

**UNIVERSITY OF CAPE TOWN**



**Assessing the role of solar home systems in poverty  
alleviation: Case study of Rukungiri district in Western  
Uganda.**

A dissertation submitted to the Faculty of Engineering & the Built  
Environment in partial fulfilment for the award of the degree of  
Master of Philosophy in Energy and Development Studies

By

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## DECLARATION

I, Julian Hakirii, hereby declare that the above dissertation is my original work, except where stated. I have not received any assistance in writing this dissertation whatsoever except guidance from supervisors. This dissertation has not been submitted in the past or been submitted at any other university for a degree or examination.

Signature:

## **DEDICATION**

I dedicate this dissertation to my dear Parents Mr. & Mrs Kwesiga Johnson and Mwongyera Samuel for their overwhelming support.

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I would like to thank everyone who has contributed both directly and indirectly through my academic journey at the University of Cape Town.

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## LIST OF ABBREVIATIONS AND ACRONYMS

Amh	Ampere hours
CIA	Central Intelligence Agency
ERA	Electricity Regulatory Authority
ERT	Energy for Rural Transformation
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GOU	Government of Uganda
HDI	Human Development Index
HDI	Human Development Index
HH	Household
HHQ	Household Questionnaire
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IPP	Independent Power Producer
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MEMD	Ministry of Energy and Mineral Development
MFPEd	Ministry of Finance Planning and Economic Development
NFA	National Forestry Authority
PAF	Poverty Action Fund
PEAP	Poverty Eradication Action Plan
PEPD	Petroleum Exploration and Production Department
PJ	Petajoule
PREP	Priority Rural Electrification Projects
PSFU	Private Sector Foundation Uganda

PVMTA	Photovoltaic Target Market Approach
REA	Rural Electrification Authority
RESP	Rural Electrification Strategy and Plan
SHS	Solar Home System
UBOS	Uganda Bureau of Statistics
UEB	Uganda Electricity Board
UEDCL	Uganda Electricity Distribution Company Limited
UEGCL	Uganda Electricity Generation Company Limited
UETCL	Uganda Electricity Transmission Company Limited
UNDP	United Nations Development Programme
UNHS	Uganda National Household Survey

## ABSTRACT

Not only does Sub-Saharan Africa have the highest number of people who live below the poverty line, the region has the lowest rate of modern energy access at 32%. The provision of modern energy access in rural un-electrified areas has the potential to contribute to alleviation of poverty. The main objective of this study has therefore been to investigate the impact of Solar Home Systems (SHSs) in poverty alleviation in Uganda. The paper focuses on the impact on four socio-economic categories namely: economic, education, health and gender equity. Our study was carried out in Kebisoni, Uganda. The main finding from our study is that access to solar power does indeed alleviate poverty. The data indicated an increase in households' disposable income due to the use of solar energy for lighting. Savings were generated from a reduced expenditure on alternative lighting fuels such as kerosene. Some households used these savings to meet medically related expenses. Furthermore, our results revealed that there was an improvement in indoor air quality. Children in solar electricity connected households benefited, as they were now able to increase their hours of study at night. Lastly, the study also revealed that access to lighting from SHSs enabled women to supplement household income by engaging in businesses.

**Key words;** Energy poverty, photovoltaic, poverty alleviation, solar home systems.

## DEFINITION OF KEY TERMS

Economic growth is the increase in productive capacity of a country, which is reflected by an increase in Gross National Product (Haller, 2012; WebFinance, 2015; WordPress, 2015).

Empowerment is defined as *“the expansion of assets and capabilities of poor people to participate in, negotiate with, influence, control, and hold accountable institutions that affect their lives”* (World Bank, 2011:1).

Gender equality is a phenomenon in which women and girls deserve the right to be treated fairly and given the same opportunities as men. The United Nations states that gender equality is a pre-requisite for alleviating poverty (United Nations Population Fund, 2015).

Health is defined as the *“state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”* (World Health Organisation, 2003:1). For purposes of this research health focuses on respiratory diseases.

Poverty alleviation is the means by which governments and various organizations both local and international seek to improve the standard of living of the poor for example the World Bank Poverty Alleviation fund (World Bank, 2015c).

## CHAPTER ONE: INTRODUCTION

### 1.1 Overview

Africa as a whole has experienced tremendous economic growth over the last two decades. Sub-Saharan Africa alone has shown an average Gross Domestic Product (GDP) growth of 4.6% in 2014 from 4.2% in 2013 (World Bank, 2015a). The majority of Africa's population however, still lives in rural areas. Karekezi and Kithyoma (2002) argue that the population in the rural areas is expected to change in the years to come as more people move to urban areas in search of employment and better living conditions. Furthermore, Madlener and Sunak (2011) suggest that in the next 40 years, the urban population in developing countries will increase from about 2.6 to 5.3 billion people. Despite this increase in urbanisation, 83% of the world's population will still be living in rural areas in 2050 (Madlener & Sunak, 2011).

According to IFAD (2015), approximately 70% of inhabitants of Africa reside in rural areas, which are characterized by poverty and inadequate access to modern fuels. The term "modern" energy is used to differentiate traditional forms of energy like firewood and agricultural residue from commercial (modern) forms of energy like electricity and liquefied petroleum gas (LPG) (Brew-Hammond, 2010). Due to the lack of access to modern fuels, the majority of the rural population relies heavily on traditional fuels to meet their energy needs (Brew-Hammond, 2010).

Access to energy is one of the essential elements for socio-economic development (Brew-Hammond, 2010; Adandari *et al.*, 2014). However, approximately 1.3 billion people globally are living without access to electricity and another 2.6 billion people are dependent on traditional biomass (Groh, 2014). Furthermore, Groh (2014) states that about 84% of the 2.6 billion people that rely on traditional biomass live in rural areas. Almost 90% of the Sub-Saharan African population relies on traditional biomass for heating, lighting and

cooking (Adkins *et al*, 2012). The use of biomass fuels has a number of adverse effects. Fuelwood collection places a burden on women and children as it is time consuming and laborious. Additionally, the unsustainable use of fuelwood puts pressure on local forest resources, particularly in places where fuelwood is scarce. Indoor air pollution caused by exposure to domestic smoke from biomass fuels is a major cause of respiratory diseases such as bronchitis in the developing world (Adkins *et al*, 2012; Sood, 2013). The World Health Organisation states that approximately 4.3 million people die annually as a result of household indoor air pollution, which is caused by the heavy reliance on solid fuels (WHO, 2015).

It is therefore imperative that this large segment of the population is provided with modern energy services to alleviate poverty and improve their welfare.

## **1.2 Ugandan context**

Woodfuels in Uganda account for almost 93% of the country's final energy use followed by petroleum products and hydro-electricity, which accounts for 5% and 1.5 % respectively (Tumwesigye *et al.*, 2011). Tumwesigye *et al.*, (2011) further show that the main energy source for heating and cooking in both rural and urban areas is woodfuel. Woodfuel used by the poor in the rural areas consists of firewood, which is collected from woodlands and used directly for heating and cooking. In urban areas charcoal is the main fuel used by the poor. The high demand for wood fuels has resulted in the depletion of forests and an increase in the rate of land degradation (Tumwesigye *et al.*, 2011).

Electrification levels in Uganda are very low and are ranked among the lowest in Africa with the recent figures showing a national grid electrification level of approximately 9% in 2013 (Sustainable Energy for All, 2014). At the same time, 42% of the urban population has access to electricity (Okure, 2009). Rural electricity access is less than 3%, yet about 84% of the country's population lives in the rural areas (Buchholz and Silva 2010).

Additionally, the growing annual population rate, coupled with a growing annual electricity demand of 3.7% and 7.8% respectively has worsened the country's energy shortage situation (Walekhwa *et al.*, 2009). Whilst Uganda is endowed with abundant renewable energy sources, these resources are underutilized. The inadequate exploitation of the renewable energy resources mostly due to lack of financial and institutional capacity has led to insufficient supply of energy.

Whereas Uganda has abundant energy resources, the country still struggles with widespread energy poverty, especially in the rural areas. The United Nations Development Programme (UNDP, 2000) defines energy poverty as “the absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe, and environmentally benign energy services to support economic and human development” (Karekezi & Majoro, 2002:3). From this definition, it is evident that energy poverty still exists in Uganda, especially in rural areas at household level. Energy poverty in Uganda is evidenced by the low levels of consumption of modern energy forms such as electricity, inadequate and poor quality electricity services and the dominant reliance on traditional biomass (Karekezi & Majoro, 2002).

Not only are the levels of energy poverty in Uganda ominously high, the government also struggles with the provision of electricity in rural areas where there is no grid infrastructure (Kaijuka, 2007). Several factors affect the extension of grid electricity to the rural areas, which include; high investment costs coupled with high operating costs (maintenance and operation costs of transmission lines) and low revenue from consumers in these areas (Clark, undated; Buchholz and Silva 2010). Additionally, households in the rural areas are isolated, hence rendering grid extension an uneconomic investment in such areas (Kaijuka, 2007; Buchholz and Silva 2010). A strategy to provide access to modern energy in these rural areas would involve the use of renewable energy technologies. Renewable energy is the most viable and least expensive option for areas that are not within close proximity to the grid compared to grid based

electricity, which is centralised thus requiring huge investments (Karekezi & Kithyoma, 2002, Obeng *et al.*, 2008). Renewable energy technologies can also be integrated with the ongoing rural electrification programmes so as to widen electricity access to poor households for poverty alleviation (Obeng *et al.*, 2008).

For the purpose of this research, solar photovoltaic technology has been considered. Solar photovoltaic technology has been identified because the technology has been disseminated in the rural areas of Uganda (such as Kebisoni). This research will look into detail how the welfare of the Solar Home Systems (SHS) users has changed.

### **1.3 Purpose of the study**

Over 80% of Uganda's population live below the poverty line, many of whom do not have access to electricity. Smith, (2014), Jacobson (2007) and Furukawa (2012) have shown that providing access to energy is essential in reducing both income induced poverty and human based poverty<sup>1</sup>. This study will therefore investigate the ability and impacts of solar energy access towards poverty alleviation. The findings derived in this study could support policymaking by providing evidence on which decisions could be based. Policymaking could be directed towards increasing energy access in rural areas. Furthermore, the findings from this study will also provide case study specific socio-economic impacts of solar energy access in Uganda.

### **1.4 Research objectives**

#### **1.4.1 Main Objective**

The main objective of this research is to assess the role of solar home systems, in as much as they provide access to modern energy services, and contribute to poverty alleviation in Rukungiri District located in the Western part of Uganda.

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<sup>1</sup> Human based poverty is defined by Pochun (undated: 1) as "... The deprivation that people suffer throughout their lives" such as the lack of food, shelter and clothing.

## Specific objectives

- To determine the fuels used by the rural poor and their main uses
- To investigate the perceptions of the community towards solar home systems
- To investigate the socio-economic impacts of solar home systems in Rukungiri District using the Theory of Change framework.

### **1.4.2 Research questions**

Below are the main research questions for this study;

1. What energy sources are households in Rukungiri district using?
2. For what purpose are the energy sources used?
3. What is the link between solar photovoltaic systems and poverty alleviation?
  - a) Do households have more disposable income from savings realised by adopting solar energy for lighting?
  - b) Are households able to access information better via media such as television and radio?
  - c) Do households have better health now?
4. Does the provision of solar systems promote income-generating opportunities in the rural areas of Rukungiri district?
  - a) Do solar systems extend working hours for business enterprises?
  - b) Are women able to benefit from solar home systems by engaging in income generating activities?
5. Has safety in the community improved with access to SHS?
6. Do school going children benefit from solar home systems? If so how do they benefit?
7. Does access to a solar home system promote empowerment?

## **1.5 Scope of study**

The research investigates the link between solar photovoltaic access and poverty alleviation. The study also explores how solar access initiatives have facilitated or improved enterprise development in rural areas. The study has been limited to Uganda in Rukungiri District, Kebisoni village, mainly due to the uniqueness of this area. The area of study is not connected to grid electricity and few people within the district boundaries use solar electricity. Furthermore, the survey population has been limited to a select sample composed of households, income-generating enterprises and focus groups.

## **1.6 Ethical considerations**

Only participants above the age of 18 years were selected and interviewed. Participants were presented with a consent form to acknowledge their willingness to take part in the research. Each participant was required to answer a set of questions. Responses were written down on each questionnaire and the process did not take longer than 40 minutes. Information sought from the participants covered a range of issues, some of which was confidential such as household income. Non-confidential information included household fuels and uses. The information was treated anonymously, therefore information provided could not be traced back to the respondents. Photographs/images related to the research such as solar components and houses were taken after consent had been granted (refer to consent form in appendix A).

## **1.7 Structure of the dissertation**

The previous chapter has provided an introduction and overview of the dissertation. The next chapter presents solar energy use in the Ugandan context and reviews literature on solar energy use and poverty alleviation. Chapter three of the dissertation presents the theory of change and its applicability to the research. The fourth chapter provides the methodology and research tools used

in the study. Subsequently, chapter five presents an analysis of the findings while chapter six presents the conclusions drawn and recommendations for further action.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

Chapter one has provided a brief overview of the link between energy, lack of modern energy in the form of electricity and how energy access is seen as a necessary input to alleviate poverty. Chapter two will present an overview of Uganda's energy sector, the level of poverty and a review of select case studies on rural energy access.

### 2.2 Global Energy Overview

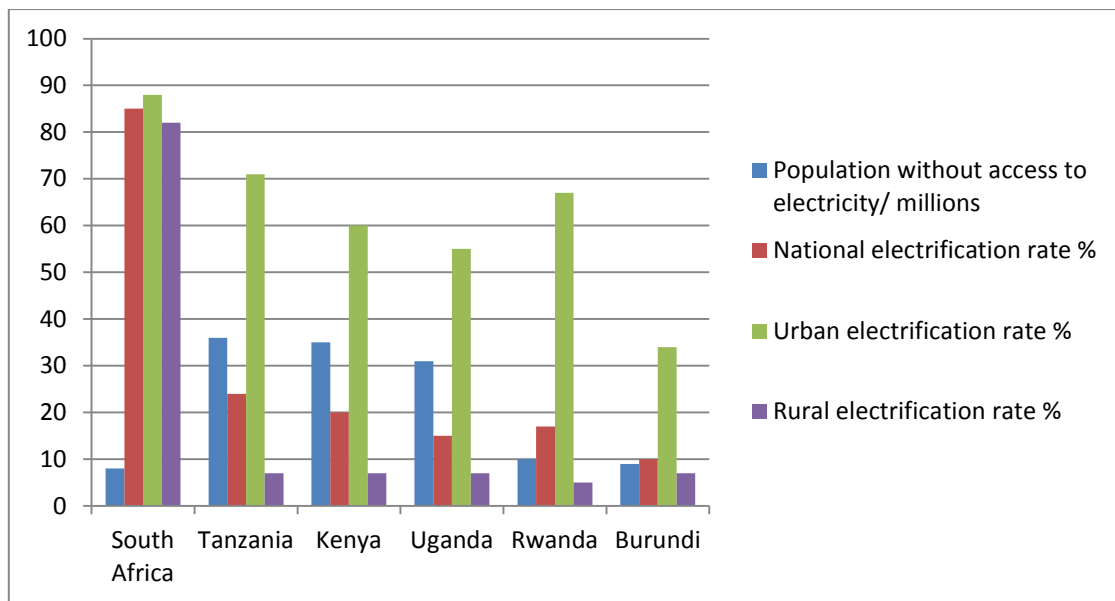
Energy plays a significant role in society. Various forms of energy are used in the different sectors of an economy i.e. commercial, agricultural, transport, domestic and industry. Therefore, a lack of access to energy encumbers social and economic development within society (Walekhwa *et al*, 2009). Even though energy is regarded as a necessity, many rural areas of developing countries continue to lack access to modern energy and therefore depend on traditional forms of energy to meet their energy needs (Sagar, 2005). Kaygusuz (2011), Sagar (2005) and Karekezi (2002) have all emphasised the negative externalities associated with continuous reliance on traditional fuels, among which are health implications caused by inhalation of smoke, loss of productive time and strenuous in terms of collecting fuel wood (Sagar, 2005).

Karekezi (2002) states that about 70% of Africa's population lives in the rural areas and is faced with extreme levels of poverty varying between 50% and 77% depending on the country. Sub-Saharan Africa particularly has high levels of poverty compared to other regions of Africa such as Northern Africa (Karekezi, 2002). Furthermore, Karekezi (2002) argues that since 1980's the number of poor people living on less than 1\$ has continued to grow and "the absolute

number of poor in Africa has grown five times more than the figure for Latin America, and twice that for South Asia” (Karekezi, 2002; 915).

Poverty alleviation is not only a major challenge for many African countries but also the world. For this reason, poverty alleviation has been on the development agenda for many multinational and donor organisations (Laufer and Schäfer, 2011; Sagar, 2005; Kanagawa and Nakata, 2007). Poverty and lack of access to modern energy services are often inter-related whereby lack of access to modern energy aggravates poverty by limiting opportunities for the population to better itself (Kanagawa and Nakata, 2008; Kaygusuz, 2011).

Electricity is one of the many forms of modern energy and is considered as a unique energy carrier because of its ability to provide many energy services such as lighting, cooking, heating and transport. Even though electricity access is important to promote both social and economic development, many households in the rural areas remain un-electrified (Cook, 2011). In 2012, Sub-Saharan Africa had the lowest levels of rural electrification globally with an estimated electrification level of 16% compared with South Asia that had a 48% electrification level (IEA, 2014b; Kaygusuz, 2011; Cook, 2011). Figure 1 provides a snap-shot of a few select sub-Saharan countries’ rural electrification and people without access to electrification.



**Figure 1: Level of electrification and population without access to electricity in 2012**

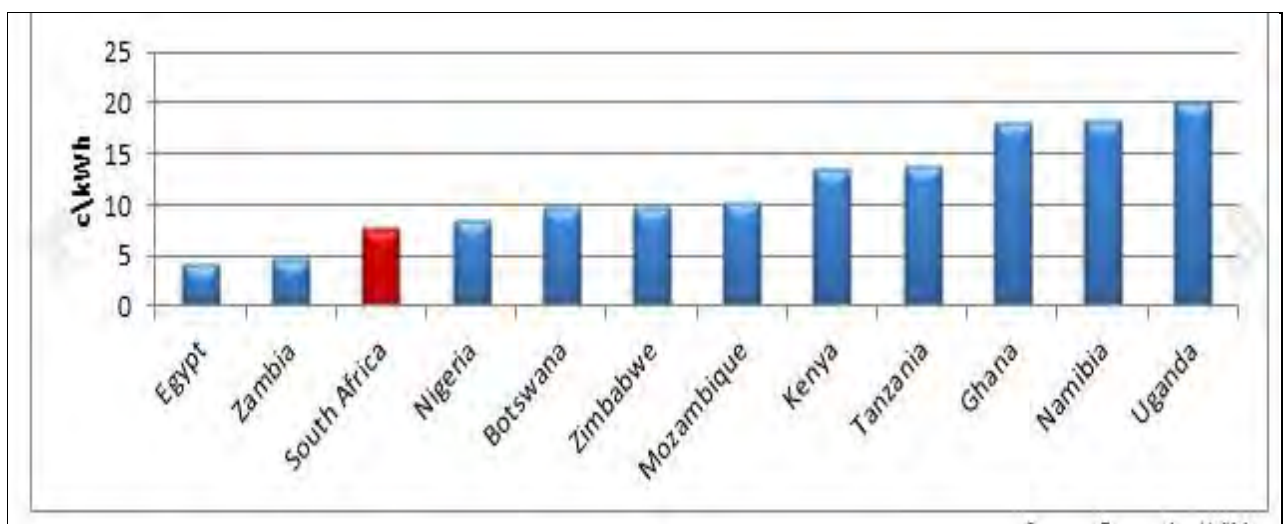
Source; IEA (2014b)

Low levels of electrification in rural areas are due to high investment costs for grid extension to rural areas, isolation of households and end-users inability to pay for the service since they do not have stable incomes (Buchholz and Silva, 2010). Renewable energy technologies have been suggested as a strategy to counteract these challenges, some of which have been implemented such as solar home systems, biogas technology and small hydro plants (Karekezi and Kithyoma, 2002).

Whereas sub-Saharan Africa has a rich energy resource, about 620 million people do not have access to any form of electricity (IEA, 2014c). Kirchner and Salami (2014), state that Africa has a massive hydropower potential that is almost three times the electricity production as of 2011. This reflects the region's high electricity generation potential. Even with this high energy potential, the number of un-electrified households in Africa represents almost half of the global population, therefore being the biggest un-electrified region (IEA, 2014c). This challenge is mainly attributed to either underutilization of resources due to lack of capacity or lack of financing (IEA, 2014c).

Energy poverty is one of Uganda’s major challenges. Uganda, like many other countries in sub-Saharan Africa, relies heavily on traditional biomass<sup>2</sup> such as firewood, dung and crop residues to meet its energy needs (Karekezi *et al.*, 2012). On the other hand, trading and growing of wood especially firewood and charcoal is a source of income for many of the poor households. Woodfuels also create a number of job opportunities along the entire value chain. The high demand for woodfuels further exerts pressure on the existing forest resource (Byakola, 2007, MEMD, 2002).

Additionally, the high cost of modern energy<sup>3</sup> in the form of electricity makes it hard for the consumers to access these services. Uganda has one of the highest tariffs in the region at about 20c/kWh as seen in figure 2 (BusinessTech, 2015).



**Figure 2: Residential electricity tariffs for selected African countries**

Source: BusinessTech, (2015).

### 2.3 Ugandan Context

Uganda is a landlocked country located in the Eastern part of Africa and is bordered by South Sudan to the North, Tanzania to the South, Rwanda to the Southwest, Kenya to the East and Democratic Republic of Congo to the West.

<sup>2</sup> Traditional energy (biomass) is usually burned using local and inefficient technology such as “three stone fire places” (IEA, 2010).

<sup>3</sup> Modern energy is used to describe clean, efficient and commercial forms of energy such as LPG, electricity, biogas and paraffin (IEA, 2010).

Geographically, Uganda lies between latitude and longitude 1.0667°N, 31.8833°E and it measures approximately 241,038 square kilometers. This surface area is made up of both land and water bodies representing 197,100 square kilometers and 43,938 square kilometers respectively of the total surface area (CIA, 2014).

Uganda is administratively divided into 4 regions that are the Central, Eastern, Western and Northern regions. Uganda has 111 districts and one capital city, which is Kampala (see figure 4). The districts are further divided into counties, sub-counties and finally to village level which is the lowest administrative unit. This is the level at which issues and problems of community members are addressed (Mazimpaki, 2012).

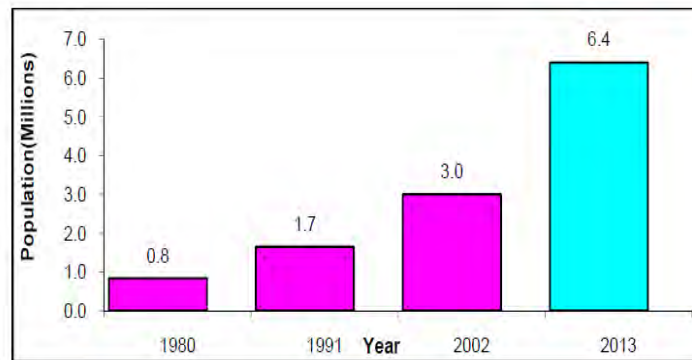


**Figure 4: Administrative map of Uganda**

Source: [www.katyanovablog.com](http://www.katyanovablog.com)

According to UBOS (2013), Uganda's population is estimated to be 35.4 million and with a population growth rate of 3.24% per annum (CIA, 2014). Uganda, like other developing countries, is experiencing a growing rate of urbanization currently estimated at 12% and with prospects of growing to 30% by 2030

(Brown, 2014). Even though the country is experiencing rising rates of urbanization, the majority of the population still lives in the rural areas (Brown, 2014). Uganda's rural population accounts for approximately 80% of the total population while the urban population is estimated at about 16% while 4% of the population is peri-urban (UBOS, 2013). Figure 3 shows the urban population trend between 1980 and 2013.



**Figure 3: Urban population between 1980-2013**  
Source: UBOS (2013)

Uganda's economy has grown steadily over the years showing an increase in real gross domestic product (GDP) growth rate from 2.8% in 2012 to an estimated 5.2% in 2013 and it has been further projected to reach 6.6 % in 2014 (Oling *et al.*, 2014). In 2013, the country had a GDP of US\$ 21.48 billion, a GDP per capita of US\$ 572 (Word Bank, 2014) and a human development index (HDI) of 0.484 placing the country at the 164<sup>th</sup> position out of 187 countries and territories (UNDP, 2014). Some of the neighbouring countries' rankings are as follows; Kenya 147<sup>th</sup>, Rwanda 151<sup>st</sup>, Tanzania 159<sup>th</sup>, Burundi 180<sup>th</sup> and DRC 186<sup>th</sup>, close to the bottom of the list (UNDP, 2014).

