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ASSESSING THE DIFFUSION OF RENEWABLE ENERGY TECHNOLOGIES AND ITS IMPACT ON SOCIO-ECONOMIC DEVELOPMENT OF RURAL LIVELIHOODS IN UGANDA

A ripple effect analysis of two policy choices in dissemination of clean-burning, fuel-efficient cook-stoves and inclusive solar power technologies: photovoltaic systems for street lighting, institutional and home applications in Hoima District, Uganda

Defended on 03/09/2019 Before the Following Committee:

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DECLARATION

I, **Evelyn KABASINGWA,** hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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APPROVAL

This research project is submitted for examination with my approval as the University Supervisor.

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DEDICATION

This project paper is dedicated to my lovely husband for his unrelenting support and encouragement and to my beloved children for understanding about my absence in pursuit of knowledge.

I also dedicate this work to my affectionate mother Mrs. Elizabeth Yatuwa and my siblings for their unwavering support, prayers and encouragement that have made this academic journey a success.

To all mothers and their children who still use traditional forms of energy such as the three stone fires in Uganda, Africa and the world at large.

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LIST OF ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
ARC	Aprovecho Research Centre
CEM	Clean Energy Ministerial
CSP	Concentrated solar power
FDI	Foreign Direct Investment
GACC	Global Clean Cook-stoves Alliance
GET FiT	Global Energy Transfer Feed-in Tariffs
HDI	Human Development Index
ICS	Improved Cook Stoves
IEA	International Energy Agency
IFPRI	International Food Policy Research Institute
IMF	International monetary Fund
IRENA	International Renewable Energy Agency
kWh	kilowatt hour
LED	light-emitting diode
MEMD	Ministry of Energy and Mineral Development
MW	Megawatt
NPA	National Planning Authority
NSDFU	National Slum Dwellers Federation of Uganda
OECD	Organisation for Economic Co-operation and Development
PVs	Photo-voltaic systems
RE	Renewable Energy
RESP	Rural Electrification Strategy and Plan
RVO.nl	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SDGs	Sustainable Development Goals
SE4ALL	Sustainable Energy for all
SHS	Solar home systems
SPSS	Statistical Package for Social Sciences

STATA	Statistics and data
STEM	Science technology engineering and mathematics
TWh	Terawatt hour
UBOS	Uganda Bureau of Statistics
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
USMID	Uganda Support to Municipal Infrastructure Development Program

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ABSTRACT

This study assessed the diffusion of renewable energy technologies and its impact on socio-economic development of rural livelihoods, focusing on the ripple effect analysis of two policy choices: disseminating clean-burning, fuel-efficient cook-stoves and photo-voltaic systems in Hoima District, Uganda. The specific objectives were: to identify the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves, to assess the level of investment and the market for clean burning, fuel efficient cook-stoves, and to determine the socio-economic benefits of photo-voltaic systems for street lighting, home and institutional use in the development of rural livelihoods of the study area. The multistage sampling technique was employed, beginning with the purposive selection of Hoima District as the major study area. Secondly, respondents were purposively selected for a desired sample size, where by a sample size of 146 respondents and 8 focus group discussions was taken. The data collected were analysed using SPSS version 20 and STATA version 13.0 software. The results from the regression model indicated that education level, household income, household head occupation, access to information, training service and technical support have facilitated accessibility and adoption of clean burning, fuel-efficient cook-stoves and are statistically significant at 1% level. However, all these variables are attributed to the availability of artisanal fabricators that produce different sizes and designs of stoves at segmented prices from various materials, satisfying the customers' choices and preferences. Age, distance from fuel sources and from the market negatively affect the adoption at 10% level. Investment in fabrication on the other hand, is still low, but highly influenced by cheap raw materials that are easily available, high ready market, access to credit, expenditure levels and low levels of education leading to unemployment because most of the fabricators are the youth, implying an unemployed age bracket in the African trend. The study also established that photo-voltaic systems significantly transform rural livelihoods through energy services, money savings, business activities, environmental sustainability, employment, improved study conditions, increased business opportunities all of them at 1% level; PVs increase fish harvests and lead to emergence of new businesses like casinos, salons, and football/cinema show centres (ebibanda), thus significantly transforming rural communities. Therefore, the government should prioritise the investment and promotion of the diffusion of renewable energy technologies to eradicate all forms of poverty sustainably.

RÉSUMÉ

La présente étude a évalué la diffusion des technologies des énergies renouvelables et son impact sur la croissance socio-économique des niveaux de vie en milieu rural, en se focalisant sur l'analyse de l'impact sur deux choix politiques : la diffusion des cuisines écoénergétiques à haute performance et de systèmes photovoltaïques dans le district de Hoima en Ouganda. Les objectifs spécifiques étaient de : identifier les facteurs influençant l'accessibilité et l'adoption de foyers de cuisson à combustion propre et à haut rendement énergétique ; évaluer le niveau d'investissement et le marché desdits foyers ; déterminer les avantages socio-économiques des systèmes photovoltaïques pour l'éclairage des rues, des ménages et institutions pour la croissance des niveaux de vie de la population dans la zone d'étude. La technique d'échantillonnage en plusieurs étapes a été utilisée et le district de Hoima a été pris comme zone d'étude principale. Les répondants ont été choisis à dessein en fonction de la taille de l'échantillon souhaitée et donc 146 personnes ont été interrogées et 8 groupes de discussion ont été organisés. Les données collectées ont été analysées à l'aide des logiciels SPSS version 20 et STATA version 13.0. Les résultats du modèle de régression indiquent que le niveau d'éducation, le revenu du ménage, l'occupation du chef de ménage, l'accès à l'information, les services de formation et l'assistance technique ont facilité l'accessibilité et l'adoption desdits foyers et qu'ils sont statistiquement significatifs au niveau de 1%. Cependant, cela est rendu possible grâce aux fabricants artisanaux produisant des cuisinières de différentes conceptions et à des prix variés permettant ainsi les choix et les préférences des clients. L'âge, la distance pour l'accès au combustible et le marché ont une incidence négative sur l'adoption à 10%. En revanche, les investissements dans la fabrication sont encore faibles, mais fortement influencés par des matières premières facilement disponibles, un marché prêt à l'emploi, l'accès au crédit, des niveaux de dépenses et un faible niveau d'éducation menant au chômage, car la plupart des fabricants sont des jeunes, impliquant une tranche d'âge sans emploi dans la tendance africaine. D'après cette étude, les systèmes photovoltaïques contribuent fortement à l'amélioration des niveaux de vie en milieu rural grâce aux services énergétiques, aux économies d'argent, aux activités commerciales, à la sauvegarde de l'environnement, à l'emploi, à l'amélioration des conditions d'étude, à des opportunités commerciales accrues au niveau de 1%, ce qui entraîne l'émergence de nouvelles petites entreprises et les centres de spectacles (ebibanda). Par conséquent, le gouvernement devrait donner la priorité à l'investissement et à la promotion de la diffusion des technologies des énergies renouvelables afin d'éliminer durablement toutes les formes de pauvreté.

1 INTRODUCTION

1.1 Background

Energy is the life-breath and blood of every modern society. Without energy, there is no life in a nation as it is an indispensable element in all aspects of life, especially economic and human development. The universal access to modern energy is directly linked to the rest of the Sustainable Development Goals (SDGs) and Agenda 2063; it is a weapon for combating poverty, fostering economic growth and improving health and gender equality (OECD/IEA, 2017). However, most people in Sub-Sahara Africa face severe energy poverty; it is the part of the world with the largest number of people lacking access to modern energy. More than two thirds of the region's population, almost a half of the world's total, has no access to modern energy, yet 80% of these reside in rural areas. The region is also dominated by traditional forms of energy that are a threat to health albeit the abundant endowment of energy resources. Moreover, those with electricity access depend on the under-developed system which is very expensive and unreliable for their needs (OECD/IEA, 2014). See Figure 1.1 below of how Africa appears at night compared to other continents due to severe lack of electricity access.

Figure 1.1: Map of Africa as seen from space at night

Source: *NASA Earth Observatory, 2016*

This energy poverty is escalated by the fast growing population in the region leading to high energy demand. This critical challenge implies huge amount of funds for investment to meet the target of universal electricity access by 2025. It is estimated that $60 billion is needed per year to achieve the target (Heffron et al, 2017). Thus, energy deficit is an impediment to economic development, especially in the rural communities of Africa. This challenge must be addressed in a more sustainable way, considering system thinking, to avoid repeating the past mistakes made in the name of economic development that are empirically evident globally as climate change effects and other anthropogenic effects. A steady yet accelerated transition in energy systems is inevitable if we intend to make the world a better place for all the generations. Climate change is global issue as reflected by the "*seven climate records in 2016: melting of Arctic ice; consecutive hottest months; hottest day in India ever; highest temperature in Alaska; consecutive and biggest annual increase in CO2; hottest Autumn in Australia ever; and highest amount of destruction in Australia's Great Barrier Reef*" (McCaauley & Heffron 2018). Some of the climate change effects arise from energy emissions that occur during various economic activities. Therefore, a meticulous and holistic energy system development of Africa's abundant energy resources would transform the continent to leapfrog from a subsistence economy to a modern and desirable economy.

Uganda, in particular, is one of the countries with very low modern energy access. Electricity access at national level stands at 26.70% from 15% by 2013 (10%:2010; 9%: 2006; 5.6%:1991) (World Bank, 2018). However, the question is, are these figures enough to reflect the number of people utilising the electricity in reality?

1.1.1 What does electricity access mean in reality?

Electricity access does not necessarily mean being connected to electricity. The World Bank Group developed a Multi-Tier Framework to define and measure energy access since binary indicators are insufficient in fostering and tracking the SDG7. Consequently, affordable, reliable and modern energy should entail households, productive engagements and community facilities with seven attributes: capacity, duration, reliability, quality, affordability, legality as well as health and safety (SE4ALL, 2016). The framework is divided into five tiers as illustrated in Figure 1.2 below.

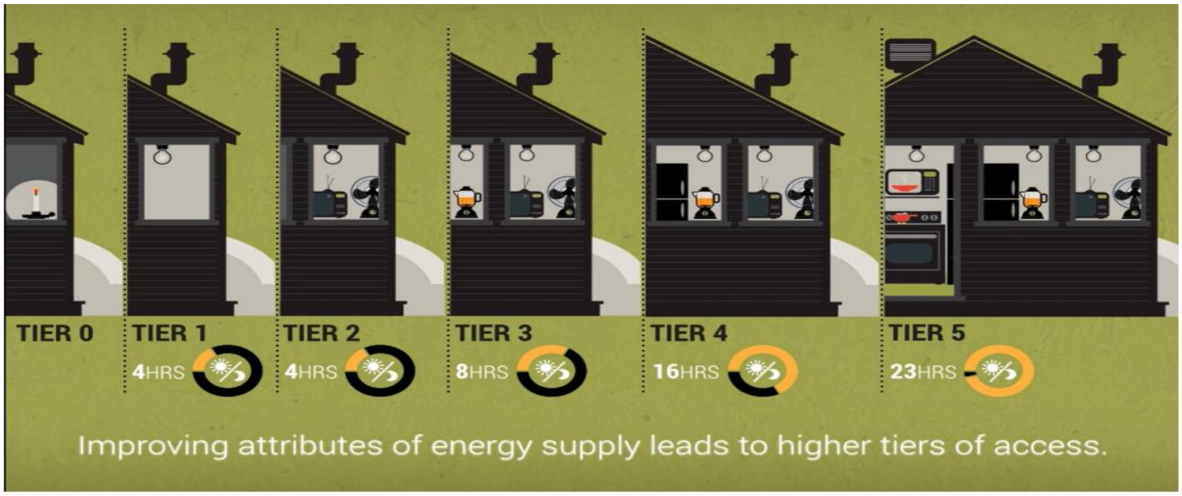

Figure 1.2: The multi-tier framework continuum level of electricity access

Source: *SE4ALL, 2016*

The lack of access to reliable, affordable and modern energy in Uganda has stagnated country's development because energy is the dividing line between the rich and the poor and between the developed and the developing countries. For a country to achieve sustainable development, it should put the development of energy at the forefront to serve as an economic confrontation. Therefore, there is need to increase energy access especially in rural communities of Uganda to improve the local economic activities and add value to goods and services to enable them compete on the global market. This strategy can be achieved through renewable energy integration by using the locally available renewable resources to promote public health and environmental sustainability.

Incorporating off-grid solutions such as the use of solar photo-voltaic systems would be an important source of renewable energy, which has the potential to trigger strategic and sustainable development by transforming lives and economies through improving health and safety, increasing incomes as well as enhancing educational development. However, due to financial constraints, it is not easy to purchase these systems or to make them readily available in Uganda because of the upfront costs involved. Nevertheless, Uganda needs a steep increase in energy supply to leapfrog from a subsistence economy to a middle class modern economy with equitable economic growth and inclusive sustainable development. Moreover, off-grid energy has proven to be better than grid electricity in Uganda in terms of access when considering the Multi Tier Framework. See Appendix D for details on Multi Tier Representation of the households in Uganda in 2010

1.1.2 Rationale for the study

This study explored two policy choices as enabling frameworks in dissemination of renewable energy and critically evaluated the economic and non-economic barriers that stand in the way of greater penetration in rural areas of Uganda. The study was carried out in one of the upcountry districts called Hoima in western Uganda. Clean-burning, fuel-efficient cook-stoves and solar power technologies as PV systems for powering street lights, institutions and homes have been promoted as a means of reducing negative health and environmental impacts resulting from the burning of solid biomass fuels in this rural district in Uganda. International initiatives such as the Global Alliance for Clean Cook-stoves reflect consensus in the policy-making community that investments in fuel-efficient cook-stoves provide large returns to society in terms of health benefits, time savings and reduced pressure on forests and climate change. However, with a few exceptions the adoption and long-term use of alternative stoves remains low. This research study intended to survey the history of solar power technologies as street lights, solar photo-voltaic systems and improved cook-stoves adoption so as to reflect on current models of stove dissemination to identify best practices in clean cook stove program design and dissemination. This research study intended also to find out best practices from the history of cook-stove intervention attempts and evaluate the best practice techniques to transform the cook stove challenge into an opportunity for a more effective scaling-up strategy

Disseminating clean-burning, fuel-efficient cook-stoves, whether through aid or low-cost distribution programs, has recently risen up the global public agenda since the establishment of the ‘Global Clean Cook-stoves Alliance (GACC) in September 2010. The GACC is a private-public partnership including the United Nations Foundation, the United States’ Environmental Protection Agency and the Shell Foundation, among others (United Nations Foundation 2011; Smith 2010). UNEP is an official implementer of the Alliance and is actively working with over 250 other organizations towards a ‘100 by 20’ target in which 100 million homes adopt clean and efficient stoves and fuels by 2020. The potential benefits of shifting from current cooking technologies to clean-burning, fuel-efficient cook-stoves include reduced exposure to harmful indoor air pollution, decreased pressure on wood resources for firewood and charcoal, reduced workloads for women and children (the traditional collectors of firewood in many cultures), lower monthly expenditure on fuel, and reduced burns and injuries in the home. There are also benefits for the global environment in the form of reduced emissions of greenhouse gases (GHG) and black carbon (soot).

However, in order to meet the 100 by 20 goal, we must examine the past. Interest in stove interventions dates back in the 1970s when concerns were centred mainly on forest conservations. The justification for interventions in household energy broadened over the years to incorporate concerns about public health and climate change, with forest conservation taking a lesser role. Through these shifts, it became apparent that, despite potentially large social and environmental benefits, successful stove dissemination was not easy to achieve. This study therefore, reviewed accessibility and adoption of clean-burning cook-stoves, examined the links between local cooking habits and global climate change, and then examined ways in which the international community can support the widespread dissemination of efficient cook-stoves in line with developmental and environmental goals. The entire study analyzed critically key experiences from the past, current financing opportunities for the development practitioner, and issues related to stove adoption and gender dynamics that are also the key to a cook stove project's success on the ground. The purpose of this study was to unveil the current knowledge on cooking-stove promotion and diffusion, and to finally propose the best practices for fuel-efficient cook stove program design, dissemination and local level adoption.

1.2 Statement of the problem

Uganda is one of the countries with the lowest energy access yet already experiencing climate change effects. Therefore, the Ugandan government aims to achieve universal modern energy access by 2040 and 100% Renewable Energy by 2050. In spite of the significant investment required and the high number of different development programs related to electricity access and renewable energy deployment, analytical work and empirical evidence on the socio-economic impacts of such efforts remains relatively limited. Only a few studies have evaluated the relationship between inclusive solar power technologies access: photovoltaic systems for street lighting, institutional and home applications and human development indicators, and the vast majority of these have focused on Asian and Latin American countries (Lenz et al., 2015). With this study, the intention is to shed light on both the developmental effect of obtaining access to modern energy and the local value creation generated through renewable energy deployment. Uganda is arguably the country facing the most pressing energy needs yet the region with little evidence on the topic. By focusing on Uganda, this study hopes to bring a more comprehensive and empirical-based evidence and identify factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities, understand the socio-economic impacts of inclusive solar power technologies as street lights and institutional as well as solar home systems in Hoima District, Uganda.

1.3 General objective

1.3.1 Global objective

The global objective of the study was to assess the diffusion of renewable energy technologies and its impact on socio-economic development of rural livelihoods in Hoima District-Uganda.

1.3.2 Specific Objectives:

1. To identify the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities in the study area.
2. To assess the level of investment by stove fabricators and the market for clean burning, fuel efficient cook-stoves in study the area.
3. To determine the socio-economic benefits of solar power technologies as PV systems for street lighting, institutions and home applications in the development of rural livelihoods in the study area.
4. To develop a policy brief and framework for accelerating the diffusion of Renewable Energy Technologies in the study area.

1.4 Research Questions:

1. What are the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities in Hoima District, Uganda?
2. What is the level of investment by stove fabricators and the market for clean-burning, fuel-efficient cook-stoves in Hoima district, Uganda?
3. What are the socio-economic benefits of solar power technologies as PV systems for street lighting, institutions and home applications as fully-fledged policy programs for sustainable development in Hoima District, Uganda?
4. What should be done to accelerate the diffusion of Renewable Energy Technologies in Uganda?

1.5 Significance of the study

As indicated, renewable energy investments are projected to increase access to electricity for productive purposes, lighting and clean, fuel efficient cooking means, with potentially high impacts on economic and human development. With both the public and private sectors committing to invest billions of dollars into solar power technologies such as solar photovoltaic systems and clean-burning, fuel-efficient cook-stoves as renewable energy deployment in developing countries like Uganda, an evaluation of such massive investments and their socio-economic impacts is vital for making informed policies and investment decisions on renewable energy developments for the welfare of both humanity and ecosystem.

1.6 Scope of the study

This study focused on the analysis of a ripple effect of two policy choices in disseminating clean-burning, fuel-efficient cook-stoves and inclusive solar power technologies: photovoltaic systems for street lighting, institutional and home applications in Hoima District, Mid-Western Uganda. The analysis was done on improved cook-stoves fabricators and users as well as PV users at both household and institutional levels.

1.7 Organisation of the study

This study is presented in six chapters. The first chapter comprises the general introduction which constitutes the background of the study, statement of the problem and significance of the study. Chapter two presents the literature review on the implication of improved cook stoves and PVs while chapter three highlights the overview of Uganda as the case study, including energy profile of the country. Chapter four presents the methodology used during the study. Furthermore, chapter five is a presentation of results of the study and discussions and finally, chapter six presents the conclusion and recommendations derived from the study.

2 LITERATURE REVIEW

This literature will support our analysis of the ripple effects generated by Scatec Solar's investment in Uganda. The second part of the chapter reflects on the opportunities for value creation in the renewable energy (RE) sector. This will build on a comprehensive review on the topic conducted by the International Renewable Energy Agency and the Clean Energy Ministerial (IRENA & CEM, 2014). The third part of the chapter focuses on the significance of improved cook-stoves as well as the socio-economic impacts of improved electricity access in developing countries and will support and supplement our analysis of the ripple effects that stems from electrification. Finally, the last section highlights the description of the case study, Uganda overview.

2.1 The economic impact of FDI in developing countries

Many Sub-Saharan countries lack adequate financial and technological resources to foster a sustained socio-economic development. Although international aid constitutes the largest contribution to external financial inflows into the African continent, attracting alternative finance is believed to be increasingly important in order to close the resource gap (UNCTAD, 2005; Ayanwale, 2007). The World Bank defines FDI as: "a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy" (World Bank, 2016G).

Throughout the last three decades, the inflow of FDI into the African continent has grown dramatically in response to increasing economic globalization, higher capital mobility and integration of financial markets (UNCTAD, 2005). In recent years, slow global economic growth has also made the faster-growing African economies relatively more attractive.

In response to the rise in FDI and the expected benefits there has been an ongoing debate regarding the economic impact of FDI in developing countries. The effect is widely discussed in both the theoretical and empirical literature.

2.2 Opportunities for domestic value creation along the value chain

A central question to the assessment of value creation in a RE sector is to what extent the value creation is being generated locally where the RE project is located, and how much of the value is a result of imported inputs. This depends on the maturity of the RE sector in the country where the project is being realized. Domestic economies that cannot supply the needed inputs to the value chain, must import either the needed material or expertise. In the following we present the opportunities for value creation in the different segments of the RE value chain, with emphasis on the solar PV sector. We will be looking at opportunities within the planning stage, manufacturing, installation, grid connection, operation and maintenance.

For example, in planning phase, the project-planning phase includes activities within resource assessments, feasibility studies, and planning of infrastructure. Experienced and specialized personnel are required to conduct such activities. With many RE projects being developed in a country, the level of domestic know-how and expertise can be expected to be substantial, which places a large share of the value creation during the planning stage to the country. Where the RE sectors are less mature, it is more likely that foreign consultants are engaged in the planning.
Enhancing education and training is thus important to bridge the gap of skills that exists in some cases, in order to retain the value creation at the local level. In the solar PV industry, the planning phase mainly consists of the planning and projecting of modules, which can be undertaken by the installer or a project developer.

In manufacturing phase; a certain degree of industrial capability in the country is necessary to generate value creation locally. If so, manufacturing can generate value in all its processes and offer large job creation potential depending on how technically advanced the different production processes are. A Japanese study on the employment potential related to manufacturing, construction, operation and maintenance of solar PV and wind power technologies shows that employment in manufacturing stands for approximately 70 percent of overall employment for both PV and wind (Matsumoto et al., 2011).

The manufacturing process in the solar PV sector includes the production of the PV modules, from silicon and components for the balance of system (inverters, mounting systems, combiner box and other electrical components) (IRENA, 2012). Manufacturing of PV cells and modules is mainly driven by technology innovation and economies of scale.

Energy costs are also an important aspect for the development of a PV manufacturing industry, while labor costs play a less significant role as production is highly automated. In the recent years, the manufacturing of PV systems has been concentrated to Asia due to large investments made in production capacity in order to exploit the scale potential in the production (IEA, 2014).

At Installation phase, the installation process relates to the construction and assembling of the renewable power plant, and the coherent infrastructure works. This phase includes labor-intensive civil engineering, infrastructure work including groundwork, foundations, channeling, water supply, buildings and roads, which are typically delivered by local companies. Complete system installations are more complicated to conduct when it involves imported equipment, which is often the case when installing solar PV modules. The manufacturers of the modules are therefore often involved in the installation activities with their own equipment and personnel. This leaves less work for local companies. Still, local companies can participate in delivering required services especially if the expertise already exists in the local area.

2.3 The relationship between electricity and socio-economic development

Access to electricity is widely believed to contribute to economic and social development (UN, 2010). The underlying assumption of this belief is that access to electricity can enhance quality of life at the household level and stimulate the economy at a broader level (Khandker et al. 2013). Intergovernmental organizations and financial institutions have therefore, supported electrification programs in many developing countries. In order to justify the international donor support, the impacts of rural electrification have received a lot of attention in the recent years. A number of studies have attempted to empirically test the relationship between rural electrification in developing countries and socio-economic indicators.

(Lenz et al., 2015) argue that apart from job creation and the development of training skills, there are various benefits of electricity access to the communities. These benefits range from increased income generation, which is visible in businesses to improved quality of life. These benefits, among others, are illustrated in in the figure 2.1 below.

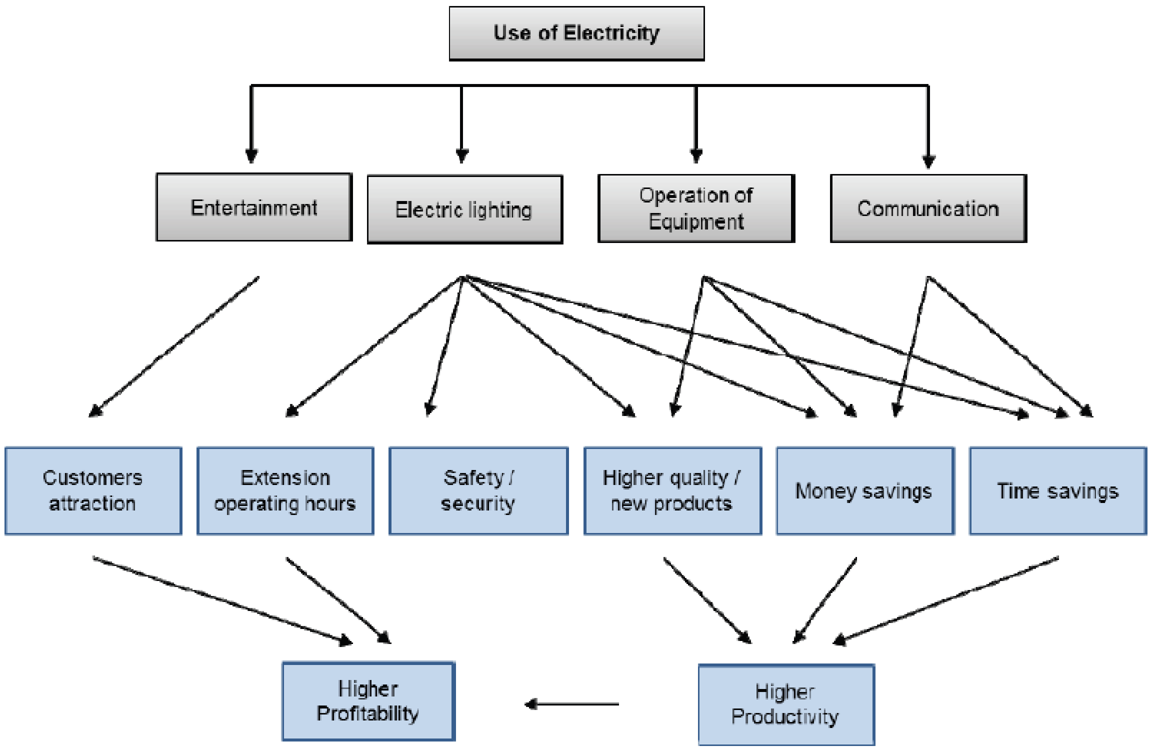

Figure 2.1: Pathways from electricity access to income in local SME's

Source: *Lenz et al., 2015*

2.3.1 Empirical evidence from the developing world

The bulk of the existing literature is based upon evidence from Asia and Latin America; although some impact studies have also been conducted in Africa (Dinkelman, 2009; Jacobsen, 2006; Lenz et al., 2015). Researchers argue that electricity has a positive impact on development through the effect on the three components of the Human Development Index (HDI) and the environment. In the remaining part of this subchapter, we will present relevant evidence from a number of influential papers from the developing world.

