Dissertation Title: The factor influencing the adoption of improved cook stove for low-income households. Case of Rwanda

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Declaration

I, the undersigned, declare that this Project proposal is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials used in work have been fully acknowledged in the correct academic format.

HAGENIMANA Jean Claude

DEDICATION

To

My Lovely parents;

Brothers, Sisters, and relatives

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ABSTRACT

Majority of rural households in developing country uses traditional cooking technologies with high-energy inefficiency and biomass use. The results are a high pressure on forest that serves as source of firewood. The improved cook stove has been promoted as potential solution to slow the loss of biomass. Majority aim of study was based on assessment of factors influencing adoption of improved cook stoves among low income households in different sectors of Gisagara district. To achieve this, the study assessed the cooking technologies and energy use among households, determined factors associated with the adoption of cook stoves, and assessed the benefits of adopting and using improved cook stove among low income households in Gisagara. A sum of 398 households was sampled form 77,259 households in Gisagara sectors and questionaires administered. More than halth of households 63% use improved cook stove (rondereza/cana rumwe/ DelAgua) 15.8% use traditional three stove stoves, multipurpose woo/charcoal at 1.5%, metal stoves 12.8%, LPG at 3.8% and also found that households use electricity for cooking count to 03% respectively. The main source of information was neighbor, seminars and meeting. The stoves were priced between 2000 Frw and above 10 000 Frw with cook stove obtained from Ndora market at 16.7% and 30% of stove are given by companies like DelAgua and Amayaga Green Project .two-third of the study households indicates cost effectiveness and availability of fuels as major factors influencing adoption. In conclusion, initiative aimed at adoption of improved cook stoves should up scaled by effective dissemination of information on the characteristics of cooking technologies. To increase the adoption, I recommend increase awareness of their benefits and affordable pricing of the devices and energy including option such as financing or subsidies by major stakeholders and the government.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

VUP: Vision Umurenge Program

SDGs: Sustainable Development Goals

EAC: East African Community

LPG: Liquified Petroleum Gas

MT: Million Tone

CO: Carbon monoxide

CO_2: Carbon dioxide

NISR: National Institute of Statistics

SSA: Sub-Sahara Africa

ACCES: Africa Cleaning Cooking Energy Solution

ICSs: Improved Cook Stoves

EAPCSI: East Asia and Pacific Clean Stove Initiative

GDP: Gross Domestic Product

PM: Particular Matter

BC: Black Carbon

IPCC: Intergovernmental Panel on Climate Change

WRI: World Resources Institute

NAPCOD: Namibia's Program to Combat Desertification

DRFN: Desert Research Foundation of Namibia

NBEMP: Namibia’s Biomass Energy Management Program

GHG: Green House Gases

WYMO: Maendeleo Ya WanaWake Organisation

NGOs: Non-Government Organizations

REMA: Rwanda Environment Management Authority

KCJ: Kentan Ceramic Jiko

HAP: Household Air Pollution

ARI: Acute Respiratory Infection

ESS: Energy Saving Stove

FAO: Food and Agriculture Organisation

CHAPTER ONE: STUDY BACKGROUND

1.0 Introduction

This chapter presents the background, the problem statement, objective of the study, research questions, and scope of the study and organization of the study.

1.1 Background

Low-income households characterized by lacking enough resources to provide the necessities of life include transportation, energy access, work schedules, and financial constraints, similar to constraints experienced by low-income households in food shopping generally which is the basis for the measure (Galt, 2017). But this may be too unstable over time to provide an accurate description of an individual's well-being.

The empirical microeconomic studies of consumer behavior have shown that consumer behavior is determined more by income or expenditures can be traced back to Milton Friedman's permanent-income hypothesis (Friedman 1957), which suggests that consumption decisions are guided not by a consumer's current income, but by a measure of an individual's permanent income, consisting of his or her ability to earn income over a longer time period and expectations of future earnings and wealth. However, while expenditures may fluctuate less than income, using expenditures to measure individual well-being at a point in time is also susceptible to know the level of income whether is low or high. (Castner, Laura, James Mabli, 2010).

Many researchers have focused on grouping or classifying households into different categories based on either income/consumption or household assets. However, these practices may lead to an inadequate classification due to Rwanda's unique family structure. In Rwanda, households are classified into classes known as "Ubudehe categories" (Nizeyimana, Pacifique, Kee-Won Lee, and Songyong Sim, 2018).

This classification is based on subjective perceptions of people. This categories are well classified where households in first category has low income and get support from government through vision umurenge program (VUP) (Nizeyimana, Pacifique, Kee-Won Lee, and Songyong Sim, 2018).