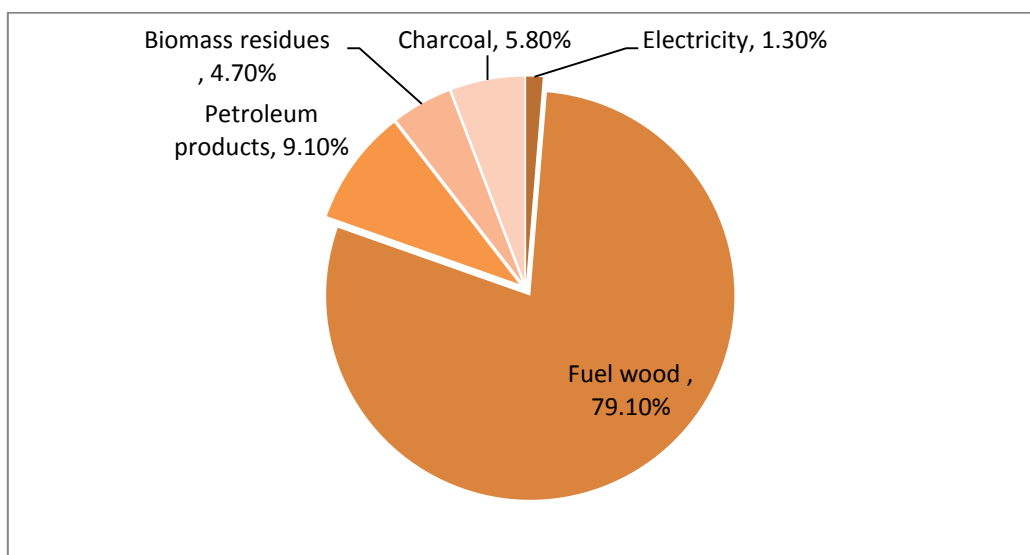
Poverty is one of the many challenges that Uganda has continued to face:- statistics from the 2012/2013 National Household Survey (UNHS) points out a reduction in absolute poverty levels from 24.5% in 2009/10 to 22.2% in 2012/13 (Oling *et al.*, 2014). However, not all aspects of human development

have improved, in fact there has been no improvement in some areas such as HIV/AIDS prevalence, health and education (Oling *et al.*, 2014).

### 2.3.1 Uganda's Energy Sector

The energy sector in Uganda is generally managed and overseen by the Ministry of Energy and Mineral Development (MEMD) whose mandate is to ensure that energy and mineral resources are sustainably utilised to make sure that both social and economic development goals are achieved (Tumwesigye *et al.*, 2011, MEMD, 2002). For this research, Uganda's energy consumption has been categorized into modern and traditional energy; the traditional energy sector is monitored by the National Forestry Authority (NFA), which falls under the Ministry of Water and Environment. The modern energy sector, which covers both the power and petroleum sectors, is monitored by the Electricity Regulatory Authority (ERA) and the Petroleum Exploration and Production Department (PEPD) respectively, all under MEMD (Tumwesigye *et al.*, 2011, Okure, 2009).

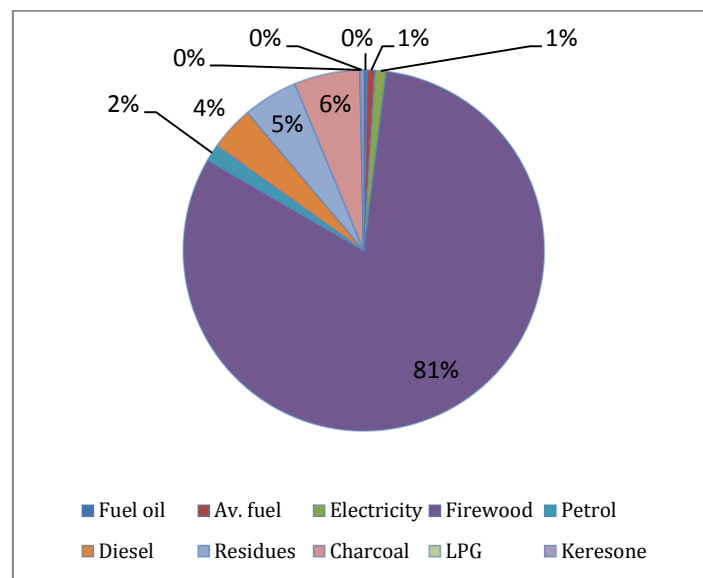
In addition to biomass, other sources of energy include petroleum products and electricity that account for approximately 9.1% and 1.3% respectively of primary energy supply, as shown in figure 5 (Whitley and Tumushabe, 2014).



**Figure 5: Uganda's energy mix (2011)**

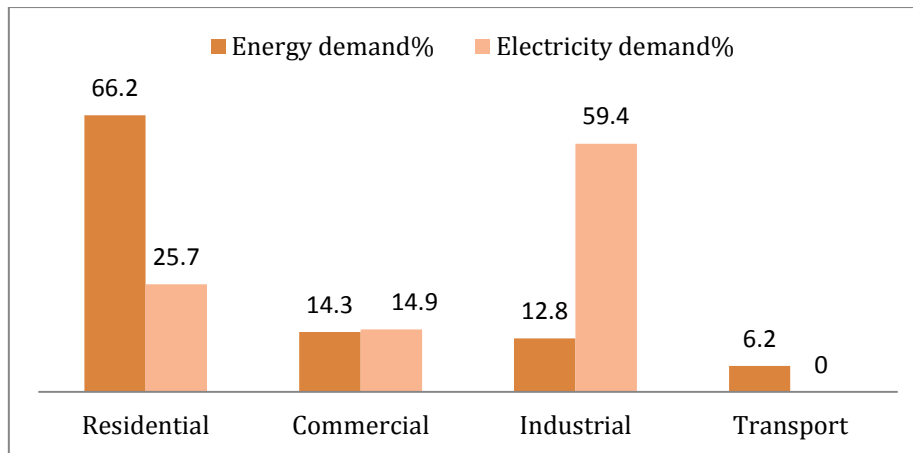
Source: Whitley and Tumushabe (2014)

In comparison with the African region as a whole, Uganda’s dependence on biomass is high, the regional contribution is 48% (IEA, 2011). The country’s high dependence places the country at risk of deforestation. However, statistics from the 2011 energy mix indicate that the use of traditional fuel has reduced by about 2% from the 2006 statistics (see figure 6).



**Figure 6: Uganda’s energy mix (2006)**  
 Source; Author’s own using data from Yu-Ting Lee (2013).

Uganda’s sectorial energy demand is dominated by the household sector that accounts for 66.2%, followed by the commercial sector that accounts for 14.3%, the industrial sector which accounts for 12.8% and finally the transport sector at 6.2% (see figure 7)(MEMD, 2010). On the other hand, electricity consumption is highest in the industrial sector which consumes over half of the electricity generated, followed by the residential sector which consumes 30% and the commercial sector which demands just above 10% of the electricity supplied (Whitley and Tumushabe, 2014).



**Figure 7: Sectoral energy and electricity demand.**

Source; MEMD (2012a)

Even though the national level of electrification has grown from about 5.6% in 1990 to 9% in 2009 (UCR), this is still low because about 90% of the total population still lacks access to electricity (Whitley and Tumushabe, 2014).

Table 1 shows an extract of Uganda's energy balance. It is clear that that primary biomass contributed about 88% to total primary energy, compared to modern forms of energy such as electricity and petroleum products, which contributed about 12% in 2010 (United Nations, 2012). Uganda's energy consumption per capita in 2009 of 4.02MWh per capita (UCR,undated) is extremely low compared to other countries with in the region.

**Table 1: An extract of Uganda's Energy balance**

Energy sources & products (across) Product and utilisation (down)	Hard coal, brown coal and peat	Coal products and peat products	Primary oil	Light oil products	Heavy Oil products	Other oil products	LPG, refinery gas, ethane	Natural gas	Manufactured gases	Electricity	Primary biomass /waste biomass	Char coal	Heat	Total energy
1 Products of primary energy										5777	372889			378666
2 Imports				19989	26032	438	200			105	0	1		46765
3 Exports										-271	0	-1		-273
4 Marine/aviation bunkers														
5 Stock changes														
6 <b>Total energy supply</b>				<b>19989</b>	<b>26032</b>	<b>438</b>	<b>200</b>			<b>5611</b>	<b>372889</b>	<b>0</b>		<b>425159</b>
7 <b>Transformation</b>										3065	-51247	274		-28823
8 Briquetting plants														
9 Coke ovens														
10 Gas works														
11 Blast furnaces														
12 Oil refineries														
13 NGL plants and gas blending														
14 Electric power plants					-8119					3065	-193			-5248
15 Heating plants														
16 Other transformation												274		
17 Net transfers												78		-23575



### **2.3.2 Modern Energy**

The Ugandan power sub-sector has achieved a great deal since its liberalisation in 1997; however, the country still faces various challenges such as unreliability of supply, frequent load shedding and lack of adequate infrastructure to match the growing demand for energy (Tumwesigye *et al.*, 2011). Additionally Uganda's expenditure on its power subsidy is extremely high placed at 212 billion Ugandan shillings annually, yet the household power tariff<sup>4</sup> remains high compared to other countries within the region (Tumwesigye *et al.*, 2011). Tumwesigye *et al.* (2009) argue that Uganda's tariff is the second highest worldwide after Sweden.

### **2.3.3 Power sub sector**

The Uganda Electricity Board (UEB)<sup>5</sup>, the state owned utility company, was a monopoly entity in the power sector until 1999 when the power sector was liberalized (Kapika and Eberhard, 2013). This kind of liberalisation was the first of its kind on the African continent; hence this set precedent for other countries within the continent to embark on power sector reforms (Kapika and Eberhard, 2013). Initially UEB was entrusted with the generation, transmission and distribution of all electric power within the country. Consequently, its disbanding led to the creation of three separate independent companies, responsible for generation, transmission and distribution of electric power: Uganda Electricity Generation Company Limited, Uganda Electricity Transmission Company Limited and Uganda Electricity Distribution Company Limited (Shirima, 2002, Okure, 2009).

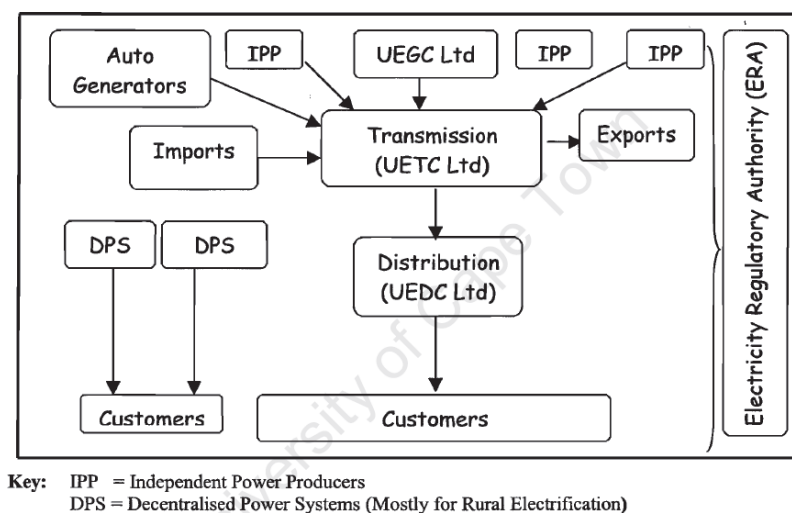
The 1999 Electricity Act facilitated the denationalization of the power sub-sector as well as the establishment of the Electricity Regulatory Authority (ERA) which works autonomously from MEMD (see figure 8)(Shirima, 2002; Tumwesigye *et*

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<sup>4</sup> 20c/kWh (BusinessTech, 2015)

<sup>5</sup> UEB was a state owned power company that was disbanded in 1999 (Shirima, 2002).

al., 2011). ERA is entrusted with regulating the power sub-sector, as well as the approval of power tariffs and standards. Additionally, ERA also issues permits for generation, distribution and transmission of electric power (Tumwesigye *et al.*, 2011, Kyezira *et al.*, 2009). Liberalization of the power sector was undertaken to address the challenges that were being faced by the power sector, specifically non-performance of UEB both financially and commercially, growing demand coupled with very low investment to meet the demand, corruption and severe power shortages (Shirima, 2002, Tumwesigye *et al.*, 2011). Undeniably the liberalization and structural reforms implemented in the industry generated a number of benefits; however, these have not met the public's expectations. Whitley and Tumushabe (2014) argue that the sector reforms have led to the improvement in investment by mobilizing private sector finance, improvement in accountability for funds and power system planning.



**Figure 8: Institutional organization of the power sub-sector**

Source; Sharimi (2002).

While UEB was the only authorized generator, transmitter and distributor for all bulk electric power within the country, other establishments were generating hydroelectricity for their own use: notably Kilembe Mines Limited, Kisizi Hospital, Kogondo Hospital and Kasese Cobalt Company limited with installed capacities of 5MW, 0.06MW, 0.06MW and 10MW respectively. This was made

possible by the Electricity Act (1948) that gave powers to the energy minister to permit other electricity generators (Sharimi, 2002). The new Electricity Act (1999) gives ERA the authority to grant permits and licenses to these establishments and any new electricity generators for their own use; the surplus can be sold to UETCL, which feeds it into the grid (Sharimi, 2002).

As earlier mentioned, UEB's disbanding took place after the new reforms were adopted, thus leading to the creation of three separate companies. However, UEB was left as a statutory company to manage any unallocated tasks or assets that were not handed over to the three subsidiary companies. The other assets were transferred to the respective bodies on a concessionary basis (Sharimi, 2002).

UEGCL, the publicly owned generation company, owns the two biggest hydropower plants, namely Nalubaale (formerly Owen fall) and Kiira, which are situated on the River Nile. The two hydropower stations have a total capacity of 380MW. They are operated by Eskom Globeq on a 20 year concession term that begun in 2003 (Okure, 2009; Whitley and Tumushabe, 2014; MEMD, 2007). The generation sector has a number of other private developers that include mining companies, sugar-processing companies and Independent Power Producers (IPPs) that generate and sell electricity to UETCL.

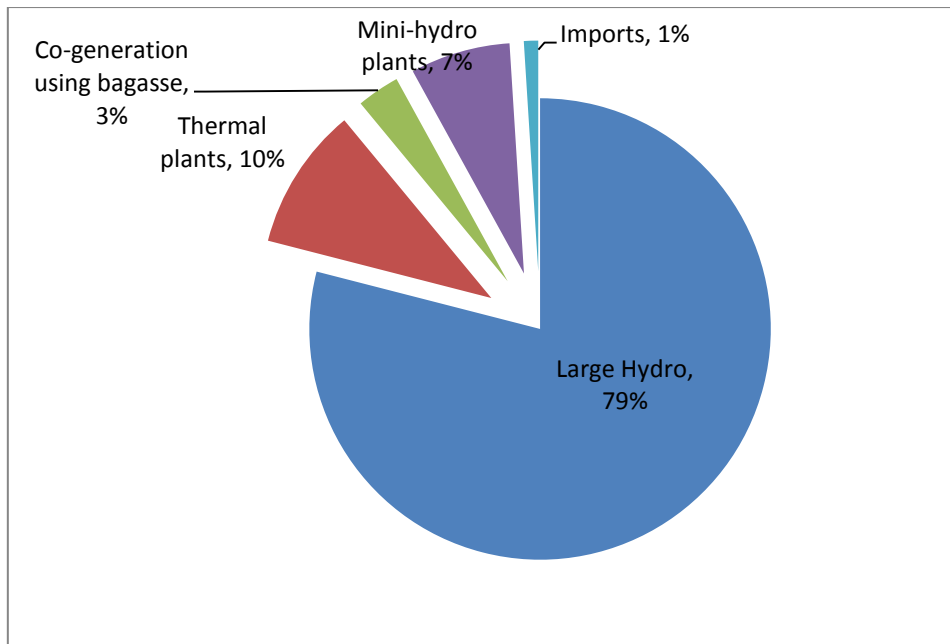
UETCL is the sole operator of all high voltage transmissions lines above 33kV and purchases all the power generated by IPPs within the country. The power is then fed into the national grid of which UETCL is the system operator on behalf of government (Sharimi, 2002; MEMD, 2007; Whitley and Tumushabe, 2014). UETCL is the main distributor of bulk power to UEDCL.

UEDCL owns the country's electricity distribution network, which is operated by Umeme Ltd (Whitley and Tumushabe, 2014). However any investments made by the government will belong to UEDCL. Umeme Ltd operates on a 20 year concession that begun in 2005 (Whitley and Tumushabe, 2014; Tumwesigye *et al.*, 2011; MEMD, 2007).

### **2.3.4 Electricity supply and demand**

Uganda's annual electricity production as of 2010 was estimated at 2486 GWh (Maweje *et al.*, 2012) with a total installed capacity of 870 MW (Whitley and Tumushabe, 2014). Generation capacity is usually low, falling to about 588MW, mainly because the generation mix is mostly comprised of hydropower plants. Hydropower generation has continuously been affected by droughts hence operating below installed capacity (Adeyemi and Asere, 2014). Cases in point are the two major hydro power plants Owen Falls Dam and Kiira Dam each with installed capacities of 180 MW and 200MW but generating at 74MW and 50MW respectively (Whitley and Tumushabe, 2014).

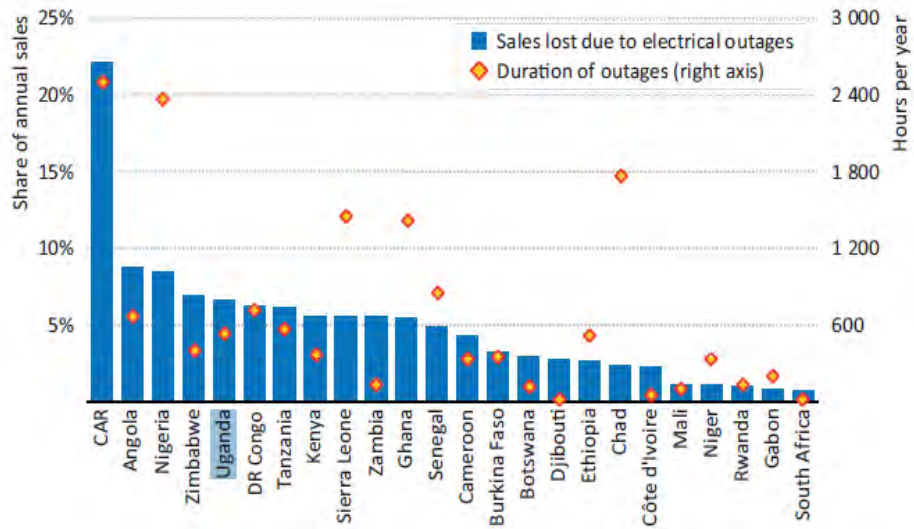
Adeyemi and Asere (2014) argue that Uganda's generation capacity could possibly reduce to between 80 and 90MW from the 135MW that is generated if the drought were to worsen. To counteract this shortfall, three thermal power plants that rely on both diesel and heavy fuel oil were commissioned to increase supply; these make up for about 10% of the generation mix (Maweje *et al.*, 2012). Other sources of electricity include mini-hydro plants, co-generation and imports. Figure 9 shows the respective percentages in the electricity mix (Whitley and Tumushabe, 2014).



**Figure 9; Uganda's electricity generation mix as of 2011**

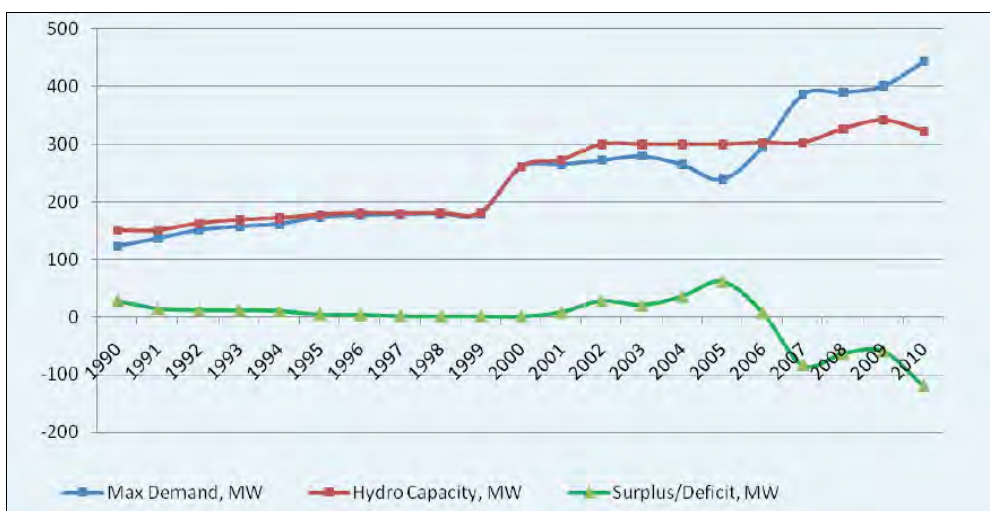
Source; Whitley and Tumushabe (2014)

Over 90% of Uganda's electricity is generated locally and about 1% of the electricity is imported (ERA, 2014). Uganda also exports electricity to Rwanda (5MWh, Tanzania (9MWh) and Kenya(30MWh) (Tumwesigye *et al.*, 2011). Despite the fact that Uganda exports some of the generated electricity, it still suffers from continuous load shedding which in turn affects businesses and households (Whitley and Tumushabe, 2014). Interrupted production processes as a result of load shedding, have led to fall in Uganda's annual Gross Domestic Production (GDP) growth to 4.5% from an estimated 6% in 2012 (IEA, 2014c; Adeyemi and Asere, 2014). Figure 10 below illustrates the impact load shedding has on business sales.



**Figure 10: Impact of load shedding on business sales in selected countries**  
 Source; IEA(2014c)

Uganda’s electricity demand has been growing at a rate of 8% per annum and yet this growth in demand is not matched by the current generating capacity, creating a deficit as illustrated in figure 11 (Adeyemi and Asere, 2014). Maweje *et al.*,( 2012) estimates that peak demand is 380 MW and there is a deficit of 75 MW. Of the 380 MW, 305 MW is met by base-load plants, while the rest is supplied from small hydro plants and sugar cane waste.



**Figure 11: Illustration showing Uganda’s demand and supply trends of electricity.**  
 Source; Maweje *et al.*, (2012)

Even though oil deposits have been discovered in Uganda, commercial oil production has not yet begun. This makes Uganda entirely dependent on imported oil and all the negative aspects that accrue to it such as high transportation costs and exorbitant prices at the pump (Okure, 2009). Walekhwa *et al.*, (2009) estimate that Uganda's annual oil (products) consumption is about 430,000 tons of oil and an estimated 22,990 barrels per day as of 2010 (CIA, 2014). Since Uganda is a land locked country, all of its oil is transported by road from both the Kenyan refinery that is located in Mombasa and the Tanzanian one in Dar es Salaam port (Okure, 2009; Yu-ting lee, 2013). Kenya imports its crude oil from overseas for use in the Kenyan refinery.

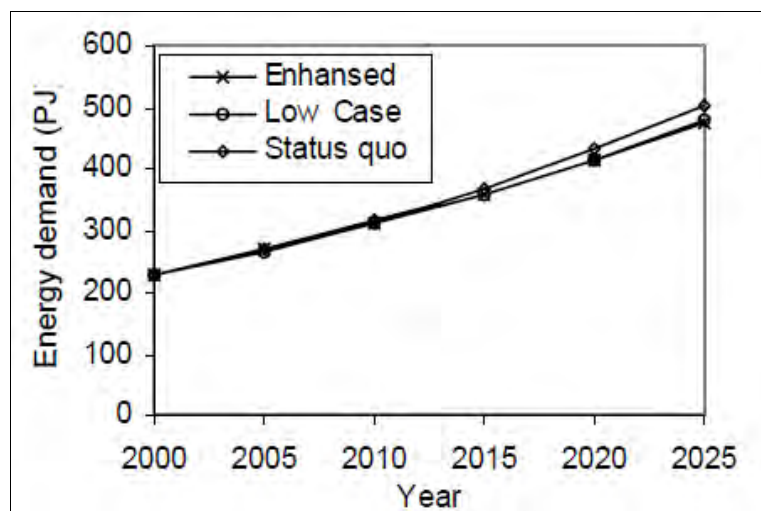
High costs incurred by the government in the transportation of oil products by road coupled with the discovery of oil reserves in the country, has prompted the government to consider the extension of the Mombasa-Eldoret pipeline to the planned oil refinery in Uganda (Tumwesigye *et al.*, 2011). The Government of Uganda has also considered constructing a pipeline from Dar es Salaam to Kampala since Uganda sources 15% of its oil products from Tanzania (Tumwesigye *et al.*, 2011).

### **2.3.5 Traditional energy**

Biomass contributes approximately 93% to Uganda's total primary energy supply (IRENA, 2013). Additionally, about 90% of the people who depend almost entirely on traditional biomass reside in the rural areas of Uganda (Yu-ting lee, 2013). In the rural areas, biomass is mostly used as a cooking fuel in form of wood and crop residues. Urban residents use biomass mainly in the form of charcoal and this meets almost 90% of their cooking energy needs (Yu-ting lee, 2013). Firewood is also commonly used in other institutions such as schools, hospitals and hotels (MEMD, 2001).

Adam *et al.*, (2004) indicates that biomass will continue to remain a dominant energy source in Uganda's energy mix. In Adam *et al.*, (2004), three scenarios are

considered namely the: status quo scenario which assumes there is a gradual increase in household income, low case scenario which assumes a decrease in household income and enhanced scenario in which the highest household income is assumed. In all three scenarios the population growth rate from 2000-2025 is constant at 3.4% per annum. Results from his projections (as seen in figure 12) indicate that in all scenarios there is an increase in biomass energy demand. The enhanced scenario indicates an increase in biomass energy demand from 230 PJ in 2000 to 437PJ in 2025.