Income is by far the most studied impact indicator throughout the body of literature. Papers examine how electrification affects household income through the usage of electrical appliances and engagement in non-farm activities that in turn, will stimulate business activity and improve productivity at the broader level. Two recently published studies from India found a strong positive relationship between electricity and firm and household earnings respectively. Rud (2012) found that electrification explains a significant proportion of the variation in manufacturing output across Indian states, while Van de Walle et al. (2013) found evidence of a significant increase in both the consumption and income level of households. Evidence of positive effects on household income is also found in Brazil (Lipscomp et al., 2012) and Vietnam (Khandker et al., 2013).

In the African context, studies on the effects of electricity on household income give conflicting results. Dinkelman (2011) found a substantial increase in female labor supply in the wake of electrification in South Africa. She ascribes this effect to the shift from using wood to the use of electric cooking and lighting. This allows women to save time on fuel collecting activities and can thus devote more time to productive work. On the contrary, Jacobsen (2006) found that electricity only supports economically productive activities to a very small extent in his study in Kenya. His results show that the central driver for electricity demand is the desire to use "connective appliances" such as television and telephones.

Educational performance is the second most studied impact indicator. Positive effects on enrollment rates and years of completed schooling are found in several studies from Asia and Latin America (Van de Walle et al, 2013; Khandker et al, 2013; Lipscomp et al, 2012).

Furthermore, researchers have also examined how electrification effects the time children spend studying after school. Positive effects on the study time of children are found in two separate studies from Bangladesh (Khandker et al., 2013; Samad et al. 2013) and El Salvador (Barron and Torero, 2014).

Health indicators are analyzed to a much lesser extent, mostly due to lack of quantitative data (Peters and Sievert, 2015). There are, however, two papers analyzing the usage of kerosene lamps as a lightning source in Bangladesh and El Salvador respectively (Samad et al. 2013; Barron and Torero, 2014). Both studies found a substantial reduction in the use of kerosene in households with access to electricity. The latter further analyzed the indoor air quality and found a significant improvement in the concentration of harmful pollutants in connected households. The authors attribute this effect to the observed reduction in kerosene usage.

2.3.2 The benefits of solar powered street lights to the community

Solar powered street lights provide different benefits to various categories of people in the community, ranging from social, economic to environmental welfare as illustrated in Figure 2.2 below.

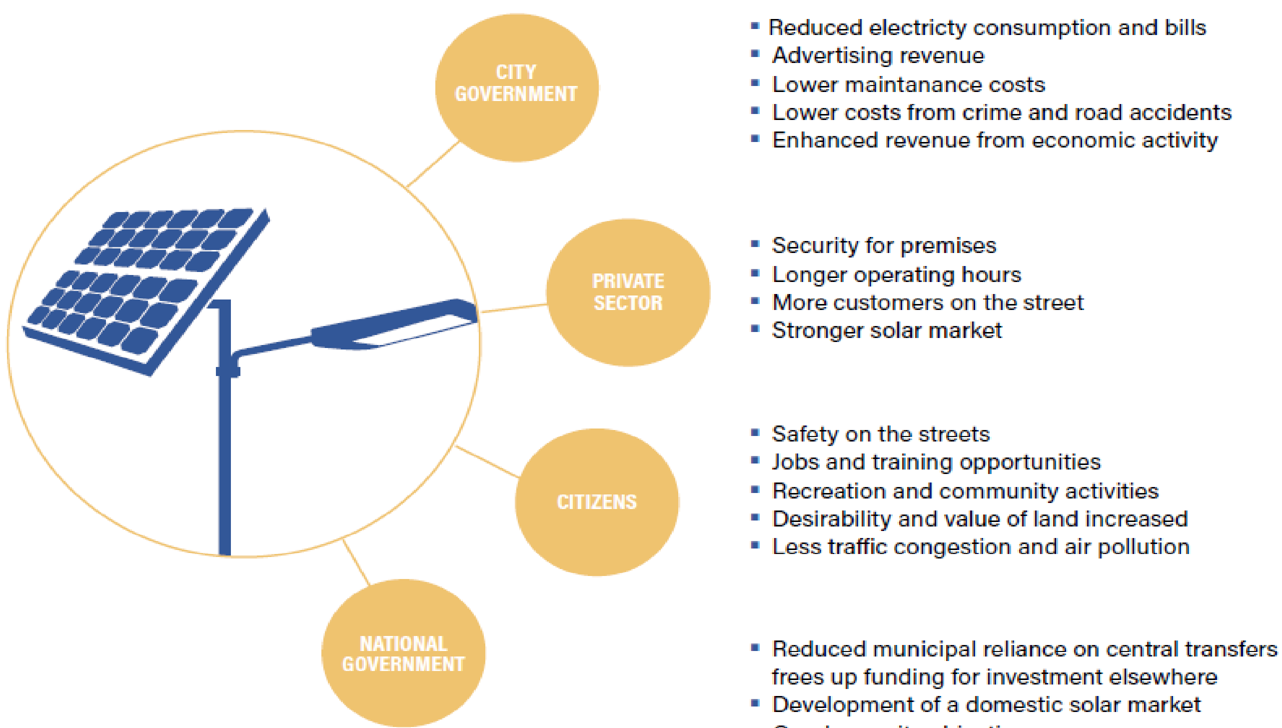

Figure 2.2: Benefits of street lighting to different stake holders

Source: *Gillard et al., 2019*

Solar-powered street lighting also presents an opportunity to develop a domestic solar market by training solar technicians and manufacturing the street lights locally (Johansson, 2011). Both Kampala and Jinja have nascent solar markets that trade components and community-based organisations that provide skills training to local people. This was especially apparent in Jinja, where, due to the involvement of NSDFU and their links with SDI (Shack/Slum Dwellers International), local businesses were contracted to produce the poles. Young people from the informal settlements were provided with training to do this, which has enabled them to continue to gain work in the sector and to pass on their skills to others in the community through workshops. This could contribute to job creation at a national scale. Improved street safety can support a wide range of social and economic activity which can enhance prosperity nationwide. When lighting is installed on busy roads and junctions, accidents are reduced and traffic is eased, which helps address congestion and air pollution. Better lighting enables street traders to work for longer and during the busiest part of the day for trading (early evening). Interviewees reported a reduction in actual and perceived crime rates, thereby making an area more appealing and helping make pedestrians feel safe. This is especially important for women, whose safety and wellbeing have been directly linked to the level of lighting on city streets (Boomsma, C. and Steg, L., 2014), Female street vendors in particular benefit because they depend on the use of otherwise unsafe public spaces for their livelihoods (IMF, 2018).

Achieving gender equality in this area can help to boost national economic growth and lead to better development outcomes. Better lighting also improves access and perceptions in affected areas, increasing the value of properties. It enables recreation and community activities by providing safe, accessible and usable public spaces and access routes for pedestrians. Again, these benefits are particularly important for empowering women and enabling them to reap the social and economic benefits of urban life. So far, in both cities, development has focused on central areas of economic activity – where city governments can extract the most revenue – but, if solar lighting was rolled out to poorer parts of the city, these wider non-economic co-benefits would be considerably greater.

Due to rapid population growth rate combined with deep-rooted poverty and lack of access to affordable, reliable and modern energy services in developing countries like Uganda, public administrators especially those managing municipalities face a lot of pressure to meet the energy needs of their population to improve socio-economic development in an environmentally sustainable manner because of the surge of urbanisation. Consequently, with the development of various advanced technologies to generate electricity off the grid, most governments are opting for solar photovoltaic systems to power street lights because of their nature of environmental sustainability and economic benefits. Also, the development of solar powered LED lights is advancing at a high rate, thus improving energy efficiency.

Securing the most efficient, effective and appropriate street lighting service is an essential aspect of inclusive development in every country today for ensuring strong visual identity and public safety, most especially among women. Initially, there have been very few street lights in Ugandan cities and towns; moreover, they were powered by the grid and were highly energy inefficient, one of the reasons for rampant load shedding in the previous years, especially during peak hours. It should be noted that street lighting involves the consumption of a great deal of energy due the types of lights used and being lit for a longer duration, throughout the night. The United Nations, established that around 15% of the world's electricity is utilised on lighting accounting for over 5% of global greenhouse gas emission, of which public lighting constitutes 8% of the electricity consumed (UNDP, 2017). More still, the global yearly energy expenses for street lighting only are projected to rise between $23.9 billion and $42.5 billion by the year 2025 (Sedziwy, 2016).

To reduce the high energy consumption and increase maximum energy efficiency, affordability, reliability and sustainability in the supply of energy, the Government of Uganda has opted to go green by embarking on solar powered street lighting projects in fourteen (14) of its municipalities (including Hoima District) through donations from Uganda Support to Municipal Infrastructure Development Program (USMID) in the very recent years. After being approved by the World Bank, the programme became effective in 2013. It was basically intended to enhance urban service delivery by improving urban infrastructure and building capacity. The project was funded by the International Development Agency (IDA), together with the Government of Uganda, running for six years (World Bank, 2017). Consequently, even the existing grid-connected street lights in the chosen areas will soon be replaced by solar powered ones to optimize the utilization of natural resources and reduce the energy costs (ibid) In Hoima Municipality, the development of solar powered street lighting systems under USMID was done in two phases. This technique was very helpful because it enabled the stakeholders to learn from the mistakes made during the first phase

2.3.3 An analysis of the benefits of cook stoves

The predominant type of fuel in the cooking energy sub-sector in rural Uganda is firewood. Furthermore, charcoal is commonly utilised in both semi-urban and urban areas of Uganda. According to UBOS, 2017 wood fuel accounted for 84% of the energy consumed for cooking by households in 2014. The use of wood has, therefore, escalated the rate of deforestation in the country. To reduce the rates at which forests are disappearing and shortage of firewood Uganda, the Ministry of Energy and Mineral Development in collaboration with the German Agency for International Cooperation (GIZ) and the Energy Advisory Project (EAP), integrated with private partnership to disseminate clean burning, fuel efficient cook stoves (a.k.a. improved cook stoves) in the country.

These stoves are one of the best practices in the utilization of biomass in Uganda. They are now locally produced after being adapted to the standards of the socio-economic status of all the classes of the Ugandan population. Their diffusion is becoming established country wide due to innovations and creativity in the use of locally available materials such as clay, cement, sand, metal as well as molehills.

The adoption of the clean burning, fuel efficient cook stoves are expected to influence the Ugandan population by impacting the environmental and socio-economic standards of the country. These impacts are already experienced as benefits by the users, and some of them are illustrated in Figure 2.3 below.

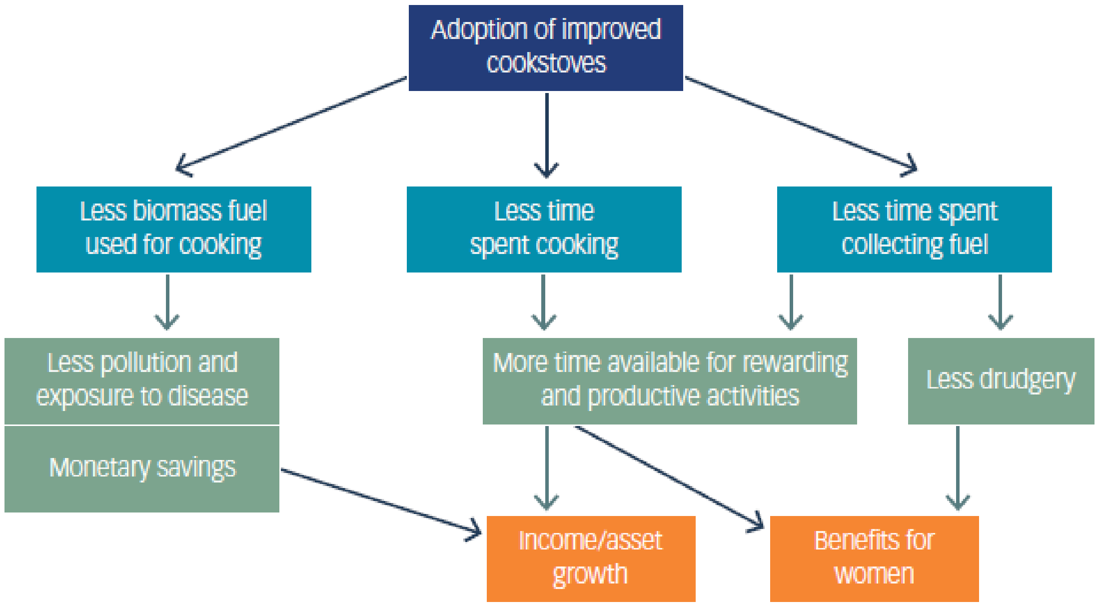

Figure 2.3: The benefits of improved cook-stoves

Source: *Barnes and Samad, 2018*

2.4 The Relationship between Solar PVs and Sustainable Development Goals

The development of Renewable Energy Technologies such as the stand alone photo-voltaic systems has the potential to accelerate the achievement of the sustainable development goals and the agenda 2063. This is due to the direct link of their outcome as seen in the table 2.1 below.

Table 2.1: The nexus between PVs utilisation and socio-economic development and the correlation of PV installation with some SDGs.

Sustainable Development Goal	Agenda 2063 Goals	Correlation with PVs installation
SDG1. Ending poverty in all its forms	Goal 1: A high standard of living, quality of life and well-being for all citizens.	• The use of solar PVs creates jobs, increases working hours implying more income, adds value to goods and services, boosts micro-enterprises and generates more opportunities to combat poverty.
SDG2. Zero hunger	Goal 5: Modern agriculture for increased productivity and production.	• Solar PVs increases income, support agriculture through irrigation and reduce post-harvest losses through dryers and refrigeration services and food processing, thus boosting food security. • The farmer gets information about weather changes through solar powered gadgets like radios and televisions to plan their seasons well.
SDG3. Promoting health and well-being	Goal 3: Healthy and well-nourished citizens.	• Provision of better health services; reduce mortality rate by aiding vaccine storage, reduce maternal rate by providing proper illumination during birthing. They also power some machines used at health stations for diagnosing simple diseases like malaria. • They involve less emissions, hence reduced health issues resulting from air pollution, especially elimination of firewood on a three stone fire place which is highly pollutant. • Reduce home accidents among children like burns, fires and poisoning form kerosene. • Attract more qualified medical personnel in rural communities • Increase food security and fight malnutrition. • Health programs are communicated through televisions and radios powered by solar in rural areas.
SDG4. Ensuring	Goal 2: Well educated	• Utilisation of Solar PVs attract and maintain qualified teachers in the villages, empower students in rural areas to compete with

inclusive and equitable quality education	citizens and skills revolution underpinned by science, technology and innovation.	those in urban areas by providing good light to study extra hours at night and to do research. • They also empower teachers to carry out more research using the internet via mobile phones and laptops and to connect with fellow teachers worldwide.
SDG5. Promoting gender equality	Goal 17: Full gender equality in all spheres of life.	• They enable women to perform economic activities that generate income other than spending many hours, walking, collecting firewood for lighting and cooking. Also, girls use the time they would be spending on collecting firewood to study, which improves their performance and later become responsible citizens.
SDG6. Sustainable management of water and sanitation	Goal 7: Environmentally sustainable and climate resilient economies and communities.	• It results into proper water management as less pressure is put on water resources for hydro power production. • Also, in the case of aquaponics, a lot of water is conserved alongside higher yields. • It can be used to purify water for clean water supply and sanitation.
SDG8 Economic growth and employment	Goal 4: Transformed economies.	• Creation of employment e.g. personnel in charge of developing, installing, repair and maintenance, sales and other indirect jobs • Increased business opportunities and working hours • Improve communication in businesses
SDG15 Life on land - Protecting ecosystems	Goal 7: Environmentally sustainable and climate resilient economies and communities.	• Utilisation of solar PVs is environmentally friendly as less emissions are involved after installation. It does not require the construction of transmission line as the case for the grid, therefore less loss of biodiversity is involved. • It promotes management of forests as it reduces the demand for firewood and charcoal for cooking as well as wooden poles for transmitting electricity.

Source: Author’s own creation, 2019

2.5 Significant Practices in Energy Resource Planning and Management

The energy trilemma, which involves energy security, energy equity and environmental sustainability, is always a challenge in the planning and development of energy systems. However, this trilemma can be offset by Integrated Resource Planning and the Energy Law. More so, integrating the Energy Law at every stage of energy system development could yield meaningful investments and proper management of energy resources. According to Heffron 2018, the energy law is directly linked to climate change and environmental law. Therefore, it provides guidelines to energy stakeholders such as policy makers to make informed decisions. For delivery of best energy services to society, the following principles of Energy Law in Table 2.2 are crucial.

Table 2.2: The Principles of Energy Law

	Principles of Energy Law
1.	**The Principle of Natural Resource Sovereignty** *- The right of a state to use their natural resources in their own national interest*
2.	**The Principle of Access to Modern Energy Services** *- Access to energy should be available to all citizens of a nation*
3.	**The Principle of Energy Justice** *- The application of human rights across the energy system*
4.	**The Principle of Prudent, Rational and Sustainable Use of Natural Resources** *- Natural resources should achieve a balance between economic development and environmental concerns*
5.	**The Principle of the Protection of the Environment, Human Health & Combatting Climate Change** *- The use of energy and natural resources should be comply with the triple objective of protecting the environment, public health and climate change mitigation*
6.	**Energy Security and Reliability Principle** *- There should be a secure supply of energy that should also be reliable*
7.	**Principle of Resilience** *- The different energy activities in the energy system should be resilient so they can plan, recover, and adapt to adverse events*

Source: *Heffron, 2018*

It should be noted that access to modern energy is not a privilege, but a right to all people in the world. It is therefore, an obligation of governments, NGOs, civil society and everyone in society to ensure universal energy access in an affordable, relaible and sustainable manner for perpetual existence of healthy humanity and the ecosystem.

3 CASE STUDY: UGANDA OVERVIEW

3.1 Geography

Uganda is situated in East Africa and not connected to the sea. It lies between Latitude 10 29’ South and 40 12’ North of the Equator and Longitude 290 34’ East and 350 0’ East of Greenwich in the heart of the Great Lakes region. The country experiences a tropical climate, but it is semi-arid in the north east. It also has two rainy seasons combined with two dry seasons. It occupies an area of 241,551 km^2, with a total land area of 200,523 km^2 (UBOS, 2017).

3.2 Demographics

The population of Uganda is growing rapidly; currently, there are more than 42 million people in Uganda (Uganda Country Report, 2018). The 2014 census established that there were almost 35 million people in Uganda (UBOS 2014a) yet the number of people is projected increase to about 90 million by 2050. See figure 3.1.

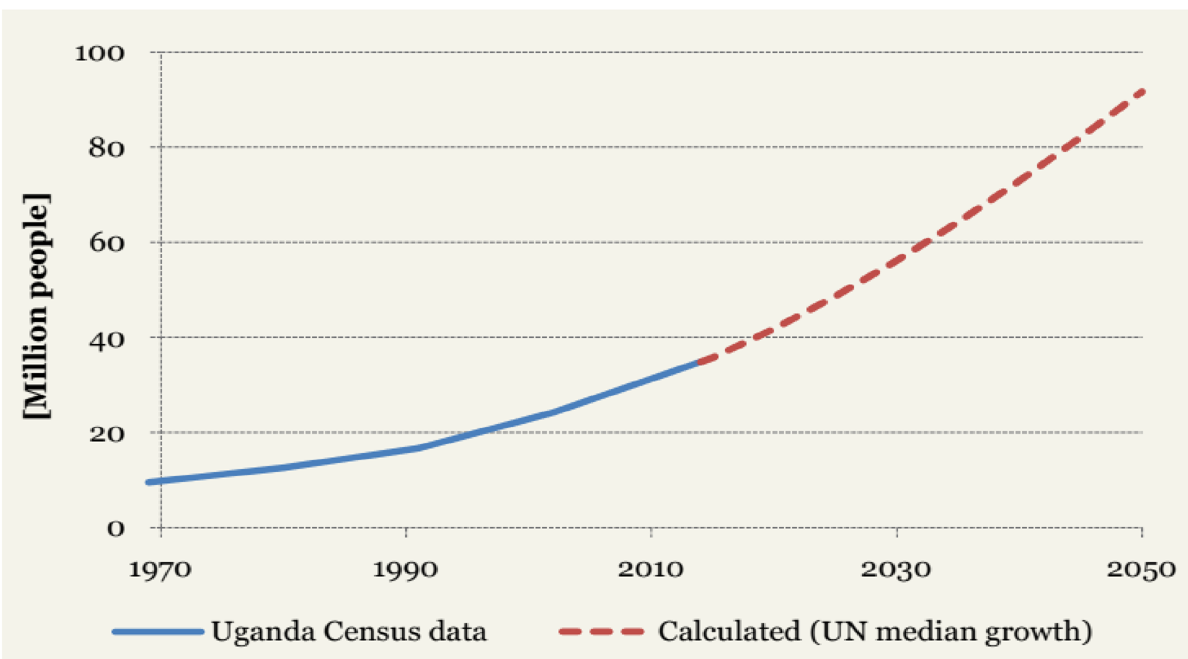

Figure 3.1: Population growth prediction in Uganda

Source: *Gustavsson, et al, 2015*

This rate implies more pressure on natural resources and increased energy demand. Therefore, there is need to increase the available small energy supply system to meet the growing energy needs of Uganda’s population for socio-economic development.

3.3 Uganda's Economy

Agriculture is the back bone of Uganda and therefore, the largest contributor to the country's GDP. However, around 69% of the households in Uganda earn their income from subsistence agriculture and 27% earn income directly from jobs. As a consequence, 11% of the households can afford only one meal per day, for adults, though (UBOS, 2017). Furthermore, around 27% Ugandans are still living under the poverty line (Mokveld & Eije 2018), implying a vulnerable economy. Due to reliance on under-developed agriculture, a bad yield would push many others under the poverty threshold.

Uganda is still among the poorest countries in the world whose GDP per capita stands at US$690 with a public debt, a percentage of GDP, escalating from 33% to more than 40% between 2015 and 2018. In addition, the GDP growth fell from 6% to around 4% by 2012, making the Ugandan shilling depreciate against the US dollar (Uganda Country Report, 2018). This is a serious vulnerability that should be addressed.

3.4 Uganda Energy Profile

Uganda is endowed with abundant energy resources which include hydropower, biomass, solar, geothermal, peat and fossil fuels. The energy resource potential of the country includes an estimated 2,000 MW of hydro power, 450 MW of geothermal, 1,650 MW of biomass cogeneration, 460 million tons of biomass standing stock with a sustainable annual yield of 50 million tons, an average of 5.1 kWh/m^2 of solar energy, and about 250 Mtoe of peat (800 MW). In addition, petroleum in an estimated amount of 6.5 billion barrels, of which 1.4 billion barrels are recoverable, was discovered in the western part of the country and production is expected to be underway by 2020 (Energypedia, 2019).

Despite the endowment of abundant resources in the country, they are unfortunately not fully exploited. Moreover, some vulnerability to climate change are already being experienced, including extreme weather conditions such as heavy rains that lead to floods, prolonged dry spells, landslides and rise in the temperatures among others (Environment Alert, 2010). These aspects are likely to have significant implications for agriculture, food security, soil and water resources; therefore, they call for a course of actions to be taken to build resilience.

3.4.1 Renewable Energy resources

Uganda's total estimation of renewable energy resources stands at 5,300 MW (Oting et al, 2018). See Table 3.1 below.

Table 3.1: Potential of different renewable energy resources in Uganda

	ESTIMATED TOTAL ENERGY AVAILABILITY (TWH/YEAR)	ESTIMATED MAXIMUM TECHNICAL POTENTIAL
Solar PV	9,470	±5,189 GWp capacity at 5 Peak sun hours (Psh)
Concentrated Solar Power	8,582	
Wind	815*	
Hydro power		39,420 GWh/year
Forestry biomass	90	
Non-woody biomass	71	

** All areas with wind capacity factor greater than 20%*

Source*: Hermann et al. 2014, MEMD 2015a*

3.4.1.1 Potential of Solar Energy in Uganda

Uganda's position along the equator makes solar energy a feasible potential in most of the areas.. Its average solar insolation is approximately 5-6 kWh M2 radiation 7 per day on flat surfaces, varying with distance from the equator, though (Oting et al 2018). Given that Uganda's land area of 236,040 km^2 and over 5kWh/m^2/day, there are more than 400,000 TWh of solar energy arriving each year on its surface area (Hermann et al, 2014). Therefore, this energy must be harnessed and used to meet the growing energy demand and foster development.

Solar energy can be converted to electricity on and off-grid through photovoltaic or concentrated solar power (CSP) technology. Over 200,000 km^2 of Uganda's land area has solar radiation exceeding 2,000 kWh/m^2/year (that is 5.48 kWh/m^2/day) and would be considered high potential for solar power investment (ibid).

