UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

TITLE OF PROJECT: SOCIO-ECONOMIC DETERMINANTS OF ENERGY CONSUMPTION IN RWANDA

A dissertation submitted to African Center of Excellence in Energy for Sustainable Development in partial fulfillment of the requirement for the degree of Masters of Science in Energy Economics

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DECLARATION

I, **Augustin NSENGIYAREMYE**, declare that this dissertation is my work and it has never been submitted for the degree at the University of Rwanda or any other university.

Augustin NSENGIYAREMYE

Signed ……………………………………………………………………………

Date: 08/11/2021

Main Supervisor: Dr. Edward KADOZI

Signed……………………………………………………………………………

Date: 08/11/2021

DEDICATION

Any demanding job requires personal effort and support from alumni specifically ones who are closer to us.

I humbly dedicate this work to my beloving

Step-Mother, brother, and sister

whose affections, love, encouragement, financial support, and prays of day and nights make me able

to get such success and honor.

Special dedication goes to Mrs. Anastasie KANTARAMA, my right-hand side person for her encouragement, caring, and affection during this study journey.

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ABSTRACT

Energy has been a crucial aspect in improving the human lifestyle of billions of people all over the world. Energy consumption is increasing in developing countries as well as in sub-Saharan Africa at a rapid rate of accessibility among households, most specifically, for lighting and cooking purposes. The key determinants that govern both accessibilities and use among different categories of households have been an empirical debate among different academicians and scholars. In the case of Rwanda, there is scant empirical evidence that fully explains factors influencing energy consumption choice among households. The current study contributes to this scholarship by examining the key socio-determinants of energy consumption choice among households in Rwanda. This study is embedded in the theoretical framework of the energy ladder and social cognitive theories that explains the energy consumption choice factors at the household level.

This study employed both OLS and logistic models to examine the key determinants of energy consumption choice for lighting and cooking energies amongst households in Rwanda by using the EICV5 dataset. The analysis categorized energies into two main groups namely: traditional and modern energies. Binary logistic regression was used to assess the marginal effects of each explanatory variable in determining the outcome variable. The findings show that area of residence, having a telephone in the household, ownership of the dwelling has a significant and positive effect on choosing modern energies for lighting purposes. On other hand, the choice of modern cooking fuels is significantly influenced by the area of residence, being married, having secondary and university studies, and household size. The study reveals that the traditional energies including firewood, charcoal as transitional, are still dominantly used in Rwanda as cooking fuels across the different socio-economic classes. The candles, torches, and batteries are the most used lighting energies in Rwanda specifically in rural areas and the use of gas (LPG) for cooking is still low even in urban regions. The findings suggest that the government of Rwanda should increase modern energy accessibility through the enhancement of clean energies related policies, subsidizing the gas distributors to encourage them to increase supply. Improvement in population capacities through enhancing education will help in reducing the use of traditional energies and mitigate related health issues. Enhancing off-grid rollout and urbanization could help in raising modern energies accessibility and use.

Keywords:* *Lighting, cooking, household, fuel, LPG, logistic, Rwanda

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List of abbreviations and acronyms

AC: Alternative Current

DC: Direct Current

EDCL: Energy Development Corporation Limited

EICV: Integrated Household Conditions Living Survey

EPD: Energy Private Developers

FAO: Food and Agriculture Organization

FDI: Foreign Direct Investment

GDP: Gross Domestic Product

IEA: International Energy Agency

Kwh: Kilowatt-hour

LPG: Liquefied Petroleum Gas

MININFRA: Ministry of Infrastructure

MW: Megawatt

NISR: National Institute of Statistics of Rwanda

RBD: Rwanda Development Board

REMA: Rwanda Environmental Management Authority

SHS: Solar Home System

HH: Household

CHAPTER I: GENERAL INTRODUCTION

1.0. Background of the study

The macroeconomic aspects such as per capita income, urbanization rate, population density have a great effect on energy consumption patterns. Researchers argued that per capita energy consumption increase is associated with a positive effect on civilization's development as cited by (Azam et al., 2016). Behind that prospective aspects, there are microeconomic factors that have a role in determining the behavior of energy use which include household socioeconomic factors (Ye et al., 2018).

However, improvement of socioeconomic behaviors of the population is needed for having better living conditions and improved socio welfare (Kaygusuz & Bilgen, 2008). Economic development cannot be achieved without considering the production increases and also taking into account environmental sustainability. Population perception on electricity saving is a key point in reducing residential energy consumption. Practicing electricity conservation attitudes daily with a combination of the use of high-efficiency appliances can contribute a lot to energy-related expenses. (Sharma et al., 2019).

Worldwide, it is projected that 3 billion people rely on solid fuels (such as biomass and coal) to satisfy their domestic necessities (Staton & Harding, 1998) and in the sub-Saharan region and developing countries, about 2.5 billion people rely on these unclean fuels for their domestic requirements and the future prediction is that in 2030 the people using biomass will rise to 2.7 billion (IEA, 2006). Those traditional and unclean energies have a great contribution to most people's health problems as well as environmental pollution as cited by (Fydess Khundi-Mkomba et al., 2020). In sub-Saharan Africa, access to clean energy has been taken as a crucial part in reducing poverty and the access is still low which has increased from 15% in 2015 to 17% in 2018 (IEA, 2019). However, that low access is a result of the region's economic growth which is relatively low 28% in 2018 (World Bank, 2018).

Considering the increasing rate of people depending on traditional fuels in developing countries, this asserts that there will more forest resources depletion and global environmental degradation if proper and specific policy measures (See Arnold & Persson, 2003). This seems to be attributed to the ever-growing increase in energy use in developing countries. The energy consumption per capita in Rwanda has raised from 175.394 Kwh in 1980 to 425.29 Kwh in 2016 (Ritchie & Roser, 2020). The report of the ministry of infrastructure on energy sector strategy (MININFRA, 2018) shows that energy consumption was increasing but, electricity accounted for only 2%, where biomass accounts for about 85% and petroleum account for 13% of all energy consumed in 2016.

Rwanda's economic growth has accelerated in recent years, and the country is equipped with significant energy resources still to be completely used(RDB, 2018; REG, 2018). Despite having abundantly available energy resources such as hydroelectric, solar, peat, gas, and biomass. Rwanda presently has just around 216 Mega-watt of installed electrical capacity to serve the entire country (RDB, 2018). However, the per capita electricity consumption of Rwanda was low 62 KWh in 2019, compared to Uganda 110 KWh, Tanzania 121 KWh, and Kenya 217 KWh (Ritchie & Roser, 2020).

We know that energy consumption is one of the key drivers of economic growth through its mediated effects as factors of production. According to the endogenous growth hypothesis, economic development is largely driven by internal forces of production, and productivity increases are linked to improvements in innovation and physical capital investment(Romer, 1997). The empirical study argues that steady-state economic growth requires a corresponding growth of energy consumption, and energy efficiency is key to production machinery and equipment (See, Zon & Yetkiner, 2003). This is supporting also the idea that energy prices are correlated to technological change then have a significant impact on economic growth (Popp, 1998).

Energy is important in human day-to-day living style (See, Tsani, 2010) and, its use has increased at a high rate in developing countries. However, we know less about the determinants of energy consumption in developing countries like Rwanda. Empirical studies (Azam et al., 2016; Hondroyiannis et al., 2002; Liu, 2009; Zaman et al., 2012) suggested some factors such as population growth, economic growth reflected through industrial development, and FDI to mention but a few. The majority of these studies are based on the realities of developed economies, and they are biased to the macroeconomic implications. However, the successful adoption of clean energy is closely linked with household demand and energy use choice (Fydess Khundi-Mkomba et al., 2020).

Depending on the structural nature of developing countries concerning energy use, the macroeconomic picture seems to run short of the comprehensive picture of determinants influencing the use of energy in the country. This study argues that the microeconomic approach would provide a contextual and comprehensive understanding of factors influencing energy use considering the heterogeneity of energy consumers. The same microeconomic factors aggregate to the macroeconomic factors. The income of households will be aggregated to the GDP per capita at a macro level, also household size will lead to population growth and prices of commodities will lead to a rate of inflation at the country level (See Gujrati, 2019). This prompts the impetus of this study to examine socio-economic determinants of energy consumption in Rwanda. The study has adopted two sources of energy use; lighting and cooking, which have been empirically adopted by different scholars in the field (Fydess Khundi-Mkomba et al., 2020).

1.1. Problem Statement

Studies considered energy as a crucial element in most economic activities and contribute to improving the social-economic development of households all over the world(see Selçuk, 2009). More so, we know from empirical studies that, energy use has both macro and micro economic implications (both positive and negative), depending on the level of development of the country, and technology employed in the energy generation, distribution, and use. Empirically, different factors influence the energy (and its type) use mostly in developing countries. In addition, the use of energy (quality and quantity) depends on socio-economic factors such as the level of poverty and socio-economic class at the household level. The quality and the quantity of energy use, as well as socio-economic factors influencing the consumption of energy sources, can plausibly be examined at the household level using household data.

In the case of Rwanda, most people use wood in cooking, there are an increase from 13.9 percent in 2014 to 16.0 percent in 2017 of charcoal and clean energies users (NISR, 2018). The government of Rwanda has put in more efforts to increase energy access, as well as increasing the accessibility to clean energy. We see a large gap among different socio-economic classes and energy use in the country. Indeed, available data indicate that poor households use 10% of electricity, while those in the rich households equivalent to 76% have electricity) even though the percentage of people who uses electricity from the grid or solar panels increased from 4 to 10.2% for quintile 1 (poor) and charcoal or clean fuels(such as gas or electricity) increased from 13.9 % to 16 % but there is a large gap between 1.3% for poor and 52.9% for rich households (NISR, 2018), this shows that the electricity access is still low among poorest households.

Implying that, energy use, for instance, electricity is biased to those in the upper level of the income distribution. But, the majority of Rwandans still use traditional biomass (85%) and the majority are in the rural areas. Implying that, the majority of Rwandans still depend on biomass for energy use. These pieces of evidence seem to signal that, unless you employ microanalysis, the actual socio-economic determinants of energy use will not be empirically determined- without using household data. Thus, the current study aims at empirically examining the energy use in Rwanda by employing Rwandan household data drawn from the Rwanda Household Survey dataset (EICV5) of NISR. The study seeks to examine the socio-economic factors influencing energy use in Rwanda; how the use of the different sources of energy plays out among different socio-economic classes in Rwanda; across the geographical areas, economic activities. We seek to understand key factors that can change the choice of energy consumption among Rwandan households.

1.2. Objectives

1.2.1. General objective

Generally, this study seeks to examine the socio-economic factors influencing energy consumption in Rwanda at the household level.

1.2.2. Specific objectives

- Examine the patterns of energy consumption in Rwanda
- Examine socioeconomic factors influencing households in choosing the source of energy to use for either home lighting or cooking.
- Examine the extent to which socio-economic class and education level influence energy use in Rwanda

1.3. Research questions

- To what extent do the socio-economic variables affect the choice of household energy use for lighting and cooking in Rwanda?
- How does energy use play out among different socio-economic classes and education levels respectively?
- What is the marginal effect of each of the socio-economic variables on energy type used by households in Rwanda?

1.4. Scope of the study

Many factors affect energy consumption at a micro level, to contextualize the microeconomic analysis, this study focuses on socio-economic factors such as region of residence, HH head level of education, household size, having a mobile phone, welfare categories/income distribution, owner of the dwelling, quintile, marital status and sex of household head on household's energy use behavior in Rwanda. The latter variables have been used as explanatory variables (independent variables), while energy use on; lighting and cooking have been used as dependent variables.

1.5. Structure of the study

The study is organized into five main parts, part one is an introduction which includes the background of the study, the problem statement, the study objectives, the research questions, scope of the study, the significance of the study, the part two study includes, present literature review which describes the major concepts, the theoretical framework of the study, and empirical narratives about socio-economic determinants of energy use at a micro-level in developing countries. The third part of the study covers the methodology and estimation techniques. The fourth chapter covers data visualization and data analysis. Lastly, the fifth chapter presents the summary of the main findings, conclusion, the policy implication of the study, and suggestions for future research.

1.6. Expected outcomes and significance of the study

1.6.1. Expected outcomes.

Based on the objectives and methodology to be used in this research, it is expected that each selected urban area has a positive statistically significant impact on the modern energy use for lighting and cooking in Rwanda. Household education level has a significant effect on modern energy use in Rwanda

1.6.2. Significance of the study

The contribution of this will be an addition to the existing knowledge about key drivers of energy use in terms of lighting and cooking in Rwanda at the household level. Also, the findings and policy recommendations of this study will increase understanding about the energy pattern in Rwanda and will inform the scholars and policymakers on what to focus on in addressing the energy access problem for promoting socio-economic development amongst Rwandans.