As African developing country Rwanda located in East and Central Africa region, small and landlocked. The number of its population is above 12 million occupying an area of 26,338km2 yet is the most densely populated country on the continent (482 inhabitants per Km2), where 72% of its populations live in rural areas (Bamundekere, 2019). Also is low-income country with an economy based largely on subsistence agriculture. The scarcity of arable land and a rapid rate of population growth has severely strained the country's efforts to develop its economy which affect low income households in Rwanda to adopt different technologies including cooking technology (Musahara, 2005).

Rwanda is aiming to achieve the universal energy access in 2024 to ensure social economic development, energy security, energy access and climate change mitigation (MININFRA, 2019) Rwanda uses a variety of technologies and natural resources, such as petroleum-based fuels, hydro, solar, methane gas, peat, geothermal, biomass, and waste contribute to the generation of electricity. Likewise, Rwandan energy sector scope goes beyond electricity and includes bio-products, such as wood fuel, charcoal, and biogas, as well as petroleum products, such as diesel, kerosene, Liquid Petroleum Gas and natural gas such as methane gas (Usengeyimana ,Ahmet, Turgay, 2016).

Biomass contributes 85% of primary energy consumed of which wood contributes a percentage of 57%, Charcoal 23%, Crop residues and peat of 5% Non-Biomass sources contribution is 14% of which Petroleum products equal to 11% and electricity contribution is approximately 4% and electricity consumption per capita (30 kWh) is the lowest in the East African Community (EAC) (Bamundekere, 2019). Based on energy- cooking fuel more than 90% of Rwandans rely on polluting solid fuels to meet their cooking needs. The negative impacts on health, climate, and the environment have led the Rwandan government to set a target of halving that number to 42% by 2024 (Čukić et al, 2021). National Master Plan to promote scale up of liquefied petroleum gas (LPG) has been developed to define (i) the necessary market conditions, (ii) public and private sector interventions, and (iii) the expected societal impacts.

Findings are reported from modeling scenarios of scaling LPG use towards the 2024 policy target and the 2030 target for “universal access to clean modern energy” (SDG7) where Household LPG use is projected to increase from 5.6% in 2020 to 13.2% by 2024 and 38.5% by 2030.

Reductions in carbon dioxide and black carbon emissions equivalents (CO_2e and BCe, respectively) are estimated to reach 25.6 million MT and 14.9 MT, respectively, by 2030(Čukić et al, 2021). Due to Rwanda's geographical and socio-economic situations have shaped the energy situation and limited access to modern fuels. Wood fuel is the main source of energy for households and its trade a source of income and jobs in rural areas. Currently 85.2% of households' land holding is less than 1 ha, insufficient to grow food and wood fuel for a household of the average size of 5.5 persons. The barriers to large dissemination of improved cooking stoves include availability, relatively low cost of wood fuels, lack of improved stove diversity on the local market and but government policy in regard to reduce carbon and indoor pollution are clear where most people in Rwanda are using LPG, Briquettes, electricity improved cook stoves and other technology as policy from government and subsidies like amayaga green project which provides improved cook stoves to low income households in Gisagara, mugina,Nyanza amd other parts of the country (Mazimpaka, Ernest, 2014).

By considering Gisagara which located in south region of Rwanda which is one of the province and densely populated area in Rwanda with a population size of 322,506, comprising of 150,455 males and 172,051females (NISR, 2012). The average household size in Gisagara district is 4.2 persons, at the Sector level, household size varies between 4 and 4.4 persons. The community also has 77,259 households. The study area is largely residential with limited commercial activities in the form of retailing in shops along the principal streets in the town (NISR, 2012).

Through the access to sustainable and effective cooking energy services the goal of many national including Rwanda and international policies, initiatives, and financial investments. Most recently, the magnitude of the challenge was highlighted by the inclusion of SDG 7 as one of the 17 goals universally identified (Mbungu, 2020). Access to modern forms of energy continues to elude the majority of households in sub-Saharan Africa (SSA) where 90% relies on traditional fuels for cooking which contribute to the deforestation and causes different respiratory diseases (Sundblad, 2014). In southern province due to many people in low income class (ubudehe first category) 60,000 households in the Districts of Gisagara, Nyanza, Kamonyi and Ruhango get improved and energy-efficient cooking stoves with capacity to reduce firewood wood by more than 50% compared to traditional stoves. The cook stoves will contribute to restoration of the natural forests by restoring 263,000 hectares of degraded forests; reduce about five million tons

of greenhouse gas emissions meaning 15 million tons in the next 20 years compared to the air pollutants currently being experienced in Rwanda (Michel, 2021).

The aim of this study is to analyze in the Developing countries context the impact of appropriate cooking technology to low income household. We will use the literature review to present different views of scholars and theory. Based on them we will come up with certain factors that prove the importance of improved cooking stove to economic, social and environmental aspects of sustainable development. Those proving factors will be used with the aim to identify different cooking stove technologies and find the appropriate technology for low income households in Developing countries through empirical research.