**Figure 12: Biomass usage scenarios**

Source; Adam *et al.*, (2004)

Not only is the demand for biomass exceeding its supply, with annual energy consumption of wood at 20 million tons per year (Walekhwa *et al.*, 2009), UBOS (2013) also reported that forest cover had gone down by 26% between 1990 and 2005. The National Biomass Energy Demand Strategy (2001) also indicates that there is an annual supply deficit of 3,805.20 tons per year. With a growing demand for biomass energy coupled with an annual supply deficit, it is imperative that an approach that promotes a sustainable and efficient use of biomass be implemented. A sustainable approach should reduce the burden placed on the remaining biomass resources. Additional methods such as tree planting have been encouraged to counteract the negative impacts of climate change (Byakola, 2007).

Additionally an increasing population places further pressure on existing forest cover hence causing its quick depletion and worsening poverty levels for households who depend on forests for their livelihoods (Mwaura *et al.*, 2014). Case in point is in Nakasogola district in which some areas have faced complete scarcity of biomass resources, switching, to paraffin as cooking energy source. However, only well-off families can afford using paraffin as a cooking fuel while the rest resort to poor quality fuels such as dung and crop residues (Mwaura *et al.*, 2014). This in-turn has adverse effects on the health of households especially sick adults, pregnant women and infants. This is not only the case for Nakasongola district but also in other areas of the country (Mwaura *et al.*, 2014).

## **2.4 Energy potentials**

Although Uganda depends mainly on energy derived from biomass and hydro sources, the country is also richly endowed with other energy sources, including wind, geothermal and solar (MEMD, 2002). Most of these renewable energy sources have not been exploited mainly due to the apparent financial and technical risks involved. All these renewable energy sources combined have an electrical power potential of about 5300MW (MEMD, 2007). Unfortunately, renewable energy sources (save for biomass) only contribute approximately 5% to Uganda's energy mix and about 10% to the electricity generation mix, a small fraction relative to its massive potential (Tumwesigye *et al.*, 2011; MEMD, 2007; Whitley and Tumushabe, 2014).

### **2.4.1 Solar**

Uganda has an average solar radiation of around 5.1 kWh per m<sup>2</sup> per day and an estimated solar electrical power potential of 200MW (MEMD, 2007; Tuwesigye *et al.*, 2011; Okure, 2009). The Ugandan solar market has grown over the years, particularly the demand for solar home systems. Solar energy in Uganda is utilized in the form of solar home systems for lighting and solar drying in agricultural enterprises (Tuwesigye *et al.*, 2011; Okure, 2009).

Increased uptake of solar technologies has also been observed in institutions such as hospitals, hotels, schools and affluent households. Solar technologies in these institutions have been used in the form of solar photovoltaic systems for lighting and solar water heaters (Okure, 2009). Solar water heaters have a relatively small and yet growing market, mainly attributed to their quick pay back periods (Okure, 2009).

Photovoltaic systems are commonly used in areas where there is no access to grid electricity and generally areas where extension of the grid would not be economical (Tuwesigye *et al.*, 2011). Solar thermal power for electricity generation has not yet been exploited; however, the government has recently invited interested developers to bid for the development a 50 MW solar thermal plant (Tuwesigye *et al.*, 2011).

## **2.5 Rural electrification**

Developing countries such as Uganda are no exception to the low electrification levels which are common in many countries of Sub-Saharan Africa. Uganda's low rural electrification level of less than 5% coupled with a large rural population makes development a challenge (MEMD, 2012b; Mafumbo and Wandera, 2009). Although access to electricity fosters economic development, it should be noted that access to electricity does not in itself lead to development, but rather provides avenues that fosters local productivity within an area (Quoilin and Orosz, 2013; Mafumbo and Wandera, 2009).

As a result of the country's low rural electrification rate, the Rural Electrification Authority (REA) was created to support the country's objective of achieving 100% rural electrification. REA also works hand in hand with Independent Power Producers to promote both grid and off grid electrification (Mawejje *et al.*, 2013). In addition to the establishment of REA, the Government of Uganda (GOU) has also created a Rural Electrification Fund (REF).

The REF's purpose is "to promote the equitable coverage of rural electrification in Uganda through increased provision of access to electricity for economic, social and household use" (Whitley and Tumushabe, 2014:29). The REF is controlled by REA, which is obliged to invest these funds in renewable energy projects such as solar energy projects. Donors such as the European Union, World Bank and Norway provide these funds (Mafumbo and Wandera, 2009; Maweje *et al.*, 2013; "Uganda: brave reforms and new growth", undated; United Nations, undated).

As the need for rural electrification intensified, the Rural Electrification Strategy and Plan (RESP) was approved by cabinet in 2001 (Tumwesigye *et al.*, 2011). RESP is a policy document under MEMD that lays out the government's 10 year target and approach on how to increase rural electrification (MEMD, 2012 b). The current RESP covering the period between 2013-2022 sets out a target of achieving a rural electrification level of 22% by 2022 from the current 5%, which is in line with the country's overall goal of achieving universal electrification by 2040 (MEMD, 2012b, European Union, 2015).

The current RESP aims to achieve this target by expanding both on grid and off grid services, mainly via solar PV installations. This is projected to create about 1.42 million new rural electricity consumers, bringing the total number to 1.6 million rural electricity users (MEMD, 2012b). While the RESP 2001-2010 did not achieve the desired target of achieving a 10% rural electrification level, this current RESP has been formulated taking into considerations the inaccuracies of the previous RESP (MEMD, 2012b).

Although the main objective of the RESP was to promote rural electrification by engaging the private sector given that the government offers an enabling environment, there has been limited success (Whitley and Tumushabe, 2014, NRECA, 2015). This is because rural electrification is such an expensive venture (grid extension) that requires enormous investment and little return that the private sector is not willing to undertake (Whitley and Tumushabe, 2014).

To counteract this challenge, the government has adopted an alternative method in which it uses either loans or grants from donors for example Norway, World Bank, African Development Bank and Japan International Cooperation Agency to finance the construction of new transmission and distribution projects (Whitley and Tumushabe, 2014). Before financing is undertaken, each individual project is assessed on whether it would be economically viable for the government to pursue it. The projects which include interconnections, grid expansion and grid restoration are then later leased to private companies which operate and maintain the same (Whitley and Tumushabe, 2014).

Energy for Rural Transformation (ERT) is one of the other programs that is being implemented to promote rural electrification and alleviate poverty (Keating, 2006; Bena, undated). The ERT forms a sub-component of the RESP programme therefore it promotes rural electrification with an emphasis on small-scale renewable energy. The programme is integrated with on-going rural electrification initiatives such as mini-grid extensions to rural areas, Priority Rural Electrification Projects (PREP) and solar PV installations (Tumwesigye *et al.*, 2011).

All supported initiatives must conform to both Uganda and World Bank environmental and social policies (Tumwesigye *et al.*, 2011). The World Bank is the majority financier of the project (about US\$400 million) (Tumwesigye *et al.*, 2011). Other stakeholders involved in the project include the Bank of Uganda for the financing aspect, Private Sector Foundation Uganda (PSFU) for the business development and planning and REA for the subsidy allocation (Okure, 2009).

## **2.6 Legal and regulatory framework for energy in Uganda**

The efficient and effective management of the energy sector is an important aspect needed to support economic development. It is only recently that Uganda has developed some of the legislative framework to govern this sector despite

the importance of the same to economic development. Some of the policies include;

***The Electricity Act, 1999 (GOU, 1999; Mathiassen et al., 2005)***

The Electricity Act of 1999 is the general legal framework that regulates Uganda's electricity sector including generation, transmission and distribution. The Electricity Act led to the formulation of the ERA whose role has been highlighted in the previous paragraphs.

Part VII of the Electricity Act explicitly highlights the role of government in promoting rural electrification and the relevant strategies such as the rural electrification strategy, rural electrification fund and the rural electrification database.

***The Energy Policy for Uganda, 2002 (MEMD, 2002; Mathiassen et al., 2005)***

Uganda's energy policy's main "goal is to meet the energy needs of Uganda's population for social and economic development in an environmentally sustainable manner" (MEMD, 2002:1). It came into effect in 2002.

The energy policy provides relevant information on the country's energy resource potentials, energy use in the various sectors of the economy and the key issues in the various areas of the energy sector. The policy also makes provision for investment in the sector and increased energy access by providing strategies.

Furthermore, under 4.2.3 the policy includes strategies for the promotion of renewable energy technology through financing, standards and policy. This is aimed at increasing supply from renewable energy in the country energy mix.

***The Renewable Energy Policy for Uganda, 2007***

The renewable energy policy recognizes the need for modern renewable energy inclusion in the energy supply mix, setting a target of increasing the same from 4% to 61% by 2017. The renewable energy policy further highlights the

resources and potentials of renewable energy reserves in Uganda. The policy states that more financing mechanisms are to be targeted towards increasing investment in the renewable energy sector alongside dissemination of information on renewable energy potentials in Uganda, so as to attract investment in the same.

### ***Rural Electrification Strategy and Plan (RESP), 2013-2022 (MEMD, 2012b)***

The RESP is the Government of Uganda's planning tool on how to achieve increased rural electrification through solar photovoltaic installations. The main objective of the RESP is "To position the electrification development program on a path that will progressively advance towards achievement of universal electrification by the year 2040, consistent with the existing policy of the Government, while ensuring the displacement of kerosene lighting in all rural Ugandan homes by 2030" (MEMD, 2012b:ii).

The initial RESP was developed and adopted in 2001 and covered 2001 to 2010. The RESP provides for the installation of SHS in rural households to increase electrification and thus has a target of reaching 22% rural electrification by 2022 (MEMD, 2012b).

## **2.7 Solar energy use in Uganda**

Although not widely used in Uganda, adoption of solar technology has steadily been growing. There are mainly two products that have been popular on the Ugandan market and these are solar photovoltaic systems and solar water heaters. Solar thermal technologies are used mainly by the middle to high-income households and by institutions such as hotels and schools (Okure, 2009). On the other hand, solar photovoltaic systems come in various capacities; thus, even the low income earners can make use of this technology. Solar PV is also currently used in schools, hospitals, health centers, administrative offices and in businesses.

Even though Uganda has a good solar resource potential, this resource has not been fully exploited (Okure, 2009) and only has an installed capacity of about 1.1 MW of all solar technology currently used in Uganda (Kyezira *et al.*, 2009). The main challenges associated with the poor uptake of the technology are the high upfront costs and inadequate financing mechanisms especially for household use (Tumwesigye *et al.*, 2011; Clark, Undated).

To solve this problem, the government has put in place strategies and programs aimed at increasing the uptake of renewable energy, some specifically focusing on solar technology. Increased uptake of solar technology will enable the government meet its renewable energy targets (MEMD, 2007) and at the same time increase national electrification levels. Some of these programs include the PV Targeted Market Approach (PVTMA), Energy for Rural Transformation (ERT), the Rural Electrification Strategy and Plan and the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) (Tumwesigye *et al.*, 2011, Okure, 2009, Whitley and Tumushabe, 2014). The programs are regulated by the MEMD and supervised by the Rural Electrification Agency (Whitley and Tumushabe, 2014).

Several companies are engaged in doing business in Uganda's solar market and these including both local and international companies. Some of the notable companies include Barefoot Power, SolarNow, Solar Sisters, Ultra Solar, Solar Energy for Africa, Incafex Solar Systems and Global Solar systems (Okure, 2009; Whitley and Tumushabe, 2014).

Uganda's solar market has slowly grown over the years as evidenced with over 100 solar dealers and suppliers, but remains inefficiently regulated (Whitley and Tumushabe, 2014). The market has been flooded with substandard and poor quality products (Whitley and Tumushabe, 2014) and users of these solar products have given poor reviews particularly of batteries and light bulbs (Harsdorff and Bamanyaki, 2009). Poor quality products coupled with inadequate financing and high upfront costs have been the major barriers in fast

uptake of solar technology (Whitley and Tumushabe, 2014; Harsdorff and Bamanyaki, 2009). In order to promote the technology, the above issues need to be addressed by the government and solar service providers.

## **2.8 Overview of poverty**

Poverty is a multidimensional phenomenon that cannot easily be defined (World Bank, Chapter 2; 26). The World Bank's definition of poverty focuses on three aspects. Poverty is "defined as whether households or individuals have enough resources or abilities today to meet their needs; inequality in the distribution of income, consumption or other attributes across the population; and vulnerability" (World Bank, 2011:1). The World Bank estimates show that in 2010, approximately 2.4 billion people globally were living on less than \$2 per day.

Reduction of poverty is top of the agenda of many multinational organizations including the United Nations (UN). The UN established a set of 8 Millennium Developmental Goals (MDGs), which aim at achieving 8 goals by 2015. They are: to eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality, improve maternal health, combat HIV/AIDS, malaria, and other diseases, ensure environmental sustainability and develop a global partnership for development (UNDP, 2015). Eradication of extreme poverty is an extremely difficult task; however strategies can be adopted to alleviate poverty. Access to modern energy is one of the strategies that can be adopted to alleviate poverty (UNDP, 2005).

Kraai (undated) indicates that poverty alleviation is aimed at improving poor people's standard of living and welfare by decreasing the undesirable effects of poverty. Kraai further stresses that poverty alleviation strategies are more long term, permanent and developmental than poverty relief programs, which are usually short term in nature.

### **2.8.1 Ugandan context on poverty**

Uganda has made tremendous efforts in achieving economic growth over the years as seen in the various sectors of the economy such as banking, construction, mining, energy especially oil and gas and the telecommunication sectors (Lwanga-Ntale and McClean, 2003; Byekwaso, 2010; Whitley and Tumushabe, 2014). Fan *et al.*, (2004) indicates that Uganda's economic growth rate rose from 3% in the 1980's to about 6.9% in the 1990's. However due to recent withdrawal of donor funds, the economy has slowed, with the IMF projecting an annual economic growth rate of about 4.3% in 2012/2013 (Whitley and Tumushabe, 2014). This economic growth has mainly been attributed to the economic reforms that were undertaken by the government in 1987 to revive the economy (Fan *et al.*, 2004).

Linked to this growth, has been a reduction in poverty levels. However, Byekwaso (2010) argues that the country's growth rates are not a satisfactory reflection of Uganda's ability as a producer of goods and services. Furthermore, Byekwaso (2010) argues that the country has continuously incurred trade deficits because of the disparity between total imports and total exports. Because growth rates are not a reflection of the internal enterprise development, unemployment as a problem has not been addressed, leading to persistent poverty levels (Byekwaso, 2010). Uganda, like many other developing countries is also hugely reliant on foreign aid (Byekwaso, 2010), rendering the country's economic growth figures inaccurate since grants fund more than 70% of total investments (Byekwaso, 2010).

The majority of Ugandans engage in agriculture and this in most cases is their main source of income (MFPED, 2014). At the same time, Byekwaso (2010) argues that the contribution of the agricultural sector to economic growth has since the 1980's reduced by 50%. As earlier mentioned, this sector is a main source of income for majority of the Ugandans, if its contribution to economic

growth continuously falls then many of the Ugandans will be vulnerable to falling into the poverty bracket (Byekwaso, 2010).

Furthermore, due to a lack of employment in the industrial sector coupled with the slowing agricultural sector, a considerable number of youth have now been absorbed in the informal sector (MFPED, 2014). Informal sector employment is usually characterized by irregular incomes, making it a very unsustainable form of employment. Such challenges need to be addressed if the country is to reduce its levels of poverty (MFPED, 2014).

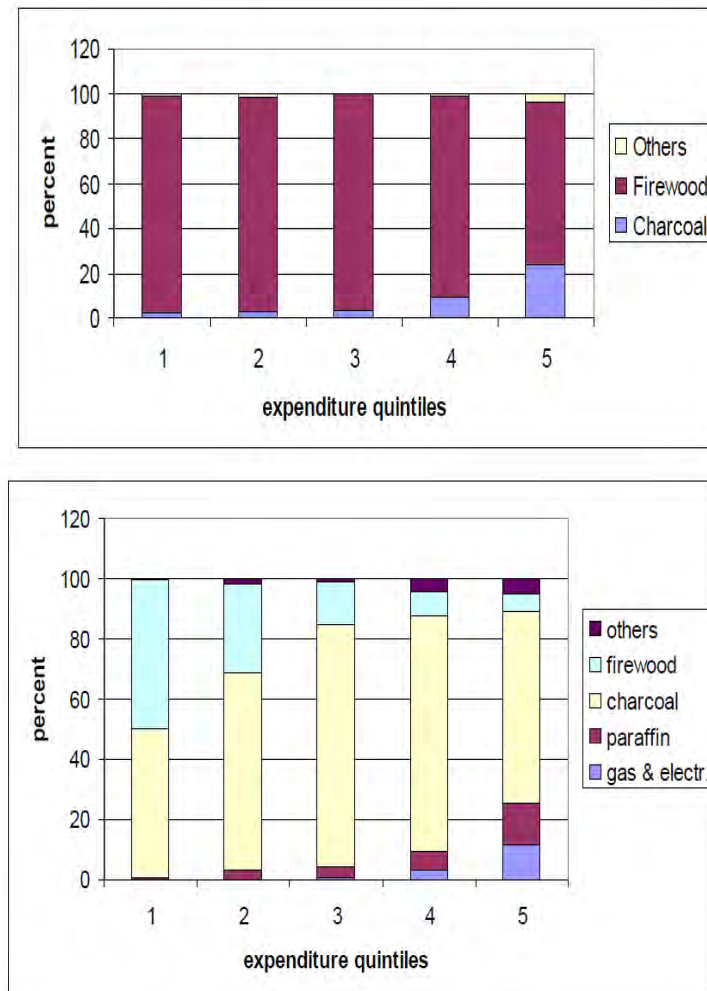
Regardless of the high numbers of people living in poverty, Uganda has made tremendous efforts in reducing poverty rates from about 56% in 1992 to 44% in 1997 (Abuka *et al.*, 2007; IFAD, 2013). A further reduction in poverty rates from 44% in 1997 to 34% in 2000 was noted (Abuka *et al.*, 2007; World Bank, 2015b). The World Bank (2015b) indicates that as of 2012 Uganda's poverty rate was estimated at 20%.

Even though there was a significant reduction in poverty rates between 1997 and 2000, the level of inequality on the other hand widened (Ssewanyana, 2009). Not all citizens benefited from economic growth and this led to an increase in income inequality (Ssewanyana, 2009). Furthermore, the World Bank (2015b) states that the country's population has more than doubled since the 1990's therefore the absolute number of poor people has increased.

Nevertheless, Uganda has made enormous efforts in reducing the national poverty level, although poverty still remains deep-rooted especially in the rural areas (IFAD, 2013). For example in the years 1992, 2000 and 2003 the respective urban and rural poverty levels were as follows 28%, 10% and 12%; 60%, 37% and 41% respectively (Abuka *et al.*, 2007).

The widespread level of poverty in Uganda is further reflected in the choice of energy fuels as evidenced by Figure 13 (Mathiassen *et al.*, 2009). In this study, both rural and urban population was divided into 5 income groups (using their

expenditures as basis) with 1 being the lowest and 5 as the highest. In rural areas, the population largely uses firewood for cooking (Mathiassen *et al.*, 2009; Mwaura *et al.*, 2014).



**Figure 13: Level of expenditure on energy used for cooking by the rural population (top) compared to the urban population (bottom) in Uganda**

Source; Mathiassen *et al.*, (2009)

Mathiassen *et al.*, (2009) show that the lowest quantile (1) of the rural population in Uganda use firewood as their main cooking fuel while the lowest quantile (1) of the urban population use both charcoal and firewood as the main cooking fuel.

Therefore, it is imperative that the poor are not only provided with modern energy but also energy that has the potential for productive uses (Harsdorff and

Bamanyaki, 2009). In order to reduce household poverty in rural Uganda, Abuka *et al.*, (2007) suggests that there is a need to diversify to non-farm employment to create additional sources of income. Non-farm employment can be achieved through access to modern energy such as electrification coupled with other services such as education and infrastructure which has the potential to induce enterprise development in rural areas (Abuka *et al.*,2007; Kanagawa and Nakata, 2007).

The main program implemented by government with the aim of reducing poverty is the Poverty Eradication Action Plan (PEAP) (Lwanga-Ntale and McClean, 2003). Initiatives under PEAP are funded by a component in the budget known as the Poverty Action Fund (PAF).

#### Poverty Action Fund (PAF)

The Poverty Action Fund (PAF) established in 1997, was created with the main objective of providing funds to poverty reduction programs such as the PEAP. The PAF forms part of a component under the Government of Uganda budget (IMF,2005; Fan *et al.*, 2004; Lwanga-Ntale and McClean, 2003).

Poverty Eradication Action Plan (PEAP) is an all-inclusive plan that was formulated in 1997 with the aim of guiding economic development so as to reduce poverty in Uganda (MEMD, 2001; Brown, 2014; Abuka *et al.*,2007; Canagarajah and Diesen, 2011). The five focus areas that have been earmarked to help achieve the goals of the PEAP are health, education, agriculture, roads, water and sanitation (Lwanga-Ntale and McClean, 2003). Modern energy access is a direct pre-condition for the achievement of the goals enshrined in the PEAP. Provision of energy in the education, agriculture and water and sanitation sectors is imperative to meet the targets of the PEAP (MEMD, 2002).

Other aspects of poverty such as lack of access to clean water, medical care, food and level of education have also been highlighted as poverty indicators. For example the Uganda Poverty Status Report, 2014 states that only 36% of poor

households in Uganda are able to live in houses with iron sheet roofing (MFPED, 2014). Also about 86% of children in poor households are unable to have a pair of shoes (MFPED, 2014).

Access to education varies among different regions mainly due to underlying historical factors. For example, Northern Uganda has experienced periods of instability due to the war between LRA rebels and the government (France-Press, 2012). Only about 8% of the population in Northern Uganda has access to secondary school education, reflecting the lowest figures in region (World Bank, undated). At the same time, Northern Uganda has the lowest levels of electricity access at only 2% of the entire Northern Uganda population (World Bank, undated).

On the other hand, access to clean water has registered success with about 68% of the country's population having access to clean water. At regional level, Central, Eastern, Northern and Western Uganda have the following safe water access levels, 61%, 83%, 78% and 58% respectively (World Bank, Undated).

## **2.9 Access to Solar PV and poverty alleviation**

Access to modern energy in the form of electricity has facilitated poverty alleviation in areas where it has been applied. This has been demonstrated by a number of studies as discussed below;

Buragohain's (2012) shows the findings from a social impact study carried out in villages of six states namely Assam, Meghalaya, Jharkhand, Odisha, Madhya Pradesh and Chhattisgarh in India.

A household survey was undertaken to collect information from 1000 households. A structured questionnaire was used in this study and this was supplemented by focus group discussions to collect additional information on the impacts of the initiative. Electricity was supplied from either a solar plant or from solar photovoltaic systems, which were acquired on a cash basis.

Households using solar photovoltaic were supplied with a 50-Watt peak solar system.

Findings from this study revealed that households using solar energy for lighting reported a significant reduction in kerosene consumption by more than half. This was observed in areas of Jharkhand, Meghalaya and Assam. Households noted that they were able to use the available light provided by the SHS for a number of activities such as household evening chores, entertainment, cooking and helping children with homework and studying.

Helping children with homework and study benefits the children's education, hence eliminating child illiteracy in the long-run. In that sense children benefited the most from solar energy lighting.

Convenience and a slight improvement in the standard of living were also noted in the surveyed households. About 2-3 percent of the surveyed households also noted an increase in household income.

Buragohain's (2012) findings revealed that SHS connected households in the study area derived numerous social benefits from access to the solar electricity in the area. Some of these benefits include the ability to engage in social gathering in the evenings, access to media, improved security, decreased school dropouts and convenience in carrying out household chores especially for women. Furthermore, the women noted that they could engage in other income generating activities such as basket weaving, domestic animal rearing especially chicken farming.

Another study carried out by Obeng et al., (2008) in two rural fishing communities of Bonny and Kula in Nigeria revealed that access to electrification has an impact on family planning usage amongst households. In his study, Obeng et al., (2008) show that households in Bonny, which had access to electrification, practice family planning more compared to the residents in Kula fishing community, an un-electrified area. The high uptake of family planning in Bonny is

attributed to access of family planning information that is continuously communicated via radio and television.

Households that practice family planning are able to plan for a small manageable family. Having a small manageable family enables the household to allocate resources effectively in areas such as health, education and food (UNFPA, 2006). This in turn reduces the financial burden placed on the households (Hervish and Foreman, 2011; UNFPA, 2006). Although family planning was not covered in this research, it should be noted that it plays a role in alleviating rural poverty by reducing family sizes and this is facilitated by access to media.

Samad *et al.*, (2013) also argued that improved information access from radio and television because of access to solar electrification improved welfare and also empowered users by providing them with information. Agricultural and health programs that are relayed over these media have the potential to enable households' to improve productivity and health respectively (Samad *et al.*, 2013). Jacobson's (2007) findings also reveal that information access such as that related to prices of goods and services enabled households to run their businesses efficiently thereby increasing productivity.

Pachauri and Rao (2013) indicated that access to media in India lowered instances in which women tolerated gender-based violence especially from their spouses. Furthermore, women who had access to media were more likely to influence the decision of educating girls within these families. In contrast, in Brazil, access to media accelerated divorce rates (Pachauri and Rao, 2013).

According to Pachauri and Rao (2013), access to education for the girl child has a positive impact on the choice of household fuels. Since women and girls are the most affected by the use of traditional fuels, they are highly likely to choose modern and efficient energy sources. Traditional fuels are associated with indoor air pollution, tiresome and long collection times. The burden of collecting these fuels together with carrying out other household chores is placed on women and girls (International Centre for Research on Women, 2005). Therefore, it is

imperative that energy provision policies are aligned with gender issues so as to increase the uptake of modern energy sources and technologies. A study carried out in India revealed that low quality fuels are used in numerous Indian households and this has been associated with the low status of women in that society (Pachauri and Rao, 2013). Women's low status in this study is described by the level of attainment of education, sex of the first-born child and spousal abuse.