CHAPTER II: LITERATURE REVIEW

2.0. Introduction

The key socioeconomic drivers of the choice of energy to use have been contested among different scholars and policymakers in economic development all over the world. To explain the energy choice in Rwanda, energy-ladder and fuel substitution are mainly used to investigate a theoretical explanation on household utilization of different sources of energy either modern or traditional.

Firstly, the energy-ladder asserts that there is a link between household income and switching from one fuel to another and affirms that deprived households tend to consume more dirty fuels compared to high-income people (Kroon et al., 2013). transitional fuel hypothesis affirms that clean and unclean fuels are even now used disregarding income distribution among households.

2.1. Definition of key concepts

1. Energy consumption, Energy use

According to the Cambridge dictionary, energy consumption refers to the amount of energy consumed by an individual or organization, or to the processor system of such consumption. Whereas energy use refers to the process of using energy, or the amount of energy that is used. Home energy is classified into three categories: biomass including (wood, crop wastes), hydrocarbon fuels such as (gas and kerosene), and electricity. To save money on electricity, several communities utilize a mixture of biomass and hydrocarbon fuels (IEA, 2006b).

2. Biomass energy

Biomass energy is the energy derived from biological systems such as wood and garbage. For example, Nigeria's biomass resources include firewood, agricultural and industrial wastes (see, Buba et al., 2017). Biomass fuels are important in-home cooking fuels and they are free and readily available in the majority of communities.

3. Liquid petroleum gas

Conventionally, it is obtained in the petroleum and gas industries. As cited by (Buba et al., 2017), its distribution is mostly concentrated in urban areas. When compared to kerosene or fuelwood, liquid petroleum gas offers significant health and is environmentally friendly. Of course, choosing LPG may be restricted by the required money for buying cooking stoves, and the value of the equipment. Even though they are available, people are fearing the safety of the cylinders which can be stolen easily. Many individuals are concerned about the dangers and indoor air pollution consequences of explosions.

4. **Electricity**

Electricity is a fuel obtained through other energies conversion, requiring inflated technology space. Generation and distribution require high-cost equipment. More so it is used for different purposes namely industrial, commercial, and residential purposes (Babatunde & Shuaibu, 2010).

2.2. Theories related to energy use/ Theoretical Framework

The theoretical framework is very important in the research as it connects the researcher to existing knowledge. This section includes the theories explaining the energy consumption determinants among households.

2.2.1. Social cognitive theory

The theory has been started by the famous American social psychologist Bandura A, (1986). This theory suggests that individual motivation is a combination of behavior and environment. According to social cognitive theory, there exist two main important aspects of self-efficacy which is the confidence that one has in their action. The probability of finishing the tasks determines one's outcome anticipation. Positive results are supposed to encourage individual activity, and negative consequences are expected to discourage individual actions. Researchers have investigated energy-saving behavior determining factors where they are intended to see the effect of culture, economy, and education on energy consumption behavior among households. The study by (Wallis et al., 2016) found Income to have a positive effect on power and energy usage. An empirical study of (Ntona et al., 2015) in his research on student perceptions on energy usage relating to the environment, revealed that a sustainable environmentally friendly orientation. However, the study concluded that apart from education, a household is a key to promoting energy use among people in the family.

2.2.2. Theory of planned behavior

The theory was suggested by Ajzen (1985) by extending reasoned action theory. The theory postulates that an individual's conduct is the result of a complex psychological process. Referring to the theory (Abrahamse & Steg, 2009) proposed the following two hypotheses. Firstly, Household energy usage and social demographic factors have a substantial linkage. Secondly, psychological factors are the key factors determining energy usage. The regression analysis findings revealed that demographic characteristics determine residential electricity use. Yazdanpanah et al (2015) investigated a correlation between socio-psychological characteristics and renewable energy consumption. Findings revealed that renewable energy consumption is significantly influenced by socio-physiological factors. Another study by Botetzagias et al., (2014) used a telephone interview to analyze energy consumption behavior and its determination. Study results found that age, sex, and perception ability have a very important impact in determining energy-saving.

2.2.3. Self-regulated behavior change theory

The theory was started by Bamberg, (2013) based on both norm activation theory and planned behavior theory. According to him, personal actions can be changed, even though it has become custom. The hypothesis is primarily used in analyzing complex behavior. Researchers have started using this theory of (Self-regulated behaviour) to analyze residential cooking fuels consumption in recent years as cited by (Guo et al., 2018). The study (Nachreiner et al., 2015) used this framework to study the correlation between electricity data recorded by smart meters and energy-saving behaviour and this theory is based on four stages. Firstly, households are informed about their electricity consumption data are identified and helps them to plan for future energy saving.

Secondly, residents are informed about the consumption of each appliance after this people start to know which residential appliance consumes most and set future consumption behavior. Thirdly, people taught different energy-saving strategies. Lastly, residents will convert energy-saving attitudes into everyday exercise and make relevant electricity-saving plans.

2.3. Empirical Discussion

The study of (Sharma et al., 2019; Tewathia, 2014) showed that monthly residential energy use is statistically significantly explained by dwelling size, level of education, family size. Pundo and Fraser (2006) utilized a multiclass logistic regression model to study the determinants of residential cooking fuels choice amongst wood, charcoal, and kerosene. The findings found the husband and wife's education level, ownership of the dwelling, and the type of dwelling (traditional or modern) to be the important determinants of residential cooking energy choice. Empirical research by (Leahy & Lyons, 2019; Mcloughlin et al., 2012) pointed out that the age of the family member is significantly correlated with electricity consumption. Considering the economic status of the family (Fydess Khundi-Mkomba et al., 2020), empirical findings show that poor household wealth levels and residence are factors that drive the probability of using fuel for lighting in their home.

The study on factors that determine the energy use by households in Nigeria (Ogwumike et al., 2014) using multinomial probit regression model shows that as the educational level of the father increases by a year, the probability of consuming firewood falls by 0.95 percent but increases by 0.55 percent for kerosene, augmented by 0.03 % for LPG, increased by 0.03 % for electricity. Furthermore, Ogwumike et al. (2014) used a multinomial logistic model to conduct an empirical study in Nigeria on energy use drivers and discovered that most Nigerian households choose firewood for cooking as well as kerosene for lighting.

A similar study by Zou & Luo (2019) revealed that family size has a positive influence on the percentage of LPG and power use, implying that every extra member in the household results in an increase of 0.4 and 0.8 percent for using liquefied petroleum gas and electricity respectively. More so, an empirical study by Bello (2010) in Nigeria using the multinomial logistic model to analyze the factors of the household energy choice for cooking. Income, household size, and household head level of education are among the explanatory variables. Their findings found income, family size, as well as education level to be among the main determinants for cooking fuel choice. However, other empirical studies find negative claims about energy consumption and level of education, and household size. The study by (Bartiaux & Gram-hanssen, 2005; Cramer et al., 1985) revealed that an increase in education is associated with an increase in energy consumption among households this implies that higher education is associated with higher energy consumption.

A similar study by Pundo & Fraser, (2006) using multinomial logistic regression found that both husband and wife's age have an inverse relationship with using both charcoal and kerosene. Studies by (Adetunji et al.2007; Shittu et al., 2004) found that household size, heads of household's occupations, and education level have no contribution in determining the household choice of energy consumption. Another empirical work by Okunade (2010) revealed that the contribution of the level of income to influence the residential choice of energy used for cooking is not meaningful.

2.4. Theoretical and empirical gaps

Most of the empirical studies on energy use focus on the macroeconomics analysis factors governing energy patterns and this applies to the developed countries, and others studies on the developing countries using the microdata, but the exhaustibility of all variables was still debatable among scholars and still an important gap to work on. The existing empirical findings present mixed findings of different socio-economic variables from different studies, but inconclusiveness seems to be attributed to the scope and the context of the study. In the case of Rwanda, equally less, information is known about the social-economic determinants of energy consumption choice, the few that are out there are based on the small scope of the study was covering a small part of the country in their analysis. More so, previous studies did not consider variables related to energy choice like cooking and lighting in their analysis. This study fills the gap by employing the latter variables in the analysis

2.5. Energy consumption in Rwanda

2.5.1. Energy status

The report shows that electricity access is about 54%, combining both 39 percent for the grid and 15 percent for off-grid connections (EPD, 2019). Moreover, Rwanda has a target to reach 512 Mega-watt power generation capacity in 2024, the expectation is to reach 100 percent access which will be achieved through bringing together 52 percent for on-grid electricity and 48 percent for off-grid electrification as cited by (Bimenyimana et al., 2018). The traditional source of energy, biomass including firewood, charcoal, crop wastes many others is still the largest source of energy in Rwanda accounting for 85% dominantly used by rural households and contributing about 5% to the GDP. The government has organized biogas development programs in 2007 to reduce wood dependence from 90% to 50% by 2020. (Landi et al., 2013; REMA, 2013; Vander Plas, 2009)

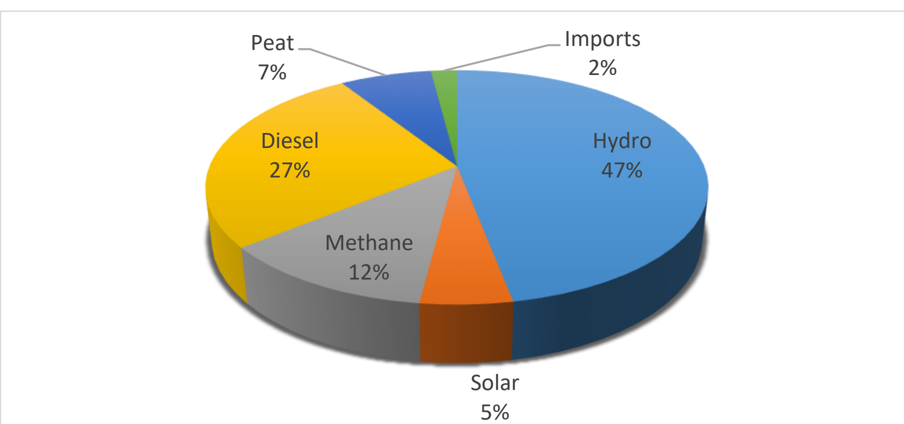

Figure 1:Rwanda energy mix, 2019

Source: (MININFRA, 2018)

As indicated in figure 1, hydropower takes the high share of the main source of electricity which accounts for 42%, followed by diesel (27%), methane (12%), peat (7%), solar (5%) respectively, while imported electricity account for 2 %. According to the report of Power Africa,(2019), in the analysis of average expenditure on phone candles, kerosene, charging phones, and batteries by households who use off-grid electricity. The information shows that monthly payment on these services for all 75 % of off-grid users is lower than 1.67 USD. This shows that people cannot pay more which is a key issue in the energy sector. This report shows that the batteries are used mostly in off-grid households compared to other sources of energy in Rwanda.

2.5.2. Energy use (on-grid electricity) by sector in Rwanda

According to (MININFRA, 2018), as depicted in Figure 2 on-grid energy consumption specifically on-grid is mainly allocated to the household for lighting their home, occupies a high proportion of consumption about 51 percent of total consumption. The second highest consumer of electricity is the industry with 42 percent for using equipment and machines in industries. A small number of major consumers dominate industrial consumption, including those in mining companies, cement, and textiles industries as well as agricultural-related industries. Electricity usage in the public sector accounts for 7% of total consumption, primarily for lighting buildings like schools, hospitals, street lighting, and pumping systems.

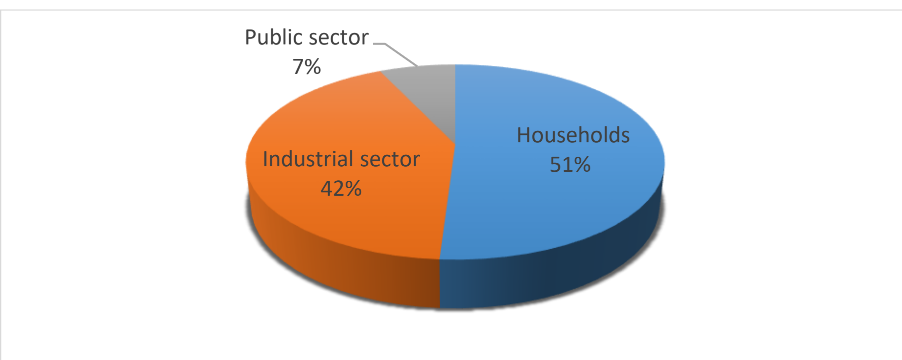

Figure 2: On-grid Electricity Consumption, 2016.