1.2 Problem statement

Researcher have invented different cooking technologies to be used on the basis of their efficiency like triangular mud stove change to three stone stoves, then different technologies keep identified like metal pyramid stove, but they do not consider affordability of consumer, emissions, efficiency and health. This improved stove done by them has high prices and did not adopt due to the low income on the basis of Household's ability, income level, family size and resource availability.

In Rwanda and other developing countries around the world, adoption of clean and improved energy for cooking meet barrier of low income and poverty.
Results to the use of traditional cook stove which is inefficient and harmful to low-income households due to high cost of cooking devices and fuel. The studies are still ongoing to find affordable clean energy for cooking.

The purpose of this study is to find the factors influencing the adoption of cook stove for low-income household, as well as to find out the affordable technology which contributes positively and efficiently to the wellbeing of the community in developing countries.

1.3 Objective of the study

1.3.1 General objective

The objective of this study is to identify factors influencing the adoption of improved cook stove for low-income households.

1.3.2 Specific objectives

The specific objectives of this study were:

i. To assess different technologies for cooking.
ii. To assess the factors influencing the adoption of cook stoves
iii. To examine factors influencing the adoption of cook stove for low-income households.

1.4 Study questions

The study was guided by the following research questions:

i. What are the different cooking technologies in Rwanda?
ii. What factors influencing the adoption of cook stoves in Rwanda?
iii. What are the factors that influence the adoption of cook stove for low-income households?

1.5 Significance of the Study

The study will be of relevance to concerned developing countries, and Advocacy groups in energy sector. It is expected to guide policymakers on enhancing the effectiveness and efficiency of cooking technologies by meeting social, economic and environmental aspects.

Also importance of involving different concerned stakeholders during a project feasibility phase and implementation phase so here the area of opportunity that will be highlighted in the work is a significant input for cooking technologies market in developing countries and guidance to Donors, and Investors. The study is important to the researchers and academicians as it will be a useful guide for future researchers interested in sustainable development and sustainability of the energy system in Developing countries.

1.6 Limitation of the Study

In retrospection, the researcher observed that the study samples will be gender neutral and no systematic attempts will be made to focus on women as principal users of ICSs. This may be attributed to the design of the questionnaire which will have specific questions for women and the user of ICSs. The study is limited to developing countries.

Also will be limited to assessing the impact of ICSs at the household level in the study area and will not involve non household settings such as hotels and restaurants that make use of cooking stoves.

1.7 Scope of the study

As well as study is limited to developing countries region. The choice of this area is partly influenced by the influence of using improved cooking stove imposed through interventions such as Africa Clean Cooking Energy Solutions (ACCESs) which is focused on helping countries meet the universal energy access goal regarding the areas of study. Main emphasis of the study will be to assess the status of cooking technologies and potential barriers to improved cook stoves in developing countries. Also will focus on different a cooking technology that use a cleaner energy source, with efficiency and which is appropriates to low-income households. Furthermore, the study focused on low-income households only and will not include food vendors (restaurants and chop bars) that used cook stoves within the study area.

1.8 Organization of the Study

This thesis is composed of five chapters. Chapter one deals with the study background, problem statement, research questions and objectives, scope and limitation, hypothesis statement and the significance of the study. Chapter Two reviews literature on different cooking technologies and sustained use of improved cook stoves. Further, this chapter also discusses the theoretical and conceptual framework of the study.

The third chapter deals with the methods of the study. This include, the selection and study area description, data type and source, research design and research strategy, sampling design and procedures, data collection and instruments, data collection procedure, data processing, definition and description of variables as well as model specification are discussed. Chapters four and five deals with analysis and discussion and conclusion and recommendations respectively.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter presents the literature review, the development of improved cook stoves around the world, Africa and in Rwanda, the various cooking technologies used by households in cooking, factors influencing adoption of cook stoves and benefits associated with the adoption of improved cook stove. This chapter discuss theoretical and conceptual framework of the study.

2.1 Theoretical Literature

2.1.1 The definition of Key Concepts:

2.1.1.1 Low-Income household

Per capita income used to measure a sector's average income and compare the wealth of different populations also often used to measure a country's standard of living and is easily calculable from readily available gross domestic product (GDP) and population estimates, and produces a useful statistic for comparison of wealth between sovereign territories. This helps to ascertain a country's development status (Markusen, James, 2013).

Rwanda GDP per capita for 2021 was $834, a 6.04% increase from 2020. The household which consume less than US$1.25 a day is need subsidies from government as they are under poverty line which compared to consumption or income per person and includes consumption from own production and income in kind. Low-income households determined on the basis of monthly expenses on food, education, health, transport and electricity. Due to the low Income households in Rwanda Government create different categories called Ubudehe. The first category includes households with low income compared to others (Nizeyimana, Pacifique, Kee-Won Lee, and Songyong Sim, 2018).