Table 3.2: Data for harnessing Solar PV in Uganda

	KM^2 FOR CSP	PV*
Total area	241,278	241,278
Exclusion area	30,828	30,828
1,800-2,000 kWh/m^2/year	1,742	-
2,000-2,500 kWh/m^2/year	203,108	210,450
2,500-3,000 kWh/m^2/year	5,600	0

Source: *Hermann et al. 2014*

The country also has sufficient solar radiation as depicted by Figure 3.2 below.

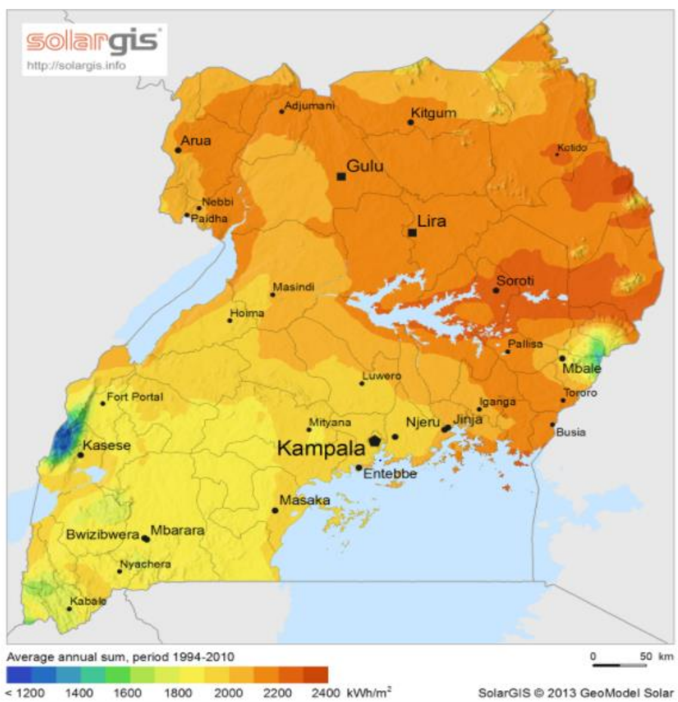

Figure 3.2: Solar radiation for different areas in Uganda

Source: *World Bank, 2019*

For PV potential, Uganda has the best performance in developing countries of Africa with the highest percentage of days with fully charged batteries for solar street lighting (Teves de Almeida, 2014). See figure 3.3 for details.

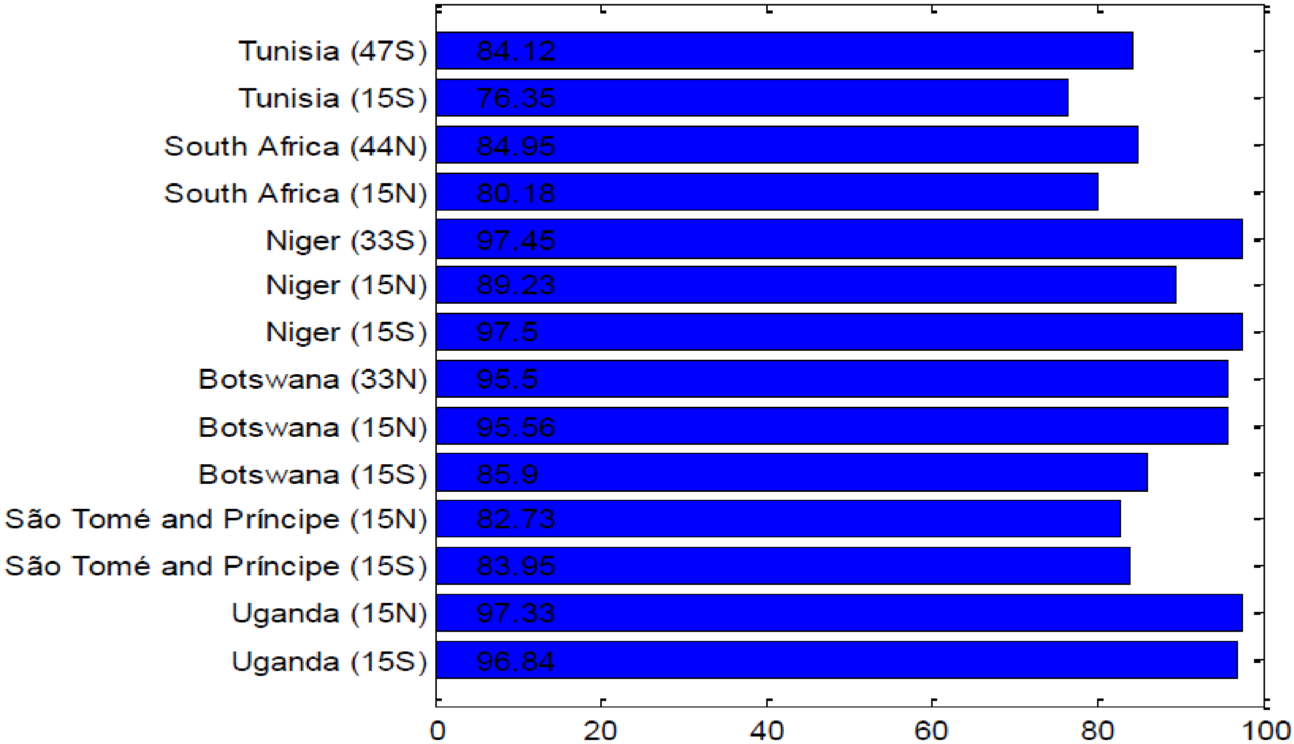

Figure 3.3: Percentage of days with fully charged battery

Source: *Teves de Almeida, 2014*

This solar PV potential is sufficient for a significant contribution to sustainable development if harnessed.

3.4.1.1.1 Solar Energy Status in Uganda

With various private companies dealing in solar equipment of different sizes, the solar electricity demand in Uganda has been growing steadily in the previous decades (Hansen et al. 2014). See figure 3.4 below for increase in solar installation.

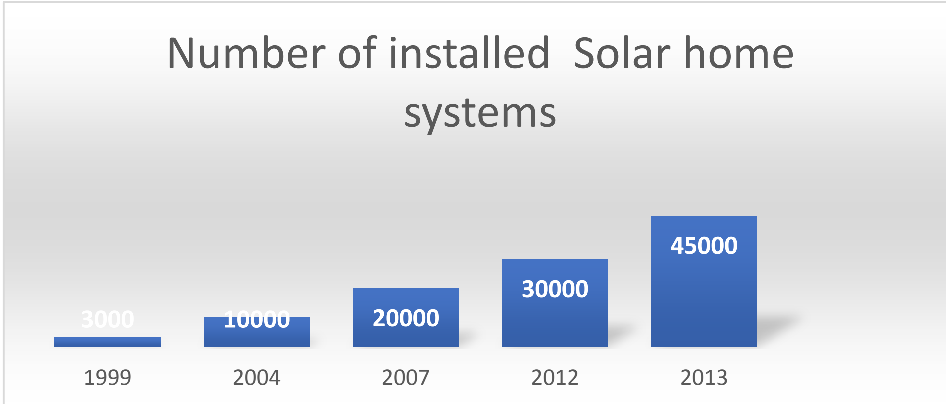

Figure 3.4: Exponential increase in the installed home solar systems in Uganda

Source: *Hansen et al., 2014*

This progress in SHS units led to another 0.9 MW on installed capacity of SHS in 2009-2013, reflecting a high advance after 2009. Over 1.1 MW in off-grid systems was installed as of 2012 advancing the industry at over 20% growth per year (ibid).

3.4.1.1.2 Grid-connected Solar Power in Uganda

Since the introduction of feed-in trariifs, Uganda brought two solar power plants on line, the largest solar power plants in East Africa. The Tororo and Soroti solar plants went online in 2016 and 2017 respectively and another 500MW solar project is in pipeline(IRENA, 2018). The success of the project is partially attributed to the GET FiT programme and the performance of both plants is in line with required standards (Uganda Country Report, 2018). Thus, they have increased energy capacity to the country. See figure3.6 for the energy generated from both plants.

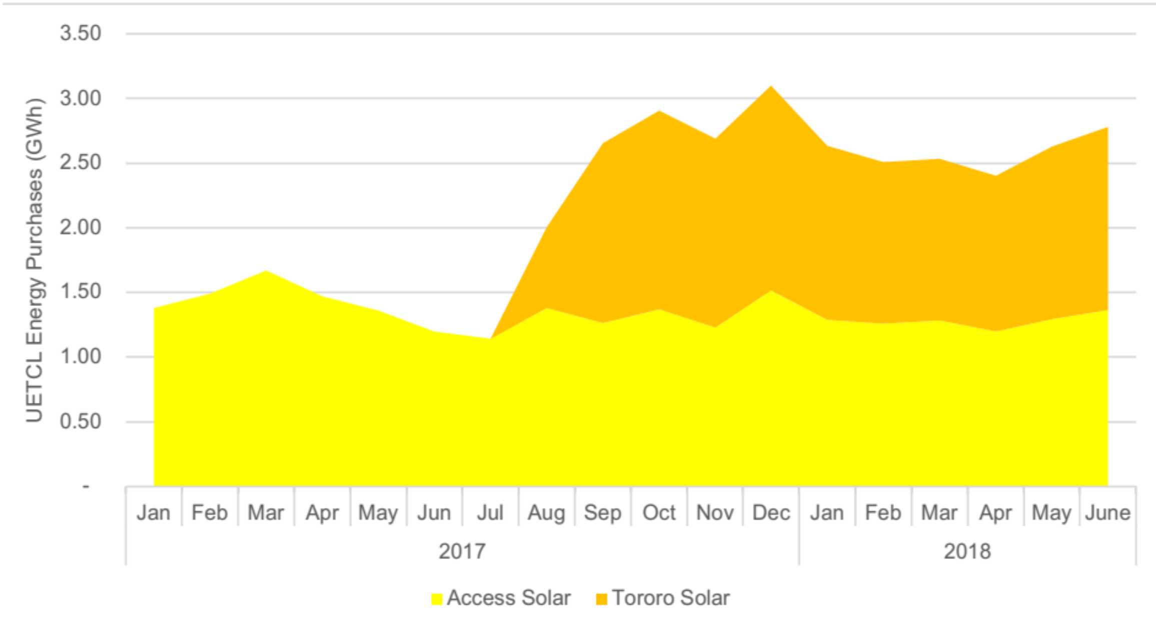

Figure 3.5: Energy delivered by Uganda's Soroti and Tororo solar PV plants, January 2017–June 2018

Source: *Uganda Country Report, 2018*

Fi

gure 3.6: The Soroti and Tororo solar power plants in Uganda

Source: Uganda Country Report, 2018

3.4.1.2 Wood Biomass in Uganda

Fuel wood and charcoal provides almost all thermal energy requirements for rural and urban households respectively with both being harnessed with low efficient technologies such as earth kilns for charcoal and the three stone cooking place for firewood (MEMD, 2013).

Various sources supply biomass, among them the different vegetation and land use types. The major sources are hardwood plantations, which consist of eucalyptus (50%), pine trees (33%) and cypresses (17%). The total standing biomass stock is stated with 284.1 million tons with a potential sustainable biomass supply of 45 million tons. However, accessible sustainable wood biomass supply stands at 26 million tons (ibid).

3.4.1.2.1 Charcoal Production

According to the national charcoal survey of 2015, 2.1 million metric tonnes of charcoal are produced per annum a big percentage mainly supplied to the areas of Kampala, Mbale, Gulu and Mbarara. The main source of wood (47%) for charcoal production in Uganda is from forests owned privately. Central forest reserves and on-farm tree contribute about 22% and 20% of the wood used for charcoal production that is according to the figure 3.7 below.

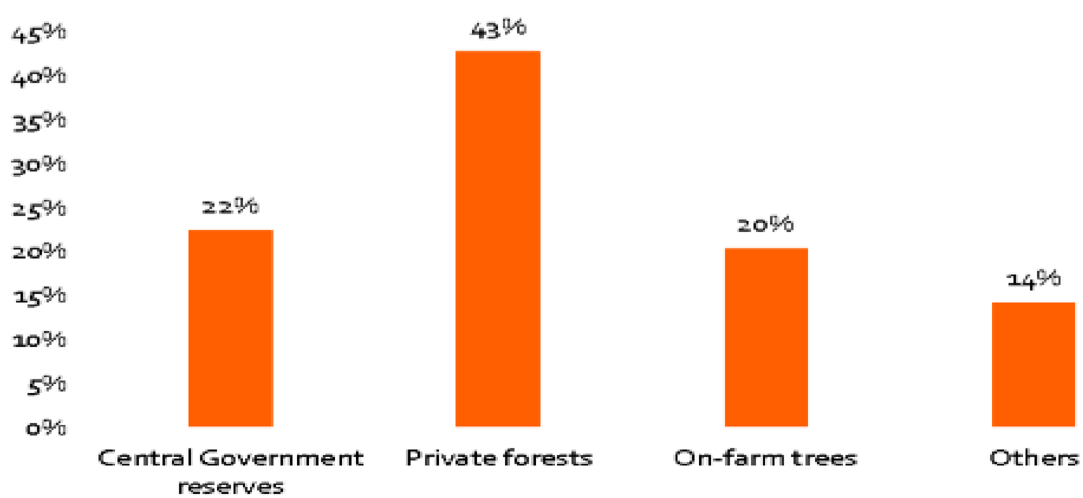

Figure 3.7: Wood biomass in Uganda

Source: *National Charcoal Survey, 2015*

3.4.2 Uganda Energy demand

The total energy demand in end-use sectors in Uganda in 2013 was 136 TWh (MEMD,2014) for four general sectors as seem in Table 3.3 below. Per capita energy demand in 2013 was 4,050 kWh/person/year, with the major portion supplied from woody biomass and only a small portion is in the form of electricity. The government plans to increase per capita consumption of electricity from the current 80 kWh per capita to 588 kWh by 2020 and 3,668 kWh by 2040 (NPA, 2015).

Table 3.3: Uganda Energy consumption by sector

DEMAND:	PORTION OF OVERALL ENERGY SUPPLY	PORTION OF ELECTRICITY SUPPLY
Household	66.2%	25.7%
Commercial	14.3%	14.9%
Industrial	12.8%	59.4%
Transport	6.2%	0.0%

Source*: MEMD Statistical Abstract 2014*

According to the above data, households consume 66% of the total energy supply followed by the commercial sector with the industrial sector leading by far in terms of electricity consumption

3.4.2.1 Household Energy consumption

3.4.2.1.1 Energy for lighting

The prime form of energy for lighting in Uganda is ‘Tadooba’ (wick canister candle). By 2014 the ’tadooba’ was utilised by 52% of the households while 20% of the households used electricity for lighting. In rural areas, the tadooba was used by 60% compared to 25% in urban areas (UBOS, 2017).

3.4.2.1.2 Energy for cooking

The main fuel for cooking in Uganda is biomass accounting for 94% of the households: firewood and charcoal accounting for 64% and 30% respectively. Electricity, kerosene and gas altogether account for 6% only in the cooking system. In urban areas, 66% use charcoal compared to 16% of the rural households (Uganda National Housing Survey 2016/2017). This kind of energy has a significant implication on the health of people due to expected indoor pollution.

Wood-burning, "three stone stoves" found in rural Ugandan households has a low efficiency. Efficiency rates for such stoves vary widely; in lab tests thermal efficiency ranges between 20 to 30%, while in actual practice efficiency of as low as 5% can be experienced (ARC, 2012). The stoves also expose family members to numerous pollutants causing health problems such as acute respiratory infections (Jagger & Shively. 2014).

3.4.3 Electricity situation in Uganda

3.4.3.1 Electricity Supply

Hydro power dominates the electricity generation sector in Uganda. The total installed capacity of electricity power sources in for Uganda was 895.5MW in 2016. There was no increase since 2014 as portrayed in Figure 3.8, which implies a crisis in power supply.

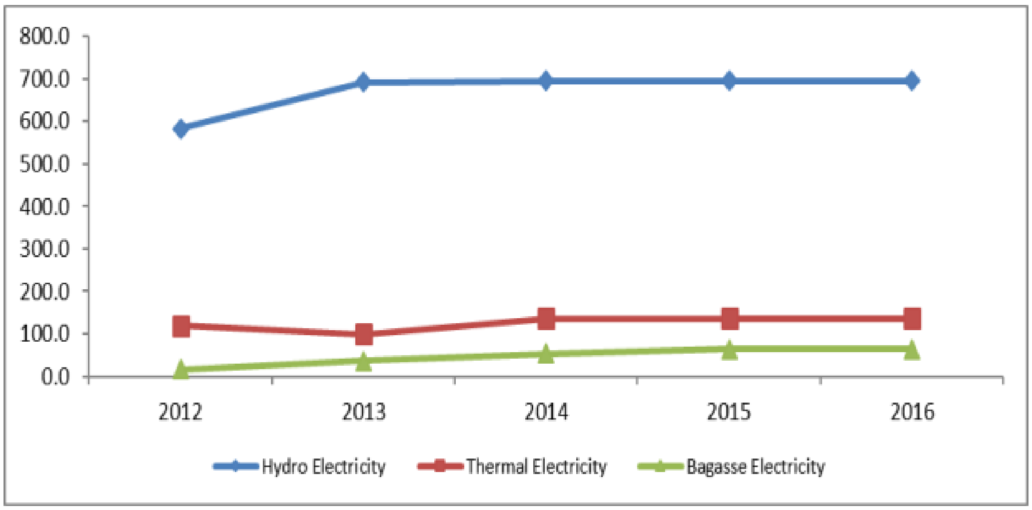

Figure 3.8: Installed Electricity Capacity in MW (2012-2016)

Source: *UBOS statistical abstract, 2017*

Though the installed capacity remained constant for some time, the demand for electricity increased from the additional consumers. According to Uganda Bureau of statistics, there was an exponential increase among various categories of consumers: domestic by 24.6 %, commercial by 17.5% and industrial by 11.2 percent. This increase signifies an additional 24% consumption from 704,637 customers in 2014 to 872,836 customers in 2015 as seen in Figure 3.8 below. The implication here is an increased demand versus constant supply.

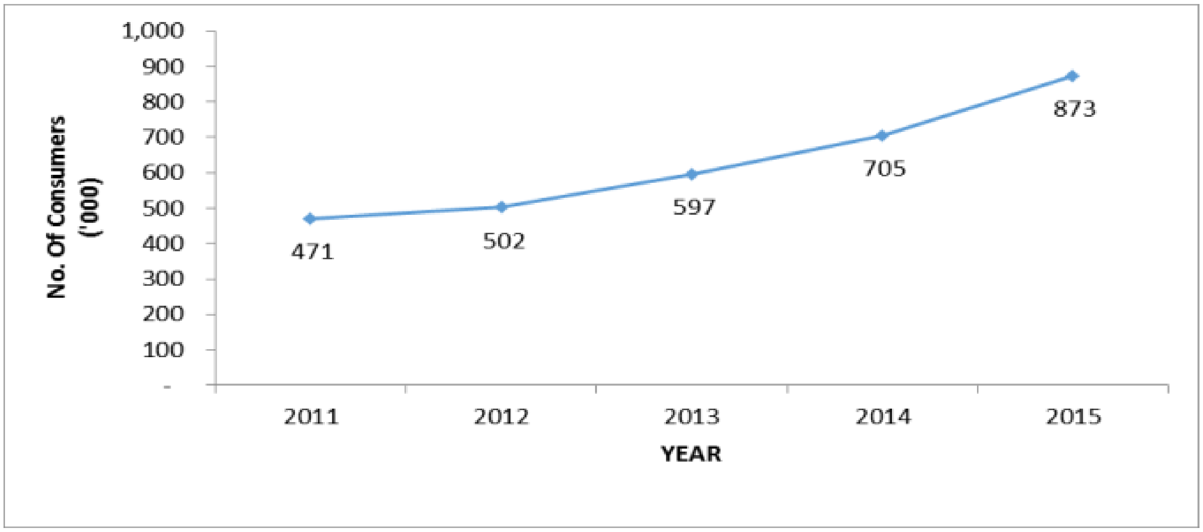

Figure 3.9: Total number of electricity consumers, 2011-2015

Source: UBOS statistical abstract (2017)

Despite the constant capacity for a long time, some projects were being implemented. Therefore, additional generation capacity was added from 2016 to 2017 with the investment of more renewable energy as such as on-grid solar as shown on figure…. below.

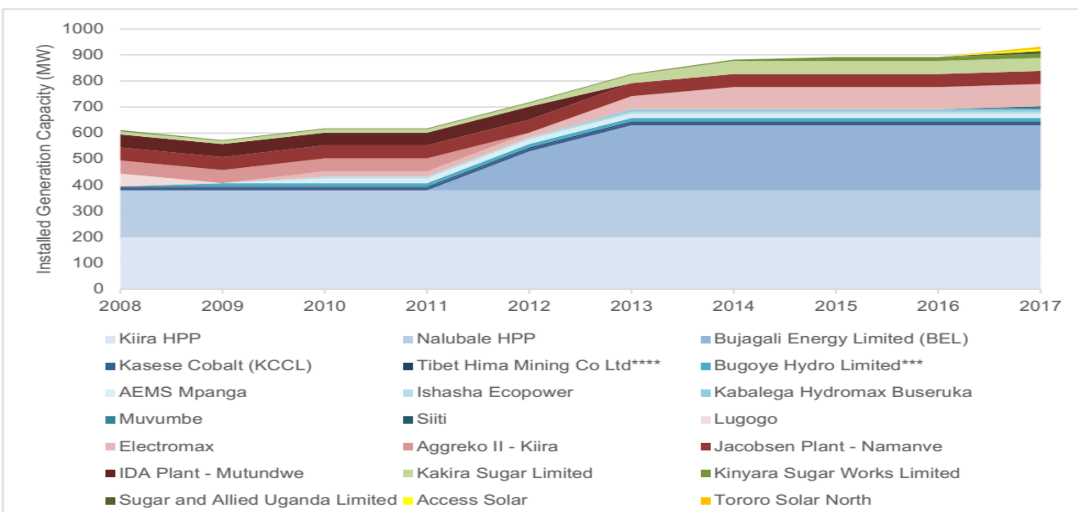

Figure 3.10: Installed Generation Capacity (MW)

Source: *Uganda Bureau of Statistics, 2018*

Note: Blue = hydro power; red = thermal power; green = biomass; yellow = solar power.

3.4.3.2 Per Capita Consumption

The per capita electricity consumption is estimated at 75 kWh and is one of lowest in the world with unequal access rates for rural and urban households (Mawejje 2014). It is also the lowest in the region. See Figure 3.11 and this has significant implication on the economy.

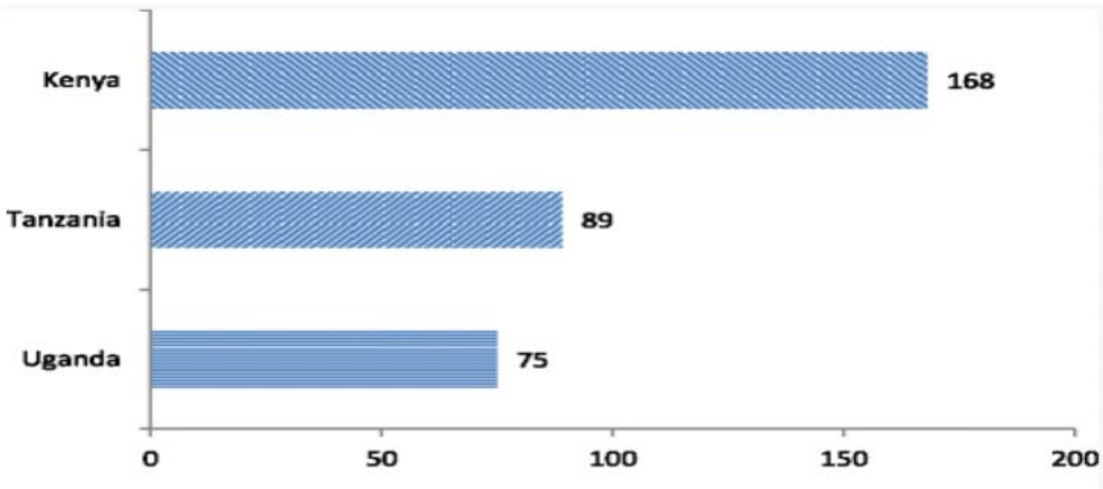

Figure 3.11: Regional comparison of the per capita consumption of electricity

Source: *World Bank Development indicators, 2013*

3.4.4 Electricity Access in Uganda

Uganda is one of the countries with the lowest electricity access estimated at 26.70% (World Bank, 2018). Moreover, national electricity access was 22.0%, with urban access at 50.0% while rural access was at 11.4 in 2017 (World Bank Group, 2017). See Figure 3.12 for slow and low electrification trend. These low rates may have affected the economy in one way or another especially in rural areas due to a big disparity because electricity consumption is directly related to economic development.

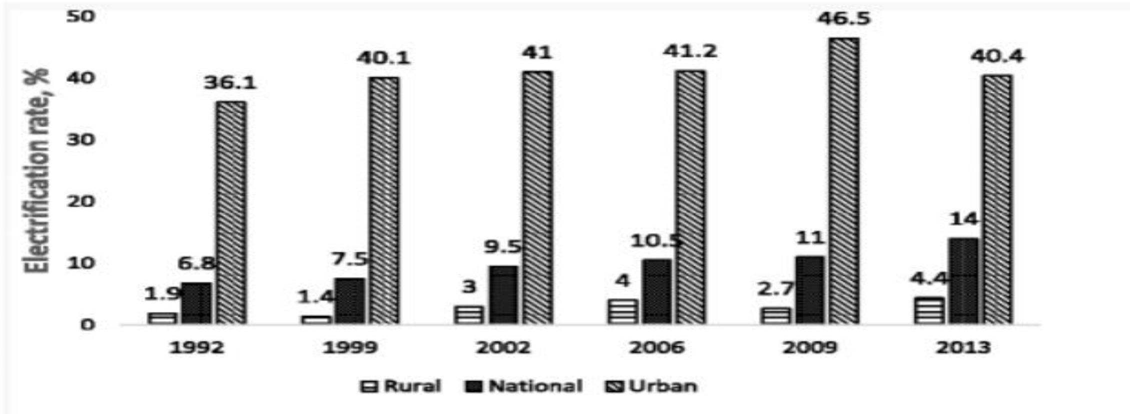

Figure 3.12: Trends in the electrification rate for Uganda

Source: *Uganda Bureau of Statistics, Uganda National Household Survey Datasets*

3.4.5 Electricity Demand

There is a strong industrial demand for electricity accounting for 62 % of the electricity consumption in Uganda. The share of electricity demand by the different categories of consumers, including industrial, commercial, and domestic consumers, and export is shown in Figure 3.13 below.