Source : (MININFRA, 2018)

2.5.3. Off-grid electricity in Rwanda

In the case of off-grid electricity Solar home system is involved to be a solution to areas where on-grid electricity is unaffordable. The report of EPD, (2019) shows that solar home systems' total sales have risen from 48,564 households in 2016 to 301,089 households in 2019. In addition to SHS, Solar and Hydro mini-grid have connected 4,780 families by 2019 and approximately 24,000 individuals are benefiting from electricity this has a significant impact on energy access as well as the socio-economic development of the beneficiaries. Table 1 below shows the number of customers of Solar Home System and lamp market considering ubudehe categorization. Table 1 shows that some people in category 1 can afford to buy SHS (5%) even they can buy lamps (9%) in their capacity (Energising Development(EnDev) Rwanda, 2017).

Table 1:Customer segmentation according to the ubudehe categories

	Ubudehe 1	**Ubudehe 2**	**Ubudehe 3**	**Other (without classification)**
SHS Market	5%	41%	50%	4%
Lamp Market	9%	35%	42%	14%

Source: Energizing Development Rwanda report, 2017

In Rwanda, off-grid electrification is mainly dominated by two main systems; solar home systems that generate electricity from using solar panels with batteries to store power to be used any time. While Mini-grids are used by households that are far away from the national grid. Those mini-grids include both solar and hydro. Figure 3 shows that ignite was the leading company in selling solar home systems by 37% of total sales in 2017. The government has put the mini-grids development in the private sector to enhance its feasibility. Because of the low capacity to afford these sources of energy government has put subsidies to the households to facilitate access. The subsidy range differs according to ubudehe category; ubudehe 1 the subsidy range between 80-90% of the total cost of the Solar system, for ubudehe 2 55-65% ubudehe 3 30-45% (REG, 2020)

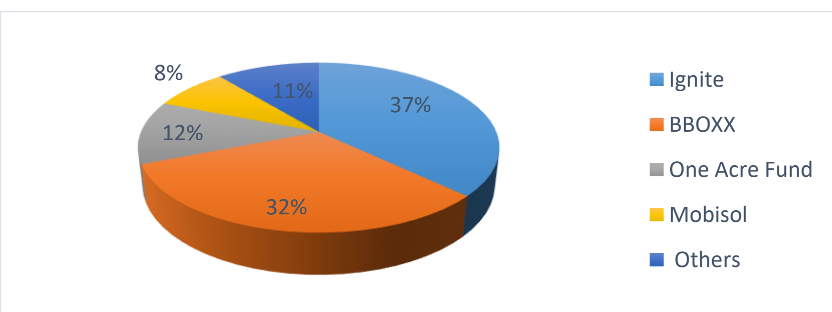

Figure 3: Percentages shared of solar home systems by company in 2017

Source: Energising Development(EnDev) Rwanda, 2017

Previously, the mini-grids sector was mainly composed of hydro energies after the decrease of the cost of solar, solar has taken part in min-grids and has helped in increasing electricity access to rural areas cited (Power Africa, 2019). Table 3 below show private mini-grid projects in Rwanda, with their respective customers by 2017.

Table 2:Mini-grids in Rwanda with the respective number of served households by 2017

Company	**Technology**	**Size**	**Number of households connected**
Mesh Power	Solar DC	1 kilowatt (kW) x 57 systems	2,046
Mesh Power	Solar AC/DC Hybrid	4 kW AC/1 kW DC	78
NESELTEC	Solar AC	30 kW	183
RENERG	Solar AC	30 kW	121
Absolute Energy	Solar AC	50 kW	505
ECOS	Hydro	11 kW	303

Source: Power Africa, 2019.

2.5.4. Energy consumption at Household Level

At the household level, energy is used for different purposes according to the need and this study discusses energy usage in form of home lighting and cooking. The quantity and type of energy used depend on the socio-economic characteristics of households (Marathe & Eltrop, 2017), and the area of residence. As per the Fifth Integrated Household Living Conditions Survey, which was released in 2018, 65 percent of urban households use charcoal as a cooking fuel, 26 percent use firewood, and 5 percent use gas. In rural regions, however, 93 % use wood, 6 % use charcoal, and 0.2 % use gas. (NISR, 2018).

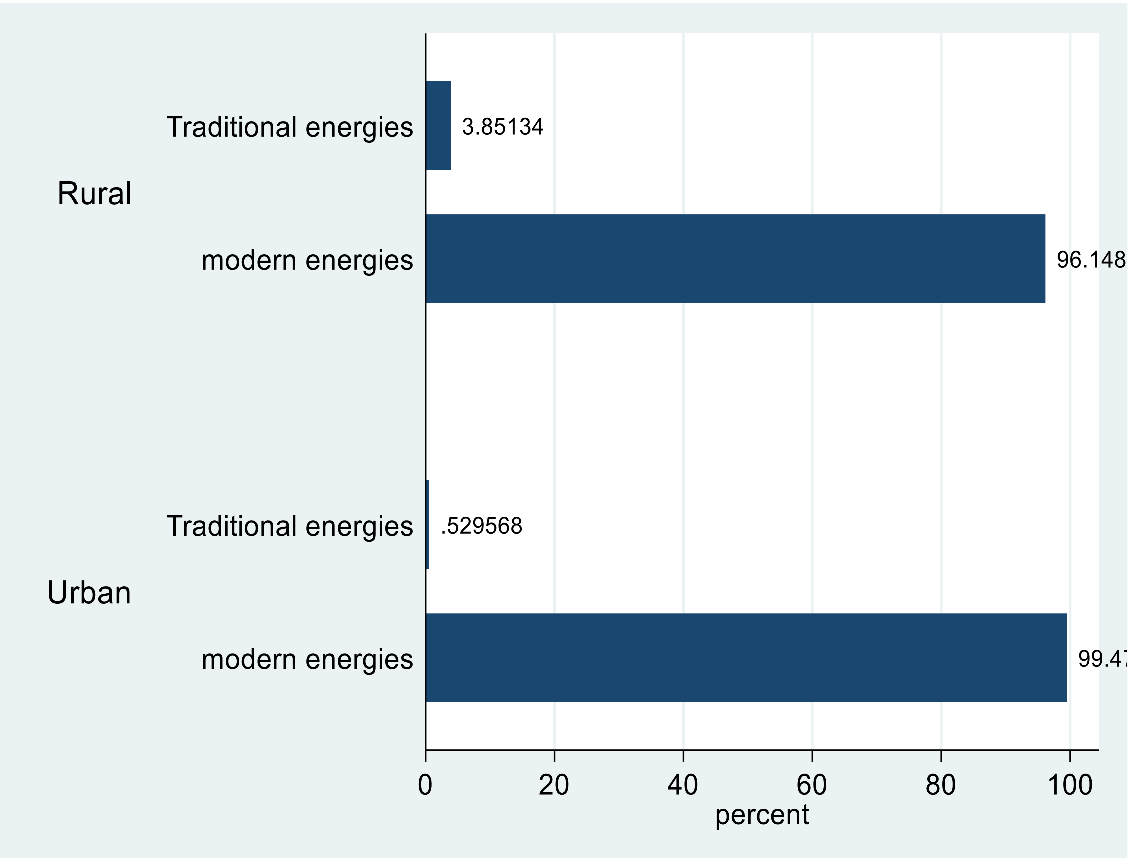

Figure 4:Distribution of Lighting energy use at the Household level by areas of Residence

Source: Produced by Author using the dataset, EICV5.

Figure 4 above shows the energy usage in form of lighting at the household level by area of residence in Rwanda. A high number of households in rural areas use modern energies for lighting their home (96.14%) and in rural areas, the use of traditional energies is greater compared to urban areas as shown in figure 4. It shows that the urban households most of them use modern energies for lighting their homes such as electricity, solar panels) that they have many appliances that require electricity to function this push them to adopt modern energies most of the electricity. Even though the use of electricity in rural areas is still low, they mostly use candles, batteries, and torches that are considered modern sources of energy for lighting.

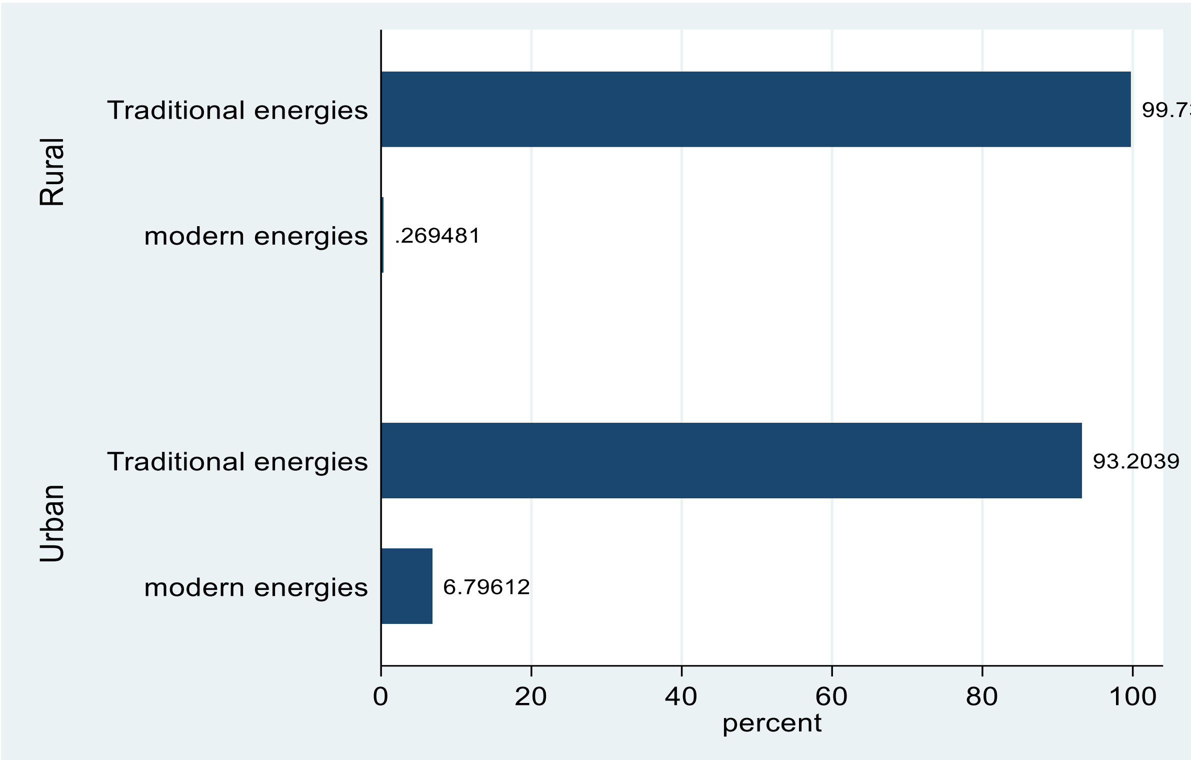

Figure 5: Distribution of Cooking as main Source of Energy at Household Level by Areas of Residence.

Source: *Produced by Author using the dataset, EICV5*

Figure 5 above shows the energy usage in form of cooking at the household level by area of residence in Rwanda. Similarly, most households in urban areas use traditional energies when cooking (such as biomass, kerosene, firewood) about 93.2%, the same most rural households use traditional energies (97.7%) such as biomass, kerosene, firewood). Conversely, the use of modern energies in Rwanda such as gas, electricity, kerosene is still low. Amongst households in urban areas only (6.79%), of rural households (0.269%) use modern energies sources when cooking.

2.6. Conceptual Framework

The study's conceptual framework was informed from the theoretical and empirical review of previous works on energy consumption choice. This conceptual framework comes clearly to explain the causal relationship between outcome variables and control variables. The socioeconomic factors in this study are split into two broad categories: economic and non-economic factors; under the economic category, we have welfare categories/income distribution, quintile, while social or non-economic are the level of education, area of residence, dwelling ownership, household size, gender, marital status, have a telephone. The inclusion of those independent variables was informed by empirical review, and the choice of outcome variables of lighting and cooking fuel choices by related energy studies (see Bedir et al., 2013; Fydess Khundi-Mkomba et al., 2020; Guo et al., 2018; Jan et al., 2012; Marathe & Eltrop, 2017; Ogwumike et al., 2014).