2.1.1.2 Traditional cook stove

The most known traditional cook stove includes mud stoves, three stone cook stove and others. In developing countries, biomass fuels are typically burned using an open fire or in an inefficient stove without adequate ventilation.

Many pollutants including carbon monoxide (CO), particulate matter (PM), sulfur oxides and nitrous oxides are generated from burning biomass fuels, and high concentrations of these pollutants have been seen in households using open fires or inefficient cook stoves.

(Yoder, 2014). Indoor smoke contains arrange of health-damaging pollutants including small dust particles that are able to penetrate deep into the lungs Every year, IAP is thought to be responsible for the death of 1.6 million people (Saksena S, Subida R, Büttner L, Ahmed L, 2007).

2.1.1.3 Improved cook stove

Cooking over open fire on traditional three-stone-stoves is common in the study area as well as in other parts of the developing world (Hoigt, 2019). There is a wide range of improved cooking stove which can be made out of clay, mud or metal, be portable or stationary and they can be made for use with different fuels mainly in the form of biomass. However, all of these stove have one thing in common, the combustion is much more efficient and complete than with traditional open fire cooking places.

Hence, they can save fuel and produce less harmful emission , Even though the stoves are mostly kept at a low cost, the initial investment cost can still be too high, even though the benefits of an improved stove weigh out the initial investment cost as Jan (2012) describes it see more in section 3.2. Further, industrial produced stoves can often not be purchased in rural areas. Thus, improved mud stoves seem like a perfect option for remote areas. (Hoigt, 2019).

2.1.2 Different technologies for cooking

A majority of rural households in the developing world use solid biomass fuels for cooking. This use has severe negative health effects, is often either expensive or time consuming, and contributes to global warming. Options for policy interventions include the promotion of improved cook stoves (ICS) and enabling households to switch to more modern fuels, like liquefied petroleum gas (VAHLNE, 2015).

In the rural areas of many developing countries, a major part of the used Energy comes from biomass such as wood and agricultural residues (Wesley Foell,Shonali Pachauri, Daniel Spreng, Hisham Zerriff, 2011).

However, inefficient combustion, which is the norm, entails several problems. One of the most serious is indoor pollution, which is a major cause of illness and death in many developing countries (Torres-Duque, C., Maldonado, D., Pérez-Padilla, R., Ezzati, M., & Viegi, 2008) Other often mentioned problems include the time-consuming firewood collection (Joshi, Janak, and Alok K. Bohara, 2017).

Similar to most countries in sub-Saharan Africa (SSA), the household energy market in Rwanda is dominated by cooking energy, and cooking energy is dominated by reliance on solid fuels. The primary fuels used for cooking are firewood used by as many as 83% of rural households of whom more than a quarter can gather firewood for free and charcoal which is the most common fuel in urban settings, with more than 40% of urban households relying on it . While use of liquefied petroleum gas (LPG) or bottled gas for cooking are 5.6%. (Čukić et al, 2021)

2.1.2.1 The Traditional Stove

The traditional stove basically consists of three stones or bricks that are positioned around a fire in a triangular formation. The pot is placed on the stones, while fuel wood can be added from between the stones. The stove can be considered highly versatile and functional. It is highly versatile, for it burns all kinds of biomass, can be adjusted to fit pots of any size and it can easily be controlled by adjusting the fuel wood supply. It is highly functional, for it performs a number of tasks besides the cooking of food. Its heat can be used for space heating, its fire for lighting and the smoke to keep away insects and to preserve the thatch, food and timber (Karekezi, Stephen, Kusum Lata, and Suani Teixeira Coelho, 2004).

Finally, the stove can be important as a gathering place or carry symbolic value. The view that traditional stoves have a very low efficiency has changed over the last years, for nowadays its multi-functionality and the flaws of early tests are acknowledged. For many years however, low efficiency values were accepted as common knowledge without testing this assumption states that most low figures given in the literature are anecdotal, while tests resulted in a wide range of efficiency. (Kuhnhenn, 2003).

Nevertheless, the traditional stove has a Brick or Stone Fuel opening number of drawbacks. First of all, although acknowledging that the efficiency of the traditional stove is not as low as has been assumed, it is still not as high as that of some improved stoves.

The results are a high consumption of wood and long cooking times. Secondly, the stove emits significant amounts of smoke, which can pose a health threat to the persons staying close to it. Finally, the openness of the stove can result in accidents, leading to injuries or damages to the dwelling

2.1.2.2 Liquefied Petroleum Gas (LPG)

More than a quarter of global emissions of Black Carbon (BC) are estimated to originate from combustion of solid fuels for cooking and, in Africa and Asia, where reliance on solid fuels is highly prevalent, such use has been estimated to contribute 60–80% of total BC emissions. Using electricity and gas (including LPG) for cooking is thus recommended by the Intergovernmental Panel on Climate Change (IPCC) as a preventive measure to reduce BC emissions from cooking (Čukić et al, 2021).