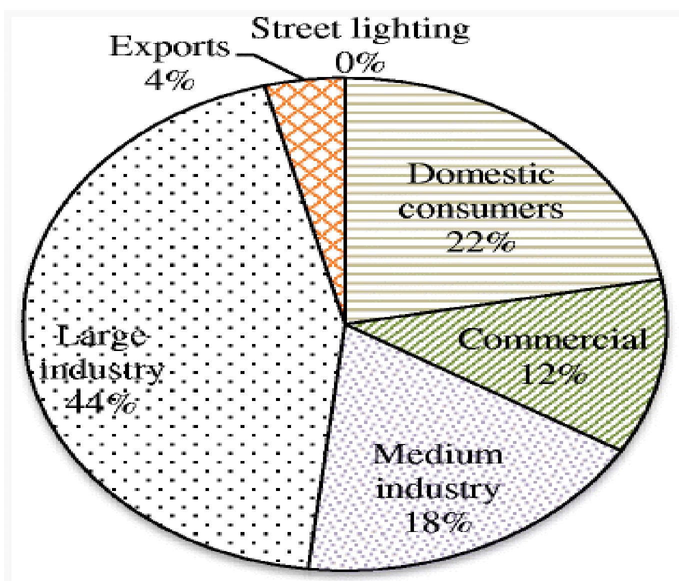

Figure 3.13: Electricity demand in Uganda by sector

Source: *Mawejje, 2016*

3.4.6 The Rural Electrification Strategy and Plan

Uganda launched its second Rural Electrification Strategy and Plan covering the period 2013-2022 "*to promote national economic and social development and integration and in line with the Government's vision of Universal access to electricity by 2040 aiming at eradicating rural poverty in all areas of the country."* The prime objectives of the RESP is to create an enabling environment to scale-up rural electrification to 26% from the then 7% by the year 2022 and to foster development through increasing electricity access of the country, by replacing kerosene lighting and other forms of traditional cooking with all forms of modern energy by 2030. The plan aims to pull overall access to 51% and 100% by 2030 and 2040 respectively. A total of 138,500 from solar PV home systems (SHS) and mini-grids is expected to be installed (MEMD 2013).

3.4.7 Promoting non-electricity modern energy services in the RESP

The programme aims at promoting a comprehensive approach to accessing modern energy services in all forms. The electricity services include grid/mini-grid power, solar systems, solar lights and LED lamps by using the available electricity service providers. LPG cookers, gas lamps, improved charcoal stoves and others are promoted. A package of incentives is offered out to encourage service providers and micro-finance institutions are reinforced to provide credit services for these energy appliances in the same way they are currently doing for the solar PV program (ibid)

3.4.8 Institutional Framework

The institutions in charge of managing the energy sector in Uganda include the following among others:

3.4.8.1 The Ministry of Energy and Mineral Development

The Ministry mandate is to "*Establish, promote the development, strategically manage and safeguard the rational and sustainable exploitation and utilisation of energy and mineral resources for social and economic development"*.

3.4.8.2 Electricity Regulatory Authority (ERA)

ERA is mandated to regulate the generation, transmission, distribution, sale, export and import of electricity. It is also responsible for the issuance and regulation of compliance with licenses, and tariff structure setting as well as approval of rates of charges.

3.4.8.3 Electricity Disputes Tribunal (EDT

It is concerned with the arbitration of cases in the electricity sector. Any stakeholder, who may not be satisfied with ERA's decisions, can appeal to the tribunal.

3.4.8.4 Rural Electrification Board (REB)

It manages Rural Electrification Fund (REF). Its secretariat is the Rural Electrification Agency (REA). The REB provides subsides to support rural electrification projects.

3.4.8.5 Rural Electrification Agency (REA)

REA manages rural electrification projects to increase the rural electricity grid coverage and implement Rural Electrification Strategic Plans (RESP) to increase rural electricity access.

3.4.8.6 The Uganda Electricity Generation Company Ltd (UEGCL)

The company is responsible for concessioning and monitoring the concessioned facilities to ensure quality and reliable electricity generation as well as to offer technical services that may involve: oversight of the operations and maintenance of the generation complex; safety surveillance of civil and dam structures.

3.4.8.7 The Uganda Electricity Transmission Company Ltd (UETCL)

It operates the transmission infrastructure operating above 33kV. It is responsible for the transmission, dispatch, bulk electricity buying from generators and for the export and import of electricity.

3.4.8.8 The Uganda Electricity Distribution Company Ltd (UEDCL)

UEDCL builds and owns distribution network at 33kV and below. However, it leased out its assets to Umeme Ltd. Currently, Umeme Ltd is the distribution concessionaire.

Figure 3.14 below shows the key stakeholders in the electricity sector.

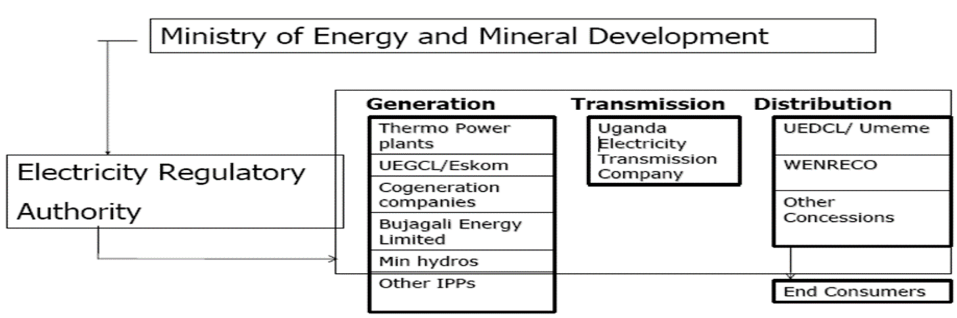

Figure 3.14: Electricity regulation systems in Uganda

Source: *MEMD, 2013*

3.4.9 Key Policies in the Energy Sector

- The 1999 Electricity Act
- Energy Policy for Uganda 2002
- The Renewable Energy Policy, March 2007

3.4.10 Energy Outlook

Having opted for SE4All (Sustainable Energy for All), the Ugandan Action Agenda sets the goal of having more than 98% of the population with access to electricity and more than 99% with modern energy access by 2030, while achieving more than 90% of renewable electricity production (Atkins SE4ALL 2015). See Table 3.4 below.

Table 3.4: Uganda's SE4ALL goals by 2030

Universal access to modern energy services		Doubling global rate of improvement of energy efficiency	Doubling share of renewable energy in global energy mix	
Percentage of population with electricity access	Percentage of population with access to modern cooking solutions	**Reduce national wood consumption by 40% and improve energy efficiency of power users by min 20%**	Renewable energy share in Total Final Energy Consumption	
			Power	**Thermal**
>98%	**>99%**		**>95%**	**36%**

Source: *Atkins SE4ALL, 2015*

Diversification of renewable technologies will increase the energy mix by implementing both mini and micro-grids. Uganda also embarked on energy efficiency for energy savings potential in households, commercial enterprises, industries and buildings to reduce wood fuel by 40% and increase energy efficiency in electricity sector by minimum 20% by 2030 (Atkins SE4ALL 2015).

4 RESEARCH METHODOLOGY

4.1 Introduction

This section describes the procedures that were followed in conducting the study. It incorporates the introduction of the chapter, research design, the area, population of study, sampling techniques, data collection techniques, data processing and analysis.

4.2 Research Design

This study employed a mixed methods approach whereby both quantitative and qualitative were used. This approach enables a researcher to lessen weaknesses of one method, offering combined strengths of both methods, by engaging deductive and inductive analysis in the same research study, hence obtaining a comprehensive understanding of the phenomenon (Cresswell, 2015). Also, a social survey was conducted, whereby a cross-sectional research design was used in which data from respondents was collected at a single point at a time whereby both purposive and cross-sectional data collection approach were adopted. The population of interest constituted people accessing and adopting clean burning, fuel-efficient cook-stoves among rural communities, stove fabricators, and users of solar solar photovoltaic systems for street lighting, home and institutional application in Uganda. The sampling units were households, local authorities and institutions. Then, a systematic random sampling procedure was used to select the sample size of 146 respondents and 8 focus group discussions from Hoima District in Uganda.

4.3 Sampling technique and sample size

The multistage sampling technique was employed in this study. The first stage was the purposive selection of Hoima District as the major study area. In the second stage, respondents were purposively selected to make a number of desired sample sizes. Then, sample sizes of 146 respondents and 8 focus group discussions were selected in 2019.

4.4 Research Site and Rationale

This study was conducted in the Mid-Western region in Hoima District of Uganda. The area was chosen because of the recent discovery of oil, of which exploitation is expected to commence by 2020. The area is now called the Oil City; therefore many economic developments are taking place thus leading to high population. Moreover, according to UBOS (2017), electricity access in this area is very low, estimated at 16.8% and 58.3 of the households were using wick canister candles (tadooba) by 2014. Also, the district performed best among the fourteen (14) municipalities selected for USMID projects which involved installing solar powered street lights. Lessons for project replication could be drawn from this area.

According to the 2014 National Survey and Population Census, a total of 572,988 inhabited the district on a surface of 3612.17Km^2 land area.

4.5 Research Instruments

In order to collect data from respondents in study area, a semi-structured questionnaire was developed and distributed to the respondents. Broadly, the questionnaire covered various aspects such as extent of assets acquisition, money savings, level of income generation, living standards, expenses, trainings, improved cook-stoves use, level of investment, photovoltaic systems solar use in Uganda.

4.6 Data collection techniques

Both primary and secondary data were collected based on the study field survey. Primary data mainly were collected using structured questionnaires with open and closed-ended questions and the checklist for key informants. Other methods included direct observation and focus group discussions, key informative interviews and photography. Secondary data was obtained through a review of relevant documents including published and unpublished information/data were collected from different sources from individual, private and public offices. Several literatures were visited and important information related to the study was collected according to the need of relevant data.

4.7 Pilot test

To ensure that the tools to be used in collecting data provided accurate data, a pre-test was conducted where by a sample size between nine and twelve respondents were picked randomly, and the responses given enabled the researcher to ascertain that tools used were reliable in respect to the objectives of the study and purpose.

4.8 Data processing and analysis

In this study, data collected were analyzed using descriptive statistics, qualitative and quantitative methods. Descriptive statistics such as percentage and frequency were used to analyze respondents' demographic and socio-economic characteristics. Multiple regression analysis was employed to identify the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves, level of investment by stove fabricators and the market for clean burning, fuel-efficient cook-stoves and the socio-economic benefits of solar photovoltaic systems in the development of rural livelihoods in Uganda. In order to draw conclusion, data collected from the primary source and the analysis of quantitative data were done with the aid of both SPSS version 20 and STATA version 13.0 software.

4.9 Limitations of the study

The researcher was affected by resources, time, language barrier and long distances to the rural communities during data collection among other challenges.

The researcher faced a challenge of long distances to penetrate into the remote areas of the district. Some areas that were surveyed are located around Lake Albert and are wedged between escarpments with cliffs and mountains (rough terrain). They are sometimes called the hard-to-reach areas. No public means of transport are available in such areas. To achieve the objectives of the study, it required a great deal of transport facilitation which was not at hand at the time of data collection. Therefore, the researcher bore extra costs which were not planned for.

Communication barrier: Since most of the data was collected in rural communities, language barrier was a big problem as the majority of the people in rural areas do not understand English. In addition, there are many people in Hoima District with distinct languages which the researcher is not well acquainted with. Some of these are refugees from different neighbouring countries such as Democratic Republic of Congo and South Sudan. To overcome this challenge, the researcher hired two students from the nearby University, who knew at least two languages spoken in the area, to work as research assistants and help with the translation during the interviews. Although this technique was a good idea, it slowed down the process and in one way or the other influenced the information provided.

During data collection, it was hard for some respondents to open up and give the required information. Some potential respondents were not cooperative enough to allow the researcher interview them. Others put a pre-condition of money whereas others would keep promising the researcher to come the following day for the necessary information. The researcher always sought for consent from respondents of their willingness to participate in the filling of the questionnaire and interviews and assured them of the anonymity and confidentiality of their responses. Respondents were made aware that the information provided would be used for academic purpose only, and that there would be no disclosure of the information to anyone whatsoever.

Lack of resources was a serious constraint of the research process because it involved many expenses ranging from printing, travelling and analysis among others. This coupled with limited time on both the researcher's and respondents' sides: some interviews would even be interrupted because the respondents would be required to attend to emergent tasks. All these had a direct influence on the span of data collection, thereby forcing the researcher to adjust the work plan.

4.10 Ethical considerations

Ethical considerations were highly observed before, during and after the study. The researcher obtained an authorization letter from the university to carry out the study. Before the interviews and administering of the questionnaires were held, the researcher explained the prime objective of the study to the potential respondents. Informed consent was sought from all the respondents and local authorities to be involved in the process, and only those willing participated. The participants were assured of confidentiality and anonymity of the information provided, only to be used for academic purposes whatsoever. Also, efforts were made to respect their wishes and desires. For instance, most of them refused to take photos, and this was highly respected. The researcher also ensured that the respondents' name was not included on the questionnaires as it would intimidate the respondents about their identity and privacy.

5 RESULTS AND DISCUSSIONS

5.1 Demographic and socio-economic characteristics of respondents

The study used three categories of respondents, where accessibility and adoption of clean burning efficient cook-stoves presented the first place with total sample size of 60 with 58 reviewed respondents. The second category was level of investment by stove fabricators and market for fuel-efficient cook-stoves with total sample size of 20 with 15 respondents surveyed. The third and last category was based on the benefits of solar PVs for street lighting, home, and institutional use in the development of rural livelihoods with a total sample size of 75 with 73 surveyed respondents. The general total sample size of the reviewed respondents was 146. The demographic and socio-economic characteristics of respondents for three categories were analyzed and presented below.

5.1.1 Accessibility and adoption of clean burning efficient cook-stoves

In this study, the first category targeted 60 respondents while 58 respondents were surveyed and the results in Figure (5.1) show that the majority 54% of the respondents were females while 46% were males. The implication here is that more women are involved in home chores, especially energy utilisation, cooking and other family responsibilities such as food provision and family management more than men. In addition, due to the low occupations of other kinds, most of the female household heads are involved in jobs related to house feeding in order to improve household feeding in order to improve nutrition and welfare of the families.

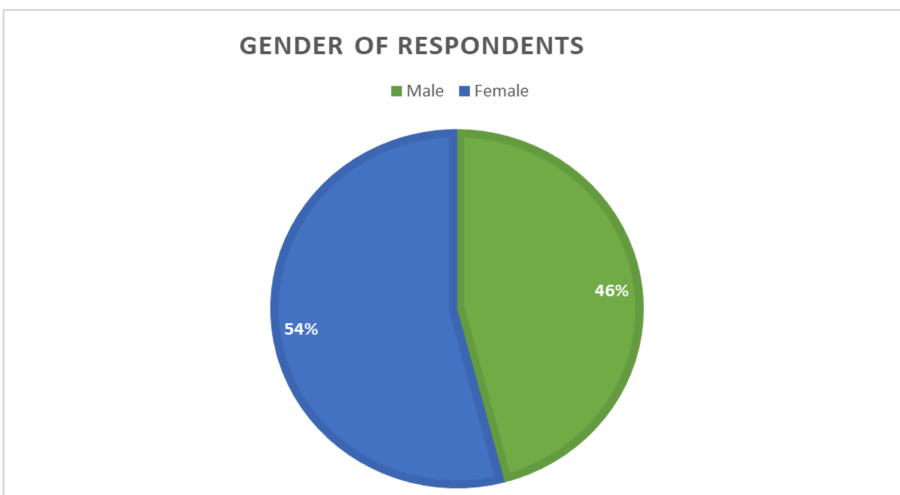

Figure 5.1: Gender of respondents of ICS users

Source: *Primary data, 2019*

The majority of the surveyed respondents' age ranged between 21-30, represented by 36.21%, followed by 31-40 range represented by 25.86%. The range between 41-50 years of age is represented by 17.42% while 51-60 range and over 60 years are represented by 12.07% and 3.45 respectively. This distribution indicates that the majority were capable of doing productive work hence improving the economic status of their households as respondents are economically in the active group. Also, younger people are curious about gaining information on new technologies and innovation and are more amenable to their adoption than older people. Hence, age is one of the factors influencing the adoption of improved cook stoves.

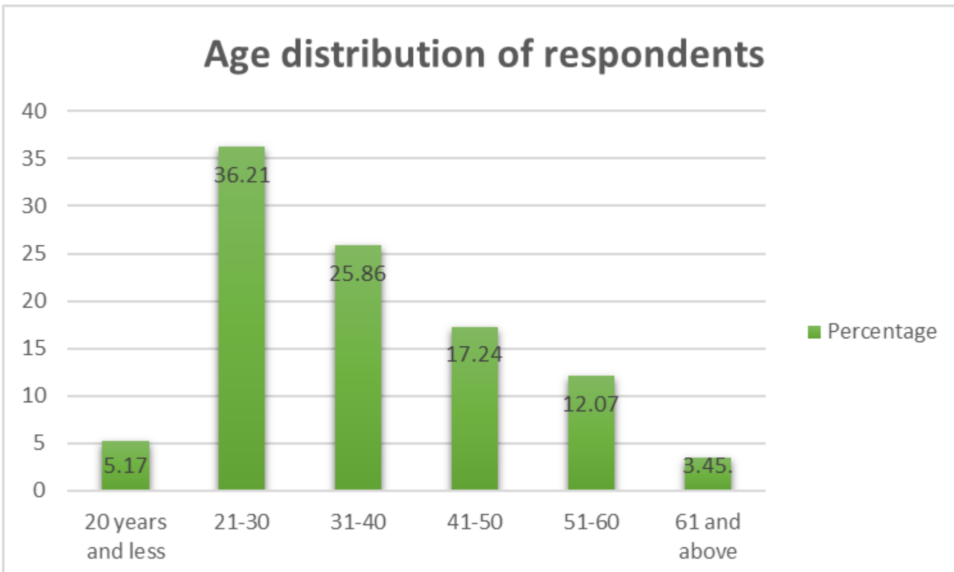

Figure 5.2 Age distribution of respondents of ICS users

Source: *Primary data, 2019*

The results indicated that the majority of the surveyed respondents had household size of three and less represented by 32.76%, followed by the household ranging between 3-5 members with 27.58%. The third class ranged between 6-8 members and is represented by 15.52% while the fourth class was over eight family members with 24.14%. These statistics show that household size rate was high, hence easy to influence in the adoption and provision of labour of clean burning, fuel-efficient cook-stoves among rural communities, as well as the increase of the level of investment by stove fabricators and the market for clean burning, fuel-efficient cook-stoves through any opportunities of training in this domain in the study area. Therefore, if only the majority could adopt, they would improve household income savings and overcome poverty because most of the households in developing countries have large families with many members to feed.

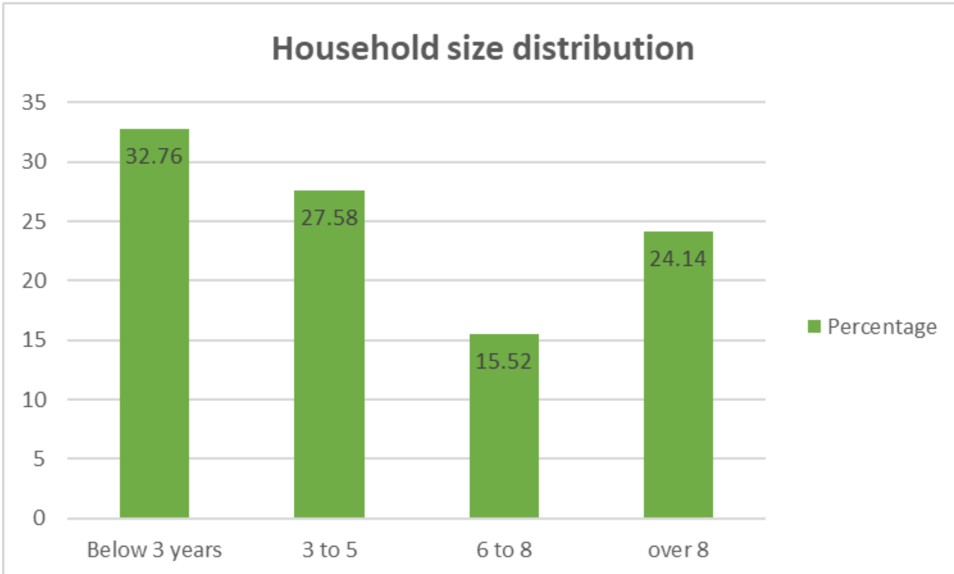

Figure 5.3: Household size distribution of respondents of ICS users

Source: *Primary data, 2019*

The results in table (5.1) also show that household heads attained formal education levels; junior secondary school and tertiary were at the first place with 26.02%, followed by senior secondary school and primary school with 17.8% and 13.71% respectively. The results also reveal that household formal education level attained by a wife, primary school was at the first place with 28.76 %, followed by tertiary with 21.91%; junior secondary school and senior secondary school were represented by 17.8% and 13.69% respectively. These statistics imply the results in table (5.1) also convey that household heads attained the formal education levels; junior secondary school and tertiary were at the first place with 25.86 % followed by senior secondary school and primary school with 17.49% and 13.79% respectively. While the results also reveal that household formal education level attained by a wife, primary school was at the first place with 29.31% followed by tertiary with 22.42%, 17.24% and 13.79% respectively represented junior secondary school and senior secondary school. These statistics imply that the higher the level of education of an individual, the easier it is to adopt new innovation and technologies and vice versa.

Table 5.1: Demographic and socio-economic characteristics of respondents of ICS

Formal Education level attained by HH head	Frequency	Percentage (%)
No formal schooling	5	8.62
Primary school	8	13.79
Junior secondary school	15	25.86
Senior subordinate school	10	17.49
Tech/ Vocation	5	8.62
Tertiary	15	25.62
Formal Education level attained wife		
No formal schooling	7	12.07
Primary school	17	29.31
Junior secondary school	10	17.24
Senior secondary school	8	13.79
Tech/ Vocation	3	5.17
Tertiary	13	22.42

Source: *Primary data, July 2019*

In this section of the study, the results reveal that the majority of the respondents surveyed receives monthly income below Shs. 300,000 represented by 58.62%, followed by Shs. 500,000 and Shs. 500,000-1,000,000 both of them represented by 20.69%. This implies that the study area has low monthly income levels compared to the daily basic needs.

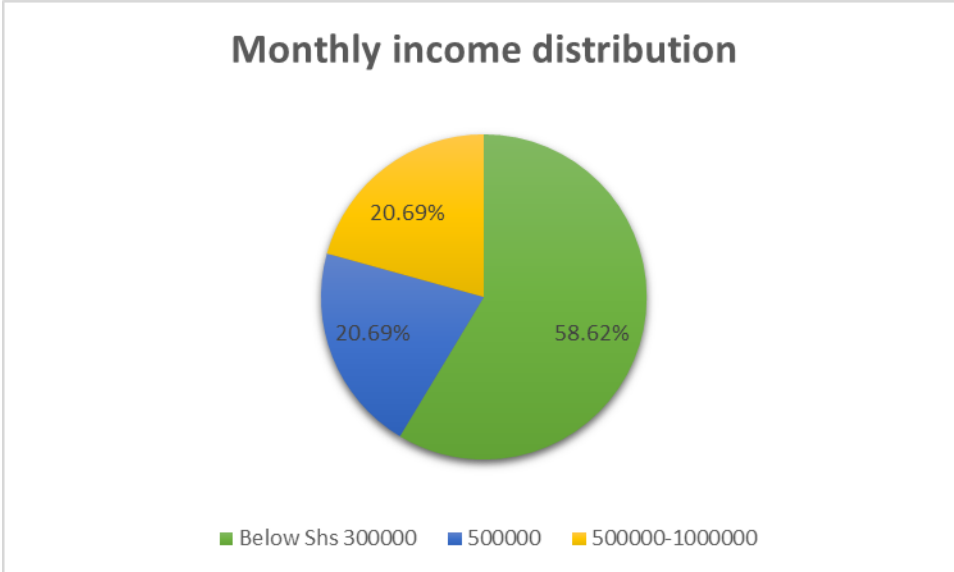

Figure 5.4: Monthly income distribution of respondents of ICS users

Source: *Primary data, 2019*

The income earned by the people in the study area has a significant impact on the adoption of the clean burning, fuel efficient cook-stoves since some types are very expensive, yet firewood seems cheaper or is even be freely available for low income earners. This therefore implies the common trend in developing countries that, low levels of income affect the adoption of improved cook stoves in an area.

5.1.2 Age, Education and Fabrication

The majority of the fabricator heads surveyed had ages between 21-30, represented by 40%, followed by 31-40 range of age, represented by 26.67%. The range of 41-50 age group is represented by 13.33% while the rest of the classes namely; between 51-60 range, 20 or less and 61 or above are represented by 6.67% for each. Therefore, the fabrication sector constitutes majorly of able bodied youth who are commonly hit by unemployment as in the African trend, yet they are at the stage that requires them to develop themselves. Thus, they end up creating their own jobs.