To explain the energy consumption in the context of Rwanda, we have decided to use energy use in terms of lighting and cooking as proxies the reason here is that the micro dataset from NISR, contains only the main source of lighting and cooking in explaining the consumption behavior of the households who are the unit of analysis of this study. This is also based on the available previous empirical and theoretical studies on energy use that consider lighting and cooking in their analysis (see, Fydess Khundi-Mkomba et al., 2020; Ouedraogo, 2006). The study analyses two empirical models for energy for lighting and cooking separately as outcome variables. The sources of lighting and cooking are categorized into two main groups; modern energies, traditional energies

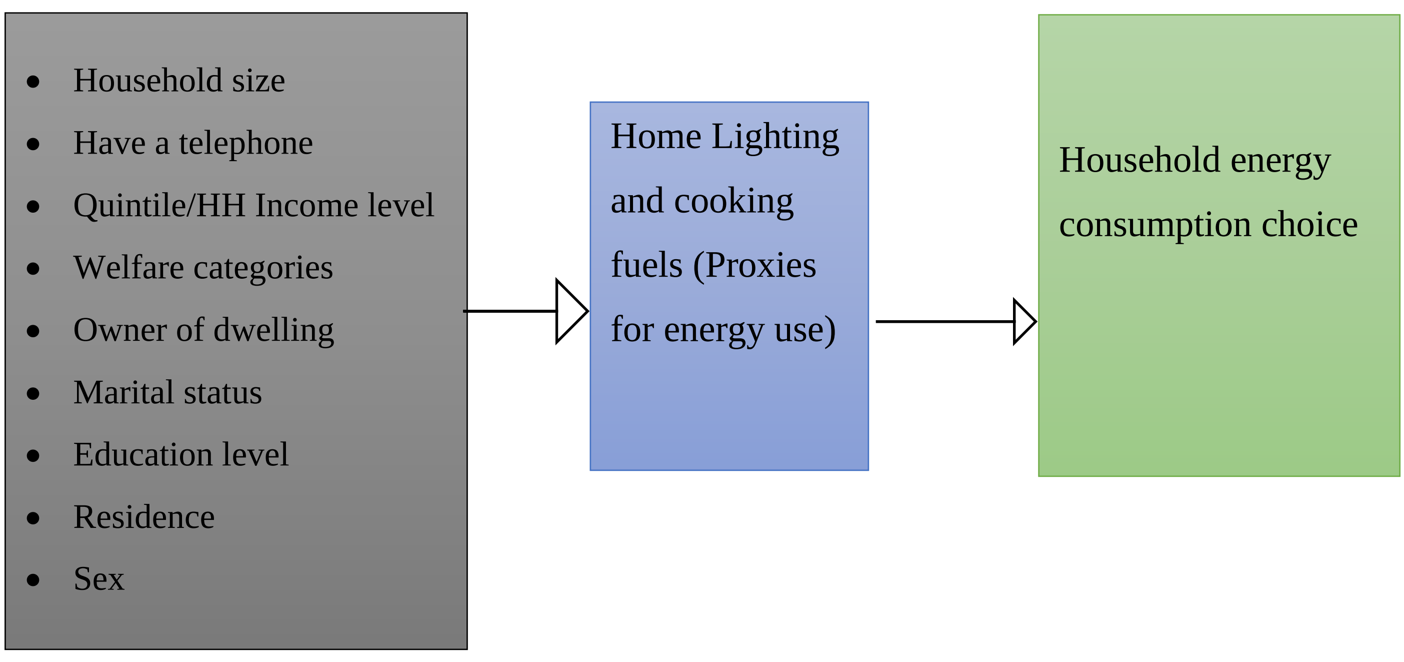

Figure 6:Conceptual framework

Source: Adopted from (Danlami, 2015)

Empirical studies (Ouedraogo, 2006; Pundo & Fraser, 2006) showed that the household size, dwelling ownership status, and level of education have a significant impact on household energy use choice. People with more education levels tend to shift from firewood to charcoal and kerosene. Similar to the study by Ogwumike et al.,(2014) pointed out that Nigeria uses firewood as cooking fuel and kerosene for lighting.

Considering the energy choice for lighting, the study of Fydess Khundi-Mkomba et al., (2020) showed that in Rwanda, residing in rural areas and ownership of dwelling both increases the likelihood of using solar panels. Similarly, the same research revealed that the probability of using solar was less for the poor compared to the richest people. It has been argued that the age of a household has an impact on energy use for lighting and cooking among households (Mekonnen, 2014). Those empirical findings and many others support our main hypothesis that socioeconomic characteristics have a significant impact on energy use fuels choice.

CHAPTER III: RESEARCH METHODOLOGY

3.1. Data

The study employed the data from the fifth Integrated Living Standards Survey (EICV5) carried out by the National Institute of Statistics of Rwanda (NISR). The sample in this survey was 14580 households' units and the survey has taken place in 2016-2017. The individuals asked about their spending behavior, income sources (NISR, 2018). The advantage of using a micro dataset is that contains households' characteristics that reflect the real picture of human lifestyle in the society (than macro data).

3.2. Study variables.

The outcome variables are the main source of household lighting and cooking which are both categorical outcome variables. The selected variables as covariates in this study are household size, residence (Urban or Rural), having a telephone, HH Head level of education, welfare categories/ income distribution, marital status, owner of the dwelling, quintile, Sex household head as **depicted in table 3.**

3.3. Econometric analysis

For modeling consumer behavior, we take into consideration consumer preference. The consumer is always willing to the consumer the most preferred products and subject to their budget (Varian, 2010). There are a lot of factors that may influence household fuel consumption choices. The data analysis in this study has used a nested approach to capture well the microeconomic key drivers of the household's energy use in Rwanda.

3.3.1. Ordinary Least Square method

To reach the research goal, the descriptive analysis has been followed by the baseline analysis using Ordinary Least Square (OLS) has been done to show how the selected variables in the study affect the choice of energy use for lighting and cooking at the household level.

3.3.2. Binary Logistic Model

This study uses the binary logistic regression model to assess socio-economic factors of energy consumption in Rwanda. The choice of binary logistic model was determined by the nature of the dependent variable, which is dichotomous, has two outcomes 0 and 1. The Logit model for this study takes into account the probability that a person with a set of certain socio-economic characteristics (x) will use a source of Lighting and a source of cooking. Then, Pi = 1 is a chance that any household uses modern energies. This means that Pi = 0 is a chance that any household uses traditional energies given a set of socioeconomic and demographic characteristics.

3.4. Model Specification

The baseline Ordinary Least Square model used in the analysis For the main source of home lighting and source of cooking. Model 1 depicts the analysis related to the choice of lighting as the source of energy, while model 2 analyzed cooking.

Model1 : $lighting = \beta_0 + \beta_1 residence + \beta_2 Education + \beta_3 telephone + \beta_4 HHsize + \beta_5 poverty + \beta_6 \text{quintile} + \beta_7 \text{Sex} + \beta_8 \text{ dwelling} + \beta_9 \text{Maritalst} + \varepsilon$

Model2: $Cooking = \beta_0 + \beta_1 residence + \beta_2 Education + \beta_3 HHsize + \beta_4 poverty + \beta_5 \text{Sex} + \beta_6 \text{ dwelling} + \beta_7 \text{Maritalst} + \varepsilon$

Where β_0 : is the intercept ; $\beta_1, \beta_2, \beta_3 \ldots \beta_{10}$ are the coefficients

The analytical framework adopts the following logistic regression model,

For the main source of Lighting:

$$\frac{\partial P}{\partial X_j} = \beta_j \times P(1-P); \;\; j = 1,2,3 \ldots \ldots 10$$

For the main source of Cooking:

$$\frac{\partial P}{\partial X_j} = \beta_j \times P(1-P); \;\; j = 1,2,3 \ldots \ldots 6$$

Where P_i: Probability that any household uses modern energies (lighting or cooking)

X: vector of household characteristics in the model

β: vector of parameters

Table 3:List of variables used in the study with their descriptions

Name of Variable	Variable label/Explanation
lighting	Main Source of Home Lighting [1]
Cooking	Primary Source of cooking [2]
Residence	Area of residence
Education	Household head' level of education
Telephone	The household has a telephone,
HHsize	Household size
Poverty	Welfare categories
Dwelling	owner of the dwelling
Quintile	household quintile
Maritalst	Marital status of household head
Sex	Sex of household head

Source: Author's design, 2021

The results can be positive or negative, therefore a positive sign shows that the variable is increasing the likelihood of the outcome. whereas the negative it is reducing the likelihood of the outcome to happen. A large coefficient showing that the variable has a high impact on an outcome and small or nearly zero means that the effect is very low.

[1] Main source of home lighting has been categorized into two: Modern and traditional energies
Modern energies include: Solar, electricity from Eucl, Electricity from other distributors, oil lamp, candles, agatadowa, torch, batteries. The traditional energies include firewood

[2] Primary source of cooking has been categorized into two: Modern and traditional energies
Modern energies include: electricity , gas, biogas . The traditional energies include firewood, charcoal, kerosene, crop waste.

Table 4:Definition of the exogenous variables of logistic model for lighting and cooking fuel choice

Variable name	**Unit of account: modalities of variables**
Household size	1: household size <4, 2: household size=4 3: household size >4 [3]
Sex of the household head	1 if male, 0: female)
Marital status of the household head	1: Married 2: Mixed married 3: Single
Level of education[4] HH head	1: no education, 2: Primary 3: Secondary 4: University
HH has a telephone	1: household own telephone; 0: otherwise)
Residence	1: Urban, 0: rural)
Wealth categories of household	1: Severely poor, 2: Moderately poor 3: Non-poor
Quintile of household	1: quintile 1, 2: quantile 2 3: quantile 3 4: quantile 4 5: quantile 5
Owner of the dwelling	1: household owns its dwelling, 0; others[5]

Source: Author's design using EICV 5.

[3]Household size categorized into three categories, Household size<4, household==4, household>4

[4] Level of education is categorized into four main groups; no education combines pre-primary, those who don't know their education and have not completed P1. Primary combines Primary 1, 2, 3,4,5,6,7,8 and post-primary 1,2,3,4, 5,6,7,8; secondary combines Secondary 1 up to Secondary 6 University combines university 1 up to university 7.

[5] Others includes state, relatives, non-relatives, private company

CHAPTER IV: EMPIRICAL RESULTS AND DISCUSSION

4.1. Introduction

This part of the dissertation presents descriptive statistics and empirical analysis related to the energy use in form of cooking and lighting using Rwanda household data from EICV5 conducted to 14,580 households in 2016-2017. Furthermore, the chapter presents the nested empirical results of OLS, binomial logistic regression model, and Marginal effect of each explanatory variable to the outcome variables.

4.2. Descriptive statistics of households

The distribution of households is most important in any study which helps researchers to examine the correlations between different data from various variables considering responses from households. The socio-demographic characteristics measured in this research are Sex of household head, HH head education level, area of residence. The sampled 14,580 households reduce to 11172 households during the analysis and the findings are discussed in the below sections.

4.2.1. Distribution of the households by the main source of Home Lighting

Table 5 shows the main source of lighting in Rwanda. These results indicate that the number of households who use modern energies was 96.82%, whereas 3.18 % use traditional energies[6]. Implying that the highest number of people in Rwanda uses modern energies[7] for lighting, which depicts good progress in energy access.

Table 5: Distribution of the households by the main source of Home Lighting

The main source of Home Lighting	Freq.	Percent
Traditional energies	355	3.18
Modern energies	10817	96.82
Total	11172	100.00

Source: Author's computation using EICV5.

4.2.2. Distribution of the households by the main source of Cooking

Table 6 shows the distribution of the main source of cooking in Rwanda, these results indicate that the number of households who use modern energies was 1.59%, whereas 98.41 % uses traditional energies. Implying that

[6] Examples of traditional energies for lighting in this study include: firewood
[7] Some examples of modern energies for lighting in this study include; electricity, solar panel, torches, batteries, oil-lamp, candles

the highest number of people in Rwanda still rely on traditional energies for cooking.

Table 6:Distribution of the households by the main source of cooking

The main source of cooking fuel	Freq.	Percent
Traditional energies	10994	98.41
Modern energies	178	1.59
Total	11172	100.00

Source: Author's computation using EICV5

4.2.3. Distribution of household's head by education level

Table 7 indicates the distribution of education levels of household heads in Rwanda. Results indicate that out of all households head under study 3.71% have no education, 80.45% have primary, 10.72% have secondary and 5.11% have university education respectively. The majority of households head have primary level education (80.45%) followed by secondary education (10.72%).

Table 7: Distribution of the households by education level

Level of education	Freq.	Percent
No education	415	3.71
Primary	8988	80.45
Secondary	1198	10.72
University	571	5.11
Total	11172	100.00

Source: Author's computation using EICV5**.**

4.2.4. Distribution of the households by Residence

Table 8 shows rural-urban distribution among households, these results indicate that the highest number of households live in rural areas, 79.72%, the number of households living in urban is 20.28 %.

Table 8:Distribution of the households by residence

Area of Residence	Freq.	Percent
Rural	8906	79.72
Urban	2266	20.28
Total	11172	100.00

Source: Author's computation using EICV5

4.2.5. Distribution of the households by welfare categories

Table 9 shows welfare categories distribution among households, these results indicate that the number of households who belong to severely poor was 11.13%, the number of households belonging to the moderately poor category was 18.89 % in Rwanda and 69.98% are in the non-poor welfare category. Therefore, the highest number of households are in the non-poor category.