Blunck (2008) carried out a study in Bangladesh to evaluate the potential of solar photovoltaic technology to generate income by assessing its use in productive activities. Blunck (2008) established that solar photovoltaic technology can increase a household's income when used either directly or indirectly in productive activities.

From the findings, it was noted that the majority of the solar home systems were being used in households for domestic purposes, mainly for lighting and leisure especially entertainment. In a few cases, about 10 to 15 percent of the surveyed households used solar electricity lighting to extend working hours by engaging in activities such as local soap manufacture (Blunck, 2008) (see figure 14). Furthermore, Blunck (2008) states that the creation of new business enterprises did not increase after acquiring a solar PV but rather that a solar PV enhanced an already existing business.



**Figure 14: Local soap factory making use of solar electricity in Bangladesh**

Source; Blunck (2008).

At the time of the study, it was also noted that about 5 to 10 percent of the procured solar home systems were owned by shop owners whose businesses were established in the local market (Blunck, 2008). Solar energy provided lighting in the evening for the shops and also enabled the shops to stay open for a few extra hours. Additionally, solar energy gave these shops a competitive edge over other shops with no solar power access (Blunck, 2008). Shops connected to solar PVs usually played music on either radio or television, therefore attracting more customers. Even though production statistics were not made available, Blunck (2008) argued that solar energy access in businesses has indeed created a positive impact for its users.

The use of solar energy in the agricultural sector had been explored in Bangladesh and as such reports of both increased productivity and decreased kerosene usage had been noted. Blunck (2008) stated that solar energy had been adopted in both poultry and fish farming in Bangladesh. One of the major benefits of using solar electricity on fish farms in Phulpur district was the reduced theft of fish from the ponds, whereas the benefit to one of the poultry farmers was reduced kerosene expenditure to the tune of 4,000 BDT Taka (US\$ 51), per month, which in turn increased savings (Blunck, 2008).

Samad *et al.*, (2013) also showed the findings from a study in Bangladesh. The objective of this descriptive study was to assess the benefits of solar energy access in Bangladesh. A household survey was undertaken to collect information from a sample of 4000 households in 128 villages, both SHS users and Non-SHS users.

From the study, Samad *et al.*, (2013) established that households that used solar home systems noted a reduced consumption of kerosene, from 3 litres to 1 litre per month. This was established by comparing average kerosene consumption of both SHS users and non-SHS users. Samad *et al.*, (2013) argued that adoption of SHS did not completely cut kerosene consumption; however, it reduced household's kerosene consumption. Given that energy costs take up a considerable portion of poor household's budget, eliminating inefficient fuels enables a household to save (Samad *et al.*, 2013).

A result from another study conducted by Lighting Africa Initiative revealed that about 15 to 30 percent of Kenyan household's income is used to purchase kerosene (Esper *et.al.*, 2013). In another study conducted by SolarAid in Kenya in 2012, it was shown that adoption of solar technology from SunnyMoney enabled households save about 9% of their income on a monthly basis (Esper *et.al.*, 2013). The savings were generated from reduced kerosene expenditure (Esper *et.al.*, 2013). Respondents in Kenya revealed that they were able to spend their savings on food and business. While in a similar study by SolarAid in Tanzania with the same proportion of savings, some households spent their savings on school fees, food and agricultural inputs (Esper *et.al.*, 2013).

Like the previous case studies, Samad *et al.*, (2013) also noted that access to SHS enabled its users to extend working hours by making use of a clean and efficient lighting source. Households could use this time to engage in local income generating activities such as basket weaving, preparation of snacks, making beaded jewellery and tailoring. Income from these activities enables households' to supplement their income (Samad *et al.*, 2013).

With the advancement of technology, manufacturers have been able to provide mobile phones for all the different consumers on the market. As such, even the rural population has acquired mobile phones. However, there still is a challenge of charging mobile phones in these rural areas that do not have electricity access (Samad *et al.*, 2013). With a SHS, opportunities to provide phone-charging services have been created. Samad *et al.*, (2013) states that phone charging services provided additional sources of income for business owners in Bangladesh.

Samad *et al.*, (2013) also suggested that children, especially girls, had been able to benefit from the adoption of SHS. Children were now able to study in the evening. Access to education enabled the children to gain knowledge and with further education, they could gain skills and find employment in the formal sector (Samad *et al.*, 2013).

Access to solar technology also reduced the burden placed on women and children in firewood collection especially for households that used firewood for lighting. In the Samad *et al.*, (2013) study, it was established that the amount of time spent collecting wood by women is reduced by 9 percent. Women could use this free time to engage in small-scale income generating activities.

On the other hand, findings from a study conducted in 2003 by Jacobson (2007) in Kenya revealed that access to a SHS did not lead to an increase in income. Information was collected from 76 households using solar home systems who further indicated the usage of SHS for income generating activities. The study revealed that thirty-two percent of the sample population used SHSs for income generating activities (Jacobson, 2007).

Furthermore, Jacobson (2007) argued that the adoption of SHS enabled cell phone users to charge their mobile phones and in that case they were able to keep in touch with their customers, suppliers and access other markets hence improving business.

SunnyMoney is one of the modern energy provision initiatives which begun in 1997 under SolarAid. SolarMoney has operations in Kenya, Tanzania, Zambia and Malawi (Esper *et.al.*, 2013). SunnyMoney conducted a study to assess the impact of solar electricity on children.

Esper *et.al.*, (2013) summarized the benefits of solar electricity to children's well-being in 3 categories; relationship well-being, economic well-being and capability well-being. Under relationship well-being, the benefits derived were that children were able to participate in classroom exercises because of studying in the evening. Hence, the students were now more knowledgeable. Furthermore parents were able to interact with their children and also help with homework in a relaxed and stress free atmosphere without having to worry about purchasing more kerosene (Esper *et.al.*, 2013).

The benefits derived under economic well-being included the ability of parents to save because of reduced kerosene usage. This in turn increased disposable income that could be spent on other children's needs or household items, thus increasing well-being (Esper *et.al.*, 2013). Furthermore, with access to solar energy there was a reduced expenditure on treating pollution related illnesses or accidents caused as a result of household usage of kerosene. This also freed up income that could be spent on other household necessities (Esper *et.al.*, 2013).

The study further revealed that under capability well-being, the children improved their grades as a result of access to solar lighting. This placed them in a better position to upgrade in their educational life (Esper *et.al.*, 2013). About 84% of the children in solar energy connected households reported an improvement in their academics (Esper *et.al.*, 2013). Additionally as a result of improved air quality, the children did not have to worry about falling sick, hence they could concentrate better on school work and neither did they have to lag behind after they skipped school (Esper *et.al.*, 2013). Another study was carried out by Furukawa (2012) to assess the health and safety benefits of replacing kerosene for lighting with solar lanterns in Uganda. Field data from a study

conducted by Barefoot Power in Masaka District was supplemented with findings from the National Household Survey 2005/2006 to provide results for the analysis.

The following observations were made: children in households that used kerosene for lighting reported higher illness symptoms as a result of indoor air pollution especially during exam period. Some of these included teary eyes, continuous coughing and black soot in the nose. It was also observed that during exam period, children studied for longer periods and thus they spent more hours in a polluted environment (Furukawa, 2012).

Furukawa (2012) argued that households using kerosene had a higher probability of experiencing fire accidents and in 5 years, this probability rose from 2.7 percent to 5.7 percent. Given that the majority of kerosene users are low income households who are usually clustered together in unplanned areas, a fire out-break in one household could potentially affect the entire cluster/area (Furukawa, 2012).

Findings from a study carried out in Sri-Lanka (Laufer and Schäfer, 2011) revealed that the general welfare of SHS beneficiaries improved even though the level of household income did not necessarily increase. Some of benefits realized from the SHSs were the extension of working hours, especially for income generating activities; substantial reduction in use of kerosene; and children were able to study and do their homework (Laufer and Schäfer, 2011). From this research, Laufer and Schäfer (2011) concluded that for poverty reduction to be achieved in rural areas, access to energy services should be implemented with the aim of increasing productivity and income generating activities.

## **2.10 Conclusion**

The chapter has provided a snapshot of Uganda's energy sector including the level of access to modern energy in the rural areas. It has given a brief overview of the evolution of Uganda's electricity sector and the efforts the government of

Uganda is undertaking to increase electricity access. The main initiatives are have been enshrined in the Rural Electrification Strategy and Plan that focuses on renewable energy such as solar energy and mini-grid installation.

Furthermore, it has also provided an overview of the level of poverty in Uganda and the various strategies that the government has employed to combat this phenomena. The PEAP was identified as the all-inclusive framework that outlines the focus areas that will help the government in achieving the poverty reduction objective.

Additionally, previous research has been reviewed and the main finding from these studies is that most of the SHS users noted an improvement in welfare. There was also a noted increase in savings because of reduced kerosene expenditure.

## **CHAPTER THREE: THEORY OF CHANGE FRAMEWORK**

### **3.0 Introduction**

The previous chapter has provided an overview of Uganda's energy sector. Furthermore, it has also looked at a few select studies of modern energy provision, specifically solar energy and their contribution to poverty alleviation. This chapter will provide a detailed analysis of the Theory of Change theoretical framework and the applicability in this research. The theory of change framework will provide a more detailed analysis of the socio-economic impacts of solar energy access in the study area.

### **3.1 Theory of change**

The "Theory of change" is a theoretical frame work/tool often used to analyse and evaluate activities, policies, initiatives, or interventions. Connell and Kubisch (1998; 2) define the theory of change as "a theory of how and why an initiative works." A theory of change consists of all the building blocks that are necessary to achieve a long-term goal (The Centre for Theory of Change, 2013). While developing a theory of change, it is imperative that the objectives of the initiative are defined from the onset (Organisational Research Services, 2004). Theories of change are believed to provide solutions to a number of complex social problems and they have been widely used in a number of initiatives to solve community problems (INSP, 2005).

Two components make up the theory of change framework:

a) First we need to conceptualise and operationalise the three core frames. The three core frames include the target population; interventions that will be carried out to produce the desired outcomes; and lastly the outcomes (INSP, 2005).

In this research, the target population has been the selected sample in Kebisoni, which consists of 40 respondents. The intervention in the study is the access and usage of solar home systems as a source of electricity. Access and usage of solar home systems is expected to produce both outcomes and impacts. The major outcome is the increased access of modern energy and the expected impacts include an increase in disposable income, improvement in education, better health and improvement in social welfare (Obeng & Evers, 2009).

b) The second component encompasses an understanding of how the three core components inter-relate with each other. This relationship is shown diagrammatically in the form of a map/ 'pathway of change' as shown in figure 15 (INSP, 2005).

Additionally, Anderson (2005) further discusses other success factors of the theory of change. These factors include;

- i. Indicators, which ought to be, clear enough to measure how successful the intervention is. These indicators have been discussed below in relation to the corresponding impact.
- ii. Clearly defined assumptions clarifying why the theory is plausible.
- iii. The pathway of change should show the relationship between the different outcomes.

### **3.2 Steps in the Theory of Change**

Anderson (2005) identifies the following key steps in the community developer's approach to the theory of change;

#### *a) Identify the Long-Term Outcome*

The project/initiative's intended long-term outcomes must be clearly defined from the start to avoid any confusion. By identifying the long-term outcomes,

appraisal of the initiative can be done to assess whether the intended objectives have been achieved. Additionally the intended outcomes should be unpacked and simply stated (Anderson, 2005; Obeng & Evers, 2009).

*b) Develop a Pathway of Change*

This following stage is very time consuming and also an important stage in developing the theory of change as it forms the main mantle of the theory. Under this stage, all the preconditions that are necessary to achieve the initiative's outcomes are identified. Once the preconditions have been identified, a linear relationship between the pre-conditions and outcomes is developed. The relationship is then illustrated in the form of a "pathway of change map" (Anderson, 2005). It is important to note that developing the pathway of change map takes a backward process, in other words the map is developed from the final stage to the first step (Anderson, 2005; Obeng & Evers, 2009).

*c) Operationalize Outcomes*

The operationalization process entails the testing of the pre-conditions by treating them to the question; "what evidence will we use to show that this has been achieved?"(Anderson, 2005:13). The answer forms a basis for measuring project progress. Operationalization of the outcomes at all the stages of the pathway of change will lead to the identification of various assumptions; which will be dealt with at the final stage (Anderson, 2005; Obeng & Evers, 2009).

*d) Define Interventions*

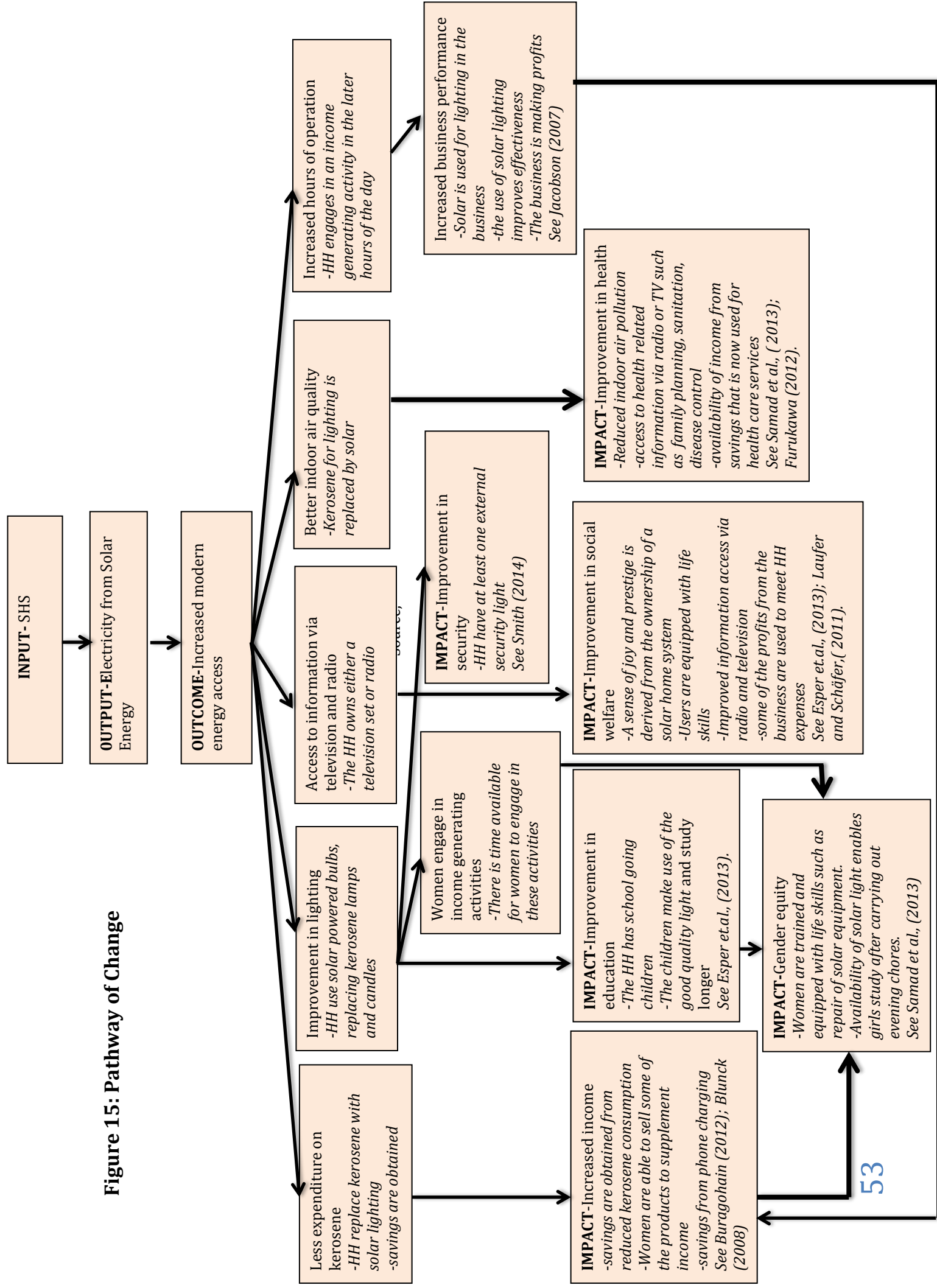
Interventions in this case are regarded as strategies or initiatives or policies or actions that need to be implemented so as to achieve the desired outcomes that have been illustrated on the map. At this point, it is important that the researcher knows that some outcomes will be generated as a result of the "domino effect". Hence, there is not necessarily the need to develop an individual strategy for

each particular outcome (Anderson, 2005; Obeng & Evers, 2009). However, Anderson (2005) does not provide a clear distinction between impacts and outcomes while developing the theory of change. Figure 15 provides a clear distinction of the various outcomes (intermediate steps) and impacts.

*e) Articulate Assumptions*

This is the final stage under the community builder's approach to the theory of change. Under this stage, the researcher lays down all the assumptions that will be used in the process of using the theory of change to come up with the desired outcomes. These assumptions include but are not limited to; assumptions underlying the environment, in which the theory is applied, assumptions about the connection between an initiative and its resultant outcome in a particular context (Anderson, 2005; Obeng & Evers, 2009). Even though articulating assumptions has been defined as a step on its own, assumptions are developed along the entire process but more articulated at this stage.

**Figure 15: Pathway of Change**



In order to achieve the desired long-term outcome under the theory of change framework, certain assumptions need to be made. The assumptions made in this study include;

**a) Increased modern energy access**

Assumptions

- *Households will continuously use the solar home systems.*
- *New households adopt the technology*
- *The Solar Home Systems remain active over the long term. No serious maintenance issues, and if there are, they are fixed by the solar technology technicians in the area*
- *Households are able to pay for the systems and services*

Indicators

- Number of households with solar home systems
- Increase in solar home system sales

**b) Improved household income**

Assumptions

- *Solar access will lead to better performance of existing enterprises and some of this income will trickle down to the household.*
- *New enterprises will be established with the availability of the technology*
- *Households will engage in small-scale home based businesses to supplement household income.*
- *Savings are realised from a reduced kerosene usage.*

Indicators

- Increased expenditure on other pressing household needs such as education, health, food
- Increase in number, quality and diversity of household assets
- House improvements such as renovation, addition of extra rooms.

### **c) Gender equity**

#### Assumptions

- *Women are trained and equipped with life skills such as repair of solar equipment*
- *Availability of solar light enables girls to study after carrying out evening chores.*

#### Indicators

- Women have engaged in income generating activities

### **d) Improvement in education**

#### Assumptions

- *The household has school going children*
- *The children make use of the good quality light and study longer*
- *Availability of income enables the children to further their education*
- *Good grades as a result of studying longer motivates the children to enrol for further education*

#### Indicators

- Longer hours of study and ability to do homework

### **e) Improved social welfare**

#### Assumptions

- *A sense of joy and prestige is derived from the ownership of a solar home system*
- *Users of SHSs are able to establish income-generating enterprises to supplement family income such as bazaar/neighbourhood shops.*
- *Improved information access via radio and television*
- *Women are empowered (economic, social and political)*

#### Indicators

- A sense of fulfilment
- Ease in carrying out household chores
- More cash in hand
- Access of information via radio or television

- Entertainment

#### **f) Improvement in health and safety at home**

##### Assumptions

- *Reduced indoor air pollution*
- *Access to health related information via radio or TV such as family planning, sanitation, disease control*
- *Availability of income from savings that is now used for health care services*
- *Households have atleast one external security light*

##### Indicators

- Improved indoor air quality
- Availability of income to cater for medical bills
- Reduced theft/household break-ins
- Improved sense of security

### **3.3 Conclusion**

The Theory of Change Framework has been explained and how it will be used to analyse the social and community benefits of the intervention. The next chapter will now present an explanation of the methodology and research tools used in the study.

## **CHAPTER FOUR: METHODOLOGY**

### **4.1 Introduction**

Chapter three has provided a detailed explanation of the theory of change framework. It has provided the underlying assumptions made in using the framework. Subsequently, the indicators used to measure the impacts have also been noted. Chapter four will now provide an explanation of the methodology used and how analysis of the data collected during the course of the research was undertaken. The data collection techniques and tools together with the type of data collected are discussed under this section. The chapter further provides an overview of the surveyed area and the target population that was a focus of the research. A detailed discussion of the data analysis techniques employed to analyse the data are also discussed.

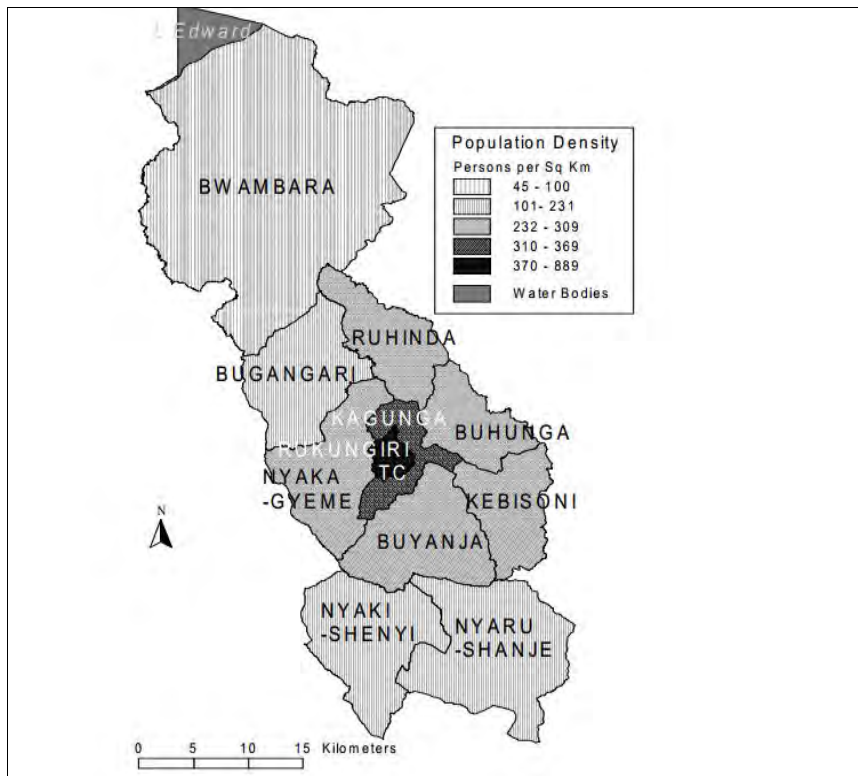
### **4.2 Research Design**

A case study design was applied for this research. This design was aimed at establishing the level of energy access and the various household energy fuels used by a sample of the population (Kumar 2005). A research survey was conducted by means of interviewer-administered questionnaires. The questionnaires were administered to heads of households or their spouses after consent had been granted. The interview guide was also administered to two selected focus groups to gather any more information that had not been collected from households.

### **4.3 Survey area**

The research was carried out in Rukungiri district, which is located in Western Uganda. Rukungiri's population is estimated at 321,300 people (2012) showing an increase from 275, 162 people (2002) (UBOS, 2012). Rukungiri district has 11 sub-counties namely Buyanja, Bugangari, Buhunga, Bwambara, Kagunga, Kebisoni, Nyakagyeme, Nyakishenyi, Nyarushanje, Ruhinda and Rukungiri

Trading Centre. The research has however focused on Kebisoni sub-county due to the characteristics of the area mainly because the study area is unelectrified. Economic activities in the survey area are mainly farming and livestock rearing.



**Figure 16: Map showing the sub-counties in Rukungiri District**

Source; Rukungiri District Local Government (2009)

#### 4.4 Data sources and tools

Data was collected from both secondary and primary sources. However before primary data could be collected, an initial desktop study was carried out to collect secondary data. Secondary data was collected from already published reports, research papers, journals, textbooks and selected websites on the internet. The process of secondary data collection included: reviewing and assessing data, which was relevant to the study being undertaken. Some of the secondary data collected included information on Uganda’s energy use, solar energy use case studies and solar usage in Uganda.

Primary data was collected from a survey that was undertaken in Kebisoni. A questionnaire with both closed and open-ended questions was used to collect the data (see appendix A). Data sourced from the survey included household energy fuels, household composition, solar energy use and energy use in business enterprises. The data comprised both quantitative and qualitative data, which was analysed accordingly and the findings presented in chapter 5.

#### **4.5 Surveyed sample**

Thirty households and eleven business enterprises were interviewed. This particular sample size was chosen because of the time and financial constraints. It should be noted the study areas is a remote and rural area with barely any road names and household register. Therefore, both the SHS users and non-SHS users were selected using purposive sampling. Purposive sampling is a non-probability sampling technique in which the researcher uses his judgement to select a representative sample for his research (Barreiro and Albandoz, 2011).

First an initial walk through was done to have a feel of the area and identify potential respondents. This lasted about fifteen minutes. After this, the first HH with a SHS was selected. The next respondent was then selected with guidance from the previous respondent since they knew who in the neighborhood had a SHS and also knew those who would be home (available to answer the questionnaire) at the time. The same principle was also applied to non-SHS users. However with non-SHS the guided recommendation from the previous respondent was limited since the number is big.

Additionally two focus group discussions were held amongst community members. This was done to get a deeper understanding of the community aspects regarding solar use and poverty. The focus group discussion was more of an open group discussion and participants were invited to take part. The majority were boda-doda (motorbike) riders since the discussions were held at

their stages. Other members of the focus group included, shop-keepers, farmers, and a teacher.