Rwanda lost 34.5 kilo hectares (kha) of forest cover through unsustainable harvesting of wood for domestic energy, representing 6.9% of Rwanda's total tree coverage and generate 8.89 MT of total CO2 emissions, including domestic and agricultural use (World Resources Institute, 2022) . Rwanda's National Strategy for Transformation (NST-1) 2017–2024 set a target of halving reliance on biomass fuels for cooking from 82% in 2017 to 42% by 2024, with an associated aspiration of achieving a sustainable balance between supply and demand for wood by 2030 (MININFRA, 2019).

The impact of adoption of LPG on Environment, Climate, and Health include: i. on Climate and environment reduce deforestation, reduce emissions and the economic value of averted CO2e emissions in terms of carbon financing. For health reduces air pollution. As part of the strategy to achieve this target, the government identified LPG which has a fuel efficiency of 55% and new design can reach about 90% fuel efficiency.

As the most rapidly scalable solution to clean cooking in the country and selected urban conurbations (Kigali and six secondary cities), and public institutions (e.g., schools, prisons) as priority targets for accelerated rollout of LPG for clean cooking (Čukić et al, 2021).

2.1.2.3 The Tsotso Stove

The Onkani Tsotso Stove project was initiated by the Desert Research Foundation of Namibia (DRFN) and Namibia's Programme to Combat Desertification (NAPCOD). NAPCOD is part of Namibia's Biomass Energy Management Programme (NBEMP), which is co-ordinated by the Ministry of Mines and Energy (MME). NBEMP, in turn, networks with the South African Development Communitywide Programme for Biomass Energy Conservation (ProBEC).

The Onkani Tsotso Stove project was started in August 2000 as part of the first phase of Namibia's Biomass Energy Saving Project (NamBESP), which represents the implementation level of ProBEC. (Kuhnhenn, 2003). In an assessment of the Tsotso Stove programme, the Energy and Energy Efficiency Bureau of Namibia concludes that "the thought that went into the design of the Tsotso is commendable and is "appropriate technology" at its best" (Kuhnhenn, 2003). Due to:

i. It's ability to burn a wide range of fuels and the provision of a safe cooking environment. The efficiency is higher than that of the traditional stove for three reasons; the Tsotso Stove acts as a windshield, its walls are insulated and the shape of it results in a focusing of the heat on the pot (Kuhnhenn, Environmental and socio-economic impact of improved stoves-the case of the Tsotso stove in northern Namibia, 2003).

ii. The parameter efficiency describes how much energy of the fuel wood is transferred to energy that is used to heat up the water. The parameter time to reach boil gives an idea of how fast the stove is. Projects aimed at improving the cooking situation in the developing world would thus be suitable since, in addition to reducing GHG emissions, a substantial increase in welfare for poor households is also possible. (Muller, Adrian, 2007).

2.1.2.4 Jiko kisasa (Maendeleo Jiko)

Jiko Kisasa is a stove that was adopted in Kenya in 80s after intensive research by many institutions under the leadership of ministry of Energy, GIZ and Maendeleo Ya Wanawake Organisation (WYMO) This technology was taken up by governments and the international community to promote its adoption and use in developing countries (Bielecki, 2014).

The jiko kisasa use both Chalcoal and fire wood, and have different size and types, in contrasting it to the open fire traditional method, it has the ability to minimize 30% of emission and energy loss (Nyankone, 2018). In Tanzania a household using three stones stove consumes around 2880 kg/year of firewood (Clough, Laura, 2012). According to this study, through the use of improved firewood stove reduce the fuel inefficiency and the high level of smoke. (Dadzie, 2018) also reduced 1728kg/year/household, annual saving is around 1152kg/household (equivalent to more than 20 tresses per year) (Benson, 2018).

2.1.2.5 The rocket stoves

Individual stove builders are the architectures in developing the rocket stoves, which uses on pot size at time just like the Jiko kisasa. However, in terms of energy saving, conservation of fuel, and efficiency, they are the best stoves available. They have the ability to conserve over 60% of wood and have an efficiency rate that exceeds the Jiko Kisasa by 20% (Kamfor, 2002). The rocket stove addresses institutional needs, for example of school canteen. EnDev Kenya launched the rocket stove technology in 2007 as new players come in today's Kenyan market, for example, instead of using firewood, the rocket stove uses plant oil, ethanol, and LPG.