Table 9: Distribution of the households by welfare categories

Welfare categories	Freq.	Percent
Severely poor	1244	11.13
Moderately poor	2110	18.89
Non-Poor	7818	69.98
Total	11172	100.00

Source: Author's computation using EICV5**.**

4.3. Distribution of the main source of Lighting considering against the area of residence, Income Status (quantile), and education level

The results in table 10, have been computed based on the source of lighting split into electricity, semi-modern energies, firewood, solar panel to see the distribution across those different types of energy. As shown in table 10 households in rural areas more than a half use candles and torches for lighting their homes. Whereas the use of solar panels in rural areas is 10%, higher compared to urban areas. This is supported by the report on off-grid market assessment on Rwanda (Power Africa, 2019) which shows that the off-grid market in Rwanda is dominated by Solar Home Systems and solar lanterns. However, off-grid systems are rural-based aimed at helping people in rural areas to have access to electricity. This explicitly explains why solar panels are more highly used in rural areas.

Table 10:Distribution of the main source of Lighting considering the area of residence, quantile, and education level (in %)

Variable	**Categories**	**Source of lighting**				
		Electricity	Semi-modern energies1	Semi-modern energies2	Firewood	Solar Panel
Area of Residence	Rural	17.15	13.07	55.6	3.85	10.33
	Urban	78.68	4.99	15.27	0.53	0.53
Quintile	Q1	5.75	14.98	65.22	9.59	4.46
	Q2	10.31	14.23	64.63	3.82	7.01
	Q3	16.62	14.4	56.71	2.27	10
	Q4	27.41	11.96	46.85	2.1	11.67
	Q5	64.71	5.38	21.53	0.9	7.48
Education of head	No education	8.19	15.42	62.89	7.47	6.02
	Primary	22.56	12.91	52.15	3.5	8.88
	Secondary	60.93	4.17	27.13	0.58	7.18
	University	90.72	0.53	4.38	0.35	4.03

Source: Author's computation using EICV5

Table 10 shows that among households in urban areas the electricity takes a high proportion for lighting purposes, 78.68% of households use electricity. This is because in an urban area the access to electricity is high which ease its use for lighting home. The use of solar in urban areas is low (0.53%) compared to rural (10.33%) just because it is used when there are electricity outages. The results in table 10 show that among households of quantile 1 more than a half uses candles and torches when lighting, the same applies to quantile 2 and 3. The use of solar panels is low in quintiles 1 and 2 as they are not able to afford its cost themselves, in that case, government subsidies on products to ease the access to low-income households (MININFRA, 2018; Power Africa, 2019). The use of electricity in quintiles 4 and 5 are dominated over other sources of energy as they are wealthy, they can afford such expenses.

The use of semi-modern energies (candles and torches) also takes a significant proportion of about half of the total no educated headed households. This is because torches are mainly used in rural areas and are dominated by non-formal educated-headed households. The use of electricity increases with the increasing level of education, that is, the more household head gets educated. For the university-educated household heads, more than 90% percent use electricity for lighting, most of the time they own more appliances than mainly require much energy to work. This directly pushes them to adopt the use of electricity in their home. The number of modern energies users increases as the level of education increases. Conventionally, the use of firewood is decreasing as the level of education is increasing. Solar panels are not priorities in the household headed by higher educated people hence its use is not high as electricity.

4.4. Distribution of the main source of Lighting considering socio-demographic characteristics

Previously in table 10, the distribution was based on the three household characteristics namely area of residence, quintile, and education level and it considers all sources of lighting, each with respective users in the sample. Later, the analysis is based on the categorization of the source of lighting into traditional and modern energies to see the distribution with respect to socio-demographic characteristics of households. As shown in Table 11, among the households headed by non-educated people 7.47% uses traditional energies, which is higher compared to the other levels of education. This shows that the number of people who use traditional energies decreases as the level of education increases, for households headed by university-educated people about 99.65% uses modern energies. The high level of using modern energies among no-education households is attributed to the fact that the torches have been taken as modern sources yet they account for high proportions in our sample.

Table 11 results show that among the households with no telephone at home 93.51% uses modern energies, which is much higher compared to traditional energies users. When people decide to own a telephone in their home, this will decrease the traditional energies for lighting their home to 1.13% and switch to modern energies. The use of modern energy is positively correlated with telephone adoption at home as the telephone needs electricity to be charged, this can be a reason to increase modern energies adoption.

Table 11: Distribution of the main source of Lighting considering socio-demographic characteristics[8]

Variables	**Categories**	**The main source of Home Lighting**	
		Traditional energies	Modern energies
Telephone	No	6.49	93.51
	Yes	1.13	98.87
Level of education	No education	7.47	92.53
	Primary	3.5	96.5
	Secondary	0.58	99.42
	University	0.35	99.65
Household size	Household size <4	3.5	96.5
	Household size==4	2.7	97.3
	Household size>4	2.16	97.84
Area of Residence	Rural	3.85	96.15
	Urban	0.53	99.47
Welfare categories	Severely poor	10.21	89.79
	Moderately poor	4.64	95.36
	Non-Poor	1.66	98.34
Sex of household head	Female	6.04	93.96
	Male	2.48	97.52
Marital status HH head	Married	2.41	97.59
	Mixed married	6.35	93.65
	Single	3.45	96.55
Quintile	Q1	9.59	90.41
	Q2	3.82	96.18
	Q3	2.27	97.73
	Q4	2.1	97.9
	Q5	0.9	99.1

Source: Author's computation using EICV5.

Table 11 results indicate that among the households located in rural 3.85%, uses traditional energies when lighting their homes, which is higher compared to 0.53% for the urban households. While most households in

[8] The distribution of main source of home lighting with respect to different socioeconomic characteristics as depicted in table is expressed in terms of percentage (%).

urban use modern energies for lighting their home, this shows that urbanization has a positive influence on modern energies as they own many appliances that need energies to be working this can be a reason to increase modern energies adoption. Findings in Table 11 indicate that among the households with households' members less than 4 about 3.5 % use traditional energies, which is higher compared to a household with higher members. An increase in the number of household members shows a negative relationship with the uses of traditional energies but is positively associated with the uses of modern energies for lighting their home.

Accordingly, Table 11 shows that the choice of energy use depends on the welfare category in which the households belong, the results reveal that households which are severely poor 89.79% use modern energies (such as solar, torch, electricity) to light their homes, the number increases to those who are moderately poor, and non-poor categories. This explicitly shows that improvement or shift from the welfare category to another has a negative correlation with the use of traditional energies and with a positive impact on using modern energies when lighting.

Considering the sex of the household head, the results in Table 11 show that among female-headed households 93.96% uses modern energies which is quite similar to male-headed households of which 97.52% uses modern energies. This shows that male uses modern energies greater than female but there is little difference. For the household head marital status, the results reveal that households headed by those who are mixed married 6.35% use traditional energies high compared to married peoples, and singles among households headed by married,97.59% uses modern energies. Marital status has a significant impact when people move from one to another (single to married).

Considering the quintile in which a household belongs, the results in table 11, show that 90.41% of households in the first quintile uses modern energies, whereas, in subsequent quintiles, the numbers of modern energy users increase which implies decreases in traditional energies users. The results highlight that the shift from one quintile to another has a significant impact on energy choice for lighting.

4.5. Distribution of the main source of Cooking considering the area of residence, quantile, and household head education level

The analysis is based on all cooking fuels and three household characteristics to capture the distribution, this shows how many users on each cooking fuel considering the area of residence, quintile, and HH head education level. Table 12 shows the correlation and distribution of the main source of cooking for the area of residence, quintile, and education level of households. The results in table 12 show that among households headed by primarily educated people, more than (80%) still use firewood when cooking. In these categories of households, the use of charcoal is still low. That is because they do have not full knowledge of the consequences of using firewood on health, environment (Such as deforestation), and country economic development.

The education level plays an important impact in the reduction of using firewood for example results show that for secondary and university heads of households the use of firewood has decreased which results in a significant shift to charcoal and gas respectively.

Table 12:Distribution of the main source of Cooking considering the area of residence, quantile, and education level (in %)

Variables	**Categories**	**Source of Cooking**					
		Firewood	Charcoal	Gas	Biogas	Electricity	Oil or kerosene
Highest education level attained by head of HH	Primary	82.5	17.15	0.27	0	0.03	0.06
	Secondary +TVET	49.46	46.47	3.83	0.08	0.08	0.08
	Postsecondary	20.04	60.57	18.3	0	0.87	0.22
	Post graduate	1.82	69.09	27.27	0	1.82	0
Area of residence	Rural	93.5	6.23	0.2	0.04	0.02	0
	Urban	28.33	64.87	6.35	0	0.26	0.18
Quintile	Q1	98.58	1.42	0	0	0	0
	Q2	97.07	2.93	0	0	0	0
	Q3	92.78	7.22	0	0	0	0
	Q4	86.36	13.56	0.04	0.04	0	0
	Q5	47.05	47.28	5.19	0.1	0.26	0.13

Source: Author's computation using EICV5.

The results show that in households in rural areas most of them use firewood as cooking fuel, this differs to urban dwellers more than half use charcoal and the use of gas as fuel is still low and needs some remarkable policies to increase such fuel usage in communities. Those reinforced by the report of (MININFRA, 2018) indicated that the wood is mostly used in rural areas while charcoal is mostly used by urban households.

The results in table 12 reveal that quantile has a significant impact in determining the cooking fuel, households in three lower quantiles (quantile 1 up 3) more than 90 percent use firewood. The results in table 12 show clearly that the use of firewood decreases significantly as one moves to the upper quintiles. The use of charcoal also is increasing in upper quintiles households. The use of gas and electricity are taking part in quintile 5 but at low proportion. However, firewood and charcoal are still dominating cooking activities in Rwanda those are reinforced by (MININFRA, 2018) who stated that biomass[9] is still dominating with 85% of total energy consumption in Rwanda. Firewood is still dominating cooking activities as cited by (Bimenyimana et al., 2018).

4.6. Distribution of the main source of Cooking considering socio-economic characteristics

Previously in table 12, the distribution was based on the three household characteristics namely area of residence, quintile, and education level, and consider all sources of cooking, each with respective users in the sample. Later, the analysis is based on the categorization of the source of cooking into traditional and modern energies to see the distribution with respect to socio-demographic characteristics of households.

Table 13 shows the correlation and distribution of the main source of cooking for different selected socio-economic characteristics of households. These results indicate that among the households headed by primarily educated people 99.64% uses traditional energies when cooking, which is highest compared to the other levels of education. The results show that the number of households that use traditional energies decreases as the head level of education increases reaches 70.91% for households headed by postgraduates (Masters and Doctorate) educated people. The number of modern energies users increases as the household head level of education increases from 0.36 to 29.09%. The results in Table 13 indicate that among the households located in rural areas (99.73%) use traditional energies when cooking in their homes, which is the highest compared to the urban people. 93.2% of urban people use traditional energies when cooking, this shows that most people captured in a study of EICV5, use traditional energies for cooking over the modern ones.

[9] Biomass include wood, charcoal, and biogas

Table 13:Distribution of the main Energy source for cooking considering socio-demographic characteristics[10]

Variables	**Categories**	**The main source of cooking fuel**	
		Traditional energies	Modern Energies
Education Level of HH head	Primary	99.64	0.36
	Secondary +TVET	95.94	4.06
	Postsecondary	80.61	19.39
	Post graduate	70.91	29.09
Area of residence	Rural	99.73	0.27
	Urban	93.2	6.8
Household size	Household size <4	98.29	1.71
	Household size==4	99.03	0.97
	Household size>4	98.43	1.57
Marital status	Married	98.84	1.16
	Mixed married	99.31	0.69
	Single	93.65	6.35
Sex of household head	Female	98.31	1.69
	Male	98.43	1.57
Welfare categories	Severely poor	100	0
	Moderately poor	100	0
	Non-Poor	97.72	2.28
Quintile of household	Q1	100	0
	Q2	100	0
	Q3	100	0
	Q4	99.92	0.08
	Q5	94.33	5.67

Source: Author's computation using EICV5**.**

This shows that urbanization has a positive influence on modern energies but there is no significant big difference in modern energies adoption among rural and urban households for the choice of cooking fuels. Table 13 results indicate that among the households with households' members less than 4, 98.24 % uses

[10] The distribution of main source of cooking with respect to different socioeconomic characteristics as depicted in table is expressed in terms of percentage (%).

traditional energies, which is low compared to a household with higher than 4 members. In the case of household head marital status, the results show that 99.31% of mixed married (this includes divorced, widow, separated) households use traditional energies higher compared to those 98.84% married and 93.65% for households headed by single. Implying that, there is a significant difference in the use of traditional energies based on marital status. Considering the sex of the household head, the results in Table 13 show that among female-headed households 98.31% uses traditional energies which is quite similar to male households' 98.43%. This shows that male uses modern energies greater than female but there is no big difference.