#### **4.6 Data analysis**

Analysis of the data was done with the main objective of showing; the link between access to SHSs and poverty alleviation by using the theory of change framework, whether SHSs have generally promoted income generation, whether household expenditure on kerosene and candles has reduced. The study also investigated whether there was a lower incidence of air quality related illnesses usually caused using kerosene.

After responses were collected, raw data was transcribed for analysis. Qualitative raw data was captured in MS word while quantitative data was processed and cleaned with the help of MS Excel. Both sets of data were analysed using a descriptive statistical analysis method especially by use of frequency distributions (William, 2015).

Descriptive statistical analysis is the method that involves the analysis of statistical data and presentation thereof in meaningful and easily understood way. This method involves the derivation of patterns from the raw data collected. (Williams, 2015; Lund and Lund, 2013).

Furthermore, the questionnaire was designed to make a comparison between solar electrified and non-solar electrified households. The household energy fuels and end-uses were compared. The likelihood of solar energy to promote income generation was analysed with the data collected from income generating enterprises using solar electricity and non-solar electrified enterprises. Perceptions regarding solar at the community level were developed with data collected from the focus group.

Additionally, the theory of change framework was used to gain a deeper analysis of the impact that solar energy has created at the community level. The data

collected provided a basis from which conclusions and recommendations were made which are explained in chapter five.

#### **4.7 Reliability and validity**

Reliability in research is defined as “...the extent to which results are consistent over time and an accurate representation of the total population under study” (Golafshani, 2003:1). Validity in research refers to the truthfulness of the data and tools used to collect the data (Twycross and Sheilds, 2004). Validity is applied in both data collection methods and the research tools. Validity in research tools aims at ensuring the tool is collecting the relevant data (Roberts *et al.*, 2006).

This study is internally valid i.e. the results were correct for the particular sample that was investigated and the interpretation of results was only limited to Kebisoni, Rugungiri district. Furthermore, the results were interpreted consistently and transparently.

The results in this study are also reliable as the researcher checked for any inconsistencies in all responses from the questionnaires. Those that were found to be inconsistent were excluded them from the analysis. This was because it was not possible to go back to the area of study to seek clarification due to lack of financial resources to travel there.

#### **4.8 Research Limitations**

During the research, it was noted that some households, for fear of tax implications, did not easily provide information regarding household income. Secondly, household income was self-reported, hence it could not be authoritatively verified. However, for the purpose of this research, information related to income was deemed to be accurate.

Furthermore, information regarding costs of the individual components of the solar home system was provided for some households. In some responses, especially on fuel consumption and usage, it was noted that some of the responses given were inconsistent.

#### **4.9 Conclusion**

To assess the impact of solar energy on poverty alleviation, a survey was undertaken in both households and income enterprises. The data collected was then analysed and findings generated. A theory of change theoretical framework was also applied to the data to analyse the social and community benefits that have accrued from the intervention.

## **CHAPTER FIVE: DATA ANALYSIS**

### **5.1 Introduction**

Chapter four has presented the methodology that was undertaken for this research and the various research tools. Chapter four has also provided an explanation of how the raw data was employed to produce the findings that have been presented in chapter five. Chapter five provides the findings from the field survey that was carried out in Kebisoni, Uganda. It analyses the energy use consumptions and solar energy usage in selected households. The findings in chapter five have been analysed by linking the data to the research questions.

### **5.2 General description**

A sample size of 30 households was selected and surveyed, however five questionnaires were deemed invalid due to inconsistencies such as missing and varying responses. Hence, for this analysis only 25 HH questionnaires have been considered.

Thirteen out of the 25 households had access to solar power and this was in the form of a solar home system. A solar home system (SHS) is composed of a PV panel, deep cycle battery, charge controller, inverter, light bulbs and cabling. It should be noted that in some households not all SHS components were available. It was revealed that the twelve non-electrified households expressed interest in acquiring SHSs, though at the time of the survey they did not have access to it for various reasons as will be explained below.

Solar home systems work by converting the light form the sun to electricity. The electricity produced at this stage is termed as direct current. At this stage, the inverter can be used to covert direct current to alternating current (Lombardi, 2012).

### **5.2.1 Demographic characteristics**

The HHQ respondents' ages in the surveyed area were between the ages of 25 and 45 years with 76 percent of HHQ respondents being female. The average household size in the survey area was five, which is almost similar to the district average household size of 4.9 (Rukungiri District Local Government, 2009). The largest household had nine members while the smallest had only three members.

### **5.2.2 Land ownership**

Land in Kebisoni like many other rural areas was neither surveyed nor authoritatively demarcated hence the land sizes provided were simply approximations. Additionally, land in the surveyed area was not individually owned, most of which was family owned land. Land holding of this nature promotes land fragmentation in such a way that individual households carve out their own parcels of land for individual household use (FAO, 2010; Sait and Tempra, 2015).

This leads to situations where small pieces of land are used on individual household basis hence not exploiting the advantages of optimally developing the land as a whole for the benefit of the entire family (FAO, 2010; Sait and Tempra, 2015). Kebisoni is a mixed farming community that has both cattle keepers and crop farmers. However, the majority are crop farmers. The most common land size holding in the surveyed area was approximately equal to 1 acre while the biggest land size holding was about 3 acres.

### **5.2.3 Amenities**

About 88 percent of the HHQ respondents owned the houses in which they lived, while 12 percent are renting their houses. None of the HHQ respondents in the surveyed area had government/institutional provided housing. Government provided housing includes houses that are built by the government and provided

to vulnerable members of the community, such as elderly people, child-headed households and people affected by natural disasters such as landslides.

The houses in the surveyed area were mostly built with easily available materials, which included clay bricks and mud bricks. The middle-income group<sup>6</sup> mostly afforded clay bricks while mud bricks were used by the low income group<sup>7</sup> and the lowest income group made use of mud and wattle to construct the walls of their houses. Mud bricks are made from a combination of earth/mud and water to form a semi-liquid mixture. Once the two components are properly mixed they are compacted into a rectangular shaped cut-out and then left to sun dry for a specific period of time (Hardwick and Little, 2010). On the other hand, clay bricks are made out of a mix of clay and water and are further processed in a locally made kiln for drying/curing (Hardwick and Little, 2010).

The commonest roofing materials in the survey area were galvanized corrugated iron sheets for the middle-income group while the poorest members of the community used grass to thatch their houses.

From the survey, it is evident that 92 percent of the HHQ respondents had access to a safe protected water source. Furthermore, 48 percent of the HHQ respondents sourced their water from a shared tap while 28 percent sourced their water from a tap in a yard. Other sources of water used by respondents within the survey area were tube wells, which were used by 8 percent, hand pump used by 12 percent of the HHQ respondents and lastly tanks used by 4 percent of the HHQ respondents. According to the Rukungiri District Local Government Report (2009), 79% of the district population has access to water at a distance of less than 1km from their homes.

The commonest sanitation facility was the pit latrine, which was used by 92 percent of the HHQ respondents. Flushing toilets (water-borne sewerage) were

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<sup>6</sup> Middle income group- Monthly household income between 200,000 – 400,000 Uganda Shillings

<sup>7</sup> Low income group - Monthly household income below 200,000 Uganda Shillings

used by 8 percent of the households. All the houses with flushing toilets also had pit-latrines facilities. All houses in the survey area had a separate bathroom.

#### **5.2.4 Electricity connections**

None of the respondents in the surveyed area was connected to grid electricity. The government through the Rural Electrification Programme is however extending the grid to this area but with very little success and few connections (Oluka, 2015). Only 3% of the district population has access to grid electricity (Rukungiri District Local Government, 2009). The process has mainly been hindered by lack of funding to extend the grid and the high up-front costs associated with getting the electricity connection from the power line to individual houses (MFPED, 2014; Oluka, 2015).

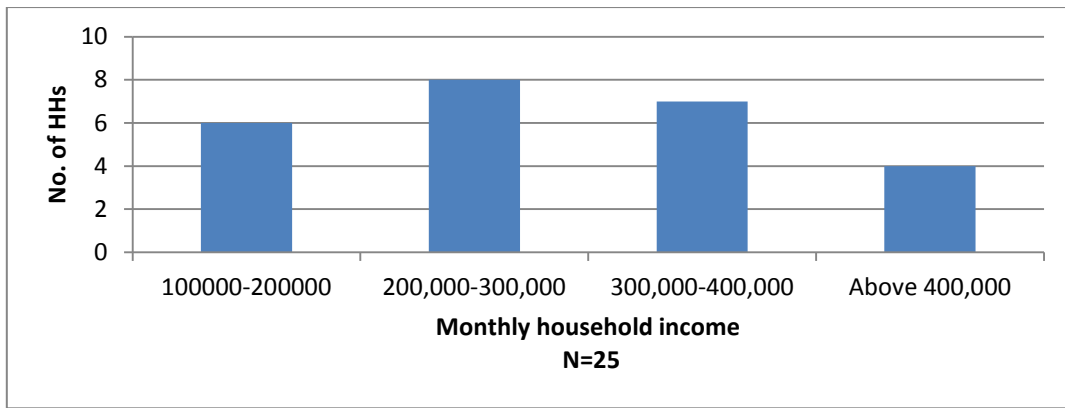
#### **5.2.5 Income levels**

For the most part, Kebisoni is a poor community that has low levels of rural electrification accompanied with low-income levels. The situation is further worsened by inadequate enterprise development within the area. In Uganda, poverty is synonymous with rural areas, which is a similar situation for Kebisoni.

Respondents' monthly income was divided into group ranges as illustrated in figure 17. Thirty two percent of the HHQ respondents had an estimated monthly household income of between 200,000 and 300,000 Uganda Shillings, which is approximately between US \$ 71 and \$107<sup>8</sup> as shown in figure 17. This income was used to meet family related expenses and needs. HHQ respondents stated that sometimes money is received from relatives who work in the big cities and or those that stayed abroad to cater for some of the family needs. Hence, the income stated is from selling farm produce, income generating activities and remittances from abroad.

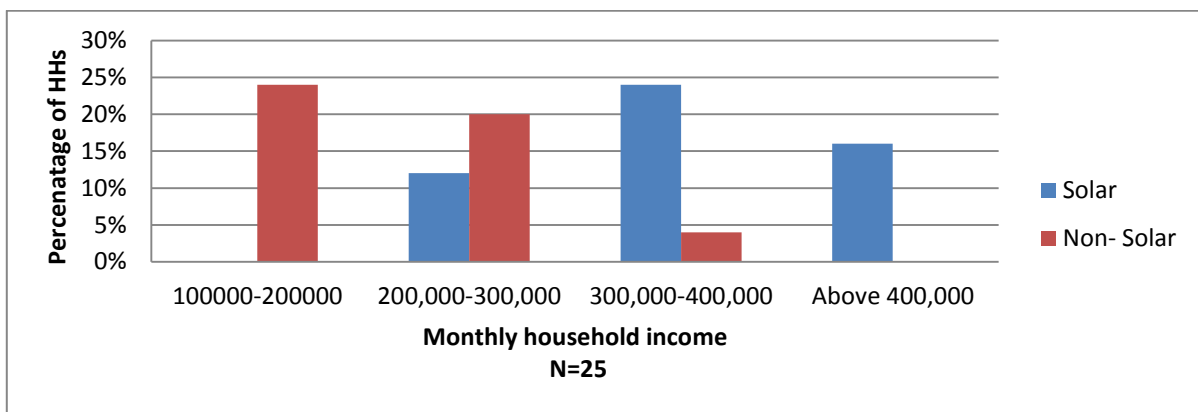
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<sup>8</sup>1US\$= 2850 Uganda Shillings



**Figure 17: Monthly income distribution of surveyed households in Kebisoni village**  
 Source; Author

Only 16 percent of the HHQ respondents had a monthly household income that was over 400,000 Uganda Shillings (see figure 17). From the findings it was revealed that the higher the household income, the higher the probability of households owning a solar home system. Furthermore, the findings also revealed that 24 percent of the HHQ respondents whose income is less than 200,000 Uganda shillings did not own a solar home system. From figure 18, it is clear that households need to earn higher incomes so as to afford a solar home system.



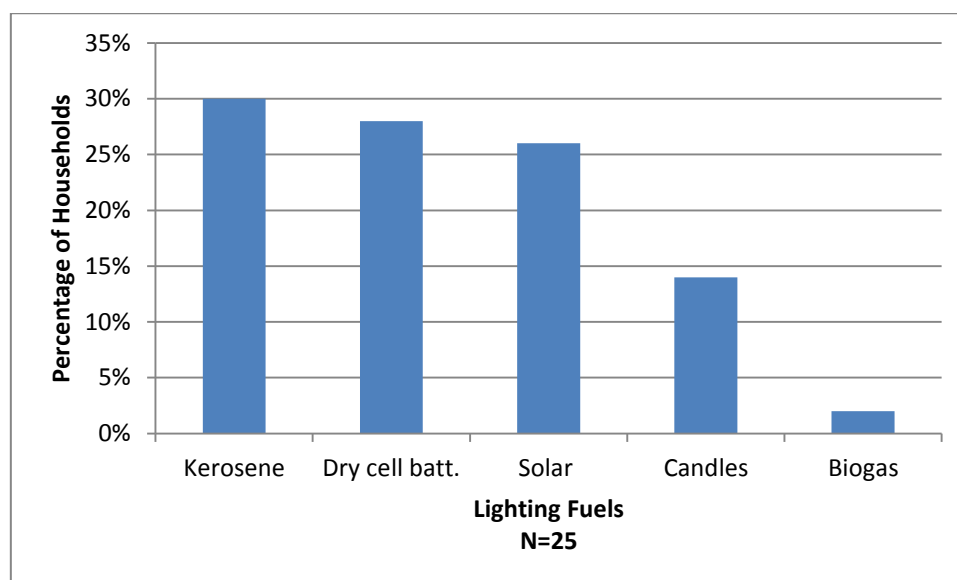
**Figure 18: Monthly household income for both solar electrified households and non-solar electrified households in Kebisoni village**

Source; Author

## 5.3 Fuel by end use

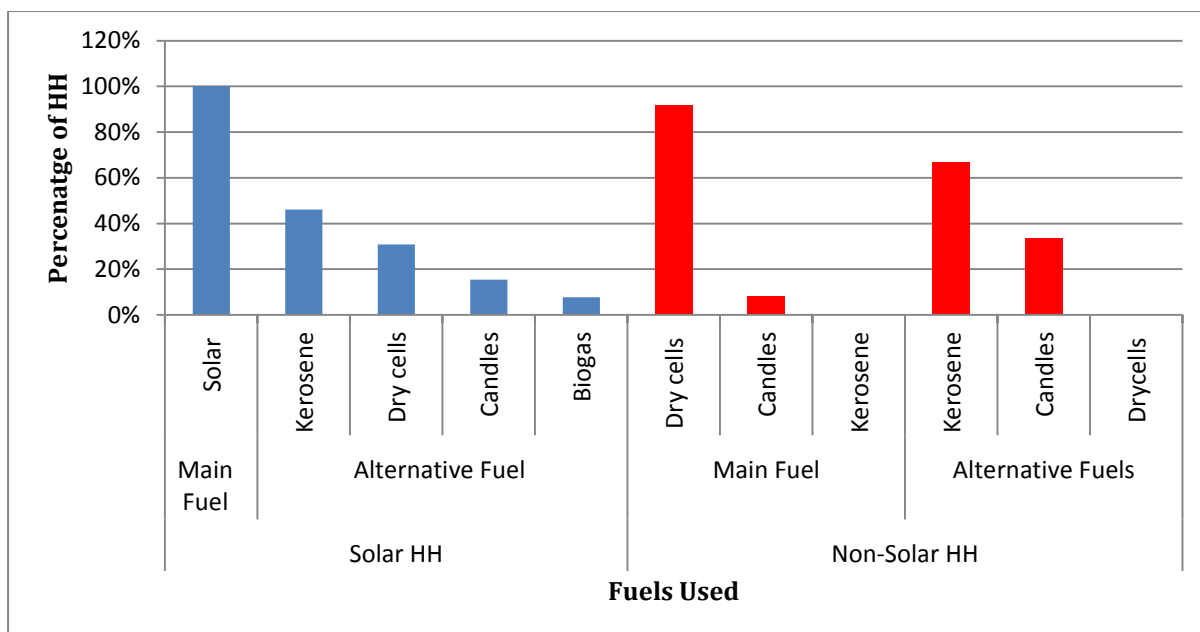
### 5.3.1 Lighting

Solar, candles, dry cell batteries and kerosene are the commonly used lighting technologies. From the entire household survey, kerosene for lighting is used by 30 percent of the households at any one time and this is the commonest lighting fuel as seen in figure 19. Dry cell batteries account for 28 percent of the lighting fuels used in the HH survey and solar energy 26 percent. Candles account for approximately 19 percent of household lighting fuels used while biogas is the least used accounting for only 2 percent of household lighting fuels. Figure 19 clearly shows that households use multiple fuels concurrently.



**Figure 19: Multiple fuels used for lighting in Kebisoni Village**

Source; Author



**Figure 20: A comparison of fuels used for lighting solar electrified and non-solar electrified households**

Source, Author

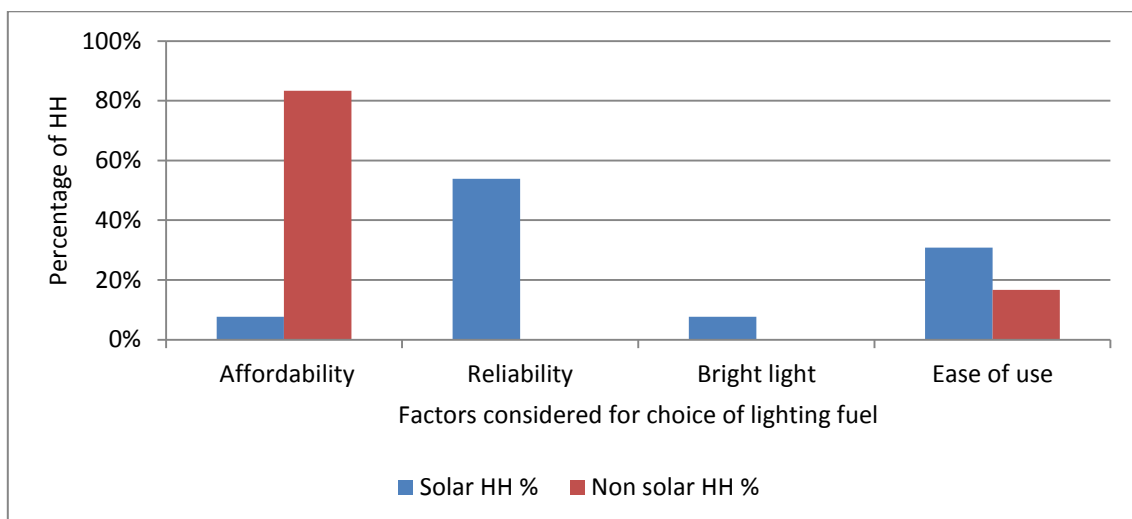
In solar electrified homes, solar is the main lighting energy source followed by kerosene, which is used in 46 percent of the solar electrified households. Kerosene is used occasionally say in circumstances when the solar home system fails or in areas of the house with no solar light. On the other hand, dry cell batteries are used as the main lighting fuel in non-solar electrified households and are used by 92 percent of these households as illustrated in figure 20. Dry cell batteries are used to power light emitting diode LED lamps.

While making a choice for lighting fuels, 83 percent of the non-solar electrified households considered the affordability of the fuel first. This was followed by ease of use (31 percent) (see figure 21). Solar electrified households chose to use solar energy because of its reliability. Reliability of SHSs was noted by 54 percent of the households. They noted that solar electricity is easily available with minimal maintenance costs.

Solar energy has high upfront costs (Katontoka, 2012) hence it is only being used by households that have a higher household monthly income. Even though none of the respondents was connected to grid electricity at the time of the study, they

still noted that they would prefer to have solar electricity compared to grid electricity. Solar home systems are preferred because of their reliability and low operating costs. Furthermore, solar energy was chosen by 8 percent of the respondents because of its bright light.

Connection to grid electricity would require a household to first wait until an electricity line has gotten within vicinity of their house. Secondly, the household would have to pay for the electricity connection and buy the required equipment such as the meter box. Lastly, it would have to pay monthly electricity bills for a service that is not reliable. However, at the time of the study, grid electricity was not an option as it had not been extended to the area.



**Figure 21: Reasons for choice of lighting fuel**

Source; Author

### 5.3.1.1 Lighting appliances

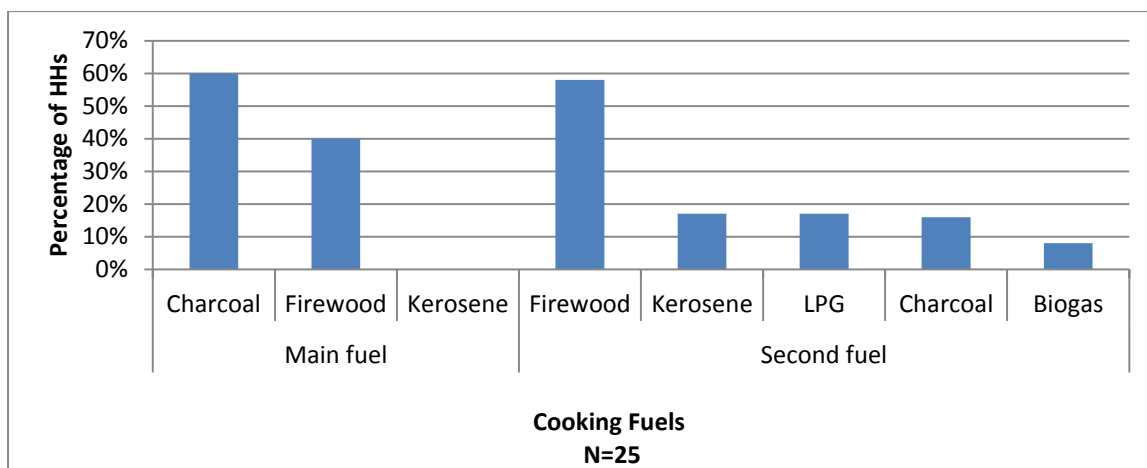
Kerosene lanterns were the commonly used lighting appliances by the entire HH sample. These were use by 65 percent of the households, whilst wick lamps (commonly referred to as *tadooba*) were used by 15 percent. Wink lamps are ordinary limiting devices made from metal and almost the size of a baseball. Twenty percent of the households used both lanterns and wick lamps. Other lighting appliances used in the survey area were dry cell powered torches and

LED lamps, which were used by 16% of the HH sample and biogas lamps by 4% of the HH sample.

### **5.3.2 Cooking**

Charcoal was the preferred main cooking fuel with 60 percent of the household sample using it. Although charcoal is widely used in the study area, it is mostly used to prepare quick cooking meals and warming food that has already been cooked. Charcoal manufacturing is one of the businesses in Rukungiri district and also contributes to household income.

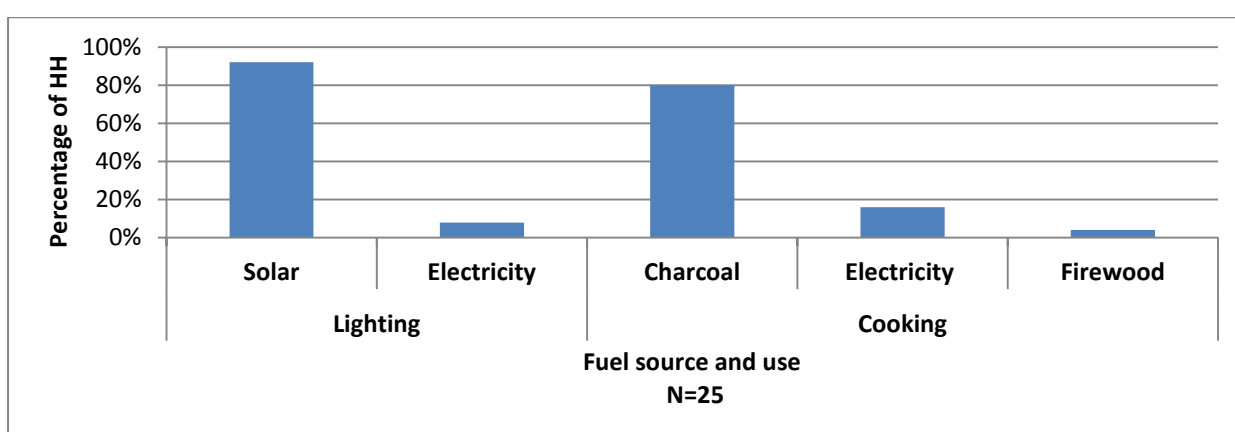
The second preferred cooking fuel used in the survey area was firewood, which was used by 58 percent of the HHQ respondents. Kerosene was used by 17 percent of the households and is only used to prepare meals that have a cooking time of not more than 30 minutes. All households that used kerosene for cooking used flame stoves. Flame stoves are stoves that use wicks/cloth that are dissolved in paraffin. The flame stove has two compartments i.e the fuel tank and the burner with a control knob, which is at the top. The wicks/cloth is dissolved through paraffin at the bottom and runs through holes that are connected to the burner (Panday and Mafu, undated). Liquefied Petroleum Gas (LPG) and biogas were also not commonly used with only 17 percent and 8 percent of the HHQ respondents respectively indicating that they used these fuels for cooking as illustrated in figure 22.



