Missing	1	1	1	1	1	1	1	1	1
Mean		4.53	4.46	4.61	4.57	4.39	3.63	4.32	4.42	4.24
Median		5.00	5.00	5.00	5.00	5.00	4.00	4.00	5.00	5.00
Skewness		-1.064	-1.312	-.758	-1.521	-1.574	-.337	-1.281	-1.635	-1.623
Std. Error of Skewness		.125	.125	.125	.125	.125	.125	.125	.125	.125
Kurtosis		2.638	2.935	-.778	3.913	2.506	-1.418	1.822	2.882	2.325
Std. Error of Kurtosis		.249	.249	.249	.249	.249	.249	.249	.249	.249

Appendix 2.2 AMOS output results on indicators of energy access in rural areas of Tanzania



Appendix 2.3 SPSS Output results on indicators of sustainability of energy access rural areas of Tanzania

Statistics

		P1) TECHNICAL INDICATORS	Energy availability(Amount of energy provided from a particular source of energy	Reliability(Measure of constant service)	Energy conversion efficiency(ability to convert from the energy source to end use)
N	Valid	384	383	383	383
	Missing	0	1	1	1
Mean			3.95	3.96	3.95
Median			4.00	4.00	4.00
Skewness			-.508	-.472	-.604
Std. Error of Skewness			.125	.125	.125
Kurtosis			2.446	2.574	2.864
Std. Error of Kurtosis			.249	.249	.249

Statistics

		P2) SOCIAL INDICATORS	Ensure reduction/removal of human drudgery	Acceptability of the energy source by the society	Reduction of adverse effects to women and children
N	Valid	384	383	383	383
	Missing	0	1	1	1
Mean			4.32	4.32	4.31
Median			4.00	4.00	4.00
Skewness			.148	-.197	-.381
Std. Error of Skewness			.125	.125	.125
Kurtosis			-.786	.482	2.326
Std. Error of Kurtosis			.249	.249	.249