Accordingly, Table 13 shows that the choice of energy use depends on the welfare category in which the households belong, the results reveal that both severely poor and moderately poor households all use traditional energies (such as firewood, charcoal, crop wastes,) for cooking in their homes, and the number decreases with those who are in the non-poor category. This shows that improvement or shift from the lower welfare category(poor) to the upper welfare category (non-poor) decreases the possibilities of using traditional energies and increases the possibilities of using the modern energies when cooking. The same for the quintiles, the results in table 13, shows that 100% of households in the first three quintiles use traditional energies, and the use of traditional energies decreases as you move to the upper quantiles (quintile 4 and 5) while increasing the use of modern energies. This shows a shift from lower quintiles to upper quintiles has an impact on the choice of cooking fuel.

4.7. Results of Ordinal Least Square Regression for Lighting and Cooking as Dependent Variables

The ordinary least square presents the effects of each selected covariate to the outcome variables holding other variables constant as depicted in Table 14. The results show that household located in an urban area has a positive effect on using modern energies for lighting. Being in an urban area increases statistically significantly the chance of using modern energies when lighting by 1.25 percentage points rather than in rural households. This shows the role of urbanization in boosting up the use of modern energies for lighting. Similarly, being in an urban area increases the chance of using modern energies for cooking by 3.78% than those households in rural areas.

The results show that household head being married increases the probability of using modern energies for lighting by 2.12% more points than being single. Similarly, being married decreases significantly the chance of using modern energies when cooking by 3.18 % rather than single people. The result shows that being mixed married (separated, widow, divorced) people decrease statistically insignificantly the chance of using modern energies when lighting by 0.25% rather than single. Similarly, it decreases significantly chance of using modern energies when cooking by 3.38% than single people. This seems to be attributed to the fact that the divorced, separated, widowed people sometimes may have children and can limit them using modern energies for cooking (tend to use firewood to reduce costs) mostly in rural areas.

Table 14 shows that owning a telephone increase statistically significantly the probability of people using modern energies when lighting by 3.21 percentage points than no telephone owners. This can be attributed to the fact that the telephone requires energy to function so this is the reason for the modern energy adoption for telephone owners. Considering the welfare categories, the results in table 14 show that moderately poor people increase statistically significantly the chance of using modern energies for lighting by 2.61 percent points rather than a severely poor group of people. While being in moderately poor people increases statistically significantly the chance of using modern energies for cooking by 0.16 percentage points rather than a severely poor group of people. On average, being non-poor households increases statistically and significantly the chance of using modern energies for lighting by 4.90 percentage points than a severely poor group of people. Similarly, it decreases the probability of using modern energies for cooking by 0.30 percentage rather than being in a severely poor category of people but insignificant.

The results in Table 14 shows that on average being in quintile 2 increases statistically significantly the probability of using modern energies for lighting by 3.18 percent points rather than quintile 1. While being in quintile 2 decreases the chance of using modern energies for cooking by 0.46 percentage points rather than quintile 1 people but insignificant. On average being in quintile 3 increases statistically insignificantly probability of using modern energies for lighting by 2.40 percent points rather than quintile 1. On other hand, being in quintile 3 decreases the chance of using modern energies for cooking by 0.93 percentage points rather than quintile 1 people by insignificant.

Table 14 shows that being in quintile 5 increases the statistically insignificant probability of using modern energies for lighting by 2.75 percent points rather than quintile 1. Similarly, being in quintile 5 increases statistically insignificantly the chance of using modern energies for cooking by 0.46 percentage points rather than quintile 1 people. The ownership of the dwelling has no significant effect on using modern energies for lighting compared to non-owners.

Table 14:Results of Ordinary Least Square (OLS) Regression Analysis for Lighting and cooking[11]

VARIABLES	OLS Light	OLS Cook
Area of Residence (Urban)	0.0125**	0.0378***
	(0.005)	(0.006)
Marital status HH head (Married)	0.0212***	-0.0318***
	(0.007)	(0.009)
Marital status HH head (Mixed married)	-0.0025	-0.0338***
	(0.008)	(0.011)
Household owns telephone	0.0321***	
	(0.004)	
Welfare categories (Moderately poor)	0.0261**	0.0016
	(0.010)	(0.018)
Welfare categories (non-Poor)	0.0490***	0.0030
	(0.017)	(0.028)
Quintile of household (Q2)	0.0318***	-0.0046
	(0.010)	(0.018)
Quintile of household (Q3)	0.0240	-0.0093
	(0.017)	(0.028)
Quintile of household (Q4)	0.0231	-0.0159
	(0.017)	(0.028)
Quintile of household (Q5)	0.0275	0.0046
	(0.017)	(0.028)
Household owns dwelling	-0.0011	-0.0072
	(0.004)	(0.006)
Household own a computer	-0.0000	
	(0.011)	
Sex of the household head (male)	0.0057	-0.0092
	(0.007)	(0.009)
Level of education HH head (Primary)	0.0176**	
	(0.009)	
Level of education HH head (Secondary)	0.0225**	
	(0.010)	
Level of education HH head (University)	0.0120	
	(0.013)	
Household size (Household size==4)	0.0106**	-0.0085
	(0.005)	(0.007)

[11] **Reference categories used in Ordinary Least Regression analysis**

Level of education: No education; Area of residence: Rural; household own telephone: No; Household own computer: No; Dwelling ownership: owned by others ; welfare categories : Severely poor ; Marital status : Single ; Quintile of household : Quintile 1 ; Household size : Household size<4 ; Sex of respondent : Female

Household size (Household size>4)	0.0124*** (0.005)	-0.0041 (0.006)
Highest education attained of HH head (Secondary+ TVET)		0.0158*** (0.006)
Highest education attained of HH head (Postsecondary)		0.1536*** (0.009)
Highest education attained of HH head (Postgraduate)		0.2483*** (0.023)
Constant	0.8445*** (0.012)	0.0444*** (0.013)
Observations	11,172	5,160
R-squared	0.045	0.136

The results were obtained by running ordinary least square regression using Stata 15. standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; shows statistically significant

Source: Author's computation using EICV5.

Whereas, dwelling ownership by households decreases statistically insignificantly the probability of using modern energies for cooking compared to non-owners. The table 14 results show that the household that owns a computer decreases statistically insignificantly the probability of using modern energies for lighting than non-owners. Male-headed household increases insignificantly the chance of using modern energies when lighting and decreases insignificantly the chance of using modern energies when cooking than female-headed household.

The households head with primary education level increase statistically significantly the chance of using modern energies for lighting by 1.76 percent point rather than household head with no education. Household head with secondary education increases statistically significantly the probability of using modern energies for lighting by 2.25% rather than no education people. University-educated heads of household statistically insignificantly increase the probability of using modern energies for lighting than those with no education.

The household size of greater than 4 members increases statistically significantly the chance of using modern energies when lighting by 1.24 % rather than a household with less than four members. Similarly, the household size greater than 4 decreases statistically insignificantly the chance of using modern energies when cooking by 0.41 % rather than household size with less than 4 members. The household size equal to 4 has increased statistically significantly probability of using modern energies when lighting by 1.06 % than a household with less than four members. Similarly, it increases statistically insignificantly the chance of using modern energies when cooking by 0.85 % rather to households with less than four members.

Households head by secondary and TVET educated people have to increase statistically significantly the probability of using modern energies for cooking compared to those with no more than primary education. Similarly, the postsecondary education of household heads has a positive significant impact on the probability of using modern energies in the household for cooking compared to those with no more than primary education. The same, postgraduate (masters, doctorate) education for the household head has increased significantly the probability of using the modern energies for cooking in the household compared to those with no more than primary education.

4.8. Results of Logistic Regression Model

By using STATA Statistical Software, we have got the following results presented in Table 15. The sample size of the study was decreased from 14,580 households to 11,172 households for the lighting model and 5160 households for the cooking model. This is because during the interview some households have not answered the questions which have been taken as missing values in data entry during EICV5. As variables contain some missing values, during the analysis we used only valid observations. Binary Logistic regression [12]was selected because the response variables; source of lighting and source of cooking are dichotomous (modern energies vs traditional energies). Furthermore, logistic regression provides an opportunity to investigate multiple factors at a time and estimate the effect of one factor.

The results in table 15 show that for household heads, having a primary education level increases statistically and insignificantly the probability of using modern energies for home lighting by 0.91 percentage points than having no formal education. Having secondary education increases statistically significantly the probability of using modern energies for lighting by 2.60 percent points than having no education.

Household head university education statistically insignificantly increases the probability of using modern energies in-home lighting by 1.89 percent points than having no education. Implying that education increases the probability of using modern energies for lighting and cooking in Rwanda, and this probability increases with an increase in the level of education. This can be attributed to the fact that the higher education the more

[12] Traditional energies have been taken as reference category for our binary logistic model

you are aware of the effects of using traditional energies, this boosts up the use of modern energies among educated communities. These findings are reinforced by similar empirical findings from China by (Démurger & Fournier, 2011) who find that more educated people tend to use modern energies.

The results in table 15 show that living in urban areas statistically and significantly increases the probability of using modern energies for lighting by 3.34 percent points than living in rural areas. Similarly, being in urban areas increases statistically significantly the chance of using modern energies for cooking by 4.40 percent points compared to living in rural areas. This is reinforced by the descriptive analysis (in section 4.3.) and can be attributed to the fact that urban areas use gas, electricity for cooking.

The ownership of a telephone in a household increases statistically and significantly the probability of using modern energies for home lighting by 3.13 percent points rather than those who do not own a telephone in their households. Those findings are reinforced by descriptive analysis and can be attributed to the reason that the telephone requires electricity to work this pushes people to use some types of modern energies.

The results in table 15 show that being in both moderately poor and non-poor people's socio-economic categories show no significant increases in the probability of using modern energies for lighting than severely poor people. The effect of married household head on the increasing probability of using modern energies for lighting is statistically significant compared to single. Similarly, the household head being married decreases the statistically significant probability of using modern energies for cooking purposes by 1.39 percent points rather than the single household head.

While for mixed married[13] household heads, the results show that their effect on the probability of using modern energies is not statistically significant for both cooking and lighting purposes compared to single. The ownership of dwelling by household decreases statistically insignificant the probability of using modern energies for lighting by 0.19 percent points rather than non-owners (dwelling owned by state, relatives, non-relatives, private company). Similarly, the results show that ownership of dwelling by household decreases statistically significantly the probability of using modern energies for cooking by 1.19 percent points rather than non-owners (dwelling owned by the state, relatives, non-relatives, a private company. The results in table 15 show that belonging in quantile 2 increases statistically significantly the probability of using modern

[13] Mixed married includes separated, divorced, widowed

energies than quantile 1 people for lighting purposes. The results in table 15 show that belonging in quintiles 3, 4, and 5 show no significant impact in increasing the probability of using modern energies compared to quintile 1. Household members more than 4 seem to increase statistically significantly the probability of using modern energies for lighting rather than a household with members less than 4. But has no significant effect on using the probability of using cooking modern energies.

The results are consistent with other people's findings (Fydess Khundi-Mkomba et al., 2020) who found that household size has a positive effect on the use of solar panels and batteries with bulbs, with a negative impact on the use of fuelwood for home lighting in Rwanda. The results in Table 15 show that household members equal to 4 increase statistically significantly the probability of using modern energies for lighting by 1.04 percent points than a household with members less than four. Similarly, its effect on decreasing the probability of using modern energies for cooking is not statistically significant.