**Figure 22: Cooking fuels used in Kebisoni**  
Source; Author

#### 5.4 Fuel preference for all uses

If all fuels were both affordable and available, 92 percent of the HHQ respondents would prefer to use solar power for lighting and 8 percent of the households would prefer to use grid electricity for lighting. Solar power is preferred for its reliability and affordability in terms of operating costs. Respondents were aware of the monthly costs associated with electricity. Eighty percent of the respondents noted that they would prefer to use charcoal for cooking (see figure 23).



**Figure 23: Fuel preference if all fuels were available and affordable**  
Source; Author

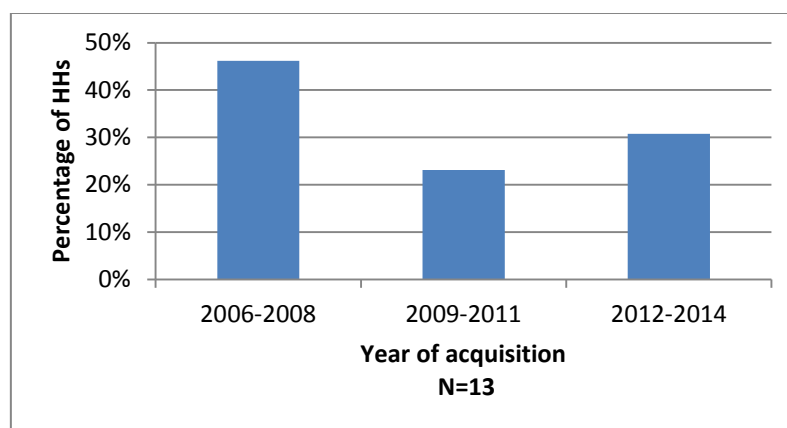
For ironing, 4 percent of the respondents would prefer to use solar electricity, 48 percent would prefer to use charcoal and the other 48% would prefer to use grid

electricity. Seventy six percent of the respondents would prefer to use solar electricity for cell phone charging and the other 24 percent of the households would prefer to use grid electricity. Respondents were not using their preferred fuel choice because of the high costs associated with those fuels.

## 5.5 Solar Home systems in the survey area

In the surveyed area, most of the SHS were acquired between 2006 and 2008 as seen in figure 24 below. The least number of SHS were acquired between 2009 and 2011. Technicians from solar dealership shops did SHS installations at no cost if the solar equipment was purchased from the shop. On the other hand, if the solar equipment was purchased from a different shop, for example by a relative from a shop in the city, the installation was done at a fee. No standard fees were applied, however they ranged between 10,000 and 30,000 Uganda Shillings, depending on the capacity of the system.

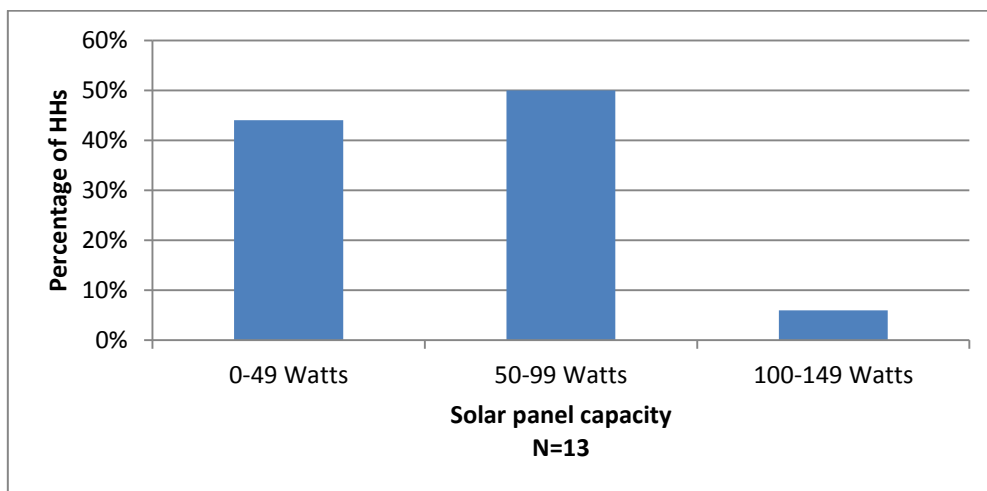
Households with only one light bulb had it installed in the centre of the house so as to provide light in all rooms (no ceiling in such houses). Households with two light bulbs had one installed in the centre of the house and another outside the house. While those with more than two light bulbs had one or more light bulbs in the sitting room, outside the house and to the different rooms in the house. A combination of both CFL and LED bulbs were used in the survey area.



**Figure 24: Year of acquisition**

Source; Author

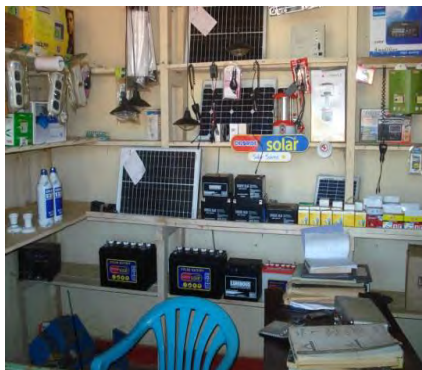
Fifty percent of the solar home systems in the surveyed area had low capacity solar panels because the poor can afford these. The popular solar panels were of a capacity between 50 and 99 Watts as shown in figure 25. All households except for two had only a single solar panel. The two households both owned two solar panels of varying capacities.



**Figure 25: Solar panel capacity within the survey area**

Source; Author

The availability of credit facilities for the purchase of SHSs was not common in the survey area. From the study, it was noted that 69 percent of the SHSs by HH were acquired on a once-off cash basis while 31 percent were acquired by paying in installments. This solar equipment was purchased from solar dealers in the area.



**Figure 26: Typical solar dealer shop and low capacity solar panels**

Source; Author

### 5.5.1 System costs

There was challenge in ascertaining the system costs especially in households where women answered the questionnaire. Men generally do purchasing of such equipment hence the women are usually not aware of the system costs. Additionally, the women did not have knowledge on the capacities and specifications of each of the components within the system. Some of the respondents had knowledge of the entire system costs but were not certain about how much each individual component cost, hence the gaps in Table 2.

From the available data, the most expensive SHS had a total cost of about 2,370,000 Uganda Shillings and it was composed of 80-watt peak solar panel, 10 light bulbs, 2 batteries each with a capacity of 80Amh and 240 Amh, as well as an inverter of 10 watts. The cheapest SHS went for about 90,000 Uganda Shillings with a 10 watt peak solar panel, 2 light bulbs and a 10 Amh battery.

At the time of the study, none of the households with a SHS mentioned that they had replaced their batteries.

**Table 2: Costs of some of the solar home system components in Uganda Shillings.**

No	Battery charge duration	Panels			Bulbs			Battery			Inverter			TOTAL SYSTEM COST
		Qty	Capacity	Cost	Qty	Capacity	Cost	Qty	Capacity	Cost	Qty	Capacity	Cost	
1	3 days	2				6W		1			1			
2	2 days	2	80W	620,000; 450,000	10			2	80AMH; 240AMH	350,000 ;700,000	1	10W	250,000	
3	2 days	1	120W + 75W	450,000	5		15,000	1			1		350,000	
4	3 days	1	10W		2		10,000	1	10AMH	80,000				
5		1	40W	150,000	1	15W								
6		1	30W	100,000	1	12W	8,000							250,000
7	3-4 hrs	1	85W	250,000	1		8,000	1		300,000	1		70,000	
8	3 days	1	50W	250,000	1		15,000	1		150,000				
9	5 days	2	75W		9			1			1			1,500,000
10	1 day	1	50W	350,000	2	5W	24,000	1	100AMH	400,000	1	300W	80,000	
11	1 day	1	15W		1			1						400,000
12	2 days	2	30W+15W	150,000;130,000	2		20,000	1	45AMH					
13	3 days	1	35W	107,000	2	12W	20,000	1		280,000				

Source: Author

### 5.5.2 Battery Charge duration

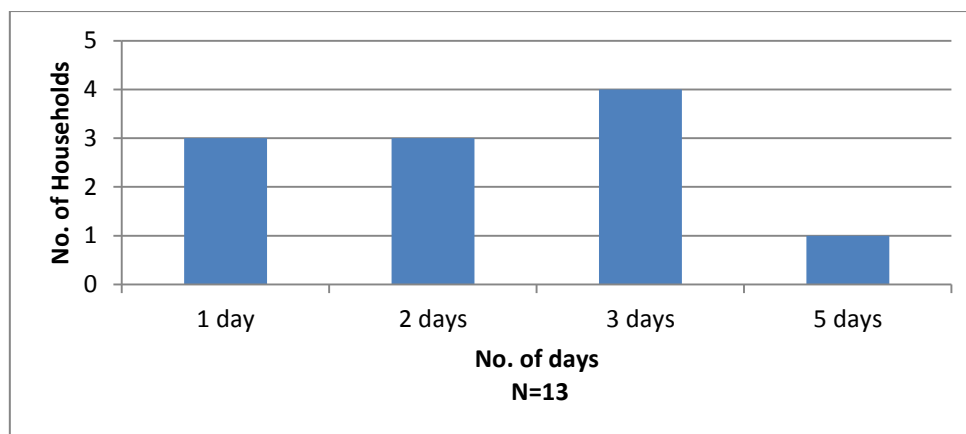
Eighty five percent of the households had a battery as a component of their solar home system. These households had the advantage of using the system on days with little or no sunshine as well as during the night. Battery charge duration has been defined as the duration the battery lasts before it needs recharging.



**Figure 27: Solar Panel and battery**

Source; Author

Most of the respondents did not know the capacity of their batteries, however the highest recorded battery rating was 240 Ampere-hours and the least was 10 Ampere-hours. Battery charge duration (how long the battery lasts before it needs recharging) was ranging from 0 days to 5 days as seen in figure 28. It should be noted that duration of the battery charge depends on charging conditions i.e. the time it takes to charge and load i.e. the number of appliances powered by the battery.



**Figure 28: Battery charge duration**

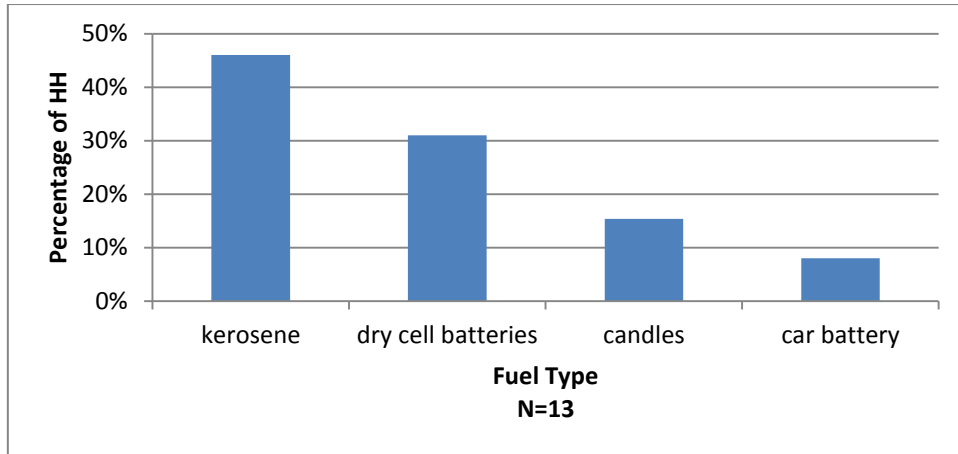
Source; Author

## 5.6 Impact of solar usage on other fuels

Households that were using solar home systems noted a significant reduction in other fuels that were used previously for lighting. Kerosene usage registered a significant reduction in its usage for lighting as illustrated in figure 29. Respondents noted that the reasons for the reduced use of kerosene, in addition to acquiring the SHS, were that the tax levied on kerosene had increased and the safety risks associated with kerosene use were high.

HHQ respondents also noted that the reason for the reduced use of kerosene, in addition to acquiring the SHS, were that the tax levied on kerosene had increased and the safety risks associated with kerosene were high.

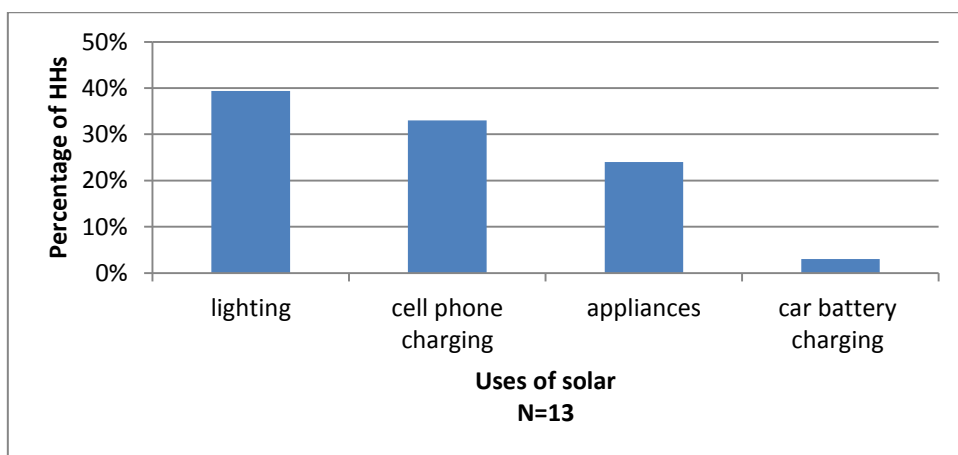
About 46% of the HHQ respondents reduced their use of kerosene for lighting (see figure 29), while only 8% of the households noted that they reduced the use of car batteries for lighting.



**Figure 29: Fuels that reduced in usage after access to solar energy**  
Source; Author

### 5.7 Solar home system uses and appliances.

Solar systems in the survey area were of generally low capacity; hence there were few uses to which they could be put. Some of these uses are illustrated in figure 30. The use of appliances was also limited because direct current solar appliances are generally more expensive compared to the ones that use alternating current<sup>9</sup>. Secondly purchasing an inverter is an extra expense, which is often looked at as a luxury. It was also revealed in the study that 39 percent of households purchased solar systems mainly for lighting.

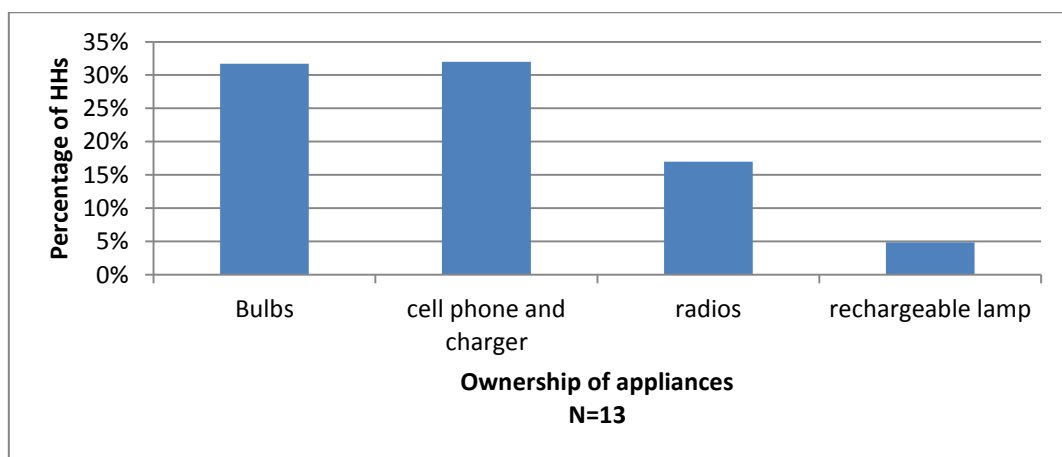


**Figure 30: Uses of Solar Energy**  
Source; Author

<sup>9</sup> Alternating current is a voltage used for transmitting electrical energy (MIT, 2013). Most appliances on the market use alternating current. Direct current is constant voltage on which electricity is transmitted (MIT, 2013).

Radios and mobile phone chargers were the commonly owned direct current appliances in the survey area (see figure 31). Even though majority of the households connected to solar technology did not own radios, they are owned by more than half of the population in Rukungiri District (Rukungiri District Local Government, 2009). Perhaps this could be as a result of owning mobile phones that have the radio functionality.

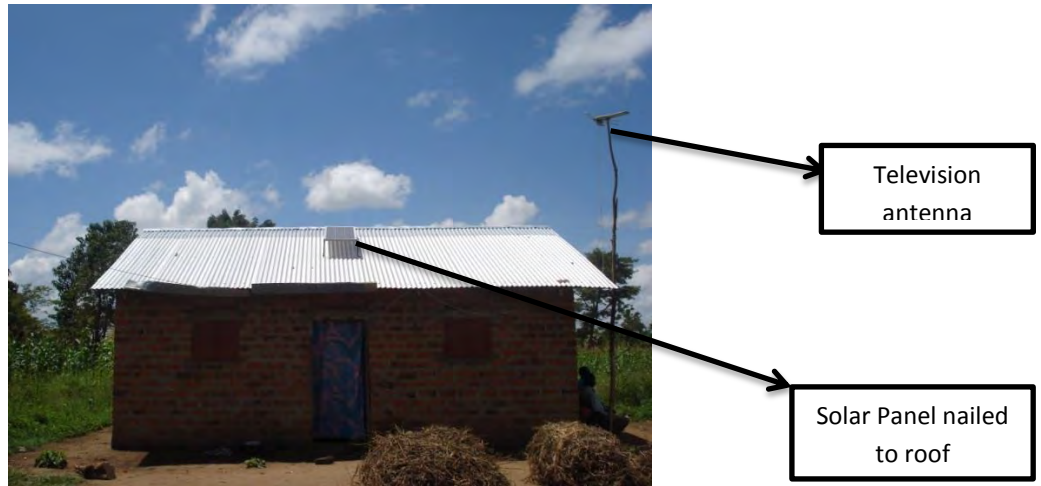
Most surveyed households did not have television sets because they had low capacity solar panels. Furthermore, the lack of inverters in some households hindered their purchase of a television set. Almost half of the households (46%) with access to SHSs had an inverter as part of the system and therefore had colour television sets. All HH without a SHS did not have a television.



**Figure 31: Ownership of direct current appliances in SHS households**

Source; Author

Ownership of assets (electrical appliances in this case) could be an indicator of improvement in the standard of living in rural areas. All households with televisions acquired them after they had purchased a SHS.

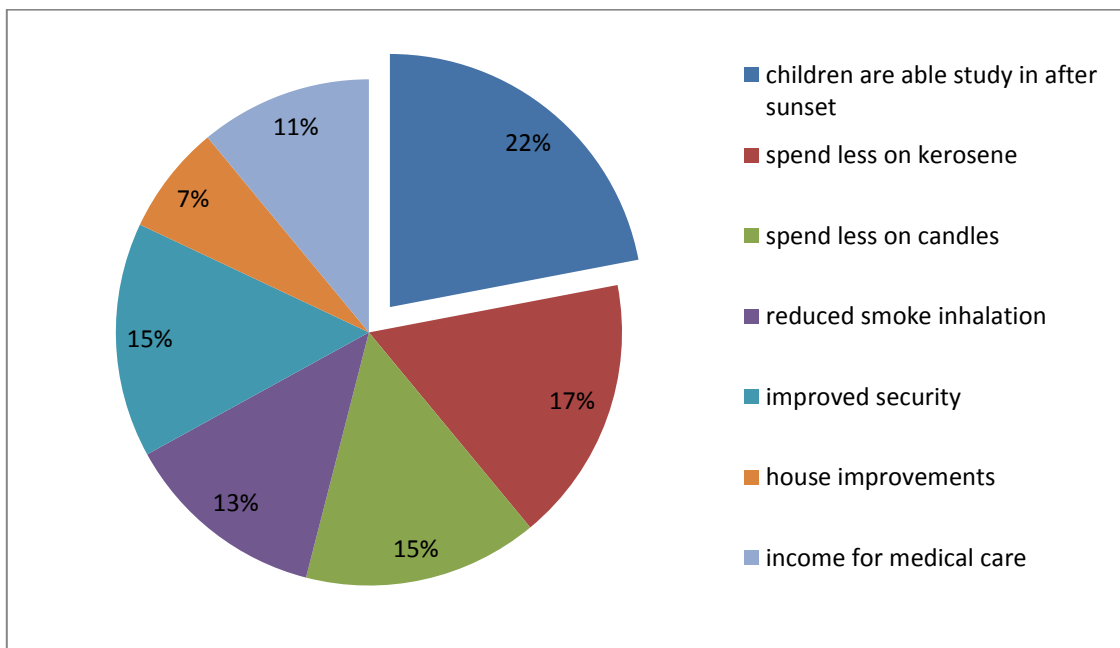


**Figure 32: House connected with a SHS and has a television**

Source; Author

## 5.8 Impact of solar energy on livelihoods

Solar technology access has had a positive impact on the livelihood of people living in the rural communities specifically the area of study. One of the greatest benefits was the ability of children to study in the evenings (see figure 33).



### **Figure 33: Benefits of solar access to households**

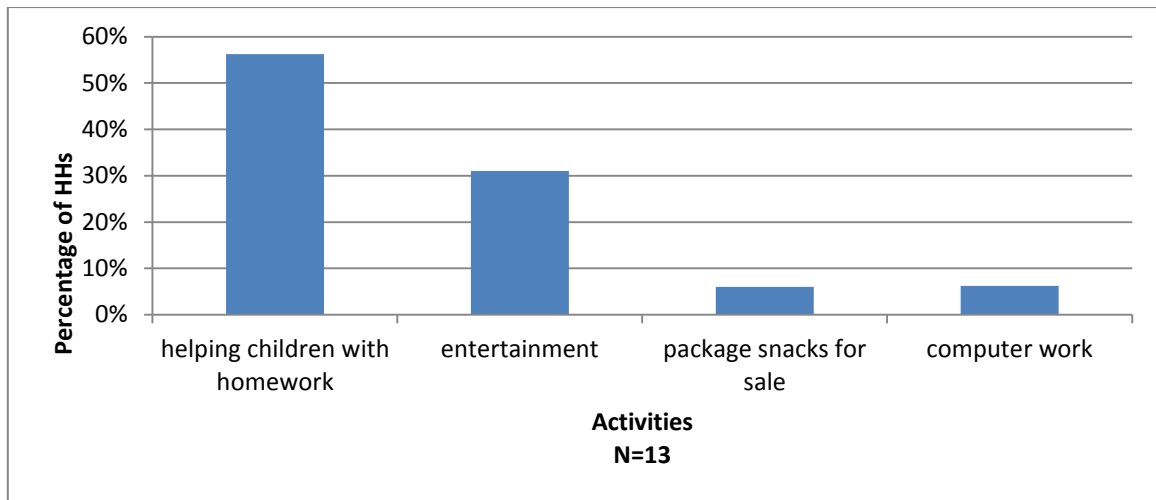
Source; Author

HHQ respondents strongly recognized the need for children to attain education therefore they cite the relevance of solar energy in helping them achieve this goal. Furthermore, HHQ respondents noted that security generally improved with in the areas (see figure 34). Respondents reported that cases of house break-ins were less rampant although numbers were not provided. A reduced expenditure on other lighting fuels was also acknowledged in addition to the reduced smoke inhalation from using kerosene.

About 69 percent of the HHQ respondents revealed that they experienced an increase in disposable income as a result of not spending or spending less on other lighting fuels. Additionally, the use of lighting from SHS to extend the working hours for those who needed to complete work at home and households that engaged in another income generating activity led to an increase in household income.

#### **5.8.1 Extending operating hours**

Having access to solar technology enables its beneficiaries to extend their operating hours with a clean and bright light. Figure 34 illustrates how these hours are spent.



**Figure 34: Activities carried out in the extra lighting hours**

Source; Author

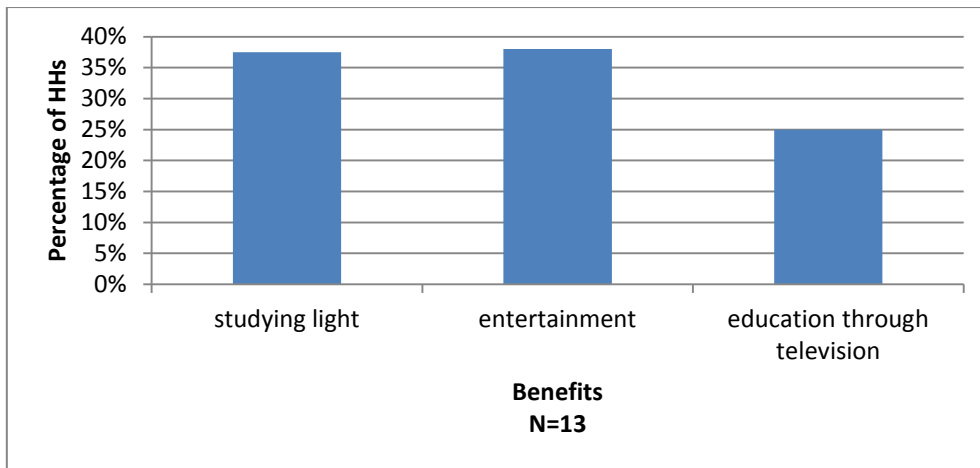
Residents also reported an improvement in in-door air quality, which is directly related to the reduction in kerosene usage for lighting and candle burning. Esper *et.al.* (2013) reported that improvement in indoor air quality has a positive impact on the health of the occupants.

Also reported was a reduced risk from both kerosene and candle related hazards such as fire outbreaks. Children have repeatedly been burnt in house fires when their parents have left them unsupervised (Bikala, 2015; Kiva, 2010; Nsubuga, 2014). Most of these parents were either going to sell food in the trading centres or to enjoy themselves in entertainment centres such as bars and nightclubs.