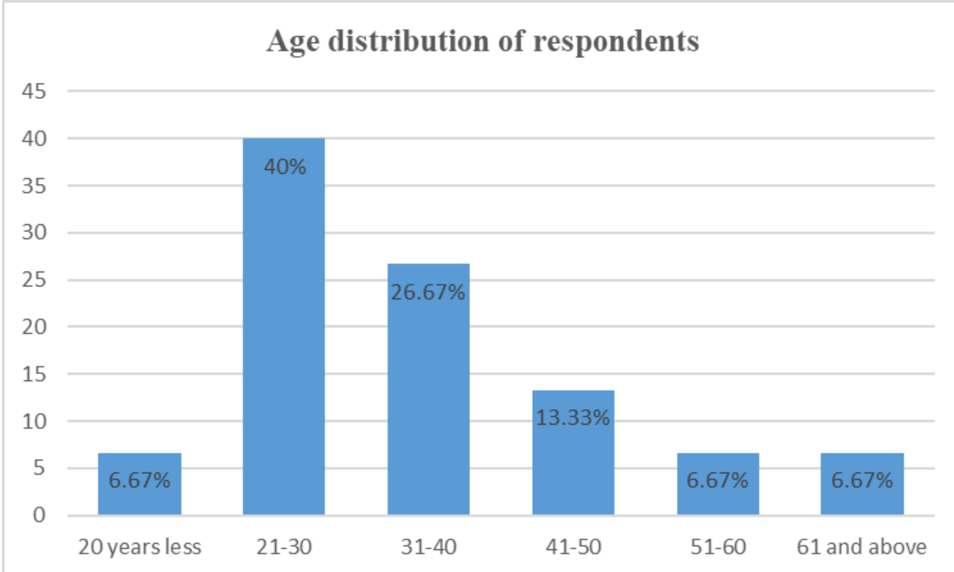

Figure 5.5: Age distribution of respondents of ICS fabricators and sellers

Source: *Primary data, 2019*

The results indicated that the majority of the surveyed respondents in this category have household size from three and less represented by 33,33%, followed by two classes represented by 26,67 % for each that are the range between 3-5 and over 8 members per household. This also shows that the household size rate was high which could facilitate the level of investment by stove fabricators and market for fuel-efficient cook-stoves.

5.1.3 Level of investment by stove fabricators and market for fuel-efficient cook-stoves

In this study, the second category targeted 20 respondents while 15 respondents were surveyed and the results in figure (5.6) below show that the majority 53.33% of the households were males while 46. 67%% were females. This indicates that most of the males were involved in fabrication designs though slightly helped by their wives. On the other hand, most females were involved in selling the finished products made by their husbands in informal and formal markets.

The above finding also shows that most middle aged men and lowly educated in rural areas are more involved in fabrication than the old men.

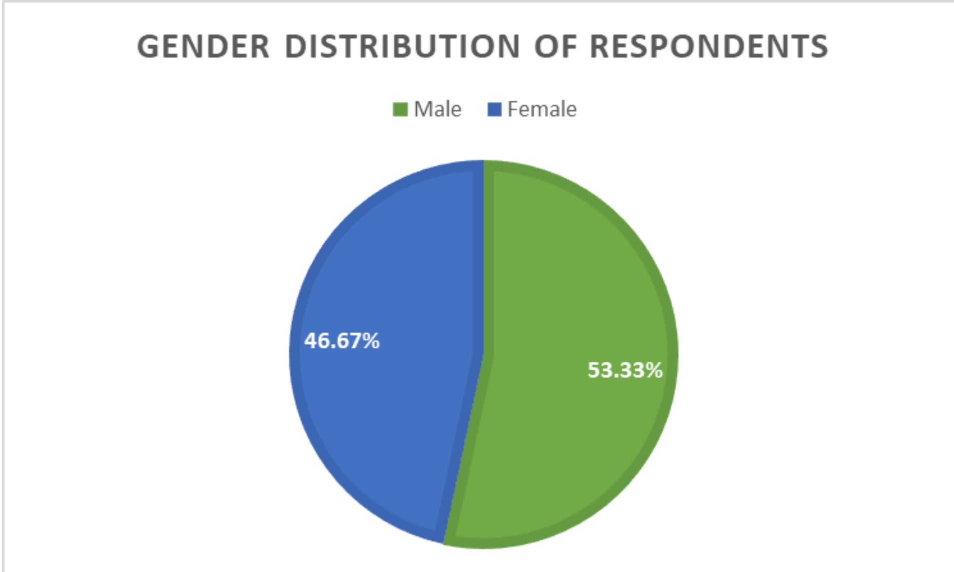

Figure 5.6: Gender distribution of respondents in fabrication and sales of ICS

Source: *Primary data, 2019*

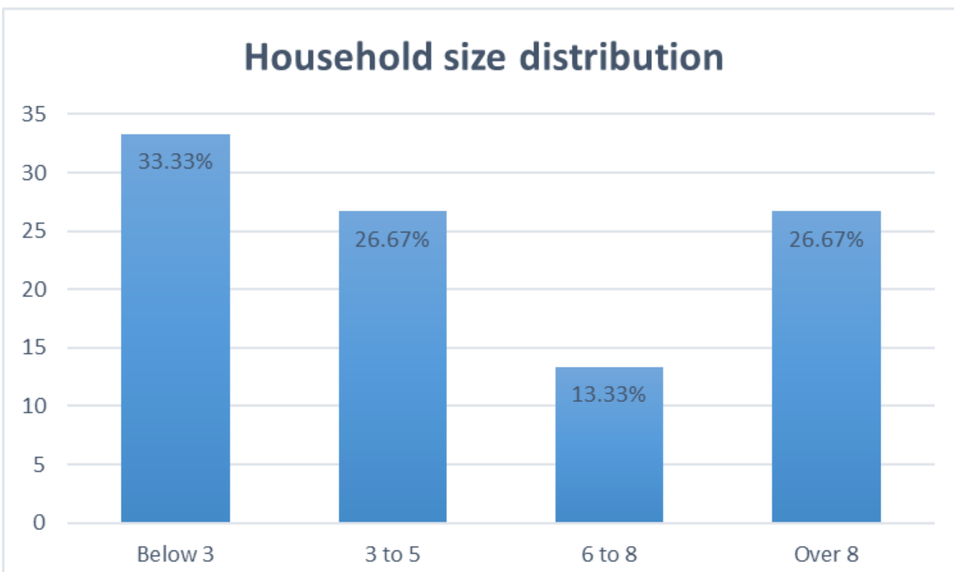

Figure 5.7: Household size distribution of respondents in fabrication and sales of ICS

Source: *Primary data, 2019*

The results in the above figure (and Table 5.2 below) also portray that household heads attained the formal education level of junior secondary school and tertiary were at the first place with 26.67 % followed by senior secondary school and primary school with 20% and 13.33% respectively. While the results also revealed that household formal education level attained by a wife, primary school was at the first place with 26.67% followed by tertiary with 20%. However, 13.33% represent both no formal school and senior secondary school. The last class is representing vocation with 6. 67%. This implies that lower levels of education leads to self-job creation due to unemployment rates, thus investing in improved cook-stoves because of ready market.

Table 5.2: Demographic and socio-economic characteristics of respondents in fabrication and sales of ICS

Formal Education level attained by HH head	Frequency	Percentage (%)
No formal schooling	1	6.67
Primary school	2	13.33
Junior secondary school	4	2.67
Senior secondary school	3	20
Tech/ Vocation	1	6.66
Tertiary	4	26.67
Formal Education level attained wife		
No formal schooling	2	13.33
Primary school	4	26.67
Junior secondary school	3	20
Senior secondary school	2	13.33
Tech/ Vocation	1	6.67
Tertiary	3	20

Source: *Primary data, 2019*

In this section of the study, the results reveal that the majority of the respondents surveyed receive also monthly income below Shs 300000 represented by 53.33% followed by Shs 500000 represented 46.67%. This implies that in the study area, the monthly income is at low level, which should be the limiting factor for investment by stove fabricators and market for fuel-efficient cook-stoves resulting into low investments.

5.1.4 Benefits of solar photovoltaic systems for street lighting, institutional and home applications in development of rural livelihoods

In this study, the second category targeted 75 respondents while 73 respondents were surveyed and the results in figure (5.9) show that the majority 54.79% of the households were males while 45.21%% were females. These statistics therefore, imply males have the capacity to access and acquire PVs, may be partly due to their occupations that facilitate higher incomes and capability to access credit than their female counterparts.

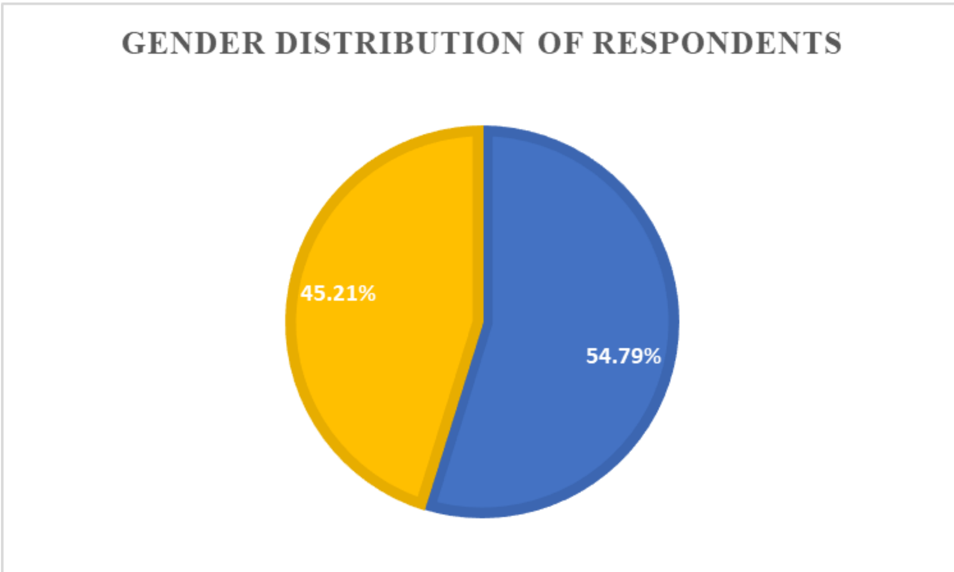

Figure 5.8: Gender distribution of respondents on solar PV users

Source: *Primary data, 2019*

The majority of the respondents surveyed had ages ranging between 21-30 represented by 36.99%, followed by 31-40 range of years represented by 27.39%, the range of 41-50 ages is represented by 16.44% while other three classes: 51-60 range is represented by 10.66%, 20 years and less represented by 5.48%, and 61 years and above is represented by 2.74% of total surveyed respondents

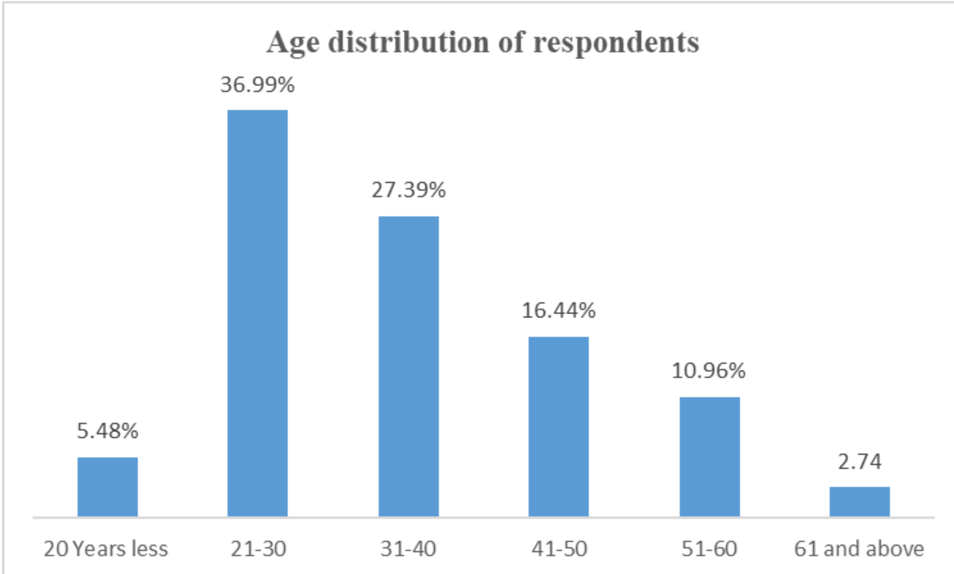

Figure 5.9: Age distribution of respondents on solar PV users

Source: *Primary data, 2019*

The results revealed that the majority of the surveyed respondents in this category have household size from three and less members represented by 32.87%, followed by the class of 3-5, represented by 27.39%. The third class for this study is ranging from 8 and over members per household. The last class that is ranges between 6-8 members per household with 15.09%. This also showed that the household size rate was high hence the more population benefiting from solar photovoltaic systems for the development of rural livelihoods.

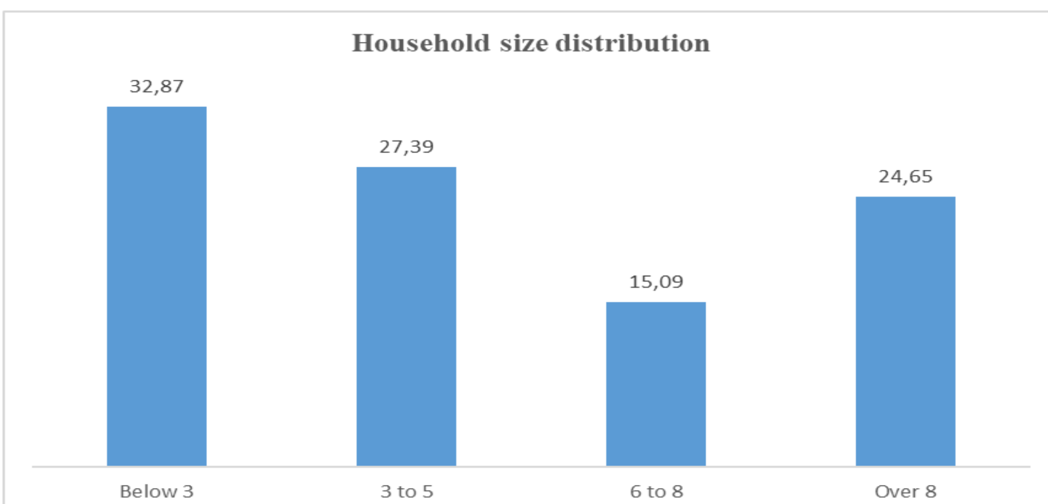

Figure 5.10: Household distribution of respondents on solar PV users

Source: *Primary data, 2019*

The results in table (5.3) show that household heads attained the formal education level junior secondary school and tertiary occupied first place with 26.03 % followed by senior secondary school and primary school with 17.81% and 13.69 % respectively. While the results also indicate that household formal education level attained by a wife, primary school was at the first place with 28.77% followed by tertiary with 2.92% and junior secondary school with17.81%. In addition, senior secondary school is represented by 13.69 % and the last place is occupied by no formal schooling with 12.33%. These statistics imply that the highly educated people utilize and benefit more from solar PVs due to information access and higher incomes and the reverse is true.

Table 5.3: Demographic and socio-economic characteristics of respondents on solar PV users

Formal Education level attained by HH head	**Frequency**	**Percentage (%)**
No formal schooling	6	8.22
Primary school	10	13.69
Junior secondary school	19	26.03
Senior secondary school	13	17.81
Tech/ Vocation	6	8.22
Tertiary	19	26.03
Formal Education level attained by wife		
No formal schooling	9	12.33
Primary school	21	28.77
Junior secondary school	13	17.81
Senior secondary school	10	13.69
Tech/ Vocation	4	5.48
Tertiary	16	21.92

Source: *Primary data, 2019*

In this third category of study, the results revealed that, the majority of the respondents surveyed receives Shs. 500000 monthly income represented by 49.32%, followed by the class of below Shs. 300000 represented 47. 94%. The last and lower class of monthly income ranges from Shs. 500000-

1000000 and is represented by 2.74%. This is still a low income scale which when addressed may improve the diffusion of PVs.

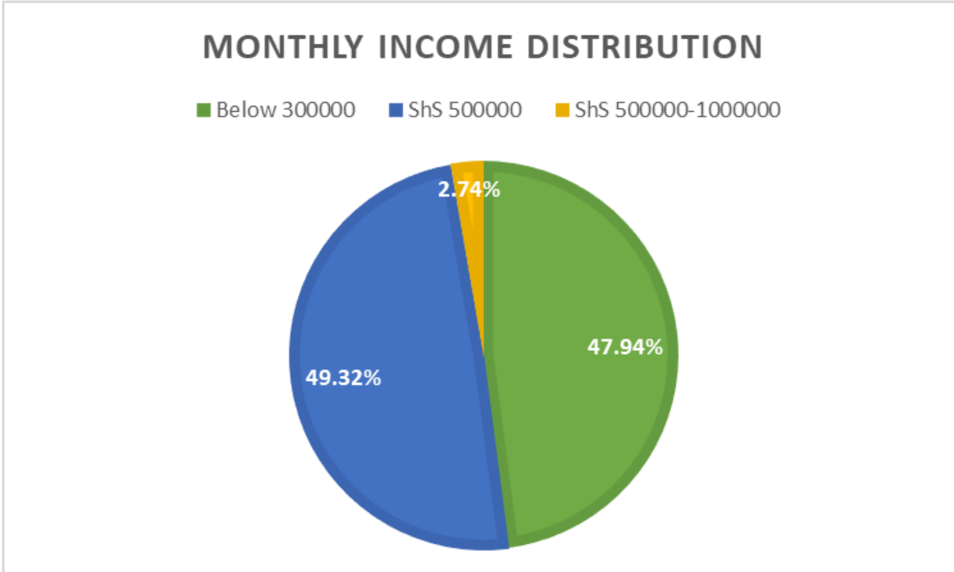

Figure 5.11: Monthly income distribution of respondents on PV users

Source: *Primary data, 2019*

5.2 Regression Analysis

5.2.1 Probit regression of the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities.

In this study, a probit regression model was used to identify the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities. The results are presented in Table (5.4) below. The following explanatory variables namely; education level, household income, household head occupation, access to information, training services and technical support have a positive relationship with accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities and are statistically significant at 1% level. Variables like gender of respondents and household size have positive relationship with accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities and are significant at 5 % level while experience influence is at 10% level. The results of regression model indicate that three variables namely age, distance to source of fuel and distance to the market have a negative relationship with accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities in the study area.

Household income was found to be statistically significant at 1%, implying that families with higher incomes are more likely to access and adopt clean burning, fuel-efficient cook-stoves among rural communities and vice versa. Therefore, a 1% increase in household income would automatically increase the accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural livelihoods by 0.87% because families with higher income would devote their time and resources to buy clean burning, fuel-efficient cook-stoves than low-income earners.

The occupation of household head was found to be significant at 1% level; households depending primarily on occupations other than farming were more likely to access and adopt clean burning, fuel-efficient cook-stoves among rural communities. The regression coefficient shows that a unit increase in occupation of the household head would increase the accessibility and adoption by 0. 22%.

Access to information and education levels were found to be significant at 1 % level, meaning that families that access information and those whose head attained formal education are more likely to access and adopt clean burning, fuel-efficient cook-stoves among rural communities.

The access to technical support and training service were found to be significant at 1% level, which implies that these two significantly increase the accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities. Therefore, a 1% increase in technical support and training service provided to the household would increase the accessibly and adoption of clean burning, fuel-efficient cook-stoves among rural communities by 0.54% and 0.1% respectively.

The distance to the source of fuel has a negative influence on the accessibility and adaption of clean burning, fuel-efficient cook-stoves among rural communities. This means that a 1 % increase in the distance to source of fuel reduces the accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities by 1.12%. This may be because when distance increase, the households prefer using traditional forms like firewood due to its availability.

The distance to market was also found to be negatively significant at 10% level. Therefore, the longer the distance between households and the market, the lower the accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities compared to those close to the market who are motivated to access and adopt easily.

The age of household head was also negatively significant at 10% level. This means that a 1 % increase in the age of old people reduces the accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities by 0.08%. This because the old people take a long time to accept and adopt new technology and innovations compared to young people.

In comparison with Ethiopia, Eshetu (2014) found out that the education status of wives did not have any significance in the adoption of fuel efficient cook stoves. However, he recognized that the adoption of such stoves was significantly stimulated by education level of husbands and the income level of the household head.

Table 5.4: Probit regression of the factors influencing accessibility and adoption of clean burning, fuel efficient cook-stoves among rural communities

Variables	**Coefficients**	**Std. Err**	**Z**	**P-Value**
Age	-0.084	0.018	-4.667	0.065
Gender	0.134	0.153	0.876	0.051
Education level	0.019	0.01	1.9	0.002
Experience	0.014	0.05	0.28	0.079
Household size	0.026	0.029	0.896	0.032
Household Income	0.870	8.35	0.104	0.000
Household Head Occupation	0.218	0.1	2.18	0.000
Distance to fuel source	-1.107	1.367	-0.809	0.017
Access to information	0.032	0.172	0.186	0.004
Distance to Market	-0.057	0.069	-0.826	0.074
Training Service	0.061	0.083	0.734	0.000
Technical support	0.537	0.512	1.048	0.000
Constant	2.019	3.541	0.572	0.001

Number of observation =58 Prob > chi2 = 0.0000

Pseudo R^2 = 0.7342

Source: *Primary data, 2019*

5.2.2 Tobit Regression estimate on the level of investment by stove fabricators and the market for clean burning, fuel-efficient cook-stoves.

The results of study (table 5 below) indicate that income level was significant ($p \leq 0.01$) and positively related to the level of investment by stove fabricators, implying that the higher the income of fabricators, the higher the level of investment in clean burning and improved cook-stoves. Therefore, a 1% increase in income level of stove fabricators would increase the level of investment by 0. 533%. In addition, expenditure level was significant ($p \leq 0.01$) and positively related to the level of investment by stove fabricators. This means that the higher the expenditure level, the higher the level of different basic materials bought to be used in fabricating improved cook-stoves and payment of labour for improved products. A 1% increase in expenditure would increase the level of investment by 0, 881%. The higher the expenditure level, the higher the quantity and quality of different materials bought for fabrication of improved cook-stoves.

Access to credit was found to be significant ($p \leq 0.01$) and positively showed a higher relationship with investment and market for clean burning, fuel efficient cook-stoves in the study area. This is because access to credits facilitated both side fabricators and buyers of improved cook-stoves. This implies that a 1% increase in the access to credit would increase the level of investment by 1.7 %. In other words, a unit increase to credit access would also increase the number of buyers at the same proportion.

Access to and ready market was found to be significant ($p \leq 0.05$) and positively showed a higher relationship with investment and market of clean burning and improved cook-stoves in the study area. Therefore, high demand increased investment levels and the shorter the distance to the market, the higher the number of buyers and sellers accessing the market. This would increase the demand for improved cook-stoves because when the demand increases, the fabricators also increase their investment in stoves fabrication to satisfy the demand of the market.

Household size was found to be significant ($p \leq 0.10$) and positively showed a relationship with investment and market of clean burning, fuel efficient cook-stoves in the study area. The higher the number of family members, the higher the labour supply and the higher the investment in buying raw materials for improved stoves fabrication and reduction of hired labourers from outside.

Table 5.5: Tobit regression estimate on the level of investment by fabricators and the market for clean burning, fuel efficient cook-stoves

Variables	Coef.	Std. Err.	T	P>t
Income level	0.533	0.113	4.716	0.000
Access to credit	1.717	0.87	1.973	0.000
Household size	1.008	1.4	0.72	0.067
Primary occupation	0.392	0.593	0.661	0.000
Access to market	0.297	0.075	3.96	0.052
Expenditure level	0.881	0.191	4.612	0.002
Constant	1.85	2.353	0.786	0.000
Number of observation=15			F(6. 139)	= 67.96
Prob > F = 0.0000			R-squared	= 0.7718

Source: *Primary data, 2019*

5.2.3 Tobit regression results of socio-economic benefits of solar PVs for street lighting, institutional and home use in development of rural livelihoods.

The results from the study presented in table (4.6 below) reveal that solar photovoltaic systems for street lighting, home and institutional applications have socio-economic benefits to facilitate the sustainable development of rural livelihoods and contribute positively in different projects such as access to modern energy service, money savings, enhancing business activities and hours, improving income generation, increasing environmental sustainability, improving communication systems, improving illumination, reducing emission of greenhouse gases, effective energy provision, reducing energy costs, safety and security, increasing employment opportunities, improving study conditions, air quality and health conditions, and increasing business opportunities.

The results indicate that the solar photovoltaic systems for street lighting, home and institution applications have significant socio-economic benefits in development of rural livelihoods and have significantly contributed to the access to modern energy services, money savings, enhanced business activities and hours, increased environment sustainability, increased employment opportunities, improved study conditions, increased business opportunities (all of them) at 1% level. Also, they improved communication systems, illumination, air quality and safety at 5% level, while improved income generation reduced emission of greenhouse gases were at 10% level.

The respondents would easily compare the benefits the solar photovoltaic systems have towards the socio-economic development of rural livelihoods unlike those are not connected to PV systems. Accordingly, a unit increase in solar photovoltaic systems connection would increase the socio-economic benefits for the development of rural livelihoods through access to modern energy service by 0.58% while a 1% increase in the solar photovoltaic systems would increase the socio-economic benefits in development of rural livelihoods through money saving by 0.26%. There is also an indication that a 1% increase in in the solar photovoltaic systems would increase the socio-economic benefits in development of rural livelihoods through increasing business opportunities and employment opportunities by 0.51% and 0.34% respectively.

The overall results from the analysis show that the increase in living standards is relatively more than other types of changes. These changes are significant as they influence the quality of life of the people. There is a potential for increasing people's economic capacity by increasing the diffusion of solar photovoltaic systems in rural communities of Uganda.

Table 5.6: Tobit regression results of socio-economic benefits of solar PVs for powering street lights, institutions and homes for rural sustainable development

Variables	Coef.	Std. Err.	T	P>t
Access to modern energy service	0.582	0.754	0.772	0.000
Money saving	0.264	0.418	0.631	0.000
Effective energy provision	1.1	1.909	0.576	0.867
Enhance business activities and hours	0.427	0.602	0.709	0.000
Improve income generation	0.738	0.897	0.823	0.075
Improve communication system	0.654	0.827	0.791	0.040
Saving energy cost and security	0.691	1.372	0.503	0.613
Reduce emission of greenhouse gases	0.39	0.218	1.789	0.080
Increase environment sustainability	0.6	0.681	0.881	0.000
Improve illumination	0.063	0.409	0.154	0.016
Increase employment opportunities	0.335	0.131	2.557	0.000
Improvement of study conditions	0.67	0.859	0.779	0.006

Improved air quality	0.012	0.295	0.041	0.013
Improvement of health conditions	0.382	0.158	2.418	0.742
More safety	0.014	0.277	0.050	0.057
Increase business opportunities	0.51	0.783	0.651	0.000
Constant	0.582	0.154	3.779	0.000
Number of observation=73		F(16. 129)	=	53.75
Prob > F = 0.0000		R-squared	=	0.7468

Source: *Primary data, 2019*

The results indicate that the solar photovoltaic systems have socio-economic benefits in development of rural livelihoods. Thus, a 1% increase will increase environmental sustainability by 0.6% because the more the utilisation of PVs for electricity, the less the emissions from conventional fuels and the better the conservation of forests arising from the reduction of using fire wood for fuel. The PV systems enhance business activities and extend working hours which means that an extra unit of a PV system would increase the social economic benefits by 0.43 % through the enhancement of business activities and hours for the people in the study area.