2.1.2.6 Cooking technology in Rwanda

Rwanda, a small landlocked country situated in East Africa, is the most densely populated country in sub-Saharan Africa with a population density of 525 per 1 square meters and a total population of above 12.952 million (2020). Most Rwandans live in rural areas where traditional biomass, mainly wood fuel has remained the leading source of energy for cooking (Čukić et al, 2021).

The average household uses around 1.8 tons of fire wood each year to satisfy its cooking needs with traditional stoves, Similar to most countries in sub-Saharan Africa (SSA), the household energy market in Rwanda is dominated by cooking energy, and cooking energy is dominated by reliance on solid fuels. The primary fuels used for cooking are firewood used by as many as 83% of rural households of whom more than a quarter can gather firewood for free and charcoal which is the most common fuel in urban settings, with more than 40% of urban households relying on it (Čukić et al, 2021).

While use of liquefied petroleum gas (LPG) or bottled gas for cooking has doubled in Rwanda since 2016. Burning solid fuels and/or kerosene results in high levels of household air pollution (HAP) Population transition from these polluting fuels, often burned in inefficient poor quality stoves, to clean, modern LPG can have significant public health, environmental, and gender benefits owing to reduced personal exposure to HAP, preservation of forests, and time savings for women and girls who typically are responsible for the gathering of fuels and for cooking (Daniel, et a, 2018).

2.1.2.7 Different Cooking fuel and technologies in Gisagara Districts

Gisagara Forests are well known as the home of regional threatened birds and important habitat to many regional species of plants and animals. More than 90% of population (farmers') productivity relies on those forest resources (Alphonse Karenzi, 2014). Unfortunately, recent findings state that these important forests continue to face several human threats like extinction of forests and some tree species mainly due to high consumption of fuel wood in inefficient cook stoves which are the only affordable cookers for around 278,000 local dwellers. Sustaining Rwanda Youth Organization signed a contract of performance with Gisagara District to collaborate in distributing Improved Stoves in 45,986 Households (Alphonse Karenzi, 2014).

Even if time and available materials did not allow the determination of exact existing carbon emission at the household level, the level of carbon emission can be observed on the roof and wall of kitchen/house as results of using this technology. Roof and walls of kitchens and houses with traditional stove like three stones stoves have become blacker than those which use improved stoves. This is due that three stones emit the smoke in all directions. It has been found that more than 96% of households are not aware of the threat of indoor air pollution on health (MUNYEHIRWE, 2008).

Table 1: The impact of the use of improved stoves on time, income and quantity of firewood used

The impact of the use of improved stoves on time, income and quantity of firewood used			
	Three stone stove	Improved stoves	Saved by those HHs which use improved stoves
Quantity of Firewood used per month	308 kg	187kg	121kg (39.2%)
Time used to collect firewood per month	11h54’	07h8’	4h46’ (40.0%)
Time used to cook per day	3h46’	2h10’	1h36’ (42.4%)
Money paid for firewood per month	Rwfr 10,098	Rwfr 5940	Rwfr 4.158 (41.1%)

Source: (MUNYEHIRWE, 2008).

In the past, firewood was considered as a “free” good which is available in random supply. But now firewood is like any other source of energy which is economically costly. The scarcity is confirmed by the increase of firewood selling activities even in the rural areas. (MUNYEHIRWE, 2008). In the developing countries, energy required for cooking often has the biggest share in the total national energy demand and is normally met mostly by biomass in which Combustion of biomass fuels (wood and charcoal) for cooking releases smoke that contains health damaging pollutants the reason people try to find ways of reducing indoor air pollution by utilizing stove like metal stoves. Women and children are the most affected and associated with acute respiratory infections (ARI) (Bhattacharya, 2020).

Government of Rwanda In terms of climate impacts, the transition from charcoal and firewood to LPG was taken as decision More than 90% of Rwandans rely on polluting solid fuels to meet their cooking needs. The negative impacts on health, climate, and the environment have led the Rwandan government to set a target of halving that number to 42% by 2024. Household LPG use is projected to increase from 5.6% in 2020 to 13.2% by 2024 and 38.5% by 2030.

Cooking will decrease total and per capita carbon emissions through two mechanisms: (i) decreased emissions from combustion of solid fuels and (ii) decreased fuel production in the case of charcoal (Čukić et al, 2021) .

In 2019, there were 759 million people globally without access to electricity and 2.6 billion people lacked access to clean cooking. Cooking with electricity could contribute to achieving universal access to energy by 2030 (eduardo, et al., 2021). Most people in gisagara they are in first category due to poor and the district has low access to electricity which limits the use of electricity for cooking, electrical coking devices are expensive and electricity cost is high which make them use fire wood and charcoal instead of electricity as source of cooking energy.

The large number of population in Gisagara districts and other districts in southern province uses traditional methods by wood fuel and metal pyramid which uses charcoal as fuel because the geographical location factor as well there are many high mountain with trees and no transport facility to all location to easier the fuel trading like LPG and other fuel. So as result people in these districts as only choice due to the poverty and low income they choose to use wood fuel due to the available resources in the areas of Gisagara and Nyaruguru.