## **5.9 Benefits of access to solar technology to different categories of people in the community**

### **5.9.1 Children**

Children have benefited the most from access to solar technology (see figure 35). School-age children were able to make use of the light for studying. Some of these children were able to benefit from education programmes relayed on television. The very young ones were not left out as they were able to enjoy kid's programmes on television such as *Kid's corner* and *Eseza ommuto*.



**Figure 35: Benefits to children**

Source; Author

One of the mothers with an infant noted that without light, her child was unable to fall asleep easily. In instances where they did not have lighting from the SHS, she had to keep the phone light on. Furthermore, the children got very excited once the television was turned on. Children also showed their excitement by telling everyone at school about the television at home.



**Figure 36: Household electrified with a SHS**

Source; Author

## 5.9.2 Women

Women too have benefited from having access to solar energy in number of ways.

Women employed in formal employment noted that they could carry work back home, which they could complete after hours or in the evening. If an employee was able to meet deadlines and finish their workload, this could translate into increased productivity at the work place.

Women were able to prepare dinner and carry out evening chores in a conducive environment with bright light. Previously women had to rely on candles and kerosene to provide lighting. Not only do these fuels provide poor quality lighting, but they are also harmful to the health of their users. In addition, these fuels could accidentally spill in the food during preparation.

Furthermore, women indicated that the houses are now kept in a tidy and organized state. Husbands viewed this as a source of pride and the women derived satisfaction from a neat house.

The women and girls were able to clean up after dinner thus they were not required to get up early in the morning to wash up dishes and utensils that had been used the previous night. In Uganda, dinner is usually served between 8 and 10pm. However in some households, if the head of the house has not yet arrived within that time, then dinner is not served until he returns. The girls noted that they were now able to get those extra hours of sleep and concentrate in class the following day.

On another positive note, having access to solar technology empowered the women socially. Mention was made of the fact that they were now better informed through mass media information that is transmitted over radio and television. They were now able to take part in conversations amongst their peers and in community meetings.

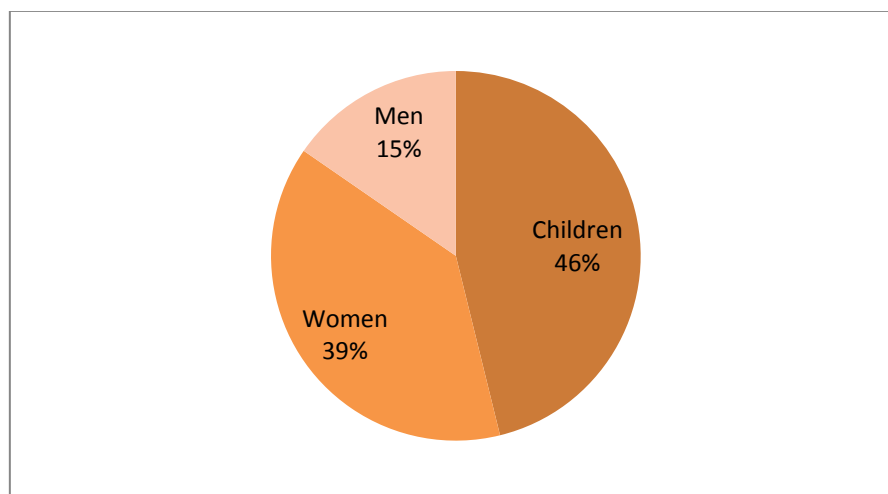
### **5.9.3 Men**

The men noted that solar technology access has benefited them as they were now spending less money on household fuels specifically for lighting. Household fuels

often take up a considerable portion of expenditure especially for low income earners (WHO, 2006). Hence, a reduced expenditure on the energy fuels avails more income for the household to spend on other items/activities such as health care and education, as earlier illustrated in figure 33.

The men in the HHQ expressed that once the woman was being entertained at home through TV and radio then she would not persistently call the man to come home early. From this particular respondent's point of view, he felt liberated.

The men also noted they were able to watch locally aired sports shows from the comfort of their homes and having access to solar technology is a source of pride for the owners. "You can't have a SHS and the entire community doesn't know of it. In fact people always refer to my house while giving directions to the nearby places", said one of the respondents. In other words, a home connected to solar energy is a reference point when giving directions within the community.



**Figure 37: Distribution of perceived beneficiaries of SHS**

Source; Author

HHQ respondents argued that children and women have benefited most from solar technology access (see figure 37). Women and children are regarded as minority groups in most Sub-Saharan African communities; increasing access to solar technology has the potential of alleviating this non-income poverty such as inequality and illiteracy (Samad *et al.*, 2013).

## 5.10 Income generating enterprises

To analyse the impact of solar energy use in business, the researcher compared two sets of businesses; those electrified with solar and non-electrified businesses.

### 5.10.1 Type of business

Eleven local enterprises were interviewed. Out of these, six of the businesses were using solar systems and five are using other lighting energy sources. Alternative lighting sources that were used in the business enterprises in the survey area were dry cell batteries and kerosene. Dry cell batteries were used to power LED lamps.

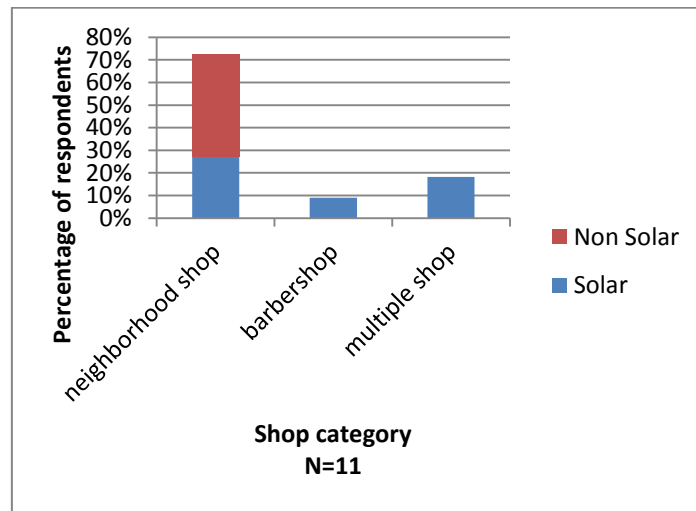


**Figure 38: Rechargeable LED lamp with battery**

Source; Author

Out of the sampled businesses, 72 percent of these were neighbourhood shops, 9 percent barber shops, 9.5 percent were neighbourhood shops together with a phone charging booth, bar and tailor shop and another 9.5 percent were a barbershop together with a phone charging booth and a music/ entertainment

centre. Field data shows that with access to a solar system (as illustrated in figure 39) multiple businesses could be carried out in one location, hence maximizing profits. From the business survey findings, only 33 percent of the shops with access to solar technology were started before acquiring the technology.



**Figure 39: Distribution of type of businesses**

Source; Author



**Figure 40: Phone charging/barber shop**

Source; Author

### 5.10.2 Business operation and ownership

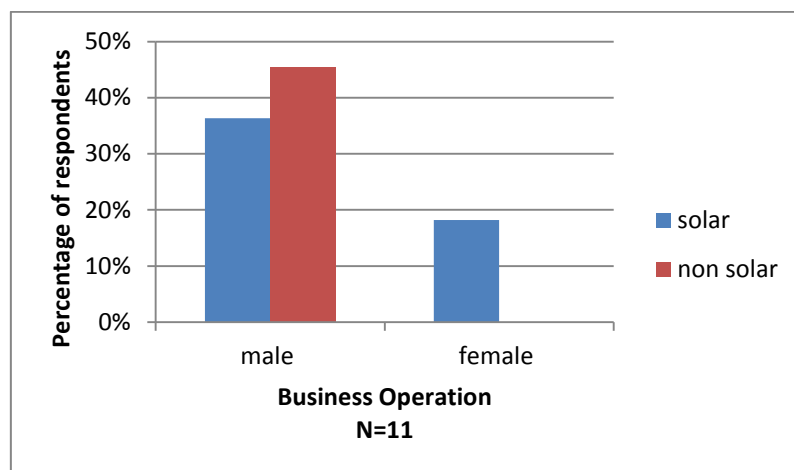
Men operated nine of the surveyed businesses, while females operated the other two. However one of shops operated by a female is also co-managed by the husband in the evening since it has a bar section (see figure 41). The other shop managed by the woman was located within the home hence she could always

multitask with the general running of both shop and home activities (see figure 42). All the businesses operated by women were connected to solar technology.



**Figure 41: Multiple business shop with both tailoring services, bazaar shop (front-picture 1) and bar section (back-picture2)**

Source; Author

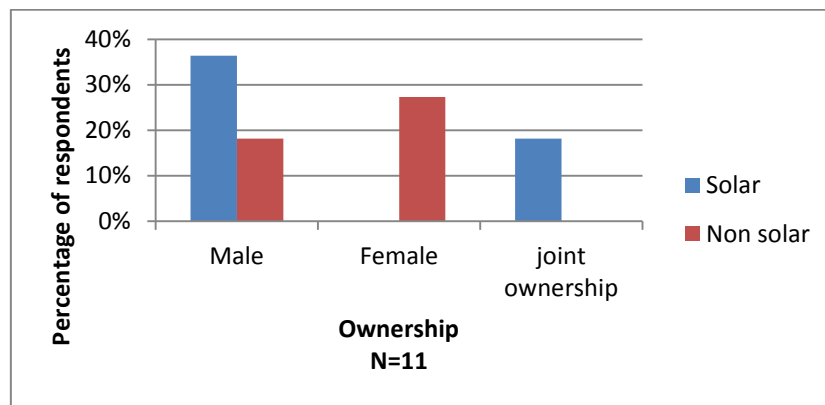


**Figure 42: Business operation in relation to access to solar technology**

Source; Author

Because this is a rural conservative community, women are generally not allowed to own property. Although women in most cases could have contributed either financially or non-financially, they still do not get joint ownership in the business except in very rare circumstances. This is a form of discrimination that reinforces gender inequality. The study indicated that men owned 55 percent of the businesses, women owned 27 percent and 18 percent had joint ownership (see figure 43). Since most of these businesses were local small-scale

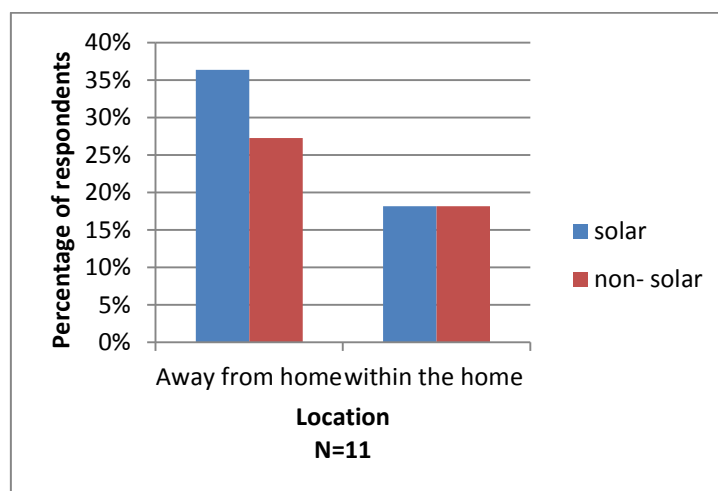
neighbourhood shops, they did not employ any staff. However, for neighbourhood shops, children usually helped around during the holidays.



**Figure 43: Business ownership in relation to solar energy access**  
Source; Author

### 5.10.3 Business location

Seven of the businesses were located away from the home (64 percent) and the remaining 36 percent were located within the home (figure 44). From the researcher’s observation, businesses that are located away from home have more customers than their counterparts located within the home and are therefore more successful. Having a solar system coupled with location advantages has the potential of increasing sales thus increasing profits.

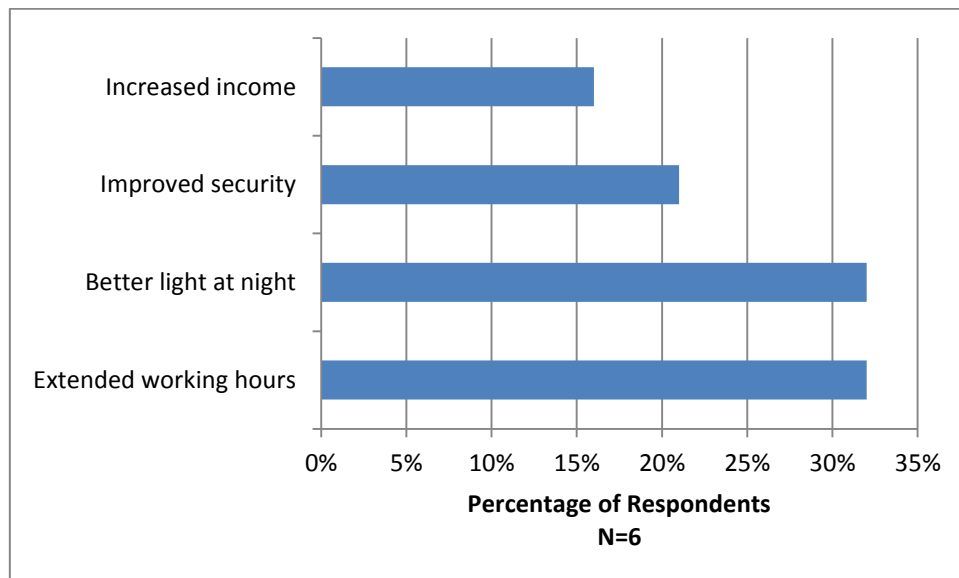


**Figure 44: Business location**  
Source; Author

#### 5.10.4 Benefits of solar technology to the business

Businesses owners noted that their hours of operation were extended. Extending working hours would in principle translate into more sales (although this was not explicitly researched in this particular study). People leaving their places of work were able to pass by the local neighbourhood shop to buy groceries after hours.

Furthermore, 21 percent of the respondents noted an improvement in security, 32 percent noted better lighting as a benefit of using a solar system (figure 45). Some shop owners noted that with the better light, people were now very observant while receiving money. The benefit of this was that they avoided receiving counterfeit notes and being cheated.



**Figure 45: Benefits derived with access to solar systems**

Source; Author

#### 5.10.5 Hours of operation for solar power connected businesses

Businesses connected with solar energy enjoy the benefit of staying open longer and also enjoy better light compared to the other businesses that use either dry cell batteries or paraffin. From the field study, it was noted that hours of

operation after 18:00 hrs are dependent on the nature of business. The neighbourhood shop/bar had the longest operating hours as it serves as an entertainment centre (see figure 46). The barbershop owner (see figure 47) noted that having access to solar electricity did not necessarily increase his hours of operation since people did not usually have haircuts after 19:00 hrs.



**Figure 46: Hours of operation after 6 pm**

Source; Author



**Figure 47: Saloon/ barbershop connected to solar technology**

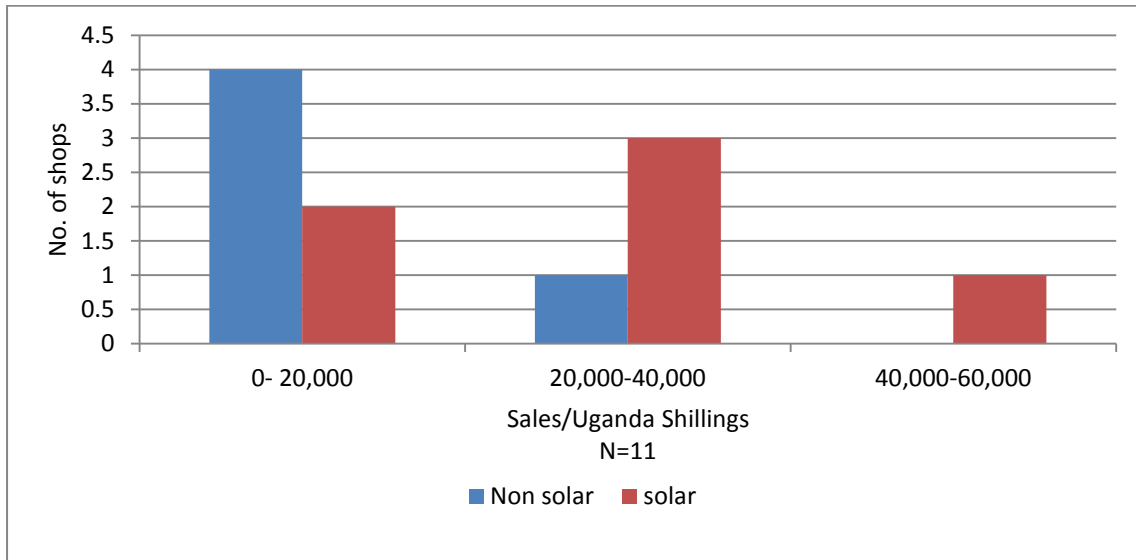
Source; Author

Panel with connected wire to saloon

### 5.10.6 Estimation of evening sales

Businesses connected to solar systems had higher sales compared to non-solar connected businesses as seen in figure 48. Respondents who have phone-

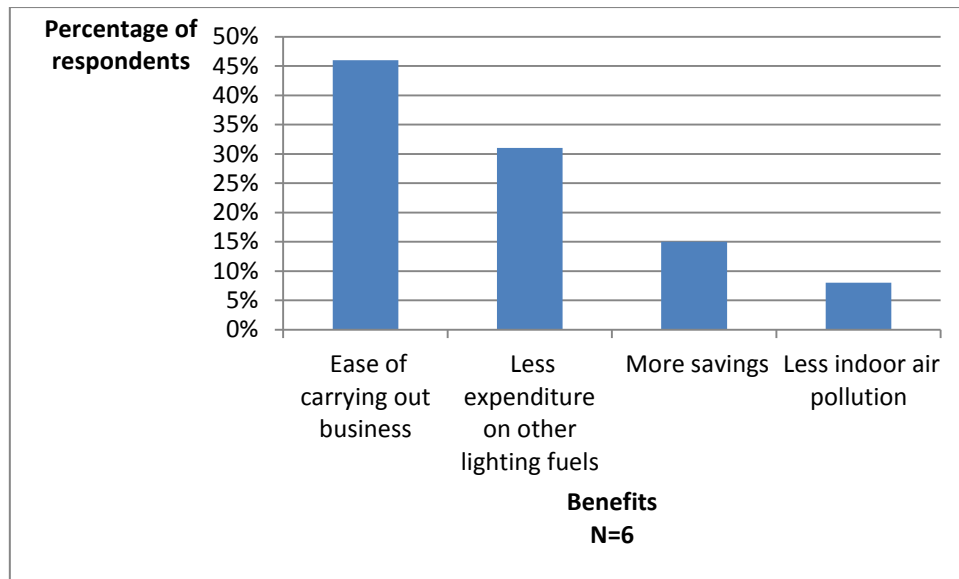
charging kiosks also mentioned that they charged more phones over the weekends compared to weekdays. Because people did not work on weekends, they were unable to charge their phones at their offices. These people formed the bulk of phone charging customers on the weekends.



**Figure 48: Estimation of evening sales**

Source; Author

With access to solar technology, businesses have noted various improvements. Notably is the improvement in carrying out business due to availability of lighting and less expenditure on other fuels. Reduced indoor air pollution was not noted as a major improvement as seen in figure 49.



**Figure 49: Improvements to the business after acquisition of a solar system**

Source; Author

However, a major challenge noted by 80 percent of businesses was that the panel capacity was insufficient to promote income generation. Respondents suggested that bigger panels with higher capacities should be provided at a cheaper price.

Due to failure of implementing standards on some of the imported solar equipment and poor workmanship, some low quality Chinese products have found their way on the Ugandan market. These are usually sold off to unsuspecting customers as genuine products hence frustrating their users. Most of these products malfunction in the long run and this creates a negative perception towards the technology.

Another challenge that was faced within this community is the theft of solar panels. It is for this reason that panels are not permanently fixed to the roof as reflected in figure 50. The owners always carry them out during the day and keep them in during the evenings.



**Figure 50: Typical neighborhood shop**

Source; Author

Panels loosely placed on roof

### 5.11 Solar technology and Poverty

Solar energy is generally perceived as a good initiative; in fact, members of the focus group discussions argued that solar energy use has promoted development within the area. Furthermore, the members of the focus group discussions agreed that solar energy has promoted more opportunities within the community. Mostly, solar energy use has created opportunity for the young generation considering that about 32% of Uganda's population is between 10-24 years of age (UBOS, 2014). Those who have been able to open up businesses have taken advantage of this initiative. The common businesses in the surveyed area were barbershops, bazaar shops and entertainment centres. Solar technology access has also been beneficial to the adults as they now spent less on other lighting fuels such as kerosene and dry cell batteries.

It was argued by members of the focus group discussions that the young people have benefited the most. When the young people open up businesses, the business attracts members of their age groups. Other members argued that middle-income groups had benefited the most. The old people have not been left out, as they are now able to walk shorter distances to charge their phones.

However not every member of the community has been able to benefit from the availability of solar energy in the community. Some of these include the poor and disabled members of the community. The poor have not benefited because they are still unable to buy the solar home systems and have no security to access funds from financial institutions. The SHSs also present a challenge for this category of people, as they are unable to carry the panels back and forth from storage to charging under the sun. As earlier mentioned, theft of solar panels is rampant hence households rarely nail them to the roof.

## **5.12 Discussion**

Solar energy was introduced within the community with the main objective of providing electricity. From 2006, solar power access and use has had an impact on the lives of the users. In-order to assess the impact of this initiative, the theory of change framework has been applied (see figure 15 and subsequent paragraph). The main assumption in the theory of change is that additional households are predicted to acquire solar home systems therefore making energy access a continuous project.

### **Major outcome; increased modern energy access in the form of electricity;**

Only about 5% of the Ugandan population has access to electricity (MEMD, 2012). Solar energy in this case has increased modern energy access in the area. For example, there was an observed increase in acquisition of solar home systems from 23 percent in the period between 2009 and 2011 to 31 percent in the period between 2012 and 2014 (see figure 24). Modern energy provides the convenience and benefits that would not otherwise have been attained from low quality fuels such as kerosene and candles (Helio International, 2014). The intermediate steps illustrated in figure 24 are the other outcomes from the initiative, which include; less expenditure on kerosene, improvement in lighting, access to information via radio and television, better indoor air quality and increased hours of operation for businesses.

The impacts derived from solar energy access in the survey area have been categorized into 5 groups; economic; gender equity; health/safety; education and social welfare.

a) Economic impact

Over a medium to longer-term period, solar energy use has the potential to increase household income. Solar energy especially for productive uses could increase household's disposable income. About 69% of solar home users noted an increase in disposable income. This income was generated from the savings due to the reduced fuel expenditure on kerosene and candles.

With access to a SHS and availability of disposable income, respondents were now able to acquire new or more assets. For example, 46 percent of households using solar home systems owned television sets. Furthermore, about 32 percent of solar connected households owned cell phones while 17 percent owned radios (see figure 31). These are some of the assets that were sampled in the survey. The survey further revealed that 7 percent of SHS users were able to carry out improvements to their houses using savings made since acquiring the SHS.

The use of solar technology in businesses has improved their performance. For example, ease of carrying out business was reported by 46 percent of the businesses (see figure 49). Furthermore, all the solar connected businesses had higher evening sales compared to non-connected solar businesses (see figure 48). Additionally 15 percent of the solar power connected businesses noted an increase in savings.

The savings generated from the businesses may perhaps trickle down to the respective households thus increasing household income. This however was not investigated in this particular study.

## b) Gender equity

The fact that women are able to engage in business is proof of a slowly transforming society. For a long time, women's role has been limited to raising children and taking care of a home (Rodriguez, 2012; Markham, 2013). This has largely been influenced by society and cultural beliefs (Giuliano, 2014). Women in the survey area are engaged in both business operation and ownership (see figures 42 and 43).

## c) Health/safety

Kerosene and candle use are known causes of indoor air pollution, which is directly related to upper respiratory infections such as asthma and bronchitis (Mills, 2014). Furukawa (2012) illustrates that users of these fuels have been prone to air quality related illnesses compared to their counter parts that use modern lighting such as electricity. Furthermore, Furukawa (2012) argues that the longer the exposure period to indoor air pollution, the bigger the impact especially for minors and infants whose lungs are still developing.

Solar energy use has not only improved the perceived air quality of its users in the study area but also seems to have reduced the risk of accidents associated with both kerosene and candle usage in these households such as fires and burns. Thirteen percent of the households noted that they had experienced reduced smoke inhalation especially since the air in the house had less smoke and soot (see figure 33).

An additional benefit of households having good health, all other factors being constant is that they do not have to spend their minimal income on medical care. Illness of a household member could possibly lead the household into deeper poverty and this is worsened if the patient is the family's wage earner (Bird and Shinyekwa; 2003; Mehta and Gupta, 2006).

An improvement in safety was noted by about 15% of the households. Smith (2014) argues that it is highly likely for children who feel unsafe to not reach their full potential in both life and education.

#### d) Education

Solar energy use has enabled children to study, read in a better-lit environment. The study revealed that 22 percent of the households noted that, with solar light their children were able to study for a longer period, especially after sunset (see figure 33). In addition, about 56 percent of the households also noted that they were now able to help children with homework because of the availability of extra lighting hours (see figure 34). Children who previously studied using light from a kerosene lamp or candle source had to endure smoke inhalation from these sources.

Children in homes with access to radio and television are now exposed to educational programmes and this was revealed by 25 percent of the households with access to SHSs (see figure 35). This increases information access and helps children gain knowledge on issues outside the classroom environment. Some of these programmes include; *Simply learn, Education Magazine, Road Safety, and Health Facts*.