5.2.4 Challenges faced by Solar Photovoltaic Systems (PVs) Users

The study recognised various challenges PVs home users are facing. To begin with, there were many modules which were un-fixed (due to lack of proper space), requiring the users to handle them in proper orientations on a daily basis. This method, of course, reduces the lifespan of the equipment through handling them every day and some modules are affected by dust since they are laid on the ground. Other challenges included lack of after sale services, inadequate human capacity and others as seen in Figure 5.12 below.

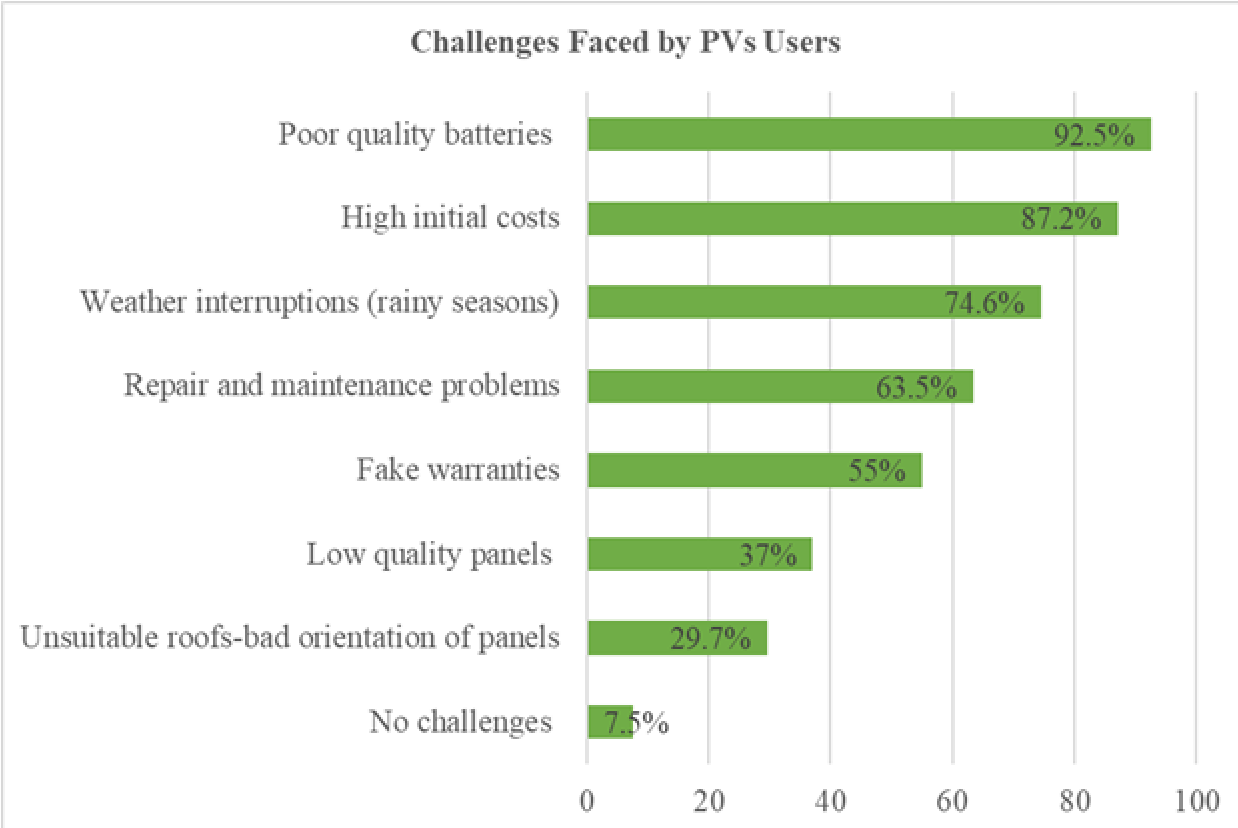

Figure 5.12: Challenges faced by solar PV users in home and institutional applications

Source: *Primary data, 2019*

A large number of respondents (92.5%) indicated that they faced the challenge of poor quality batteries implying technological quality gap, followed by high initial cost with (87.2%). The third place is occupied by weather interruptions (rainy seasons) with 74.6% while the fourth place is for repair and maintenance problems (63, 5%). The fifth position is occupied by fake warranties with (55%). This indicates a gap respondent's knowledge of renewable energy technologies and its use, which could constrain the adoption and use at the same time. Despite the challenges indicated, a few number of the respondents interviewed indicated that they were not facing any challenges and these accounted for (7.5%) of the respondents.

Similarly, (Rahman & Kholilullah 2014) established that solar panel users in rural Bangladesh faced the following challenges: shortage of power during rainy seasons, high initial costs, lower life time of battery, un-availability of credit on solar panels, switch and regulator problems, higher interest rates, low power storage capacity. Also, many users complained of unsealed battery containing toxic metal and metal salts that release gas while charging; therefore, some of them decided to change battery water for toxic problems. That even the people working as installers or technicians lacked good training. Therefore, there is need for more research and development to improve technology performance.

According to Mokveld & Eije (2018), some companies that have been active in Uganda have supplied solar products of poor quality with less services after installation, thus tarnishing the image of solar energy in the country.

5.3 The socio-economic impact of solar photo-voltaic systems and their contribution to sustainable development on rural livelihoods

The diffusion of solar energy technologies has had remarkable positive impacts on the livelihoods of the people living in remote and isolated communities where the national grid seems to be an enduring myth. Moreover, some of the impacts are short term whereas most of them are long term, leading to sustainable development most especially in the area of study, and these have been found to be both economic and social benefits as presented below.

5.3.1 Economic Benefits

In this section, the benefits have been presented and discussed in form of quotations and boxes to highlight the original opinions of the respondents in the various focus group discussions held during the data collection. During field visits, the research assistants also took photographs/pictures besides translations, and some of the pictures have been attached at the end of this report in the appendix. The following are the economic benefits of solar photovoltaic systems usage in the rural areas.

5.3.1.1 Enhancement of Fishing Activity

Like any other resourceful lake around the world, the shores of Lake Albert are filled with various landing sites. The major economic activity here is fishing. Today, everything requires creativity and innovations. The artisanal fishermen around the lake have greatly increased their level of income through the utilization of the solar photovoltaic systems lights. They charge their batteries during the day, and at night, they board their boats to go fishing with the batteries and solar lanterns. From the focus group discussion with the respondents, one of the respondents supposed, *"The solar lanterns are a good deal to us as fishermen. They help us in finding the right direction, empty our boats, and perform other tasks pertaining to fishing at night."*

Another respondent also argued,

"The lanterns you see here are used to attract more fish. We used to go fishing with kerosene tin lamps which were not bright enough. Nowadays, we are on another level due to technology. These solar lanterns attract more fish and results into increased fish catches. Consequently, our food and income have also increased due to the availability of solar PVs."

The fishing activity is majorly conducted at night in Uganda. Previously, the fishermen would do their work at night using kerosene candles and/or inexpensive torches. However, these lights are not bright enough and kerosene lamps are 'dirty' sources of light, apart from not being sustainable: the utilisation of kerosene lamps is hazardous because in involves health issues according to Mills, 2012. It is also inefficient and very expensive in the long run. According to research, for the case of kerosene, one boat is capable of using "between 1 and 2 liters of fuel" while emitting a "substantial amount of the greenhouse carbon dioxide (CO2) to the atmosphere" (Gengnagel et. al., 2013). A research carried out to assess the best substitutes for conventional energy used by Tanzanian fishermen revealed that the fishermen preferred paying six times for a solar LED light to paying for pressured kerosene lamps (ibid.).

In our study, it was established that the solar lanterns have now significantly improved productivity by increasing fish harvests and enabling fishermen to perform the fishing activity smoothly at night. The increased productivity has added another value on the availability of nutritious food (fish) and increased income. However, this technology may lead to overfishing if no precautions are taken into consideration.

The fishing activity is also enriched due to the fact that some fishermen preserve their fish harvests in freezers using solar power so that they are sold at better prices without losing value. It should be noted that most of these areas around lake Albert are in escarpments, where the grid is not viable at all. The terrain makes it very difficult for the national grid to be feasible, and the transport network is not well developed. Thus, solar energy is the best alternative to add value to fishing and other economic activities in the area for improved income generation. This analysis is further evidenced by photo plate.1 as attached in the appendix.

5.3.1.2 Casino Betting

Among emerging businesses that are booming due to the increased diffusion and adoption of Solar Photovoltaic is casino betting, where people insert some money (coins) in a machine and either get more money if they are lucky or lose it to the business owners. It is a way of earning money by both the customer and the owner through gambling. These machines cannot operate without electricity, therefore, without solar power, such games would not be available in remote and isolated communities where the central grid is not viable at all. The study revealed that casino betting is becoming a popular way of earning a living in an instant manner, and the machines are powered by solar energy as seen in Photo Plate 2 as attached in the appendix.

5.3.1.3 Charging Stations by Entrepreneurs

Entrepreneurs are benefitting by earning daily income from charging public mobile phones and radios. There are different established kiosks and centres where people without electricity bring their phones and radios to be charged. This is a very lucrative business because almost every adult in Uganda can now afford a mobile phone. With increased technology, many people either use rechargeable radios or phones to listen to the news or music. Therefore, the charging stations receive enough customers every day since the majority of the rural people cannot afford to have their own solar systems. In addition, the people in charge of running the charging businesses have diversified their services by introducing the sale of other goods and services such as cold drinks, bread, phone and radio accessories among others. Selling various goods at these centres have led to attraction of more customers and increased the owners' income, hence experiencing the ripple effect of installing PV systems. This is evidenced in photo plate 3 in the appendix.

5.3.1.4 Barbers' Shops and Salons

The study found out that, even people in rural communities are able to keep themselves kempt by not having to move to urban centres in search of barbers or hair dressers. There were a few establishments of barbers' shops and salons. Since there is no grid connected electricity, all these are powered by solar photovoltaic systems. The entrepreneurs in these businesses are earning good money while the clients are being well-groomed. Thus, both the clients and the salon owners are benefiting from diffusion of solar power technology.

We are privileged to have solar power in our village because it has improved the quality of lives. Before the coming of solar here, we would spend money on transport to urban centers to have our hair dressed, but now we do it from our own village due to the presence of solar electricity.no more spending extra money. It is really amazing!

One of the women in the focus group said.

5.3.1.5 Increased Business Hours

The study recorded that due to the diffusion of solar photovoltaic systems, there was an increase in working hours for micro business people in the area. Most of these were general merchandise shopkeepers, and restaurant attendants who stated that they would retire for the day as early as six in the evening (6:00 PM) before the installation of the panels. The extension in the number of working hours recorded ranged between 2 to 5 hours, which implies more income for them. In the study done by (Obeng and Evers, 2010), it was recognized that solar electricity made significant contribution towards the flourishing of rural micro businesses through extending working hours at night in Ghana. In addition, (Attigah and Mayer-Tasch, 2013) reported an increase in the income generated by attracting more customers in the evening. The surge in income was attributed to the extended hours of business operations after the installation of PVS in Uganda.

5.3.1.6 Emergence of New Business Activities

Some of the responses from the interviewees showed that after the installation of the solar panels, new business activities evolved. Examples of these activities included charging other people's phones and radios, football shows and sale of cold drinks among others. Of all, the sale of cold drinks due to refrigeration was the commonest, since the company (Solar Now) that sold the solar equipment to most of the respondents, also offered them a fridge as part of the package. This idea was a great one since the area has high temperatures, especially along the rift valley area, the reason why cold drinks have gained popularity, hence generating more income.

The findings show that some enterprises added value after the acquisition of solar power. For example, bars attracted more customers by playing music and selling cold beer. Moreover, most of the restaurant owners increased their income significantly after the installation of the PV systems because they attracted more customers through music and sale of refrigerated/cold drinks. This increase is attributed to the fact that having a good meal accompanied by a soft cold drink and some sweet music in the background is super relaxing, especially after some hectic work. The devices used to enhance this improvement are radios, televisions and fridges that are definitely powered by the PV systems. (Scott, et al., 2017) argue that PVs are capable of empowering enterprises to use low-wattage televisions and run refrigerators to sell cold drinks, both of which attract customers This increase is indeed regarded as a ripple effect of the dissemination of solar energy systems in the rural communities of Uganda.

5.3.1.7 Employment Opportunities

The diffusion of solar photovoltaic systems in the rural communities of Uganda has accelerated the creation of jobs, though at a low rate. A few respondents reported that after the installation of the solar panels, they created new jobs for different people. The number of jobs crated ranged between 1 and 3. However, most of these jobs were informal ones, ranging from running barbers' shops, selling cold drinks, attending casino betting machines to operating mobile money kiosks and mobile phone charging stations. In fact, there are formal jobs involved also; the technicians responsible for the consultation, assembling, installation and repair and maintenance of the systems are also employed in the sector. More to that, there are a variety of independent shops selling the solar equipment both in urban and rural areas, implying that their attendants are also employed in the same sector. In fact, a number of people have been able to generate income by working in this sector. The diffusion of solar energy technologies has great potential to create various employment opportunities such as installation, repairs and mantainence for the local communities thereby increasing expertise. These jobs can be a weapon to combat poverty among these communities by enhancing income generation in the rural areas of Nigeria (Ohunakin, et al. 2014).

5.3.2 Presentation of general perspectives on the overall benefits of solar powered street lights

In this section, this study presents the general opinions of the various focus group discussions by the respondents in various focus group discussions in form of boxes 1 to box 10.

Box 5.1: The Municipal Officers' opinions about the main reasons why some Ugandan towns/cities choose not to connect to the grid and instead opt to use solar power for street lighting.

"Solar powered street lighting systems are relatively cheaper than the grid connected ones in the long run because of reduced electricity bills. They are also cheaper to maintain. In addition, they are environmental friendly, besides being more reliable than the grid."
"They are cheap to maintain. In addition, they are not only reliable, but also convenient to use"
"It is not as costly as the grid one (UMEME). It is always there for the people when they need it unlike the grid electricity which is always on and off."
"It is one of the tools to mitigate climate change and protect the environment yet providing energy services to the population. On the other hand, building and maintaining grid connected electricity is far more expensive."
"Solar powered street lighting system is reliable, and apart from maintenance, no other expenses are incurred after installation."

Source*: Primary data, 2019; Focus group discussions group A*

Although the solar powered street lighting systems have huge upfront costs, they are ideal in energy savings in the long run thus reducing electricity bills and they come along with various benefits as discussed in the above box. Therefore, the public-private sector should consider investing more in such systems.

Box 5.2: Hoima Municipal Officers' evaluation on the importance of solar power solutions as street lights in the coming years.

"They will promote environmental sustainability by reducing the carbon footprint and reduce power tariffs."
"Although they are very important technologies, they may not last longer because some solar power system components are not that much durable in use."
"If more investment is made in the development of solar power technologies, there will be reduced greenhouse gas emissions, so climate change will also reduce."
"It will increase the percentage of energy mix to a greater extent, thereby reducing the depletion of conventional energy resources."
"It will reduce the pressure on hydro power and in turn reduce load shedding leading to economic growth."

Source: *Primary data, 2019; Focus group discussions B*

According to the respondents, the continuous use of solar powered street lights may have a significant impact on the reduction of climate change effects since they involve less greenhouse gas emissions and reduce the depletion of natural resources. However, there may be concerns of the durability of the components since it is a new technology.

Box 5.3: Respondents' views on whether solar powered street light systems are feasible solutions.

"Solar powered street lights are feasible solutions because with proper planning, they can reduce electricity bills to zero in the long term."
"Yes, they are feasible. Although they require high upfront costs, they are cost effective in the long run because they are recharged freely using the natural sun which is inexhaustible. Therefore, they are inexpensive in terms of maintenance."
"The source is always available, so the only requirements are the components of the system that can be installed to harness the energy. Therefore, it is a feasible solution."
"With financial support from private partnerships such as Non-Government Organisations, it is feasible."
"Solar powered street lights in the short run aren't feasible since it is an expensive venture. The cost of acquiring a single solar street light is equivalent to acquiring two (2) Hydro Electric Power lights. With Uganda's economy, such a project requires external funding."

Source: *Primary data, 2019; Focus group B*

Accordingly, for solar powered systems to be feasible, they demand preliminary studies and proper planning which involve financial, technical, environmental and social issues. Provided these are in place, the source of energy is free and inexhaustible, making it a feasible solution.

Box 5.4: Respondents' opinions about the major benefits of being connected to the solar power systems for street lighting.

"The system saves money on electricity bills, and this money is used to meet other needs of the Municipality. They are also more reliable especially during peak hours; we are not worried of power cuts, not at all. Apart from being easy and cheap to maintain, they promote a healthy environment."
"It generates huge savings on energy costs that can be used to finance other services and developmental projects like agriculture."

"These systems require less operation and maintenance costs. They are more reliable than the grid due to limited power shortages. They are convenient to use and install."
"It is cheaper in the long run. It is also reliable since there are no blackouts."

"Solar power is generated from a renewable resource that is available free of charge. The sun does not require any cost to recharge the system"

Source: *Primary data, 2019*; *Focus group discussion group C*

There are various compelling reasons for opting to connect to solar power as highlighted by the responses above ranging from low mantainence costs to enjoying a free source of energy. In relation to these concepts, (Panwar et al., 2011) argue that the sunlight is free of charge yet the generation of electricity is very costly. In addition, there is a probable reduction in Co2 emissions through the employment of the PV systems and the electricity generated in this process neither involve noise nor vibrations which makes it ideal.

Box 5.5: Respondents' interpretations on how urban street lighting by solar power systems affect private households.

"*It reduces their privacy. Such households are affected by lighting pollution. However, it stimulates their safety."*
"The system increases security for both their property and lives. It also enhances their trade since it allows business transactions to be extended to or carried out even at night time. This increases per capita income"
"It promotes security and safety by providing light to the nearby households. They also boost their businesses by allowing business owners to extend their working hours in the night."
"It increases safety and security as there are no dark corners and areas. It also relieves the nearby households of the burden of security light costs by providing free lighting to them and they use the money that would finance security for other developmental projects."
"It leads to reduction in crime rates in the areas where they are installed."

Source: *Primary data, 2019; focus group discussion group C*

Box 5.6: Respondents' thoughts about the extent to which solar power systems as street lights help in environmental management as compared to on-grid electricity.

"*Solar powered systems help in environmental management to a larger extent because they emit less or no co2 emissions after installation. Therefore, they involve less degradation of the environment compared to the grid-connected electricity.*"

"The solar power systems help in environmental management to a great extent because they involve limited or no environmental degradation; less radiation is emitted from solar power."

"They reduce the risks of environmental degradation because less pollution is experienced after installation."

"They lower greenhouse gas emissions."

"They reduce deforestation as the wooden electric poles for electricity transmission are not required. They also increase energy efficiency and security."

Source: *Primary data, 2019; Focus group discussions Group D*

Globally, climate change is becoming a menace, and one of the reasons for the occurrence of this 'giant' is the utilisation of fossil fuels in the name of development. A shift to renewable energy sources is, therefore, one of the pronounced weapons in fighting it. The above ideas from various respondents confirm the three pillars of sustainable development: environmental, social and economic aspects; they imply that connecting to solar powered street lighting systems is one of the indicators of thriving a sustainable economy, putting into consideration of the safety and well-being of the public together with development (people, planet and profits). The reduction in deforestation by adopting solar energy to reduce the construction of transmission lines with poles from wood will enable the carbon sinks (forests) to continue playing a great role in absorption of the carbon emissions while there will be less carbon emissions from the solar power systems after their installation unlike in the case of continuous utilization of conventional energy sources for electricity generation. The strategy is very significant in improving people's health and quality of life as well as promoting sustainable development in a healthy natural environment.

Box 5.7: Respondents opinions about if they intend to improve energy efficiency and reduce electricity bills to zero and the modalities they plan to achieve it.

"*Yes, we intend to improve energy efficiency. Since the sun shine is readily available, we intend to adopt the clean energy source by ensuring the use of solar power on all roads in the Municipality and office buildings for modern efficient lighting systems, phone charging and other energy services so that we can cut operational costs."*

" It is the Municipal's plan to invest more in green energy and energy efficiency to reduce on the grid related challenges such as overloads and load shedding."

"We aim to increase the use of solar energy everywhere so that we can increase energy security and improve efficiency."

"It is not practical to currently reduce bills to zero, but our future intention is to switch to green energy as an alternative to hydro power supply."

Source: *Primary data, 2019; Focus group discussion Group D*

According to the opinions given, switching to renewable energy is a long process that requires patience and capital during the various stages of transition. It can be achieved after a long while.

Box 5.8: Respondents' views on the changes experienced since the installation of solar street lights.

"Businesses have been boosted through the increase in the number of working hours at night due to provision of illumination. They have also increased safety and functionality of streets during night hours."

"Security has improved and theft and rape cases are not common as before the installation of the solar street lights. They have also extended working hours for business people because of free movement at any time since the roads are lit."

"Reduced fatalities and accidents for road users due to the lighting systems at night and increased movement of different people at night."

"Increased safety mostly among women and children, increased business hours and reduced robbery cases on the streets."

Source: *Primary data, 2019; focus group A*

All the above mentioned changes experienced after the installation of solar street lighting systems are important indicators of inclusive sustainable development which is essential in this modern era.

Box 5.9: Respondents' opinions about the major challenges so far faced since the start of the project.

"The major challenge so far is theft of batteries. Batteries, especially those near the bottom of the poles are stolen during the night. This has affected the project negatively. The other challenge is inefficiency from some lights, especially those installed in the first phase of the project, where panels with polycrystalline cells were used. Also some batteries were placed underground to mitigate theft, but they are affected by heat which results in malfunction of some lights."
"Some solar lights are non-functional implying that some batteries on the market are sub-standard; moreover, some produce less light."
"When it rains heavily, the solar batteries do not charge properly leading to insufficient lights."
"There is poor response and attitude from people because they are ignorant about the system."
"Theft of the solar equipment such as batteries and lights as well as installation of sub-standard components that get spoilt in a short time."

Source: *Primary data, 2019; Focus group discussion Group D*

Similarly, Ghana is facing some challenges in its installed solar street lighting systems; many of the solar powered street lights connected in towns are non-functional partly due to insufficient viability studies. Moreover, due to theft security, most of the batteries were positioned underground and therefore were damaged by floods (Teves de Almeida, 2014). Therefore, more research and technology development is required to mitigate or solve these problems.

Box 5.10: Respondents' recommendations suggested to overcome the challenges faced in the solar powered street lighting systems.

"*Installation of panels with monocrystalline cells would be more effective and routine mantainence is recommended to improve the performance of the system."*

"Use of better and standardized quality solar lights and batteries which are effective and can give more light."

"Installation of a hybrid system for back up in case one system experiences a fault to ensure effectiveness and reliability of power supply."

"Educating the public about the importance of solar powered street lighting systems.

"Award the contract of solar street lighting system installation to companies that are more competent with authentic equipment. Sensitising the society about the importance of the systems and engaging the communities to safe guard the street lighting systems."

Source: *Primary data, 2019; Focus Group Discussions Group A, B, C & D combined*

All the above strategies may be significant in the improvement of solar powered street lighting systems, especially during project replication in other areas for effective sustainable development in the country.

5.3.3 Social Benefits

5.3.3.1 Improved Lighting Facilities

The study found out that the solar photovoltaic systems are a source of safe, healthy and excellent illumination. The systems come along with special lanterns that are ideal replacements of candles and or locally manufactured kerosene tin lanterns commonly known as "tadooba" in Uganda, which have been hazardous for a long time as they have been widely used for lighting in rural areas. The majority of the population in rural areas of Uganda use kerosene tin lanterns with wicks which produce poor lights and are responsible for in-door pollution due to smoke that has caused many health issues. According to UBOS 2017, the 'Tadooba' remains the most common source of lighting being used by 52 percent of the households in Uganda. (Esper et.al. 2013) reported that solar technology has the ability to improve in-door air quality as a positive impact on the users. Besides, kerosene can be more expensive compared to solar energy in the long term perspective. This declaration was proven by (Jella, 2017) when he established in his study that light produced by candles is of a very poor quality save for the high prices of paraffin as well as batteries, yet only one solar panel already provides enough power to illuminate three bulbs. According to research, rural communities in the developing world spend a substantial amount of money on kerosene, candles and other traditional energy products ranging between US$3 and US$20 every month on kerosene, candles, or other energy products (Plastow & Goldstone 2001). This is in confirmation to what one of the household respondents declared:

> *"My family used to spend a lot of money, over PVs. 25,000, on kerosene alone every month, but now that is history. We are enjoying a very bright light, yet we no longer pay any money for fuel; this solar energy is a free resource that has made us forget about fuel costs; in fact, we save the money that would be used to buy fuel for other needs*"
>
> SOURCE: *(Focus group discussion Group E); June 2019 at Kibiro landing site*

Therefore, solar energy has saved many users the monthly costs of the toxic fuel, which would moreover pose health hazards to them. The money saved on fuel costs is used to meet other needs of the households, hence improving the quality of life. Economic savings on lighting expenses increase reusable income, thus increasing expenditure on other goods and services (Khandker et al., 2014). It can as well be channeled to other developmental projects. Consequently, Solar photovoltaic systems have profited households, health centres, schools and religious centres by providing comfortable illumination to the occupants, thereby outshining the kerosene lanterns. Gradually, rural communities are turning to green energy for better illumination, thus stepping out towards sustainable development.

5.3.3.2 Information and Communication Facilities

In this era, ICT plays an important role in the day today activities of every society. It is very evident that solar power systems have tried to advance the access of information and communication in areas that once relied on traditional methods of communication. Isolated communities are now networked to the rest of the world because of the development of solar energy, a thing that could not be possible with the reliance on the national grid. The stand-alone photovoltaic systems are used to operate telecommunication masts that help to transmit signals clearly between service providers and cell phone users in an instant. Without the masts being operated by electricity, cell phones can be of no use in an area.