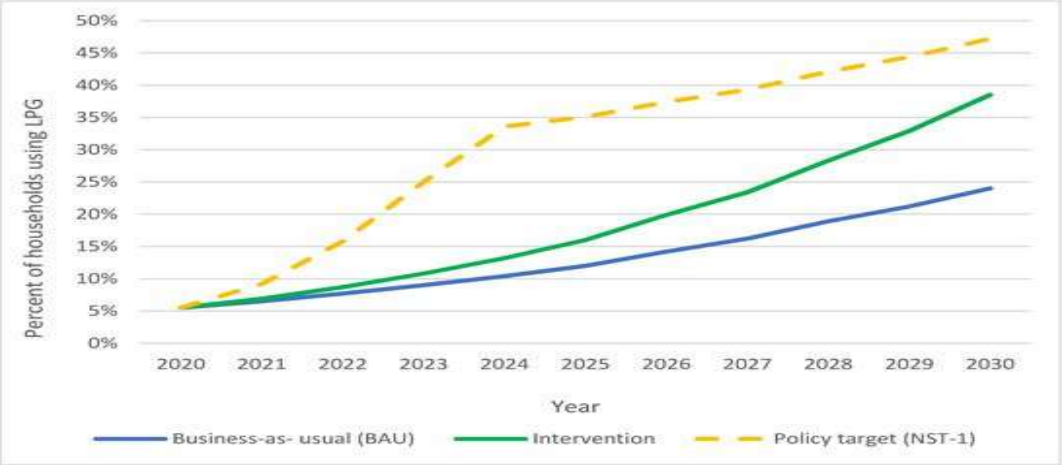
2.1.2.8 Rwanda Government policies in terms of improved cook stoves

As well the most cook fuel in Rwanda was wood fuel and three stone stoves used as technology which lead to deforestations as results Between 2001 and 2019, Rwanda lost 34.5 kilohectares (kha) of forest cover through unsustainable harvesting of wood for domestic energy, representing 6.9% of Rwanda's total tree coverage (Čukić et al, 2021). And Rwanda government to address the detrimental effects of reliance on solid fuels for energy on public health, the environment, and the climate, the government of Rwanda set as a national priority to transition a significant proportion of the country to clean modern energy within a very aggressive timeframe.

Rwanda's National Strategy for Transformation (NST-1) 2017–2024 set a target of halving reliance on biomass fuels for cooking from 82% in 2017to 42% by 2024, with an associated aspiration of achieving a sustainable balance between supply and demand for wood by 2030 (MININFRA, 2019).

The policy target for LPG adoption was set at 40% of the population (across residential, institutional and industrial sectors) by 2024. In addition to LPG, other promoted alternatives to meet the overall 42% biomass fuel target included biogas, electricity, and improved high-efficiency biomass cook stoves including pellet- and briquette-burning stoves (Čukić et al, 2021). LPG safety and regulatory best practices, market and financing models have been successfully and extensively implemented across dozens of countries globally.

Where by the projection of household LPG adoption was projected to increase from 5.6% in 2020 to 10.4% in 2024 and 24% in 2030 under the business-as-usual scenario (i.e., without market enhancement) Under this scenario, the greatest growth was projected for urban settings, with 65.9% of the households in Kigali city projected to use LPG in 2024 (from 45.1% in2020), increasing to 86.4% in 2030. Similarly, 25.2% households in 'other urban' areas were projected to be using LPG in 2024, increasing to 56.7% in 2030. By contrast, for rural contexts, only very limited growth was projected (0.6% of the households estimated to adopt LPG by 2024 rising to 3.4% in 2030).



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BAU	5.6%	6.5%	7.7%	9.0%	**10.4%**	12.0%	14.2%	16.2%	18.9%	21.2%	**24.0%**
Interventional	5.6%	6.9%	8.7%	10.8%	**13.2%**	16.0%	19.9%	23.4%	28.3%	32.9%	**38.5%**
NST-1 target	5.6%	9.2%	15.8%	25.0%	**33.6%**	35.1%	37.4%	39.3%	42.1%	44.4%	**47.2%**

Figure 1: Adoption scenarios based on proportion of households using liquefied petroleum gas (LPG) for cooking

Source: (Čukić, 2021).

2.1.3 Factors influencing the adoption of cook stoves

2.1.3.1 Social – Economic factors influencing the adoption of improved cook stoves

Improved cook stoves literature is replete with information on sociocultural hindrances to rapid ICSs diffusion, stemming primarily from the formidable competition of the open fire. Aside from cooking, open fires serve many functions: lighting, heating, drying, providing a communal gathering point, repelling insects, and others. They can also be constructed anywhere easily at zero cost and maintenance, and can be operated with great ease. ICS rejection occurs when one or more of these needs are not met by the ICS but are valued more than the promised fuel and time savings; this is most evident in areas where fuel wood is noncommercial (Manibog, Fernando R, 1984).