#### e) Improved Social welfare

Poverty does not only take up the form of income poverty but also other forms such as energy poverty, inequality, depression, lack of resources etc (Franks, 2014). Solar home system users in Kebisoni noted an improvement in their general happiness and comfort especially for the women. Ownership of the solar home system was in itself noted as a source of pride for the household.

Solar energy has enabled its users to access media from either television or radio devices. SHS users are informed and educated about the current affairs in the country and even across borders. For example, Uganda has in the past suffered from Ebola, Cholera, HIV/AIDS and Marburg fever outbreaks. To reduce the

spread of the viruses, Ministry of Health aired information on how to combat the spread of diseases and how individuals can protect themselves.

Practical empowerment was also attained in the study area. Findings show that 6% of the households were now able to enhance their entrepreneurial skills. One example was in the area of snack preparation. These snacks are later packed and sold.

Televisions and radios provided a source of entertainment to 31% of the solar home system users (see figure 34). SHS owners are able to watch their favorite shows and movies thus providing a sense of joy and happiness.

### **5.13 Conclusion**

Solar energy access has generated numerous benefits for its users both households and business owners. Most importantly solar energy has been able to provide a clean and efficient lighting alternative in an area that does not have access to grid electricity. Some of these households previously used in inefficient and dangerous lighting alternatives.

Solar access has also boosted small and medium enterprises within the area. Some of these include barbershops and computer/ entertainment centres. This has boosted the development of the area.

Furthermore, it is envisaged that the continuous use of solar energy, especially for productive use over a long period of time has the potential to create opportunity and enhance development in the rural community. This in the long-run fulfills the country's target of increasing rural energy access and also alleviating poverty within the rural community.

## **CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS**

### **6.1 Introduction**

The previous chapter has provided the findings collected from the field survey. A discussion of the findings using the theory of change has also been presented. This chapter will provide the conclusions drawn from the findings that have been presented in chapter 5. This section will also provide recommendations of how this research could be improved, as well as recommendations on the promotion of solar energy use for poverty alleviation and further action.

### **6.2 Conclusions**

Uganda has a low level of rural electrification with more than half of the rural population not having access to any form of electricity and yet the rural areas have over half of the country's population. The literature reviewed shows that availability of energy is one of the factors needed to promote enterprise development and poverty reduction. This dissertation therefore investigated the impact of solar energy on poverty alleviation using the theory of change framework. Poverty is multidimensional in nature covering a range of issues that are non-monetary such as deprivation, lack of opportunity and inequality.

Two of the research questions for this study were on identifying the sources of energy and their use in Kebisoni, Rukungiri district. The main cooking fuels that were used were charcoal and firewood. LPG and biogas were the least used fuels, with 17 and 8 percent of the households using these respectively. The sample population used charcoal as the main fuel, while firewood was used as the 2<sup>nd</sup> main cooking fuel. Solar energy was used as the primarily for lighting by 52 percent of the households in the Kebisoni sample, while dry cells are used the primary lighting fuel by 44 percent of the respondents. From this we can conclude that impact on poverty alleviation in Kebisoni will largely be via access to lighting from SHS.

The main objective in this study was to have a better understanding of the role played by SHS in alleviating poverty in Kesiboni, Uganda. One of the important questions considered in this study was on the link between solar PV systems and poverty alleviation. Access to a SHS has led an increase in disposable income for about 69% of the solar energy connected households. These households revealed that they now had more disposable income to cater for other expenses such as health. If productive members of the family were healthy then they could possibly work more and increase their earnings. This could reduce the levels of poverty faced by their households.

Access to media information through TV and radio powered by solar technology showed that the members are empowered especially the women. Women in the community showed that they were better informed especially about health/family planning information and news. When a household is able to control its family size then they are able to efficiently distribute resources thus alleviating poverty.

This research also considered whether solar systems promoted income-generating opportunities in the rural areas of Rukungiri district. The findings showed that solar energy indeed has promoted income generation opportunities. The study showed that 67 percent of the businesses surveyed were opened after acquiring the SHS. The study further revealed that businesses connected with solar technology were able to stay longer after 18:00hrs thus they made more evening sales. When a shop makes more sales, they are able to make higher profits. Business profits could trickle down to the household hence improving standards of living. In the long run there would be a reduction in poverty.

The study also revealed that women engaged in business thus promoting gender equity. Gender inequality is one of the dimensions of poverty. Hence when solar technology promotes gender equity by promoted women driven business enterprises then there is poverty alleviation.

The impact of solar technology on education was also explored, and the findings revealed that children were able to study longer. It is envisaged that when children study longer they are able to demonstrate an improvement in their grades. Children with good grades have better opportunities of getting formal employment and stable incomes. This would contribute to the alleviation of poverty.

Perceptions towards solar energy are positive within the Kesiboni community. Members of the sample community noted that solar energy access has promoted development within the area, especially by promoting business.

### **6.3 Recommendations**

The Ugandan government in partnership with funders and solar technology suppliers, can spearhead a massive campaign to promote the use of solar energy for productive uses. Whereas household income is increased, there is need for promotion of solar energy for productive uses so as to maximize the benefits, which will ultimately reduce poverty.

The government needs to ensure that there is enforcement in the quality of solar product standards on the market so as to increase confidence in the technology. Additionally solar users need to be educated on how to use the technology so as to reduce problems that may arise from poor usage of the system such as over loading and poor charging. Additionally, effort should be directed towards educating customers on standards and quality of solar components.

Government needs to provide skills training or livelihood training in the rural areas such as solar technician skills, simple courses on electrification and entrepreneurship so as to engage people in income generating activities. Some of these activities may as well be supplemented with energy from solar systems.

Strategies by government to promote solar energy use should be combined with efforts to educate the rural population about efficient biomass usage and related

technology. Some of this technology includes efficient cookstoves. This will maximize the benefits of air quality derived from solar access.

Government of Uganda should subsidize solar home systems and ensure that the subsidies are targeted towards the poor. Furthermore, the government and donors should partner with saving co-operatives at village level. The saving co-operatives shall provide an avenue for credit facilities especially for the low-income earners.

Although this research has provided useful information, it could be improved by carrying out a similar survey in an area where it is possible to do random sampling, in order to get a representative sample and eliminate any bias in the study. Additionally, quantitative data could be collected on reduced fuel usage with access to a SHS so as to provide a better analysis.

Further studies could analyze the impact of solar energy use in the agricultural sector, given that the agricultural sector is a source of livelihood for majority of Ugandans.

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## APPENDICES

### APPENDIX A: HOUSEHOLD QUESTIONNAIRE

#### **INFORMATION AND CONSENT.**

I am studying towards a Master's degree in Sustainable Energy and Development. As part of my studies, I will be completing a research project. Your participation to this research will be greatly appreciated and will allow me to understand your **views on the role of modern energy services towards alleviating poverty.**

I kindly request you to take part in this research by completing the attached survey questionnaire. I am interested in understanding how access to solar has improved your life in terms of health, poverty alleviation, income generation and equity.

Please note the following:

- Your participation in this research is voluntary.
- You can choose to withdraw from the research at any time.
- You must be at least 18 years of age to partake in this study.
- The questionnaire will take approximately 45 minutes to complete

This project is not intended to create any risk or harm to the respondents. Any confidential information provided will be handled with the highest degree of confidentiality and therefore any identifiable information will not be traced back to the respondent.

#### **CONSENT FOR FURTHER RESEARCH**

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction.

In this regard I give  /don't give  consent for my information to be used for further research and any other academic purposes.

Should you have any questions regarding the research please feel free to ask me.

**Researcher; Julian Hakirii**

**[jlnhak001@myuct.ac.za](mailto:jlnhak001@myuct.ac.za) Energy Research Centre, University of Cape Town)**

## Survey questionnaire

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### Interview details

Date of interview .....

Questionnaire number.....

Name of village: Kebisoni .

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### SECTION A: HOUSEHOLD ROSTER

In this first set of questions, we will ask about your household and household members

Sex and age of the respondent (Tick); Male ..... Female.....

**A01** How many people make up your household?

Men  Women  Children

**A02** Does the household get money from selling agricultural produce? (e.g., cattle, milk, goats, vegetables, mealies) Yes [1] No [2]

If no, GOTO **A05**

If yes, **A03** How often?

Every day [1] Once a week [3] Once a month [5]

Twice a year [2] Once a year [4]

**A 04** How much does the household obtain per month by selling? *Amount in local money*

A) 0-100,000 B) 100,000-200,000 C) 200,000-300,000 D) 300,000-400,000 E) Above 400,000

**A05** Give us your *best estimate* of the total monthly or yearly **INCOME** of your household **Monthly:**

A) 0-100,000 B) 100,000-200,000 C) 200,000-300,000 D) 300,000-400,000 E) Above 400,000

**Yearly:**

A) 0-300,000 B) 300,000-600,000 C) 600,000-1,200,000 D) Above 1,200,000

**A06** How much land does the household own?

.....

### SECTION B - INFORMATION ABOUT YOUR HOUSE / DWELLING

#### Structure of the house

**B01** Do you own or rent your house or are you provided with accommodation?

Own [1] Rent [2] Home provided [3]

**B01a** If renting or paying nominal fee – how much are you paying per month? *Amount in local money*.....

**B01b** If you own your house how much rent would you pay if rented the same house from somebody else?

**B02** How many separate buildings make up your house/dwelling excluding toilet(s) but including separate kitchen(s)?  rate

**B03** Does the household use a charcoal and or wood stove for cooking? Yes [1] No [2]  
*If no, GOTO B05*

**B04** *If yes, is this stove connected to a chimney?* Yes [1] No [2]

### Electric lighting

**B05** How many electric lights are there all together inside your house/dwelling? *If electric lighting in house GOTO B08*

**B06** How many outside electric lights are connected to your dwelling?

**B07** How many sockets are there to plug in appliances inside the house?

### Household amenities

**B08** What is the household's most common source of drinking water?

Tap in house [1] Tap in yard [2] Tank [3] Shared tap [4] Hand pump [5]   
Tube well [6] Surface well [7] Spring [8] River [9] Other  
(specify).....

**B09** If your household is not using an inside tap or tap in the yard, what is the distance to the nearest tap?

Less than 100m [1] 100m to 199m [2] 200m – 500m [3]

If more than 500m, specify the distance in kilometres [4].....km

**B10** If no access to tap water, what is the distance to the nearest protected water source (well, borehole etc)?

Less than 100m [1] 100m to 199m [2] 200m – 500m [3]

If more than 500m, specify the distance in kilometres [4].....km

**B11** Does your house have a separate bathroom? Yes [1] No [2]

**B12** Does your house have an inside toilet? Yes [1] No [2]

**B13** What type of sewerage system does your house/homestead have?

Water-borne sewerage [1] Pit-latrines [2] No sanitation facility [3]

Other (specify).....

### SECTION C- FUELS USED FOR DIFFERENT PURPOSES IN THIS HOUSE

Now we would like to know what type of fuels are used by the household.

**C01** What is the main fuel, second and third fuels the household uses for **lighting, cooking, heating water and ironing**? (If household does not have a third fuel, write 0)

<b>End-use</b>	What is the main fuel, second and third fuels the household uses for lighting, cooking, water heating, cellphone charging and ironing? <i>Electricity [1] Candles [2] Kerosene (paraffin) [3] Gas [4] Wood [5] Dung/crop residues [6] Coal [7] Charcoal [8] Solar [9] Dry cell batteries [10] Others (specify).....</i>		
	<b>Main fuel</b>	<b>Second fuel</b>	<b>Third</b>
<b>A. Lighting</b>			
<b>B. Cooking</b>			
<b>C. Water heating</b>			
<b>D. Ironing</b>			
<b>E. Cellphone charging</b>			

**C02** What are the most important reasons the household uses this as the main fuel for **lighting and cooking**? (Put the code in the 1st column in the box, which most closely reflects the respondent's first answer. If there is more than one response do the same for the 2nd and 3rd choices.)

**A. LIGHTING**

**B. COOKING**

Reasons	1 st	2 nd	3 rd	Reasons	1 st	2 nd	3 rd
Affordable/ cheap [1]				Affordable/ cheap [1]			
Easily available [2]				Easily available [2]			
Bright light [3]				Easy to use [4]			
Easy to use [4]				Safe [5]			
Safe [5]				Other (specify).....			
Other (specify).....							

**C03** If you had a choice and all fuels were available in your area, which fuels would the household like to use most for **lighting, cooking, heating and ironing**? What are the reason (s)?

<b>End-use</b>	Which fuel would the household like to use most if it had a choice? <i>Electricity [1] Candles [2] Kerosene (paraffin) [3] Gas [4] Wood [5] Dung/crop residues [6] Coal [7] Charcoal [8]</i>	If the fuel of your choice is not used regularly, what are the reason(s) for this? <i>Too expensive to use [1] Fuel/electricity not available in the area [2] Have no electricity connection [3] Don't have appliances [4] Other (specify).....</i>
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	Solar [9] Dry cell batteries [10] Other (specify).....	
A) Lighting		
B) Cooking		
C) Heating		
D) Ironing		
E) Cellphone charging		

**SECTION D - KEROSENE (PARAFFIN) SUPPLY, PURCHASE, USE AND APPLIANCES**

**Kerosene (paraffin) supply and use**

**D01** Is kerosene (paraffin) generally available in your immediate area? Yes [1] No [2]  
Don't know [3]

**D02** Does the household use kerosene (paraffin) at any time of the year? Yes [1] No [2]

*If no, GOTO section E.*

*If yes, D03* What are all the things the household does with kerosene (paraffin)?

*Indicate Yes [1] or No [2]*

A. Lighting		E. Heat water		I. Heat water for ceremonies	
B. Make polish		F. Run a fridge/freezer		J. Selling for profit	
C. Cooking		G. Heat the house		K. Brewing beer	
D. Ironing		H. Baking		L. Other (specify).....	

**D04** Fill in the table below of prices for quantities of kerosene (paraffin) bought.

	Frequency	For 1 bottle (0.75 L)	For 1L or ¼ Gallon	For 2L or ½ Gallon	For 4L or 1 Gallon	For 5L	For 10L	For 20L or 5 Gallon	For 25L	Other (specify).....
A	Every day									
B	3 times/ week									
C	4 times/ week									
D	Twice a week									
E	Once a week									

F	3 times /month									
G	Twice/month									
H	Once/month									
I	Less often/irregularly									
J	During power failures									
K	When no electricity units									
L	Other (specify).....									

**D05** How much paraffin does the household use for lighting in a month?.....

**D06** Does the household sell kerosene (paraffin)? Yes [1] No [2]

*If no, GOTO D09.*

*If yes, D07* How much kerosene (paraffin) does the household sell per month? Litres/Gallons.....

**D08** How much income does the household get per month from selling kerosene (paraffin)? Amount in local money.....

**D09** How much does the household spend on kerosene (paraffin) for all purposes (including making polish and selling) in one month? Amount in local money.....

**D10** Do you generally pay for transport to get to your usual kerosene (paraffin) suppliers? Yes [1] No [2]

*If yes, D11* How much does the household pay for the return journey to buy kerosene (paraffin)? Amount in local money .....

**Kerosene (paraffin) appliances**

**D12** Does the household have any kerosene (paraffin) appliances? Yes [1] No [2]   
*If no, GOTO section E.*

*If yes, D13* Which ones do you have? Indicate Yes [1] or No [2]

A. Kerosene (paraffin) wick lamps	D. Kerosene (paraffin) lanterns	
B. Kerosene (paraffin) flame stove	E. Kerosene (paraffin) primus stove	
C. Kerosene (paraffin) heater	F. Kerosene (paraffin) fridge	
G. Others (specify).....		

**CELLPHONE CHARGING**

**E03** Does the household incur any costs for cell phone charging? Yes [1] No [2]

**E04** How much in total does your household spend on cellphone charging per month?  
Amount in local money.....

**E05** How far from home do you take the cellphone for charging?  
Less than 1 km [1] 2 to 5 km [2] 6 to 10 km [3] More than 10 km [4]

**SECTION I- SOLAR SYSTEMS**

**I01** Does your household have any solar systems? Yes [1] No [2]

If yes, **I02** Which ones do you have? Indicate yes [1] or No [2]

A. Solar home system		B. Solar water heater		C. Solar pickle systems		D. Others (specify).....
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**I03** In which year was the solar system acquired? .....

**I04** For houses using solar voltaic systems, what are the components of the system and strength of the panel in Watts?

Item	Quantity	Capacity	Cost
Panel			
Bulbs			
Battery			
Inverter			
Connection			
		Total cost	

**I05** What was the mode of payment for the solar system?.....

**I06** Provide an estimate of how much the solar system cost (cost of the system and installation costs) .....

Do you have a battery for your SHS?

Yes [1] No [2]

**I07** If yes, how long does the battery last before it needs recharging? .....

**I08** Do you still use other fuels for lighting? Yes[1] No [2]

**I09** Which are the fuels?

a. Car battery		b. Candles		e. others (specify)
c. Kerosene		d. Dry cell batteries		

**I10** Has the quantity for the above fuels reduced after getting the SHS? Yes [1] No [2]

a. Car battery		b. Candles		e. others (specify)
----------------	--	------------	--	---------------------

c. Kerosene		d. Dry cell batteries		
-------------	--	-----------------------	--	--

**I11** Has provision of the SHS generally improved your general welfare/ situation? Yes [1] No [2]

If No GoTO **I13**

If yes **I12**, Answer Yes [1]/No [2] where it has been improved

A. Children are able to study		C. Spend less on candles		E. House improvements	
B. Spend less on kerosene for lighting		D. Reduced smoke inhalation		F. income for medical care	
E. Safety		F. Others specify			

**I13** Give reasons why

.....  
.....

**I14** For what purposes do you use the SHS? Yes [1] No [2]

A. Lighting		B. Car battery charging		C. Cell phone charging	
D. Appliances		Others specify.....			

**I15** Do you have direct current appliances? Yes [1] No [2]

If yes, **I16** which electrical appliances do you have? Yes [1] No [2]

A. Cell Phone charger		C. Coloured T. V		E. Radio		G. Others specify
B. Bulbs		D. Black & white T.V		F. Rechargeable lamp		

**I17** Has installation of the SHS helped you acquire more disposable income? Yes [1] No [2]

If No, **GOTO I19**

If Yes, **I18** in what ways has it enabled you, Yes [1] No [2]

A. Selling electricity		B. extending working hours	
C. saving money		Others (specify )	

**I19** Give reasons why

.....

**I20** Has the installation of the SHS extended your lighting hours?

Yes [1] No [2]

If No, **GOTO I22**

If yes, **I21** How have you spent this time? Yes [1] No [2]

A. helping children with homework		C. making beads		E. other home business specify .....
B. basket weaving		D. package snacks for sale		F. others specify .....

**I22** Give reasons why

.....  
 I23 Have the children benefited from the SHS?   
 Yes [1] No [2]

I24 In what ways have the children benefited from the SHS? Yes [1] No [2]

A. Light for studying and homework		B. Entertainment	
C. Educated through television/ radio		D. Others specify	

I25 *To be answered by women;*

a) How have you been able to use the extra lighting from solar? (To which activities is the solar light helpful?)  
 .....

b) Has access to solar empowered / created opportunities for you? If yes please explain.....  
 .....

*To be answered by men*

c) what in your view are the benefits of solar from a man's perspective?  
 .....

I26 In your opinion, who has benefitted most from the SHS? **Choose one only.**

A. Women		B. Men		C. Girls		D. Boys	
----------	--	--------	--	----------	--	---------	--

I27 Tell us why.....

I28 Do you think your health has changed after acquiring the solar system? Yes [1]  
 No [2]

A. Improved indoor air quality		B. More money to spend on medical care	
C. Less fire risks from candles and kerosene		D. I don't know	
Others specify			

I29 What improvements would you like to see in the delivery of Solar system?  
 .....

I10 Did any of the fuels reduce in quantity/ frequency of use after getting solar? Yes [1]  
 No [2] Choose one

a. Car battery	1	b. Candles	2	e. others (specify)
c. Kerosene	6	d. Dry cell batteries	4	

**THANK YOU**

## **APPENDIX B: BUSSINESSES QUESTIONNAIRE**

### **INFORMATION AND CONSENT.**

I am studying towards a Master's degree in Sustainable Energy and Development. As part of my studies, I will be completing a research project. Your participation to this research will be greatly appreciated and will allow me to understand your **views on the role of modern energy services towards alleviating poverty.**

I kindly request you to take part in this research by completing the attached survey questionnaire. I am interested in understanding how access to solar has improved your life in terms of health, poverty alleviation, income generation and equity.

Please note the following:

- Your participation in this research is voluntary.
- You can choose to withdraw from the research at any time.
- You must be at least 18 years of age to partake in this study.
- The questionnaire will take approximately 30 minutes to complete

This project is not intended to create any risk or harm to the respondents. Any confidential information provided will be handled with the highest degree of confidentiality and therefore any identifiable information will not be traced back to the respondent.

### **CONSENT FOR FURTHER RESEARCH**

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction.

In this regard I give  /don't give  consent for my information to be used for further research and any other academic purposes.

Should you have any questions regarding the research please feel free to ask me.

**Researcher; Julian Hakirii**

**[jlnhak001@myuct.ac.za](mailto:jlnhak001@myuct.ac.za) Energy Research Centre, University of Cape Town)**

**Interview details**

Questionnaire number.....

Name of District and county: Kebisoni, Rukungiri District .

**Survey questionnaire**

**A01** Who runs the business? Male [1] Female [2]

**A02** Who owns the business? Male [1] Female [2] Jointly owned [3]

**A03** Who else is employed in this business? Number: Male..... Female...

**A04** Where is the business located? Within the home [1] Away from home [2]

**A05** What is the nature of business/income generating activity? Yes [1] No [2]

A. Neighbourhood shop		B. Battery charging shop		E. Others specify .....
C. Cell phone charging shop		D. Bar/bottle store		

**A06** What main fuel does the business use for lighting?

<b>End-use</b>	What is the main fuel, second and third fuels the business uses for lighting ? <i>Electricity [1] Candles [2] Kerosene (paraffin) [3] Gas [4]</i> <i>Solar [5] Dry cell batteries[6]</i> <i>Other (specify).....</i>		
	<b>Main fuel</b>	<b>Second fuel</b>	<b>Third fuel</b>
<b>Lighting</b>			

**A07** Does the business have a solar system?

Yes [1] No [2]

If No, GOTO **A11**

If yes, **A08** what benefits have you derived from the solar system? Yes [1] No [2]

a. Extended working hours		b. Light at night	
c. Increased income		d. Others specify .....	

**A09** How much longer is the business opened from 6pm?

0-2hrs [1] 2-4hrs[2] 4-6hrs[3] >6[4]

**A10** How has the business improved after acquiring the solar system?

a. Business is carried out more efficiently		b. Less indoor air pollution		e. Others (specify)
c. Less expenditure on other lighting fuels		d. More savings		

**A11** Give reasons why? Yes [1] No [2]

High cost		Not informed	
Bureaucratic procedures		Others specify	

**A12** Provide an estimate of how much you sell in the evenings

.....

**A13** Is the capacity of the PV module sufficient to promote income generation and productive use? Yes [1] No[2]

**A14** What improvements would you suggest to promote income generation?

.....  
 .....

**THANK YOU.**

## APPENDIX C: FOCUS GROUP

### **INFORMATION AND CONSENT.**

I am studying towards a Master's degree in Sustainable Energy and Development. As part of my studies, I will be completing a research project. Your participation to this research will be greatly appreciated and will allow me to understand your **views on the role of modern energy services towards alleviating poverty.**

I kindly request you to take part in this research by completing the attached survey questionnaire. I am interested in understanding how access to solar has improved your life in terms of health, poverty alleviation, income generation and equity.

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Should you have any questions regarding the research please feel free to ask me.

**Researcher; Julian Hakirii**

**[jlnhak001@myuct.ac.za](mailto:jlnhak001@myuct.ac.za) Energy Research Centre, University of Cape Town)**

**INTERVIEW GUIDE FOCUS GROUP**

**A01** How was solar introduced in the community?

.....

**A02** How does the community perceive access to solar systems?

.....  
.....

**A03** Have the solar systems created more or less opportunities within the community?

.....

**A04** How and for whom?

.....  
.....

**A05** Who / which groups have benefited the most from access to the solar systems at the community level?

.....  
.....

**A06** Which groups have been unable to take advantage of opportunities or have been negatively affected by energy service provision through the solar systems?

.....  
.....

**A07** Why?

.....  
.....

**A08** Which other development projects are going on in the area?

.....  
.....

**SECTION B: POVERTY**

Now let's talk about the theme of poverty. We would like to know what you think of poverty and what its causes are.

**B01** In your opinion, what are the main types of poverty your community experiences? Choose **one** cause only

Lack of land [1] Poor soil [2] Drought/Weather [3] Lack of livestock [4]

Ignorance [5] inadequate infrastructure [6] inadequate technology [7]

Sickness [8] polygamy [9] Lack of access to water [10] Population pressure [11] Lack of skills [12] Others (specify)

**B02** What would you say are the TWO principal causes of poverty in your community?

a).....

b).....

**B03** If you had to rate your community as a non-poor community, a poor community or a very poor community, what would you rate your community?

Not poor [1] Poor [2] Extremely poor [3]

**B04** Give reasons for your answer

.....  
.....

**B05** In this community are some people poorer than others? Yes [1] No [2]

**B06** How many [proportion] poor people are there in this community?

All [1] More than half [2] About half [3] Less than half [4] Few [5]

None [6]

**THANK YOU.**