In addition, the people in remote and isolated communities are benefiting from stand-alone photovoltaic systems by charging their cell phones, which they use for communication for different purposes, including business activities. (Jella, 2017) affirms that solar electricity facilitates the charging of cell phones and purposely for enabling communication. It therefore, stimulates and improves the access to information through cell phones. Similarly, radios and televisions, the gadgets that are essential in the facilitation of information worldwide are powered by the solar energy system as an off-grid solution to keep the rural communities abreast of what is happening in the country and the world at large. It is actually through radios and televisions that governments tend to communicate its progammes to the citizens. According to (Greenstar, 2004; Amankwaah, 2005), Solar energy is an ideal alternative to power computers, radios and televisions to boost information and communication as an off-grid solution for rural communities. These devices provide the population with crucial information about businesses, education, health, environment, and other programmes that improve their standards of living. This can further be evidenced by photo plate 4 in the appendix.

5.3.3.3 Entertainment and Leisure

The study established that the rural communities were enjoying a variety of entertainments and hobbies due to the diffusion of stand-alone photovoltaic systems in the area. These range from football shows to films and other live programmes. The shows are a significant achievement in the digital world, which has an implication that the world is becoming a global village; through different digital channels, a match that is played in Europe or elsewhere is watched live by people all over the world (even in rural areas of Uganda), just by the magical power of mere stand-alone photovoltaic systems. This innovation is quite impressive. Some people often gather to watch movies at football show centres, commonly known as "ebibanda" in the local language of the area of study. Furthermore, those who are connected to Solar Home Systems listen to and watch different matches, programmes as well as movies for entertainment, leisure and educational purposes comfortably from their homes. These activities have significantly improved the people's quality of life. Therefore, the diffusion of PV systems can influence the quality of entertainment in rural areas by powering devices such as radios, televisions, computers and smart phones as reported by (Bahauddin & Salah, 2010) in their study. Also, (Obeng & Kumi 2014) recognised that the availability of solar PVs in the rural communities of Ghana not only lowered the prices of listening to radios and watching television, but also increased the ownership of these devices which enhanced entertainment at household levels.

5.3.3.4 Improved Primary Healthcare Services

The study affirmed that stand-alone photovoltaic systems have the ability to improve people's lives in a sustainable way. Most of the time, rural communities are not connected to the national grid, which makes life and health quite demanding. With the diffusion of solar photovoltaic in some rural communities of Uganda, the quality of health has significantly been upgraded. Health stations are now powered by solar panels to operate lamps during the night, refrigeration of medicines and for running some simple machines. A study conducted in India established that solar systems have the capacity to offer refrigeration, lighting as well as water pumping services in health centres (Ramji et al., 2017). The lamps are a good source of illumination that has saved lots of patients, especially mothers at the time of giving birth, thus improving maternal health. (SolarAid & SunnyMoney,

2015) reported that solar lanterns in conjunction with solar phone charging systems have resulted into improved maternal health care in Nigeria; midwives use them to attend to their patients and provide medical aid distantly and at night. Similarly, the same panel systems are used for refrigeration of vaccines, especially for young children, hence reducing child mortality rate. In addition, the refrigeration of the vaccines has also combatted some immunisable communicable diseases among children and adults such as cholera and measles that often break out around the areas near the shores of lake Albert. Also, some medical equipment for carrying out disease diagnosis such as microscopes and other simple equipment such as sterilizers are run by electricity. Therefore, the solar lamps, and the refrigeration of vaccines and other medicines, powered by the solar energy systems have served the rural communities in a better way health wise. This is evidenced by photo plate 5 in the appendix.

5.3.3.5 Healthy Environment

The study revealed a healthier environment as the photovoltaic systems are essentially and gradually replacing conventional energy resources. The implication here is that there is reduced emission of greenhouse gases due to the reduction on the use of kerosene and diesel generators. Most of the people that once used diesel generators as a source of electricity are dropping it for solar energy systems. In fact, none of the people that installed the solar panels still uses kerosene according to the responses given. Therefore, there is improved air quality. The reduction on the use of conventional energy sources signifies reduced depletion of the resources, less pressure on electricity generation from the same sources, reduced deforestation as well as reduced greenhouse gases and therefore a healthier environment.

5.3.3.6 Increased security and safety

Another interesting finding of the study is the improved security and safety. The household respondents reported that they were assured of good security after the installation of solar systems. They stated that a number of robberies had occurred previously before the installation, especially at night due to lack of security lights. One of the respondents in the focus group discussion reported.

> *"The lanterns outside the building provide lights at night, so it is not easy for thieves to come along. However, before the acquisition of solar power, thieves used to steal our property seriously, especially at night because of darkness. Nowadays, we are secure*

because of the benign solar power that provides us with security lights. I am even happy that my system is very strong; it does not go off, but I only switch it off in the morning."

Source: *Focus group discussion (Group F). Field data, June 2019*

Similarly, some solar users in other parts of Uganda were found to be utilizing their solar kits for the provision of security lights in their households after sunset (Orlandi et al., 2016). Another research conducted by solar companies in East Africa unveiled that over 60% of customers surveyed enjoyed an improved sense of security (Acumen, 2017). This sense of security is very essential for sustainable development as it makes people and their property secure and safe.
Furthermore, the survey established that solar power energy was used to enhance the security of refugees. In areas near Lake Albert are refugee camps and refugee reception centres. Uganda is a home for many refugees from neighboring countries such as Democratic Republic of Congo, South Sudan, Rwanda, Somalia and others. For different reasons, these refugees have found safety in Uganda. The refugee camps are located in remote areas, and therefore, powered by solar panels for lighting and security at night. (Little Sun, 2016) recognized that solar lamps were provided by Oxfam to the displaced women in Sudan with intentions of enhancing their safety and security, especially at night. The lamps are usually provided by humanitarian agencies such as United Nations High Commission for Refugees to reduce gender based violence especially in the times of recovery after critical disasters (Lavelle, 2015).

In addition to security, the solar PV systems have improved safety in the users' homes. Before their dissemination, accidents arising from candles and kerosene tin lanterns were rampant. (Orlandi et al., 2016) in their research examined that 30% of the burnt patients at the hospitals in Nigeria are as a result of kerosene lantern bursts, yet in Bangladesh 23% of burns among children were due to kerosene lamps. In the same study conducted, it was established that about 80,000 infants in South Africa were victims of kerosene ingestion.

These accidents are commonly triggered by young children and careless mothers trying to light the houses, and under serious cases, they have resulted into the burning of the entire house and/ or death of people as well. The household survey results also indicated that children between the ages of 1 and 5 years would accidentally be poisoned by drinking kerosene that would be kept in containers within their reach. As such, the community expressed their gratitude to the dissemination of solar technologies that further prevents such disasters. In the study conducted by (Jella, 2017), it was identified that electricity access provided by solar technology in rural areas reduces the rate of fire and other accidents that break out as a result of using paraffin candles. Therefore, solar lanterns are ideal replacements of fuel-based lighting systems due to the safety they offer.

5.3.3.7 Women Empowerment

The findings from the study also show that solar energy technologies have added value to women and girls, hence uplifting their status in society (gender equality). An empirical evidence is in the case where girls' performance in schools has highly improved due to the availability of good illumination for studying extra hours unlike before the diffusion of solar technologies where girls would spend long hours walking in search of firewood for both lighting and cooking. Some of them would drop out because the families would prioritize the collection of firewood over girls' education. The solar PVs in conjunction with the introduction of improved cook stoves have done wonders to uplift the status of women in rural communities. The women, instead of collecting firewood for several hours, now perform other economic activities such as shop keeping, working at restaurants, running salons and others that have resulted in the increase of income for the households.

Similarly, the (Samad et al., 2013) study, strongly recognized that the amount of time spent collecting wood by women is reduced by 9 percent due to solar technology. Therefore, women utilize this time that was once 'wasted' by indulging themselves in income generating activities, hence highly boosting them and therefore increasing their ability to meet their families' needs such as education, health care, food among others. (Jella, 2017) recognizes that by contributing an additional income to the family, it highly impresses the women and they feel more valuable within the household, which makes them consider themselves more equal to their husbands. Consequently, this role raises their self-esteem and increases their power to take part in decision-making. In the same study, the researcher also appreciated the prime benefit of solar power in rural Bangladesh as a catalyst in making women's life easier by providing them with an opportunity to work even after the sun has gone down without day light. Women are able to perform extra duties or accomplish their day's schedules and tasks at home, which is a compelling opportunity, unlike before the solar installation, where they used to rely on the sun light to balance both professional and house chores.

5.3.3.8 Improved Quality of Education

Education is one of the services that has lagged behind in rural communities of Uganda. This is partly due to lack of electricity access in rural schools, which makes the students day-scholars unlike in some urban schools where students are provided with accommodation at school and get extra academic services. As a matter of fact, the students in rural areas can hardly compete with those in urban areas because the latter have more time to study and their teachers have the opportunity to do more tasks at night unlike the former. Therefore, the findings reveal that the availability of solar power in rural Uganda provides an opportunity for rural students to have more time for studying at night and their teachers to perform extra pedagogical tasks during the night, which has greatly improved performance in schools. (Khan & Azad, 2014), in the study they conducted, asserted that solar power resulted into improved conditions for studying for school children by 52% due to the provision of good illumination at night in rural Bangladesh.

Also in Kenya, Siburi Mixed Secondary School at Homabay, in western Kenya is a typical example of improved school performance due to solar energy. Before 2012, the school ranked 48 out of 67 in the sub county. The girls performed poorer than the boys due to domestic chores after school. However, with the introduction of solar lamps to the school and parents by GIVEWATTS enterprise, students had more time to study and by 2015, the girls' performance was better than that of the boys. More importantly, the school now ranks second in the sub-county and the number of students going for higher studies increased from 5% to 40% after the acquisition of solar lamps (Scott et al., 2017). Solar energy also improves education by enabling teachers to carry out more research and virtually network with their fellows pedagogically through various media such as the Internet, mobile phones and computers all of which are powered by PV systems.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study used descriptive statistics to analyse social economic characteristics of respondents and regression model was used to determine the factors influencing accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural livelihoods, level of investment by stove fabricators and the market for clean burning, fuel-efficient cook-stoves, and of socio-economic benefits of solar photovoltaic systems for street lighting, home and institutional uses in the development of rural livelihoods**.**

In this study, a probit regression model was used to identify the influencing factors on accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities. The following explanatory variables namely; education level, household income, household head occupation, access to information, training services, technical support have a positive relationship with accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural communities and are statistically significant at 1% level.

The results of study indicated that income level, expenditure level, access to credit, were significant ($p \leq 0.01$) and positively related to the level of investment by stove fabricators. Ready market was found to be significant ($p \leq 0.05$) and positively showed a higher relationship with investment and market of clean burning and improved cook-stoves in study area while household size was found to be significant ($p \leq 0.10$) and positively showed a relationship with investment and market of clean burning, fuel efficient cook-stoves in the study area.

The results from study also revealed that solar photovoltaic systems have socio-economic benefits that support sustainable development in rural communities and contributed positively in different projects such as access to modern energy service, money savings, enhancing business activities and extending working hours, improving income generation, increasing environment sustainability, improving communication systems, improving illumination, reducing emissions of greenhouse gases, effective energy provision, safety and security, increasing employment opportunities, improvement of study conditions, improved air quality and health conditions, as well as increasing business opportunities. The results indicated that solar PVs have statistically and significantly contributed to access to modern energy services, money savings, enhanced business activities and extended working hours, increased environment sustainability, increased employment opportunities, improvement of study conditions, increase business opportunities (all of them) at 1% level. Improvement of communication systems, illumination, air quality and safety were at 5%, while improved income generation, and reduced emission of greenhouse gases were at 10% level.

According to the findings, solar powered street lights contribute to sustainable development in the following ways: They are cheaper to operate and maintain than the grid electricity. They are more reliable than the grid and convenient to install. They also involve fewer emissions after installation, thus a tool to mitigate climate change. The system promotes environmental sustainability and electricity is generated from a free inexhaustible source (no generation costs). It also Increases energy security through the energy mix. Further still, solar powered street lighting promotes security and safety and reduce crime rates as well as fatalities and accidents on roads. The system also reduces traffic jam, boosts business transactions at night, reduces electricity bills and increases creation of jobs and above all reduces the rate of depletion of natural resources such as forests and water bodies.

The findings also reveal that PVs contributed significantly to economic activities in remote areas by offering the following economic benefits: Enhancement of fishing activity, casino betting, entrepreneurial charging stations, barbers' shops and salons, extending working/business hours emergence of new business activities like football show centres ('Ebibanda') and employment opportunities. Social benefits realised from the use of PVs include improved lighting facilities improved information and communication systems, entertainment and leisure, improved primary health care services, healthy environment, women empowerment and improved quality of education.

Consequently, the respondents would easily compare the benefits of solar PVs whereby the results indicated that the technology contributed significantly to the development of their livelihoods as seen above. In fact, the users were far much better than the time before installation or better off than the people who had not installed them due to the socio-economic benefits they are now enjoying from the diffusion of solar power technologies. Therefore, more investments in these technologies are required to scale up the diffusion for sustainable development and a transformed modern and resilient society.

6.2 Recommendations

The following are the recommendations suggested as far as the study is concerned:

- Considering the possible relationship between adoption of clean burning, fuel-efficient cook-stoves and their benefits, there have been efforts driven by policy for the public to increase the adoption, though at a low rate. However, many types of improved cook stoves have found their way to the market. Therefore, the government should embark on standardization of the modified improved cook stoves available on the market to measure their actual efficiency so as to make necessary improvements and label them according to their efficiency. This process will help the customers to have enough information prior to the buying of these stoves, thus increasing energy efficiency.
- As the results indicated that the problem of distance to fuel source, distance to market, and age have a negative relationship with accessibility and adoption of clean burning, fuel-efficient cook-stoves among rural livelihoods, the public and private sector should improve technical support as well as public awareness to scale up the level of accessibility and adoption of clean burning, fuel-efficient cook-stoves in study area.
- In order to increase the level of investment by stove fabricators and the market for clean burning, fuel-efficient cook-stoves at a maximum level, the government or policy makers should facilitate the access to bank credits, trainings and capacity building to all people who use improved stoves. This strategy will change attitudes of some, if not all people, to the right direction and result into greater proportions of people using improved stoves.
- As Uganda is implementing new technologies and innovation in different domain, with a view to bringing about the environmental sustainability, the government should carry out mass sensitisations not only in urban centres as it is done during energy weeks, but also in rural communities where the public is still naïve about these technologies. Therefore, there should be enough budgets to increase rural population access to improved stoves and PVs to help them increase environmental protection and conservation.
- Since many household heads revealed that solar PVs have socio-economic benefits in development of rural livelihoods and contributed positively in different activities, mainly access to modern energy service, saving energy costs and offering security, government should reconsider installing solar power in the existing public buildings and have integrated resource planning for new buildings so as to realize huge energy savings in the long run.

- Gender mainstreaming in energy planning, development and management to increase participation of both genders.

Other main policy recommendations that are emerging from this study are:

1. Adoption solar-powered street lighting as the norm in rural areas. The significant fiscal and environmental benefits of solar-powered street lighting suggest that it should be prioritized over grid-based street lighting in urban planning henceforth.

2. Regulations and Standards for quality control measures. Ugandan authorities should reinforce national regulations on solar technology and provide guidelines and support for the sector and for local commissioners. To avoid technology dumping and costly inefficiencies, standardised regulations of solar technology (whether being imported or manufactured locally) needs to be introduced because most of the products available on the Ugandan market are counterfeit, and this has negatively affected the customers and tarnished the image of solar technology.

Also, for energy efficiency to be fully realized, the publicity and information dissemination policy should be reinforced and, energy appliances be labeled and above all, the importation of used and inefficient appliances completely banned. Energy auditing should also be encouraged.

3. Government should work with the private sector to facilitate uptake of solar street lights country wide. Local businesses should be supported and encouraged to install solar lights on the streets around their premises. Institutions such as universities should be encouraged to use solar street lighting systems for energy efficiency.

4. Empower local communities to be involved in urban planning and to co-produce lighting for public spaces. Meaningful engagement with local communities can empower the households that live in otherwise marginalized areas of the cities, allowing them to hold governments to account and enable them to feel like citizens who are more likely to contribute directly to city life.

5. Improve the management and accountability of municipal budgets to ensure public services are adequately funded and sustainable better budgeting for operation, maintenance and other unforeseen costs needs to take place to avoid increased future costs due to technology failures.

6. Allocate a budget for Research, Development and Demonstration to build human capacity especially at higher levels of learning. This strategy may be impactful through STEM education and training, which is a driver to scientific research, technological development and innovations

among the citizens. Therefore, this modality may result into local fabrication of some of the solar technology components, thus reducing the burden of importing them.

7 SUGGESTED POLICY BRIEF

A call for Action to Increase Modern Energy Access for Productive Purposes, Lighting and Clean Energy Cooking Systems to Achieve a Sustainable Modern Economy.

Executive Summary

The general access to modern energy in Uganda is still alarming. Over 70% of the population lack electricity access, yet those connected rely on the unreliable, expensive and underdeveloped grid for their needs. Solid biomass predominate the region, and it is responsible for in-door air pollution that claim many lives per year according to the World Health Organisation. Unfortunately, women and children are the common victims because of the nature of their roles in the households. Moreover, the rural communities are underdeveloped due to lack of electricity, and extending the grid to remote areas is not feasible at all. Therefore, the only solution is going off grid, and this can be done through the diffusion of solar photovoltaic systems and clean burning, fuel efficient cook stoves for transformation of livelihoods. This policy brief highlights the problematic areas and the credible ways to ensure optimization of increased access to modern energy in Uganda.

Introduction

Access to modern Energy not a privilege, but it is a right to all individuals. Modern energy access is a catalyst to both economic and human development. However, there is severe energy poverty in Uganda despite the abundant energy resources, and this is an impediment to the country's development. Providing affordable, reliable and sustainable modern energy can transform lives through improving health, standards of living, quality of education, food security and income generating activities, gender equality, and creation of jobs among others. All these can alleviate poverty, thus transforming the country into a modern economy.

No one should be left behind and no human right ignored (Agendas 2030&2063)

A study was carried out on clean burning, fuel efficient cook-stoves and PVs systems for street lighting, home and institutional applications as policy choices for rural sustainable development in Hoima District in Uganda. It was established that these two policies would transform livelihoods and leapfrog the country from subsistence to a modern society through improving the people's quality of life in all aspects. However, the findings reveal that there are some challenges affecting the implementation of these energy policies. Some of the challenges include financial problems, information gaps, too many counterfeit technology components on the market, gender gaps, organizational problems, low capacity, energy inefficiency and many others. Therefore, to scale up the diffusion of RETs, all of these challenges can be addressed in the following ways: Government involvement at every stage from policy planning/making, implementation, monitoring and evaluation regarding energy access in relation to financial support, public private partnership, research and development, technology advancement, global programs and community participation and awareness as seen in Figure 6:1 below.

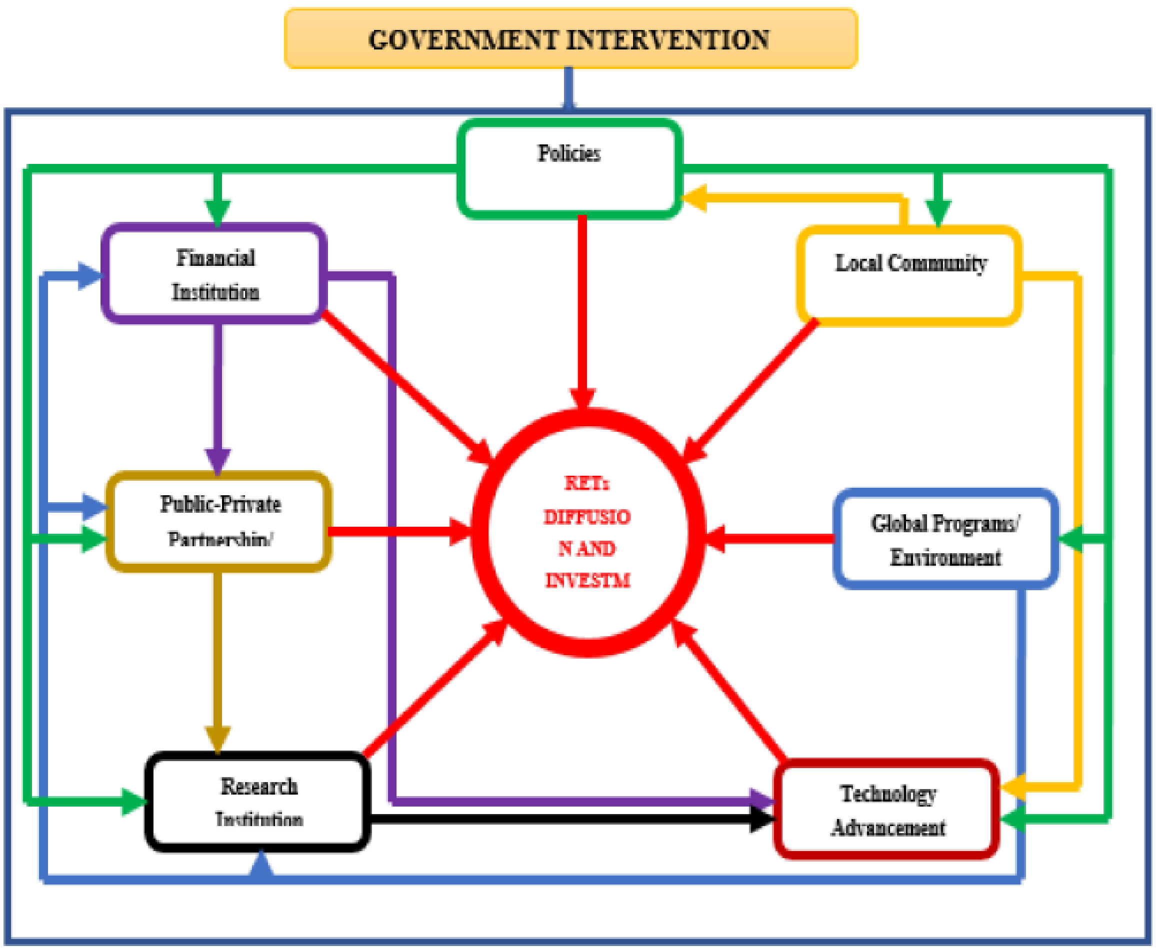

Table 6.1: Conceptual Framework for Scaling up RETs.

(Author's creation 2019)

Policies directly influence RETs diffusion by creating a conducive atmosphere for the investors, financial institutions, public private sector participation, community participation and awaareness and technology importation and or fabrication and existence of all other variables. Financial institutions dictate the kind of technology to be applied and they also have a relationship of networking with the pubic private sector and NGOs to support the deployment of RETs. Research Centres have a direct influence on the technology applied due to the type of skills transferred and the number of people trained. The community has a direct influence on the implementation of policies and regulations, creation of awareness of the available technology and its acceptability, as well as providing market. Global/environmental programs have a direct influence on the public private partnership and financial institutions to implement the programs. It should be noted that without government intervention, every other factor is vanity. Policies need support from the government to be created, implemented and reinforced effectively. The financial institutions depend on the government to flourish because they need laws and regulations to operate. The public private partnership relates to government for favourable environment and good relationships with the partners. The community also needs empowerment of local leaders, civil society and all community members to participate freely in RE projects It is the mandate of the government to develop Research Centres to build capacity and encourage research development. The technology imported depends on government policies and targets. Government has a responsibility to improve people's welfare leading it to commit itself to global and environmental programs.

Conclusion

Due to rapid population growth and the surge of urbanisation, many economic activities to meet the people's needs are on the rise leading to a high rate of anthropogenic effects arising from energy generation, transmission and consumption. Fortunately, technology is also advancing steadfastly. RETs have recently become the heart of socio-economic growth worldwide, thus leading to sustainable development in all sectors of economies. With abundant renewable energy resources, the adoption of clean burning, fuel efficient cook stoves and PVs for street lighting, institutional and home applications as off-grid solutions can influence inclusive and equitable growth by increasing access to affordable, reliable and modern energy for all, so no one is left behind. This energy can be used for both productive and consumption purposes regardless of geographical locations, hence narrowing and or bridging between the urban and rural dwellers, and hence achieving the 2030 and 2063 agendas,

7.1 Areas for further research

This research was about assessing the diffusion of renewable energy technologies and its impact on socio-economic development of rural livelihoods in Uganda. The main agenda was to analyse the ripple effect (trickle down benefits or multiplier effects) of two policy choices in dissemination of clean-burning, fuel-efficient cook-stoves and inclusive solar power technologies: photovoltaic systems for street lighting, institutional and home applications in Hoima district, Uganda. The results have been presented above. However, during the course of the study, it was established that there seems to very few or no recent studies (a big gap) revolving around "the socio-economic impact of non-renewable energy technologies on the rural livelihoods in Uganda". If there could be a study about the effect of non-renewable energy technologies on the lives of rural livelihoods (dwellers) and then we compare the benefits (ripple effect or multiplier effect) of non-renewable technologies and renewable technologies, then we come out with a strong policy choice advocating for any of the best technologies with the highest socio-economic impact on the lives of rural areas in Sub-Sahara Africa.

Also, Hoima District is one of the instrumental areas of significant economic activities such as agriculture, salt mining and fishing. However, these economic activities are not well developed due to scarcity of energy access. A feasibility study on solar power mini-grid construction for solar water pumping for irrigation to improve food security in the area since some areas are dry and for powering salt extraction in Kibiro would result into improved salt mining since the activity is done manually with traditional tools by women. If this research is done, it would attract investors, thus improving the standards of living of the local people and increasing the GDP of the country.

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APPENDIX A: QUESTIONNAIRE

Questionnaire Number………………………………………

Introductory statement: Good morning /afternoon/evening. My name is Evelyn Kabasingwa, and I am conducting a research study for the clean-burning, fuel-efficient cook-stoves (Improved Cook-stoves) as a partial requirement for a Master's Degree Research Thesis.