Table 15:Results of Logistic Regression Model for Lighting & Cooking[14]

VARIABLES	Lighting coefficient	Lighting marginal	Cooking coefficient	Cooking marginal
Level of education of HH head (Primary)	0.2755	0.0091		
	(0.198)	(0.007)		
Level of education of HH head (Secondary)	1.0768**	0.0260***		
	(0.437)	(0.009)		
Level of education of HH head (University)	0.6690	0.0189		
	(0.790)	(0.018)		
Area of Residence (Urban)	1.1504***	0.0334***	1.6600***	0.0440***
	(0.315)	(0.009)	(0.272)	(0.008)
Household owns telephone	1.0776***	0.0313***		
	(0.137)	(0.004)		
Welfare categories (Moderately poor)	0.3347	0.0155		
	(0.224)	(0.012)		
Welfare categories (non-Poor)	1.2160*	0.0403		
	(0.641)	(0.026)		
Marital status HH head (Married)	1.0475***	0.0378***	-0.4901**	-0.0139**
	(0.247)	(0.012)	(0.232)	(0.007)
Marital status HH head (Mixed married)	0.1943	0.0096	-0.4316	-0.0124

[14] **Reference categories used in logistic analysis**

Level of education: No education; Area of residence: Rural ; household own telephone: No ; Household own computer: No ; Dwelling ownership : owned by others ; welfare categories : Severely poor ; Marital status : Single ; Quintile of household : Quintile 1 ; Household size : Household size<4 ; Sex of respondent : Female

	(0.221)	(0.011)	(0.363)	(0.010)
Household owns dwelling	-0.0664	-0.0019	-0.4506**	-0.0119**
	(0.152)	(0.004)	(0.221)	(0.006)
Quintile of household (Q2)	0.6041**	0.0177**		
	(0.236)	(0.009)		
Quintile of household (Q3)	0.2538	0.0086		
	(0.648)	(0.022)		
Quintile of household (Q4)	0.2745	0.0092		
	(0.647)	(0.022)		
Quintile of household (Q5)	0.6757	0.0193		
	(0.665)	(0.019)		
Household size (Household size==4)	0.3803**	0.0104**	-0.4145	-0.0099
	(0.178)	(0.004)	(0.335)	(0.007)
Household size (Household size>4)	0.4849***	0.0127***	-0.0588	-0.0016
	(0.185)	(0.004)	(0.266)	(0.007)
Sex of the household head (male)	-0.1400	-0.0041	-0.3123	-0.0083
	(0.239)	(0.007)	(0.251)	(0.007)
Highest education HH head (Secondary + TVET)			1.7865***	0.0237***
			(0.343)	(0.004)
Highest education HH head (Postsecondary)			3.3271***	0.1050***
			(0.354)	(0.013)
Highest education HH head (Postgraduate)			3.8076***	0.1528***
			(0.465)	(0.038)
Constant	0.8011***		-5.2610***	
	(0.296)		(0.357)	
Observations	11,172	11,172	5,160	5,160

Results were obtained by running a binary logistic regression model using Stata 15. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 statistically significant variables.

Source: Author's computation using EICV5

The household head being male decreases the probability of using modern energies by 0.41% than female but is insignificant. Similarly, the household head being male decreases the probability of using modern energies by 0.03% for cooking rather than female people but is also not statistically significant.

Considering the highest education diploma /degree or certificate attained the household head with secondary and TVET certificates increases statistically significant the probability of using cooking modern energies by 2.37% compared to those with no more than primary education. Postsecondary (Baccalaureate, license, Engineer) increase the probability of using cooking modern energies by 10.5 % points compared to household heads who completed no more than primary education. The postgraduate (masters, doctorate) household head increases antisocially significant the probability of using cooking modern energies by 15.28% points compared to those with no more than primary education.

4.9. Marginal effects plots

4.9.1. Marginal Effects of poverty status on lighting

The average marginal effects (dy/dx) are determined by taking the partial differentiation of the outcome variable with respect to the predictor's variables. In this study, we considered poverty status, area of residence, education level, and quintiles. As depicted in figure 7, the predictive average marginal effects of poverty status are positive and statistically significant. This reflects that if people shift from poverty status (moderately poor) to non-poor the marginal effects on lighting increase accordingly.

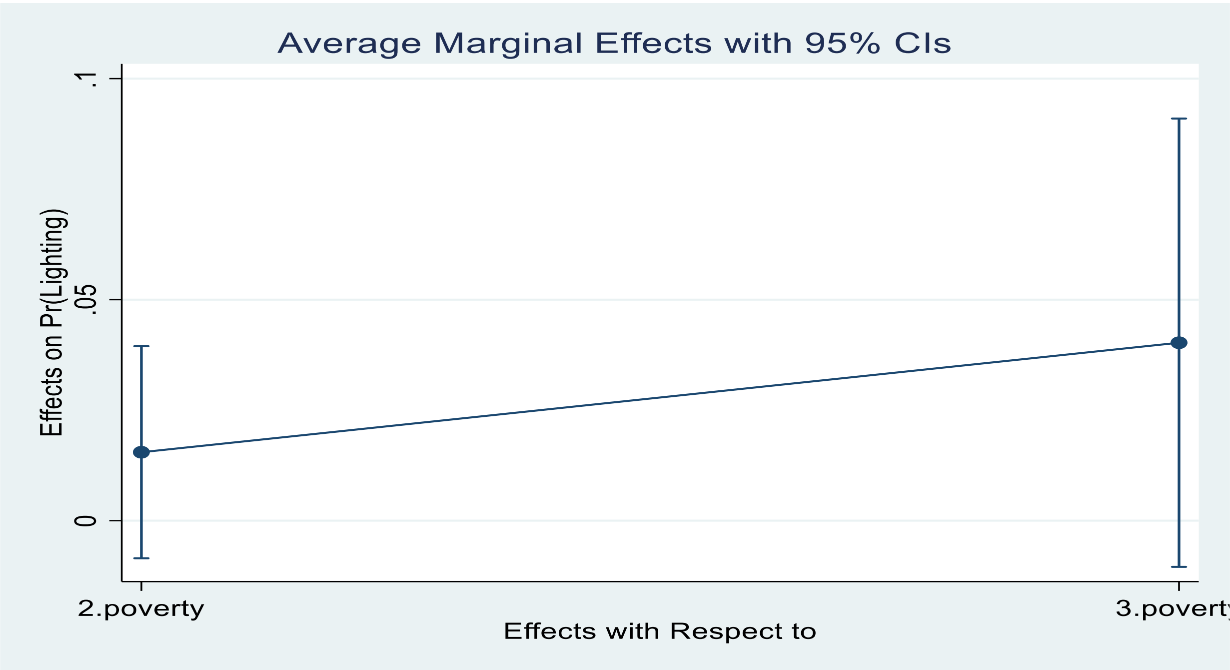

Figure 7:Predictive Marginal Effects of poverty status on lighting

Source: Author's computation using EICV5

4.9.2. Marginal Effects of education on lighting and cooking

Figures 8 and 9 show the predictive marginal effects of the education level on probabilities of using modern energies for lighting and cooking respectively, the trends in the figures show that with an increase in education level the marginal effects of using modern energies for both lighting and cooking will increase. This reflects that with higher education the probabilities of using modern energies in lighting and cooking increase statistically at a significant rate. Implying that, any change in the education level, statistically and significantly increase the consumption rate for modern energies in form of lighting and cooking. This is because the more educated people are aware of the effect of using the traditional energies for both cooking and lighting purposes. Meanwhile, the case using modern lighting energies probabilities increases from primary to secondary holders but decreases from secondary to a household headed by university-educated peoples.

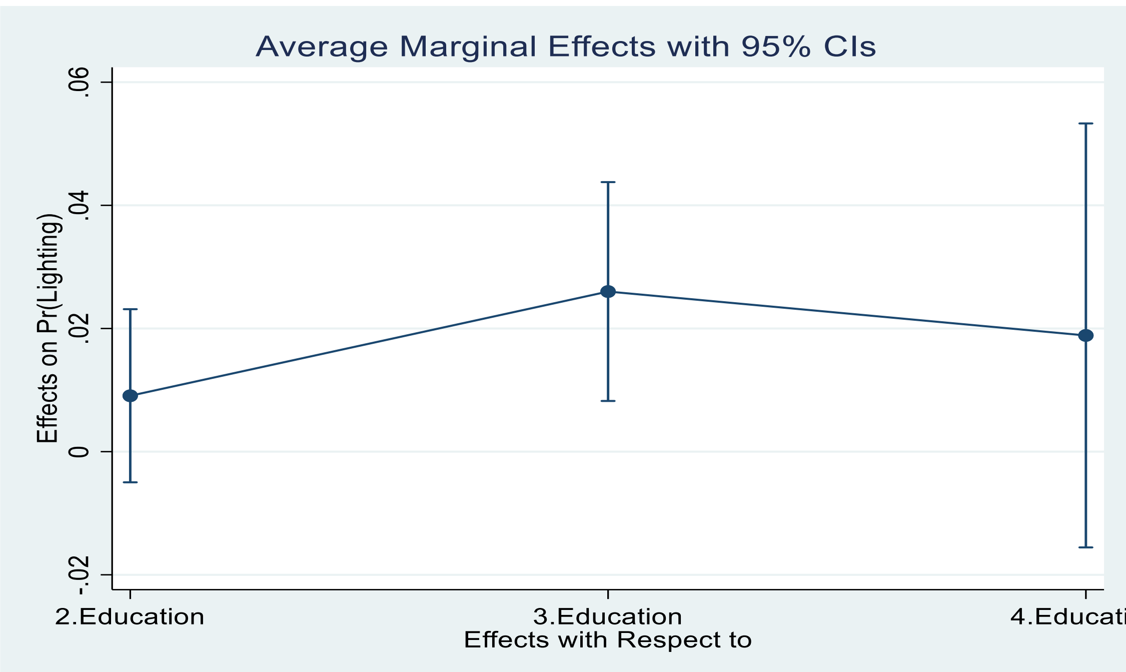

Figure 8:Predictive Marginal Effects of education on lighting

Source: Author's computation using EICV5

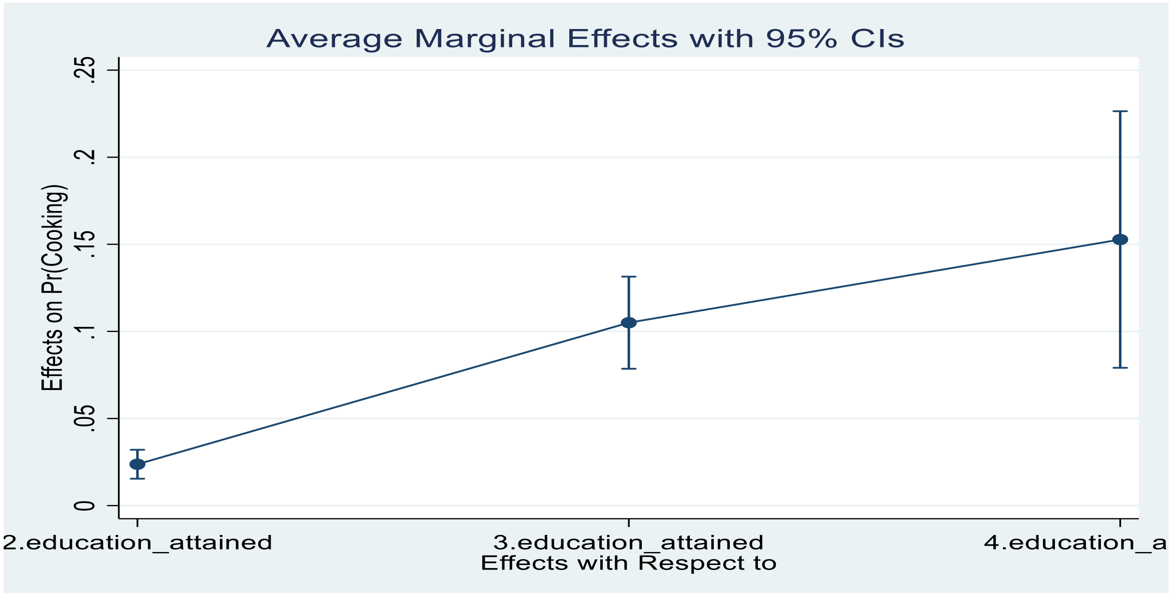

Figure 9:Predictive Marginal Effects of education on cooking

Source: Author's computation using EICV5

4.9.3. Marginal Effects of the area of residence on use of modern energies for lighting and cooking

The figure10 and 11 show the predictive marginal effects of the residence on the use of modern energies for lighting and cooking probabilities respectively, the trend in figures show that with migration from rural areas to urban areas the marginal effects on using modern energy for lighting will decrease this is attributed to the fact that in our sample torches represent nearby a half and classified as modern energies, and are mostly used in rural areas. That is where the rural areas tend to increase the probabilities of using modern energies for lighting. Figure 11 reflects that the move from rural to urban areas increases predicted average marginal effects of using modern energies for cooking increase at a statistically significant rate. This is because the urban dwellers are aware of the effect of using the traditional energies for cooking on both environments and their daily life and most of the time urban dwellers have the capacity to pay for those modern energies like gas, electricity for cooking.