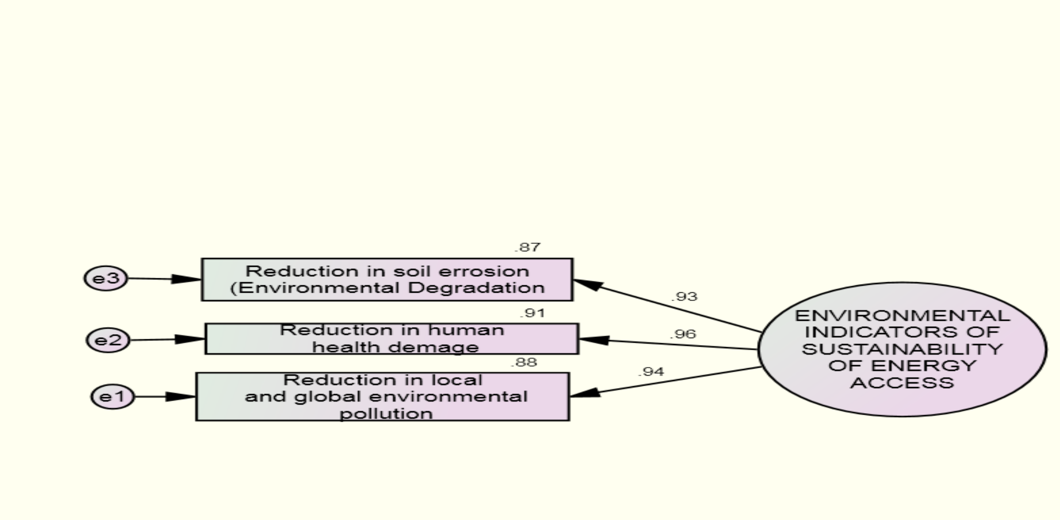
Statistics

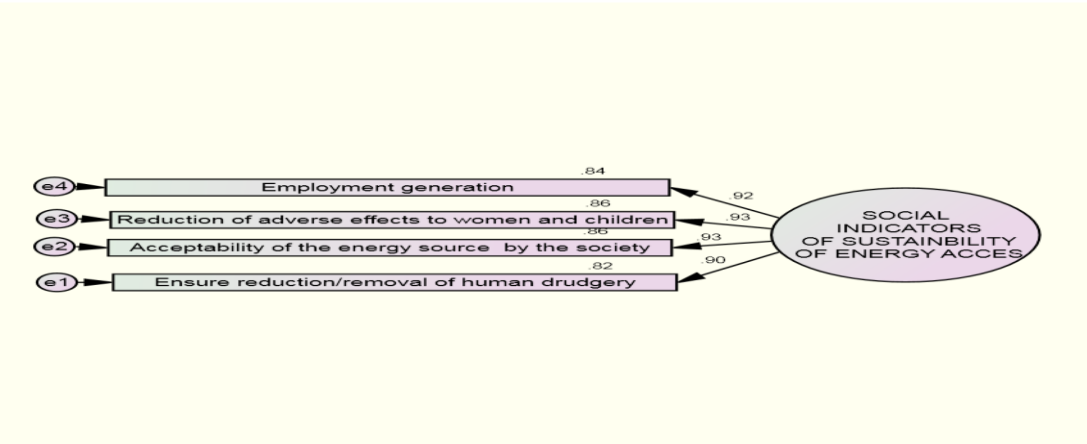
		Employment generation	P3) ECONOMIC INDICATORS	Percentage of rural households without electricity (%)	Percentage of rural households without modern cooking facilities
N	Valid	383	384	383	383
	Missing	1	0	1	1
Mean		4.32		4.13	4.14
Median		4.00		4.00	4.00
Skewness		.128		-.657	-.548
Std. Error of Skewness		.125		.125	.125
Kurtosis		-.738		1.809	1.078
Std. Error of Kurtosis		.249		.249	.249

Appendix 2.4 Some of the SEM output using AMOS software on indicators of sustainability of energy access

Statistics

		Ability to monitor and control the energy source locally
N	Valid	383
	Missing	1
Mean		4.74
Median		5.00
Skewness		-1.896
Std. Error of Skewness		.125
Kurtosis		3.505
Std. Error of Kurtosis		.249





Appendix 2.5: SPSS Output on cross tabulation of factors determining the choice of energy

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Maximum level of education of head of household * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
Age of the participant * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
Marital status * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
Sex of the Participants * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
The occupation of the participant * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
The average monthly income * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%
The numbers of household members in the house * The energy sources used by household for cooking in rural areas	384	100.0%	0	.0%	384	100.0%

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
Maximum level of education of head of household	No formal education	Count	0	1	63	1	65
		% within The energy sources used by household for cooking in rural areas	.0%	2.1%	21.8%	2.4%	16.9%
	Primary education	Count	4	22	142	5	173
		% within The energy sources used by household for cooking in rural areas	57.1%	46.8%	49.1%	12.2%	45.1%
	Secondary education	Count	2	13	61	14	90
		% within The energy sources used by household for cooking in rural areas	28.6%	27.7%	21.1%	34.1%	23.4%
	College education	Count	1	11	23	21	56
		% within The energy sources used by household for cooking in rural areas	14.3%	23.4%	8.0%	51.2%	14.6%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	79.610(a)	9	.000
Likelihood Ratio	77.133	9	.000
Linear-by-Linear Association	4.092	1	.043
N of Valid Cases	384		

a 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.02.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
Age of the participant	Less than 25 years	Count	3	8	21	2	34
		% within The energy sources used by household for cooking in rural areas	42.9%	17.0%	7.3%	4.9%	8.9%
	25 but below 60 years	Count	4	38	205	39	286
		% within The energy sources used by household for cooking in rural areas	57.1%	80.9%	70.9%	95.1%	74.5%
	60 and above years	Count	0	1	63	0	64
		% within The energy sources used by household for cooking in rural areas	.0%	2.1%	21.8%	.0%	16.7%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.137(a)	6	.000
Likelihood Ratio	42.152	6	.000
Linear-by-Linear Association	5.497	1	.019
N of Valid Cases	384		