We would be grateful for your assistance in our research. The information you provide will be treated with confidentiality.

Annex 1: Questionnaire for Fabricators of clean-burning, fuel-efficient cook-stoves or simply Improved Cook-stoves

A: Database Control/Basic Data

No.	**Variable/Question**	**Response options**	**Code**
A1		District	
A2		Name of community	
A3		Name of enterprise	
A4		Address	
A5		Date of establishment	
A6	Ownership	Individual =1;Organisation=2	
A7		If owned by individual, state SEX	
A8		AGE of owner	
A9	Is the enterprise registered?	Yes=1;No=2	
A10		If registered, state registration Authority.	
A11		Are your products graded and certified?	
A12		If "yes" to ALL, by whom?	

A13	Enumerator	Name: Date:	

B: Physical Assets
DO NOT read options
Enter appropriate code(s) in space(s) provided

No	Question	Response	**Code**
B1	Is your enterprise housed in a permanent structure?	Yes=1;No=2	/_/
B2	If “yes”, is the structure secure?	Yes=1;No=2	/_/
B3	If you do not have a permanent structure, where do you operate	Makeshift structure=1 Outdoors=2	/_/
B4	Is your work space adequate?	Yes =1;No=2	/_/
B5	What is your main source of power?	Central electricity grid=1 Solar power=2 Own generator=3	
B6	Do you have an adequate stock of required tools	Yes=1; No=2	/_/
B7	What improvements would you like in your workspace?	Construction of permanent structure=1 Expansion/improvement of existing structure=2 Provision of power source =3 Assistance to procure tools =4	/_/

C: Human capacity
DO NOT Read options
Enter appropriate code(s) in space(s) provided

No	**Questions**	**Response options**	**Code**
C1	How many personnel does your establishment have?	1-5=1 6-10=2 11-15=3 16-20=4 Over20=5	/_/
C2	What percentage of your staff are WOMEN?	0%=1 1-10%=2 11-20%=3 21-30%-4 31-40%=5 41-50%=6 Over 50%=7	/_/
C3	If there are NO or than30 percent women, what are the reasons?	Women are not interested=1 Work is too difficult for women =2 Establishment does not employ women=3	/_/
C4	If women are employed, what specific tasks do they have?	Procurement of raw materials =1 Fabrication of cook-stoves=2 Marketing of products=3 Book keeping=4 No women specific tasks=4	/_/

C5	Do you have enough workers?	Yes =1;No=2	/_/
C6	What percentage of your staff has received required technical training?	Below 10%=1 10-20%=2 21-30%=3 31-40%=4 41-50=5 51-60=6 61-70=7 71-80=8 81-90=9 91-100=10	/_/
C7	Who provides the training?	My establishment/on the jobs training=1 Tech/Voc institute=2 Others (specify)3	/_/
C8	What plans do you have the untrained staff?	On the job training =1 Send them to tech/voc centers=2 Use them as laborers=3	/_/
C9	What skills do you want to train them in?	Welding /fabrication of stove=1 Community sensitization about advantage of using improved cook-stoves =2 Marketing=3 Book keeping=4	/_/
C10	Do you require assistance to train your staff?	Yes=1;No=2	/_/
C11	If "yes", what is the nature of required assistance?	Technical advice on what to train staff =1 Financial assistance=2 Other (specify)=3	/_/

D: Sources of investment capital

Do not read options

Enter appropriate code(s) in space(s) provide.

No	Question	Response options	**Code**
D1	What are your sources of START UP CAPITAL?	Own savings =1 Remittances=2 Resources from development organizations=3	**/_/**
D2	Is available capital adequate?	Yes=1; No=2	
D3	If available capital is NOT ADEQUATE, do you have access to credit facilities?	Yes=1;No=2	**/_/**
D4	If yes to D3, what is are your main CREDIT SOURCE(S)?	Friends/relatives=1 Money spent=2 Savings =3 Microfinance institution=4 Community bank =5 Commercial bank = 6 Other (specify)	**/_/**
D5	What are the main problems you encounter with your credit sources	Lack of loan collateral =1 Loan units to small for my needs = 2 Loan repayment period too short=3	**/_/**

		Interest rate is too high= 4	
D6	Estimated MONTHLY EXPENDITURE (On personnel, rent, raw materials, energy, etc	Below PVs 30000=1 PVs 30000-60000 =2 PVs 60000-90000=3 PVs90000-12,0000 =4 PVs1200000-150000 =5 PVs 150000-180000 =6 PVs 180000-210000 =7 Over 210000 =8	/_/
D7	MONTHLY INCOME	Below PVs 300000 =1 PVs 500000 =2 PVs500000-1000000 =3 PVs 1000000-1500000 =4 PVs1500000-2000,000 =5 PVs 2 000,000-Above=6	/_/

E: Fabrication of products
Phase DO NOT read options
Enter appropriate code (s) in space (s) provide

NO	Question	Response options	code
E1		What raw materials do you use in the fabrication of cook-stoves	/_/
E2		source of raw materials 1 :metal sheet	/_/
E3		Average distance(km) to source of metal sheet	/_/
E4		Source of raw material to 2:	/_/
E5		Average distance (km) to source of clay	/_/
E6		Source of raw materials 3: cement	/_/
E7		Distance (km) to source of cement	/_/
E8		Do sources of raw materials satisfy your requirements?	/_/
E9		Do you experience problems with sources of raw materials?	/_/
E10	If “yes” what are the problems?	Availability Cost Transport	/_/
E11		List your various PRODUCTS.	
E12		State number of each products fabricated per month	/_/
E13		COST per each item	
E14		Suggestions for improving input supply.	/_/

F: Marketing and market
DO NOT Read options
Enter appropriate code (s) in space (s) provided

No	Question	Response options	**Code**

F1	Where do you sell your products	In my immediate community =1 Within my administrative district =2 Country wide =3	/_/
F2	Who sells your products	Myself /my organization =1 Commissioned agents=2 Independent entrepreneur =3	/_/
F3	If 2 or 3 (in F2) state NAMES and ADDRESSES of each.		
F4	If you do your own marketing, what is the main reason /	Lack of interested micro-Entrepreneurs =1 Do not trust micro-entrepreneurs =2	/_/
F5	If you market through agents or entrepreneurs, where are they located	In my community =1 Elsewhere in my district =2 Country wide =3	/_/
F6	How do you determine prices of your products	Demand for product =1 Currency regime exchange =2 Prices set by competitors =3	/_/
F7	Marketing arrangement with entrepreneurs	Payment upfront [=1 Payment after saPVs =2	/_/
F8	What problems do you experience in marketing	Lack of storage facility=1 Product damaged in transit to market =2 Low awareness about benefits of using cook-stoves =3	/_/
F9	Do you get networking support to stimulate use of the products?	Yes =1: No =2	/_/
F10	What do you propose to improve marketing	Provision of storage facility at market centers =1 Mass education about benefits of using cook-stoves =2 Assistance with transportation =3	/_/

G. Future plans about benefits of using improved cook-stoves

Do not read options

Enter appropriate code (s) in space (s) provided

No	Question	Response options	**Code**
G1	Do you have plans to improve and / or expand your products	Yes =1; NO =2	/_/
G2	What assistance do you require	Funding (for establishment/ improvement of physical assets) =1 Capacity enhancement training of staff =2 Provision of storage facilities =3 Awareness campaign about benefits of using improved cook-stoves =4	/_/

H. SWOT analysis

DO NOT READ options

Enter appropriate code(s) in space(s) provided

No	**Issue**	**Response**	**Code**
H1	STRENGTHS	Team of trained /experienced personnel =1 Adequate physical infrastructure=2 Well established market out =3	/_/

		Reliable links to financial institutions =4	
H2	WEAKNESSES	Shortage of trained/experienced personnel=1 Poor physical infrastructure=2 Poor access to financial services/institutions services/institutions=3	/_/
H3	OPPORTUNITIES	Favors the government policy =1 High local demand for cook-stoves =2 Wide spread deforestation=3	/_/
H4	THREATS	Widespread poverty /low income levels =1 Conservatism /reluctance to change =2	/_/

THANK YOU FOR YOUR COOPERATION

ANNEX II: Questionnaire for current and potential customers
Questionnaire number………………………………………………………………………….
Introductory statement: Good morning/ afternoon / evening! My name is Evelyn Kabasingwa, and I am conducting a research study for the clean-burning, fuel-efficient cook-stoves (Improved Cook-stoves) as a partial requirement for a Master's degree Research Thesis

We would be grateful for your assistance in our research. Information you provide will be treated with strict confidentiality.

A: Database control

No	Variables/Question	Response options	Code
A1	District		
A2	Community		
A3	Address		
A4	Name of respondent		
A5	Age of respondent		
A6	Sex of respondent		
A7	Enumerator	Name: Date:	

B: Household data

DO NOT read options

Enter appropriate code(s) in space(s) provided

No	Question /issue	Response options	Code
B1	How many persons are in your household?	Below 3 =1 3-5 =2 6-8 =3 Over 8 =4	/_/
B2	FORMAL EDUCATIONAL level attained by household head.	No formal schooling =1 Primary school=2 Junior secondary school=3 Senior secondary school =4 Tech/ Voc =5 Tertiary =6	/_/
B3	FORMAL EDUCATIONAL LEVEL ATTAINNED BY A WIFE	No formal schooling =1 primary school=2 Junior secondary school=3 Senior secondary school =4 Tech/ Voc =5 Tertiary =6	/_/
B4	Estimated MONTHLY income of house holds	Below PVs 300000 =1 PVs 500000 =2 PVs500000-1000000 =3 PVs 1000000-1500000 =4 PVs1500000-2000,000 =5 PVs 2 000,000-Above=6	/_/

C: Access and adoption of cook-stoves
DO NOT READ options
Enter appropriate code(s) in space(s) provided

No	Question/issue	Response options	Code
C1	What is your main source of fuel for cooking	Fire wood =1 Charcoal (using cook stove) =2 Kerosene stove=3 gas cooker=4 Electricity =4 Solar powered system=5	/_/
C2	If you USE cook-stoves, what is your main reason? what is your reason?	Affordable (compared with gas and electricity) =1 Charcoal easily accessible=2 Easier to use than fire wood =3	/_/
		Safer to use than other fuel sources =4	
C3	If you DONOT USE cook-stoves, what is your reason?	Not made in the community =1 Too expensive	/_/
C4	Are improved cook-stoves available in your community	Yes =1 No =2	/_/
C5	Do you have difficulty accessing them?	Yes =1 No =2	/_/
C6	How do you rate the demand for improved cook-stoves in your community?	Low =1 Medium =2 High=3	/_/
C7	Are you satisfied with the current designs of cook-stoves?	Yes=1 No =2	/_/
C8	If you are not SATISFIED with current design, what improvement would you like?		/_/

Annex III: Issues to probe in informal interviews/focus group discussions
INPUT SUPPLIERS AND MICRO ENTEPRENEURS:

No	Issue	Response
1	Name and address of enterprise	
2	What specific roles(s) do you play in the cook stove value chain?	
3	Perceived strength	
4	Weaknesses / limitations	
5	Opportunities	
6	Main source of investment capital	
7	Problems experienced in accessing investment capital	
8	Capacity to participate in the project	
9	Markets and trade flows	
10	Incentives for improving participation in the project	

ANNEX IV: Questionnaire for Solar Photovoltaic Systems Users
Questionnaire number………………………………………………………………………….
Introductory statement:
Good morning/ afternoon / evening! My name is Evelyn Kabasingwa, and I am conducting a research study for PVs users as a partial requirement for a Master's Degree Research Thesis.
We would be grateful for your assistance in our research. All the information you provide will be treated with confidentiality.

A: Database control

No;	**Variables/Question**	**Response options CODE**	
A1	District		
A2	Community		
A3	Address		
A4	Name of respondent		
A5	Age of respondent		
A6	Sex of respondent		
A7	Enumerator	Name: Date:	

B: Household data
DO NOT read options
Enter appropriate code(s) in space(s) provided

No	**Question /issue**	**Response options**	**Code**
B1	How many persons are in your household?	Below 3 =1 3-5 =2 6-8 =3 Over 8 =4	/_/
B2	FORMAL EDUCATIONAL level attained by house-holds head.	No formal schooling =1 Primary school=2 Junior secondary school=3 Senior secondary school =4 Tech/ Voc =5 Tertiary =6	/_/
B3	FORMAL EDUCATIONAL LEVEL ATTAINNED BY A WIFE	No formal schooling =1 primary school=2 Junior secondary school=3 Senior secondary school =4 Tech/ Voc =5 Tertiary =6	/_/
B4	Estimated MONTHLY income of house holds	Below PVs 3000000 =1 PVs 500000 =2 PVs500000-1000000 =3 PVs 1000000-1500000 =4 PVs1500000-2000,000 =5 PVs 2 000,000-Above=6	/_/
Acquisition of PVs			

1	Type of PVs	____________ Watt Peak (Wp)
2	When did you buy your PVs?	☐ less than 12 months ago ☐ less than 2 years ago ☐ less than 3 years ago ☐ more than 3 years
3	Have you had a PVs before the one that is installed now?	☐ no, it's the first ☐ yes, *if yes* ☐ we still use the old one in addition ☐ the last one was broken and we bought a new one ☐ the last one was broken and replaced by the provider without costs (warranty)
4	How did you know about the PVs?	☐ Neighbour ☐ NGO campaign ☐ PVS technician personally ☐ Relatives ☐ Other: (specify please) _________________
5	When buying the PVs, have you had the opportunity to decide between different providers?	☐ Yes ☐ No
6	Are you also connected to the grid?	☐ Yes ☐ No
7	Would grid be available in your place?	☐ Yes, *if yes*: why have you chosen the PVs? ☐ No
8	Do you share the electricity form the PVS with someone? (Neighbour etc.)	☐ Yes ☐ No
9	What is the total cost of the system, including initial payment and instalment payment?	________________PVs
10	How do you finance the purchase of your PVs?	☐ by monthly instalment rates from the provider of the PVs ☐ at once ☐ by my own (MSE money)

11	*If financed by instalments:* How high is the payment rate per month?	_________ PVs per month	
12	In what period of time does the credit have to be repaid? (repayment scheme)	☐ 24 months ☐ 36 months ☐ Other________	
13	What happens, when you are not able to pay the instalment rates in time? *Inverse questioning! / Do not read the answers!*	☐ I don't know, I have always paid the instalment rates in time ☐ I pay it with a delay. The total time of payments extends. ☐	☐ I have faced problems with payment ☐ I have not faced problems with payment
14	You said that the total price of the PVs was ___ (price paid). Imagine that the PVs would cost 2,000,000PVs, Would you have bought it anyhow?	☐ Yes ☐ No	

Use of PVs

20

1. What were your expectations when you bought the PVs? What did you think would change with the PVS?
2. What were the things that actually changed in the daily life due to the PVs?

Do read out categories! Tick appropriate

	Expectations BEFORE the acquisition of the PVs	Which of these improvements actually take place NOW?
money savings	☐	☐
fuel savings	☐	☐
improvement of illumination	☐	☐
improvement of study conditions for children	☐	☐
modernization	☐	☐

	better air conditions	☐	☐	
	better access to information	☐	☐	
	more time for income generating activities	☐	☐	
	improvement of life quality (watching movies etc)	☐	☐	
	improved status	☐	☐	
	more safety	☐	☐	
	no power cut	☐	☐	
	more customers	☐	☐	
	Other (specify):	☐	☐	

21	What is the most important improvement of the PVs for your livelihood? And second?	______________________ major improvement ____________________ second major improvement
22	What do you use the PVs for?	☐ Illumination ☐ TV ☐ Radio ☐ Mobile Phones ☐ other _________ ☐ other _________ ☐
23	How many hours per day can you use the electricity of the PVs normally?	__________hours

Business		
30	What kind of business are you running?	☐ production: *specify* ☐ agriculture *specify* ☐ animal breeding, *specify* ☐ shop: *specify*: ☐ trade. *specify* ☐ services *specify* ☐ other ________________________________ ____

31	How does the electricity influence the activities of your business?	☐ prolongation of existing activities due to illumination ☐ Using the electricity directly ☐ for processing of crops ☐ to run electrical machines and appliances *Please List* ☐ _________ ☐ _________ ☐ _________ ☐ _________
32	Have you started new business activities since you use the PVs that you could not do before?	☐ Yes ☐ No Which? ______________________________
33	Were you able to raise the profit due to the new or additional activities?	☐ Yes ☐ No
34	If production: were you able to intensify your production due to the PVs?	☐ Yes ☐ No How much? _______________
35	Have you extended the average working hours per day since the installation of the PVs?	☐ Yes, ☐ No *if yes*: average working hours per day NOW (________ average working hours per day BEFORE_________
36	How many employees do you have?	Number of full time employees ____________
37	Have you created new jobs due to the changes that are related to the use of PVs?	☐ Yes ☐ No *If yes:* how many? __________

Information and Communication		
40	*If TV or radio* Do you use the TV / radio to attract more customers to your business?	☐ *Yes* ☐ No, *If yes*: Does this show results? ☐ *Yes* ☐ No,
41	Do you think that the options to communicate have changed due to the installation of the PVs?	☐ no change ☐ improved, because: _____________ ☐ worsened, because: _____________
42	Do you think that you are more concern of the economic dynamics of your business? E.g. do you have now access to information on market prices, which you have not had before?	☐ Yes ☐ No If yes: do you think, that this is relevant for your business? ☐ Yes ☐ No

43	Do you have a mobile, which you charge with the electricity of the PVs?	☐ Yes ☐ No	
44	Have you had some kind of telephone before you installed the PVs?	☐ Yes ☐ No	

For how many hours do you use the PVS for illumination in the evening?

Do you now use also traditional illumination devices, in addition to the PVs? If yes, which one and how long? Average hours per day)

What are the benefits you have attained since the installation of the PVs?

What major challenges have you encountered so far since the installation of your system?

What would you suggest to be done to improve the system?

Thank you for your time and cooperation.

APPENDIX B: GENERAL INTERVIEW GUIDE

Introductory statement:

Good morning/ afternoon / evening! My name is Evelyn Kabasingwa, and I am conducting a research study for Solar Powered Street Lights as a partial requirement for a Master's Degree Research Thesis.

ELECTRICITY ACCESS ROLLOUT PROGRAM (EARP)

Q1a How important is increased power generation for the progress of the EARP agenda?

Q1b What are the main reasons why some households choose to/not to connect to the Grid and instead opt to use solar power?

OFF GRID AND ON GRID SOLUTIONS

Q2a How do you evaluate the importance of off-grid solutions in the coming years?

Q2b Are Solar Photovoltaic Systems (PVS) LED lamps and batteries feasible solutions to access modern energies for households located far away from existing energy infrastructure?

Q2c Do you see any difference in the socio-economic benefits of households powered by either off-grid or on-grid solutions or solar powered technologies?

SOCIO-ECONOMIC DEVELOPMENT INDICATORS FROM SOLAR POWER SYSTEMS

Q3a In your opinion, what are the major benefits of being connected to the solar power systems?

Q3b How do rural solar power systems affect private households?

Q3c Do you see changes in the daily routines of newly connected households?

Q3d What is the impact of solar power systems upon local enterprises?

Q3e What barrier do enterprises face when deciding whether they should invest in

Electrical solar appliances in order to increase productivity?

Q3f.How do you think solar power systems access impacts students, teachers and school performance in Uganda?

Q3g What is the impact of solar power systems upon the quality of health services?

Q3h. To what extent do households/people switch from kerosene to solar light when they get access to solar power systems?

THE ENVIRONMENT

Q4a To what extent does solar power systems substitute for the use of distributed diesel generators?

Q4b To what extent do people substitute battery-driven lamps with solar power systems?

Appendix V1: General Interview Guide on solar power technologies as street lights

Q1a How important is increased street light generated from solar power for the progress of Uganda's 2040 agenda and Africa's 2063 agenda.

Q1b What are the main reasons why some Ugandan towns/cities choose to/not to connect to the Grid and instead opt to use solar power for street lighting?

OFF GRID AND ON GRID SOLUTIONS VERSUS ON-GRID SOLUTIONS

Q2a How do you evaluate the importance of solar power solutions as street lights in the coming years?

Q2b Are solar powered streetlight systems, feasible solutions?

Q2c Do you see any difference in the socio-economic benefits of streets powered by either off-grid or on-grid solutions or solar powered technologies?

SOCIO-ECONOMIC DEVELOPMENT INDICATORS FROM SOLAR POWER SYSTEMS AS STREET LIGHTS

Q3a In your opinion, what are the major benefits of being connected to the solar power systems for street lighting?

Q3b How does urban street lighting by solar power systems affect private households?

THE ENVIRONMENT

Q4a To what extent does solar power systems as street lights help in environmental management as compared to on-grid electricity?

GENERAL OVERVIEW ABOUT SOLAR STREET LIGHTING

Apart from the fact that many solar street light companies always emphasize the wide applicability of their products, when thinking about the actual needs and problems solar powered street lights should resolve for you, the key is in understanding your individual situation and unique project circumstances.

So briefly, what was so unique in your situation here in this city/town for you to have decided to go solar street lighting?

Who needs solar street lights and why?

Do you intend to improve energy efficiency and reduce your electricity bills to zero? If yes, what modalities do you plan to achieve this?

Do you prefer to see long-term ROI by using clean energy for LED light? Do you aim to reduce your carbon footprint and benefit from renewable energy subsidies?

Do you perceive solar energy lights as a reliable standard in the street lighting industry?

What changes have been brought since the installation of solar street lights?

What are the major challenges you have so far faced since you started this project?

What recommendations would you suggest to solve the above challenges?

THANK YOU FOR YOUR COOPERATION

APPENDIX C: PHOTO PLATES

PHOTO PLATES SHOWING THE RIPPLE EFFECT AND USE OF RENEWABLE ENERGY TECHNOLOGIES IN RURAL AREAS OF UGANDA-HOIMA DISTRICT.

Photo Plate 1: The use of solar PVs in the fishing business on Lake Albert, Hoima.

Photo Plate 2: One of the solar powered emerging casino businesses

Photo Plate 3: A solar powered charging station with other commodities at Sebigoro village

Photo Plate 4: A solar powered telecommunication mast at Kibiro in Kigorobya Sub-county, Hoima.

Photo Plate 5: A surgical annex ward at Hoima Main Hospital with solar back up and a rural health centre powered by solar PVs in Hoima District.

Photo Plate 6: Some of the solar equipment private dealers with different electronics in Hoima Town.

Photo Plate 7: A refuge reception centre powered by solar energy in one of the rural areas of Hoima District.

Photo Plate 8: Night business transactions enhanced by solar powered street lighting in Hoima Municipality.

Photo Plate 9: Some of the improved charcoal and briquette cook stoves utilised in Hoima District..

Photo Plate 10: Briquette making at Golden Treasure Primary School in Hoima District.

APPENDIX D: MULTI TIER REPRESENTATION OF THE HOUSEHOLDS IN UGANDA (2010)

TABLE 2: MULTI-TIER REPRESENTATION OF THE HOUSEHOLDS IN UGANDA (2010)

APPLIANCE CATEGORY	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	Rural, Peri-urban. Very poor	**Rural**	**Rural or peri-urban settlements**	**Rural, urban, peri-urban and Kampala**	**Urban or Kampala**	**Kampala**
	Off-grid	Off-grid	Off-grid	Grid	Grid	Grid
% of households	10%	45%	37%	5%	3%	1%
Off-grid electric appliances	Torch (dry-cell)	Torch (dry-cell) PV-lantern Radio	Torch (dry-cell) Radio/music system Solar powered lantern Cell phone	Torch (dry-cell) Radio Back-up lantern	Torch (dry-cell) Radio Back-up lantern	Torch (dry-cell) Radio Back-up lantern
On-grid electric appliances	None	None	May have appliances in anticipation of connection or from earlier house	Lighting Cell phone Music system Television	Lighting Cell phone Music system Television Refrigerator Iron Kettle Fan	Lighting Cell phone Music system Television Refrigerator Iron, kettle Fan, air-condition Pump Water heating Washing machine
On-grid electricity demand (kWh/hh/yr)				2.2	1331	1862
Fuel based appliance	Traditional grass Kerosene, with tadooba	Tadooba Hurricane lantern	Hurricane lantern	Hurricane lantern	Hurricane lantern	
Primary cooking device	Three stone fire using gathered wood or waste	Three stone fire with gathered wood	Three stone fire, or traditional charcoal stove	Traditional charcoal stove or improved charcoal stove. Kerosene stove.	Traditional charcoal stove or improved charcoal stove. Kerosene stove and LPG	Traditional charcoal stove or improved charcoal stove. Kerosene stove LPG Electricity

Source: *Gustavsson, et al, 2015*

APPENDIX E: ACCOUNTABILITY FOR THE RESEARCH GRANT.

S/No.	Item	Unit/Qty	Exchange Rate at the time of transaction	**UGX**	**DZD**	**USD**
1	Stationery and Questionnaire Printing	200 paper	3,761	752,200		200
2	Internet connection (including taxes)	4.5 months	3,700	1,670,700		451
3	Research Assistant/translator 1	1 Assistant for 15 days paid 19.8 USD/day	3,761	1,117,100		297
	Research Assistant/translator 2	1 Assistant for 15 days paid 19.8 USD/day	3,761	1,117,100		297
4	Transfer charges here		3,761	75,220		20
5	Transfer charges-Algeria		??	??	??	??
6	Field transportation	21.5 USD/day (80,861.5) per day for 30 days	3,761	2,425,845		645
7	Printing and binding research report		3,680	169,650		46.1
8	Printing of final report and binding			??		30
9	Taxi Tlemcen to Algeria		3,700		3,000	27
10	Taxi Algiers to Tlemcen				3,000	27
11	Taxi Entebbe-Kampala		3,700	100,000		27.02
12	Taxi Kampala to Entebbe		3,680	100,000		27.17
13	Travel Insurance		3,700	222,000		60
Sub-total	Total					
14	International Air-ticket	Return			**98,000**	
Total						

THESIS APPROVAL PAGE

TITLE

ASSESSING THE DIFFUSION OF RENEWABLE ENERGY TECHNOLOGIES AND ITS IMPACT ON SOCIO-ECONOMIC DEVELOPMENT OF RURAL LIVELIHOODS IN UGANDA

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Name of Rector Signature Date