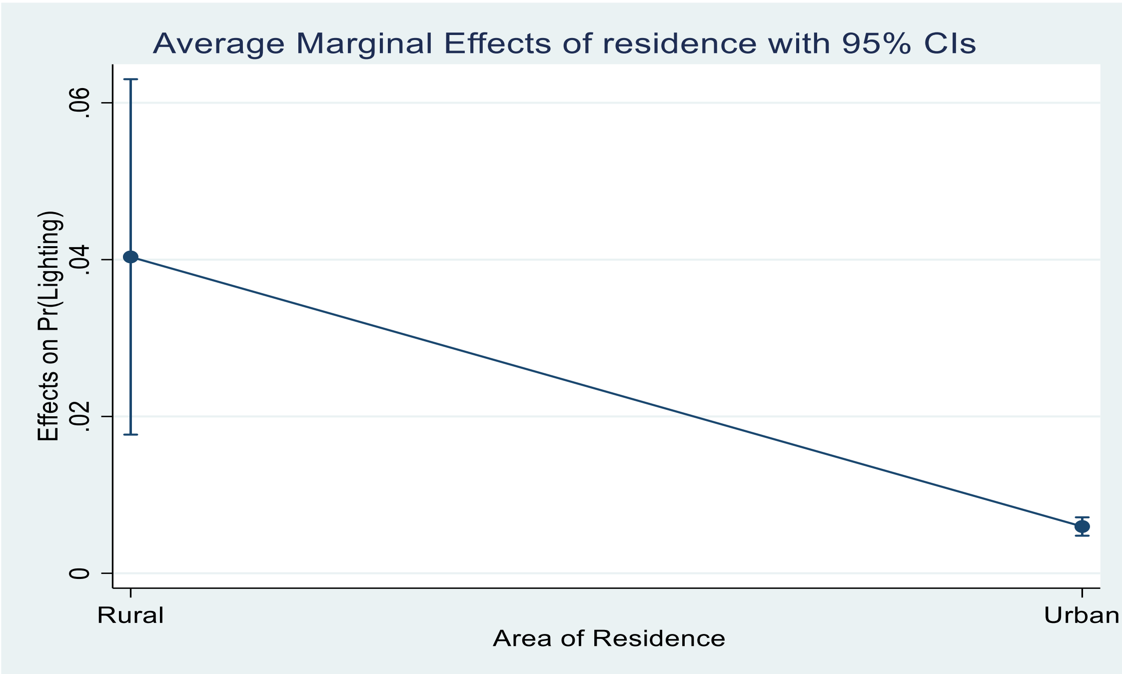

Figure 10:Predictive Marginal Effects of the area of residence on lighting

Source: Author's computation using EICV5

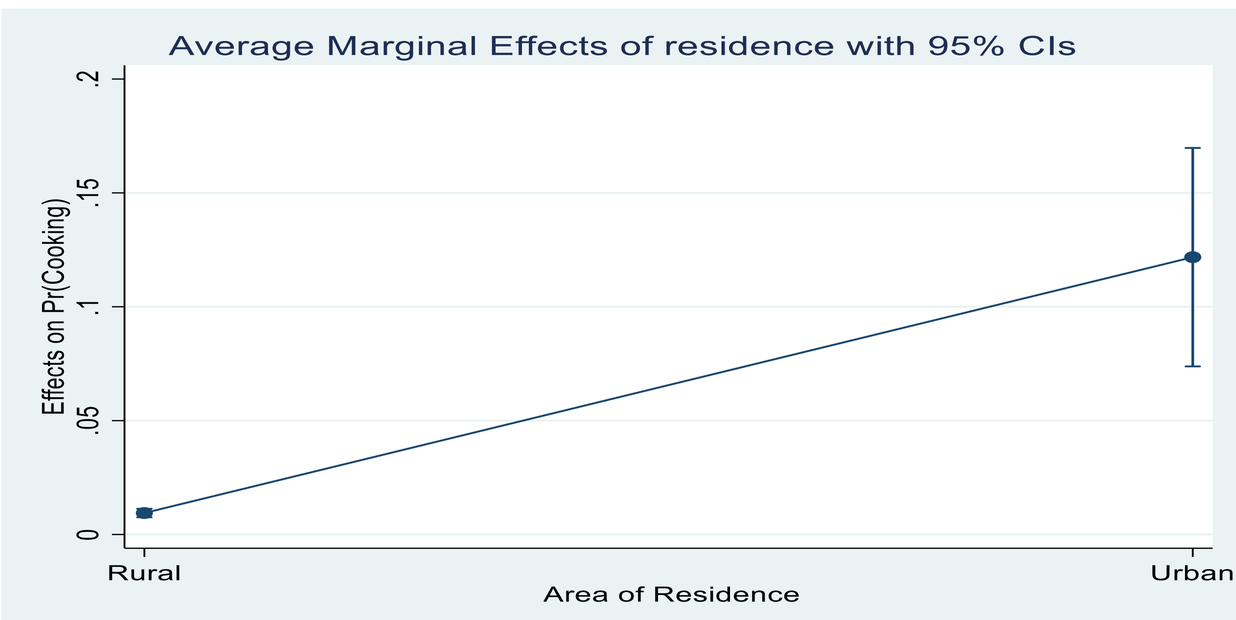

Figure 11:Predictive Marginal Effects of residence on cooking

Source: Author's computation using EICV5

4.9.4. Marginal Effects of quintile on lighting

Figure 12 shows the predictive marginal effects of the quintile (income levels) on probabilities of using modern energies for lighting, the trend in the figure shows that with any shift from quintile2 to quintile3, the marginal effects on using modern energies for lighting will decrease, between 3 and 4 the probability is constant and increases in quintile 5 households.

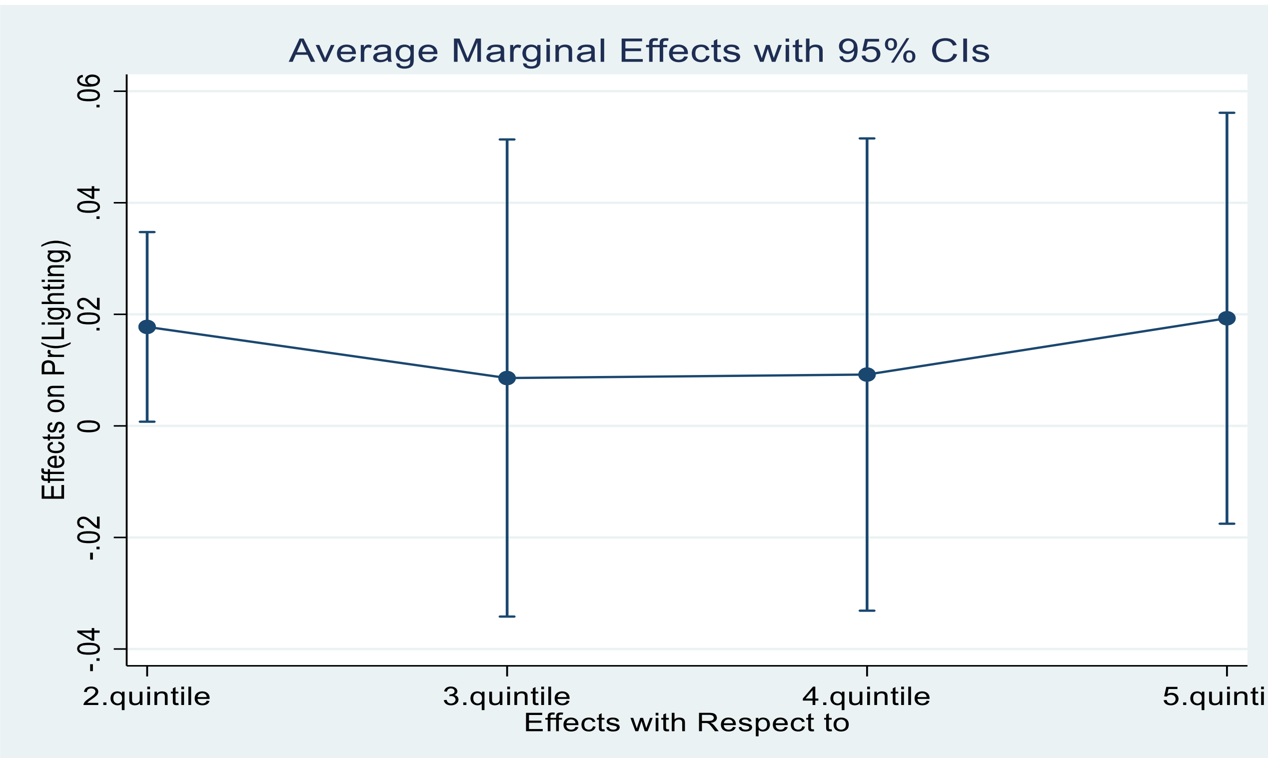

Figure 12:Predictive Marginal Effects of quintile on lighting

Source: Author's computation using EICV5

That reflects that in the upper quintile, probabilities of using modern energies for lighting correspondingly increase statistically and significantly. Implying that, high-income levels households are associated with the consumption of modern energies for lighting because the rich can afford to pay for electricity, solar panels.

CHAPTER V: SUMMARY, CONCLUSION, AND POLICY IMPLICATION

This chapter presents the summary of all findings of the study, conclusion, and policy implications. It also suggests future areas of study.

5.1. Summary of the Main Findings

The study revealed that the use of modern energies for lighting purposes in Rwanda is about 96.82%, which is showing tremendous achievement in modern energies uptakes. On other hand, only 3.18 % of the total sample uses traditional energies (firewood) for lighting. However, 98.41% of the total sample uses traditional energies for cooking. Putting Rwanda at a high rate in terms of traditional energy usage in Africa. In sub-Saharan Africa, access to clean cooking energy slightly increased from 15% in 2015 to 17% in 2018 (IEA, 2018)

The study findings showed that the use of modern energies for lighting in Rwanda is statistically and significantly influenced by socio-economic and demographic factors such as household head marital status(married), residence, HH head education level, quintile, welfare categories (income distribution), household size as well as ownership of telephone in the household. The study finds that living in urban areas increases the probability of using modern energies for both lighting and cooking compared to those living in rural areas. The study also finds that being household-headed by males shows insignificantly decreases in the probability of using modern energies for both lighting and cooking in Rwanda. Households headed by married people significantly increase the probability of using modern energies for lighting than single people. The study findings showed that households headed by secondary educated people strongly increase the probability of using modern energies for lighting and households headed by university-educated show no significant impact on lighting energies choice. A household headed by people with secondary for including TVET, postsecondary (Bachelors, engineers), and Postgraduate (masters and doctorate) strongly influence positively the choice of modern cooking energies. Household size has a significant positive impact on the use of modern energy for lighting in Rwanda.

Furthermore, the current study reveals that household head sex has no significant impact on the choice of energy fuels either for lighting or cooking in their home. The level of income (quintile) has a significant impact on energy choice in Rwanda, which means that moves from quintile 1 to the upper quintile 2 have a significant increase in the use of modern energies for lighting purposes among households. This can be attributed to the fact that the income distribution has a significant impact on spending, the more use of modern energies, the more spending. This study shows evidence regarding modern energies as being the most dominant fuels for most households for lighting their homes. This study also found that traditional energies are the most dominant source of energy used for cooking to the households belonging to all wealth status levels even across different quintiles 1 to 5.

5.2. Conclusion

This study presented a framework for analyzing determinants of energy consumption fuel choices in Rwanda by employing a binary logistic regression model using a nationally representative household-level dataset EICV5 conducted by NISR in 2016-2017 with both rural and urban households. The study examines the probability of each selected explanatory variable in determining the use of modern energies for cooking and lighting, where traditional energies are used as a reference category. The methodological and empirical analysis of this study is embedded in the theoretical framework of the energy ladder, social cognitive theory, and theory of planned behavior.

The study found that household welfare category, quintile, household size, ownership of telephone, HH head education level, HH head marital status, and area of residence is among the important factors that significantly influence the household choice of fuels for lighting and cooking purposes in their homes. The findings reveal that the uptake of modern energies for lighting (solar, electricity) and cooking (gas, electricity) is still at a low rate. The majority of households (98.41%) still use traditional energies for cooking including charcoal, firewood, which harm the environment, affect climate change, and bring adverse health effects on people. This low modern energy use can be a result of the poverty status of people in most of developing countries as well as Rwanda. Where some people cannot afford the costs of modern energies from either mini-grids or Solar home systems which hinder accessibility and energy use. Due to the constraint of data availability and composition where the dataset doesn't contain all information that can help explain household energy fuel choice, the study didn't include all factors that may influence households to choose modern energies over traditional ones or vice versa. Therefore, there is a need for further inclusion of other important variables such as tastes, attitudes, perception, and awareness levels about clean energy technologies would be helpful.

5.3. Policy implication

The policy implications are informed by the analysis and the findings of the study. Therefore, this study provides the following policy implications.

- To encourage the urbanization policy as well as to reduce the wealth inequality across different regions of the country to help people to lift up their welfare status may help households to switch to clean and modern energy sources in case of lighting as well as cooking purposes.
- Also, the enhancement of education policy in the country will reduce the use of traditional sources to mitigate the adverse health effects on people across the country as education have a significant impact on modern energies use.
- The use of gas (LPG) is still low, this should be increased by avail gas cylinders and regularize the cost of that fuel so as all people can afford to pay it. Subsidizing the gas distributors to encourage them to increase energy supply.

5.4. Suggestions for Future Research

Future studies could investigate the factors that influence the uptake of renewable energies in Rwanda and by including the ease of access, per capita income, occupation, and psychological factors in the analysis. researchers also could investigate the energy use by different economic sectors in Rwanda to show which economic activities use more energy.

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The link for the EICV5 questionnaire

Rwanda - Integrated Household Living Conditions Survey (EICV5), 2016-2017, VUP