a 4 cells (33.3%) have expected count less than 5. The minimum expected count is .62.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
Marital status	Single	Count	4	14	22	22	62
		% within The energy sources used by household for cooking in rural areas	57.1%	29.8%	7.6%	53.7%	16.1%
	Married	Count	3	32	197	14	246
		% within The energy sources used by household for cooking in rural areas	42.9%	68.1%	68.2%	34.1%	64.1%
	Widowed	Count	0	0	61	4	65
		% within The energy sources used by household for cooking in rural areas	.0%	.0%	21.1%	9.8%	16.9%
	Divorced	Count	0	1	9	1	11
		% within The energy sources used by household for cooking in rural areas	.0%	2.1%	3.1%	2.4%	2.9%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	82.317(a)	9	.000
Likelihood Ratio	78.455	9	.000
Linear-by-Linear Association	.553	1	.457
N of Valid Cases	384		

a 6 cells (37.5%) have expected count less than 5. The minimum expected count is .20.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
Sex of the Participants	Male	Count	1	10	69	9	89
		% within The energy sources used by household for cooking in rural areas	14.3%	21.3%	23.9%	22.0%	23.2%
	Female	Count	6	37	220	32	295
		% within The energy sources used by household for cooking in rural areas	85.7%	78.7%	76.1%	78.0%	76.8%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.520(a)	3	.914
Likelihood Ratio	.557	3	.906
Linear-by-Linear Association	.130	1	.718
N of Valid Cases	384		

a 1 cells (12.5%) have expected count less than 5. The minimum expected count is 1.62.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
The occupation of the participant	0	Count	0	0	1	0	1
		% within The energy sources used by household for cooking in rural areas	.0%	.0%	.3%	.0%	.3%
	Farming activities	Count	3	28	254	11	296
		% within The energy sources used by household for cooking in rural areas	42.9%	59.6%	87.9%	26.8%	77.1%
	Livestock keeping	Count	0	0	5	0	5
		% within The energy sources used by household for cooking in rural areas	.0%	.0%	1.7%	.0%	1.3%
	Business	Count	3	10	10	10	33
		% within The energy sources used by household for cooking in rural areas	42.9%	21.3%	3.5%	24.4%	8.6%
	Wage employment	Count	1	9	19	20	49
		% within The energy sources used by household for cooking in rural areas	14.3%	19.1%	6.6%	48.8%	12.8%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	113.713(a)	12	.000
Likelihood Ratio	95.298	12	.000
Linear-by-Linear Association	5.050	1	.025
N of Valid Cases	384		

a 12 cells (60.0%) have expected count less than 5. The minimum expected count is .02.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
The average monthly income	Less than 100,000	Count	3	29	234	11	277
		% within The energy sources used by household for cooking in rural areas	42.9%	61.7%	81.0%	26.8%	72.1%
	100,000/= to 500,000/=	Count	3	16	50	26	95
		% within The energy sources used by household for cooking in rural areas	42.9%	34.0%	17.3%	63.4%	24.7%
	More than 500,000/=	Count	1	2	5	4	12
		% within The energy sources used by household for cooking in rural areas	14.3%	4.3%	1.7%	9.8%	3.1%
Total		Count	7	47	289	41	384
		% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	60.710(a)	6	.000
Likelihood Ratio	54.283	6	.000
Linear-by-Linear Association	3.265	1	.071
N of Valid Cases	384		

a 4 cells (33.3%) have expected count less than 5. The minimum expected count is .22.

Crosstab

			The energy sources used by household for cooking in rural areas				Total
			Electricity	Charcoal	Firewood	Gas	Electricity
The numbers of household members in the house	Less than 5 members	Count	6	32	107	34	179
		% within The energy sources used by household for cooking in rural areas	85.7%	68.1%	37.0%	82.9%	46.6%
	5 to 8 members	Count	0	14	133	7	154
		% within The energy sources used by household for cooking in rural areas	.0%	29.8%	46.0%	17.1%	40.1%
	9 and above members	Count	1	1	48	0	50
		% within The energy sources used by household for cooking in rural areas	14.3%	2.1%	16.6%	.0%	13.0%
	8	Count	0	0	1	0	1
		% within The energy sources used by household for cooking in rural areas	.0%	.0%	.3%	.0%	.3%
Total		Count	7	47	289	41	384

	% within The energy sources used by household for cooking in rural areas	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	49.060(a)	9	.000
Likelihood Ratio	58.252	9	.000
Linear-by-Linear Association	.005	1	.942
N of Valid Cases	384		

a 7 cells (43.8%) have expected count less than 5. The minimum expected count is .02.

Appendix 2.6 A sample of SPSS output on factors determining the choices of energy sources

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	323.256			
Final	181.685	141.571	12	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	155.759	150	.357
Deviance	110.669	150	.993

Pseudo R-Square

Cox and Snell	.308
Nagelkerke	.390
McFadden	.235

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	185.925	4.240	3	.237
A	189.938	8.253	3	.041
B	194.350	12.665	3	.005
E	194.197	12.512	3	.006
G	217.896	36.211	3	.000

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

Parameter Estimates

The energy sources used by household for cooking in rural areas(a)		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
		Lower Bound	Upper Bound	Lower Bound		Upper Bound	Lower Bound	Upper Bound	Lower Bound
Charcoal	Intercept	-.482	1.943	.062	1	.804			
	A	.579	.631	.842	1	.359	1.784	.518	6.143
	B	.990	.796	1.546	1	.214	2.690	.565	12.801
	E	-.421	.430	.957	1	.328	.657	.283	1.525
	G	.038	.787	.002	1	.962	1.038	.222	4.854
Firewood	Intercept	-.919	1.873	.241	1	.624			
	A	.210	.610	.119	1	.730	1.234	.373	4.077
	B	1.979	.770	6.599	1	.010	7.235	1.598	32.747
	E	-.763	.419	3.311	1	.069	.466	.205	1.061
	G	1.147	.751	2.336	1	.126	3.150	.723	13.723
Gas	Intercept	-3.161	2.151	2.159	1	.142			
	A	1.036	.658	2.479	1	.115	2.819	.776	10.244
	B	1.709	.860	3.950	1	.047	5.523	1.024	29.798
	E	-.110	.443	.062	1	.804	.896	.376	2.134
	G	-.756	.853	.785	1	.376	.470	.088	2.501

a The reference category is: Electricity.

Classification

Observed	Predicted				
	Electricity	Charcoal	Firewood	Gas	Percent Correct
Electricity	0	2	4	1	.0%
Charcoal	0	2	37	8	4.3%
Firewood	0	4	278	7	96.2%
Gas	0	0	22	19	46.3%
Overall Percentage	.0%	2.1%	88.8%	9.1%	77.9%

Appendix 2.7 SEM output using AMOS software on model for measuring sustainability of energy access

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	69	1056.278	183	.000	5.772
Saturated model	252	.000	0		
Independence model	21	7987.697	231	.000	34.579

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.868	.833	.888	.858	.887
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.792	.687	.703
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

NCP

Model	NCP	LO 90	HI 90
Default model	873.278	774.806	979.242
Saturated model	.000	.000	.000
Independence model	7756.697	7467.996	8051.738

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	2.758	2.280	2.023	2.557
Saturated model	.000	.000	.000	.000
Independence model	20.856	20.252	19.499	21.023

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.112	.105	.118	.000
Independence model	.296	.291	.302	.000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	1194.278	1202.688		
Saturated model	504.000	534.715		
Independence model	8029.697	8032.257		

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	3.118	2.861	3.395	3.140
Saturated model	1.316	1.316	1.316	1.396
Independence model	20.965	20.211	21.736	20.972

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	79	84
Independence model	13	14

Minimization History (Default model)

Iteration		Negative eigenvalues	Condition #	Smallest eigenvalue	Diameter	F	NTries	Ratio
0	e	12		-.738	9999.000	8073.143	0	9999.000
1	e*	18		-.581	3.458	4741.216	20	.514
2	e*	15		-.930	.899	3371.464	6	.973
3	e	9		-.954	.597	2380.917	4	.980
4	e*	5		-.334	.379	1964.507	4	.648
5	e	3		-.220	.328	1641.751	5	.821

Iteration		Negative eigenvalues	Condition #	Smallest eigenvalue	Diameter	F	NTries	Ratio
6	e*	0	138461.376		.368	1437.403	5	.780
7	e	2		-.147	1.769	1423.275	4	.000
8	e	0	9174.088		.859	1182.693	7	.826
9	e	0	6586.107		.345	1137.584	3	.000
10	e	0	12959.286		.556	1088.276	1	1.182
11	e	0	24773.231		.516	1072.714	1	1.268
12	e	0	44374.954		.552	1065.383	1	1.267
13	e	0	84860.158		.522	1061.326	1	1.304
14	e	0	107009.112		.578	1059.268	1	1.198
15	e	0	270048.909		.444	1057.919	1	1.289
16	e	0	194879.846		.656	1057.527	1	.610
17	e	0	1195246.536		.320	1056.786	1	1.058
18	e	0	354109.149		.548	1056.671	2	.000
19	e	0	1571917.517		.201	1056.409	1	1.106
20	e	0	1057513.617		.297	1056.350	2	.000
21	e	0	1680418.581		.250	1056.306	1	1.287
22	e	0	1891782.011		.245	1056.287	1	1.200
23	e	0	3483533.822		.132	1056.280	1	1.218
24	e	0	4150333.016		.102	1056.278	1	1.120
25	e	0	4961848.948		.024	1056.278	1	1.059
26	e	0	5075764.466		.004	1056.278	1	1.007
27	e	0	5035771.695		.000	1056.278	1	1.000

Estimates (Group number 1 - Default model)

Scalar Estimates (Group number 1 - Default model)

Maximum Likelihood Estimates

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
P1_C	<---	TEC_ISEA	1.000				
P1_B	<---	TEC_ISEA	1.029	.041	25.216	***	par_1
P1_A	<---	TEC_ISEA	1.079	.040	26.940	***	par_2
P2_4	<---	SOC_ISEA	1.000				
P2_3	<---	SOC_ISEA	1.049	.033	32.181	***	par_3
P2_2	<---	SOC_ISEA	1.046	.034	31.121	***	par_4
P2_1	<---	SOC_ISEA	.977	.034	29.078	***	par_5
P3_3	<---	ECO_ISEA	1.000				
P3_2	<---	ECO_ISEA	.980	.024	41.109	***	par_6
P3_1	<---	ECO_ISEA	.949	.027	35.555	***	par_7
P_3	<---	ENV_ISEA	1.000				
P4_2	<---	ENV_ISEA	.961	.026	37.047	***	par_8
P4_1	<---	ENV_ISEA	.973	.028	35.072	***	par_9
P5_3	<---	INST_ISEA	1.000				
P5_2	<---	INST_ISEA	.991	.026	38.809	***	par_10
P5_1	<---	INST_ISEA	.940	.031	30.160	***	par_11
B	<---	ESCF_ISEA	1.000				
E	<---	ESCF_ISEA	-14.560	7.262	-2.005	.045	par_12
G	<---	ESCF_ISEA	1.507	.568	2.652	.008	par_13
F	<---	ESCF_ISEA	-3.751	1.079	-3.477	***	par_14
D	<---	ESCF_ISEA	-.046	.220	-.208	.835	par_15

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
P1_C	<---	TEC_ISEA	.871
P1_B	<---	TEC_ISEA	.905
P1_A	<---	TEC_ISEA	.947
P2_4	<---	SOC_ISEA	.919
P2_3	<---	SOC_ISEA	.928
P2_2	<---	SOC_ISEA	.928
P2_1	<---	SOC_ISEA	.903
P3_3	<---	ECO_ISEA	.938
P3_2	<---	ECO_ISEA	.971
P3_1	<---	ECO_ISEA	.933
P_3	<---	ENV_ISEA	.927
P4_2	<---	ENV_ISEA	.953
P4_1	<---	ENV_ISEA	.938
P5_3	<---	INST_ISEA	.957
P5_2	<---	INST_ISEA	.949
P5_1	<---	INST_ISEA	.882
B	<---	ESCF_ISEA	.171

			Estimate
E	<---	ESCF_ISEA	-1.140
G	<---	ESCF_ISEA	.168
F	<---	ESCF_ISEA	-.609
D	<---	ESCF_ISEA	-.009

Intercepts: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
P1_C	3.953	.026	155.020	***	par_22
P1_B	3.963	.025	156.809	***	par_23
P1_A	3.945	.025	155.788	***	par_24
P2_4	4.319	.027	159.749	***	par_25
P2_3	4.308	.028	153.392	***	par_26
P2_2	4.319	.028	154.102	***	par_27
P2_1	4.324	.027	160.904	***	par_28
P3_3	4.136	.035	119.702	***	par_29
P3_2	4.136	.033	126.388	***	par_30
P3_1	4.131	.033	125.213	***	par_31
P_3	4.627	.028	165.725	***	par_32
P4_2	4.634	.026	177.560	***	par_33
P4_1	4.634	.027	172.547	***	par_34
P5_3	4.736	.026	182.618	***	par_35
P5_2	4.736	.026	182.619	***	par_36
P5_1	4.736	.026	179.021	***	par_37
B	2.078	.026	81.485	***	par_38
E	1.565	.056	28.091	***	par_39
G	1.680	.039	42.887	***	par_40
F	1.310	.027	48.761	***	par_41
D	.768	.022	35.630	***	par_42

Covariances: (Group number 1 - Default model)

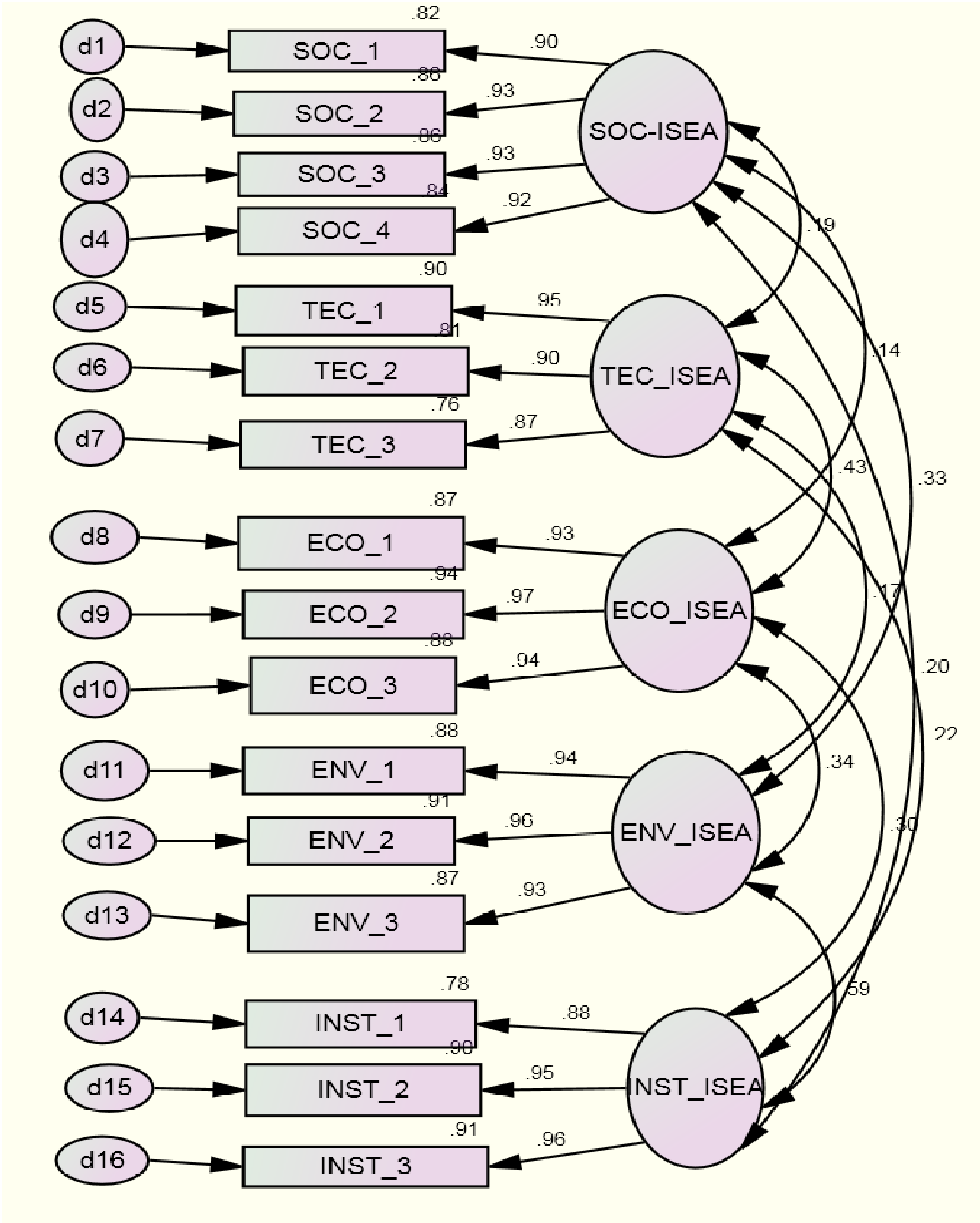
			Estimate	S.E.	C.R.	P	Label
TEC_ISEA	<-->	SOC_ISEA	.038	.013	3.009	.003	par_16
SOC_ISEA	<-->	ECO_ISEA	.005	.018	.289	.773	par_17
ECO_ISEA	<-->	ENV_ISEA	.060	.016	3.746	***	par_18
ENV_ISEA	<-->	INST_ISEA	.135	.015	8.793	***	par_19
ESCF_ISEA	<-->	INST_ISEA	-.001	.002	-.482	.630	par_20
ESCF_ISEA	<-->	TEC_ISEA	.001	.002	.717	.474	par_21

Correlations: (Group number 1 - Default model)

			Estimate
TEC_ISEA	<-->	SOC_ISEA	.181
SOC_ISEA	<-->	ECO_ISEA	.017
ECO_ISEA	<-->	ENV_ISEA	.188
ENV_ISEA	<-->	INST_ISEA	.550
ESCF_ISEA	<-->	INST_ISEA	-.020
ESCF_ISEA	<-->	TEC_ISEA	.033

Variances: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
TEC_ISEA	.189	.018	10.603	***	par_43
SOC_ISEA	.236	.020	11.655	***	par_44
ECO_ISEA	.402	.033	12.155	***	par_45
ENV_ISEA	.256	.021	12.245	***	par_46
INST_ISEA	.236	.019	12.547	***	par_47
ESCF_ISEA	.007	.005	1.326	.185	par_48
d3	.060	.006	10.754	***	par_49
d2	.044	.005	9.031	***	par_50
d1	.025	.004	5.659	***	par_51
d7	.043	.004	9.914	***	par_52
d6	.042	.004	9.487	***	par_53
d5	.042	.004	9.370	***	par_54
d4	.051	.005	10.637	***	par_55
d10	.054	.006	9.721	***	par_56
d9	.024	.004	5.671	***	par_57
d8	.054	.005	10.176	***	par_58
d13	.042	.004	9.947	***	par_59
d12	.024	.003	7.477	***	par_60
d11	.033	.004	9.072	***	par_61
d16	.021	.003	6.328	***	par_62
d15	.026	.003	7.390	***	par_63
d14	.059	.005	11.610	***	par_64
d21	.242	.018	13.584	***	par_65
d20	-.357	.472	-.756	.450	par_66
d19	.571	.041	13.805	***	par_67
d18	.174	.034	5.183	***	par_68
d17	.178	.013	13.839	***	par_69



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