This is not an easy task; ICSs should be promoted within the context of overall improvements in kitchen systems and rural living conditions. Doubts have surfaced, therefore, on the acceptability of the "rural mud stove" model, which may not be seen as much of a step beyond the "primitive" open fire, nor as being in the basket of goods aspired for in a developing rural economy. In the same vein, stove groups are giving more credence to the urban-to-rural demonstration effect in the area of "modern" ICSs. Joseph (2) cites evidence for Sri Lanka, where lower socioeconomic groups became more actively involved in the IeS program after a shift from high-mass, mud-based models to low-mass, ceramic-lined designs. (Manibog, Fernando R, 1984).

Stove projects have been carried out all over the developing world. Mainly with the same main objectives, reducing solid fuel consumption hence combatting deforestation and improved health condition for the user. Other objectives are reducing the time burden of fire wood collection and combating climate change. Unfortunately the success of improved cooking stove programs has been limited (Lewis, Jessica, and Subhrendu K. Pattanayak., 2012).

The lack of wide spread adoption of Energy Saving Stove (ESS) has been documented in many developing countries and a range of studies have been conducted. The benefits of improved cooking stoves are always outweighing the cost of the stove. (Jan, 2012). But also insufficient funds allocated to such projects and poor monitoring systems for the long term stove use are among the central factors.

In the particular study area, Jan (2012) identified lack of awareness, motivation and institutional support as most important factors for the low adoption rate. (Jan, 2012). The factors that influence the adoption of improved cook stoves according to (Benson, 2018) include:

i. Income level of family

The systematic review by (Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N., & Rehfuess, E, 2013) found consistency among research result that higher socio-economic status of a family is positive and significant factor in determining a household improved cook stoves adoption decision. (Benson, 2018). Found that Income is positively and significant factor that determined the adoption of improved cook stoves across reviewed for example as Disposable income increase, there is higher rate of households switching to cleaner and higher efficient cooking fuel techniques (Barnes, 2010).

ii. Gender

There is a distinct dimension in the household energy sector in much of the developing world(Malhora,2004). He adds that gender consideration is a vital social aspects to consider in stove program design.

The aesthetical appeal and the ability of the new cooking technology to retain its traditional cooking features would attract a higher market demand as he further argued in the study. The role of women in household cooking decisions is evidenced when the study of Reddy (2007) asserted that women headed households prefer modern fuel cooking methods as compared to men headed households. Women bearing cooking cost that are disproportionate prefer improved cook stoves in rural area but they have no power to make such decisions and calls (Benson, 2018).

iii. Family size

According to (Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N., & Rehfuess, E, 2013), postulated that households with larger family size consume larger fuel wood as compared to household's smaller family size thus resulting in influencing larger family size household to economize fuel usage and has appositive probability of adoption of improved cook stoves. Postulated size of the family as factor that increases the cost and demand for fuel needed to cater for the family consumptions needs (Benson, 2018).

iv. Education levels

It argued that educated potential customers are probably aware of the advantages, benefits, and gains accruing from the use of improved cook stoves over the uneducated or less educated customers (Inayatullah, 2012). They postulated that consumer's education based on the various financial instruments that can be deployed to acquire the improved cook stoves so as to minimize the perception that they are actually expensive. The education level of the household wife plays an instrumental role in the increasing the possibility of switching from traditional cooking approaches to modern more efficient methods (Pundo, M. O., & Frase, 2006).

v. Price of improved cook stoves

Price variables include the price of improved cook stoves, the price of fuel-wood, the price of kerosene, charcoal etc. (Grant Axén, Johanna, 2012) for example argues that the price of improved cook stoves and household's perception on the price have effect on the probability of the household's adoption. The purchasing price of cook stoves is an important factor influencing a household's adoption decision. But low affordability of the cost of improved cook stoves negatively affects the adoption likelihood by the poor who are predominantly in rural areas (Benson, 2018).

vi. Cultural factors, Political factors: here due to the country's culture they can prefer to use some kind of technology which is not improved but also the political factors affect people especially in developing countries due to many planned activities.

vii. Resources availability: Also most of the area in Africa and Rwanda as the case people has access to the forest than access on other kind of fuel so as results the use wood fuel instead of other cooking technologies mostly because biomass fuel are around and very easy to get it at any time.

The most commonly cited component of affordability of clean cooking is the upfront cost of the stove. Government subsidies also needed so that low-income households can adopt stove (Gill-Wiehl, A., I. Ray, and D. Kammen, 2021).

2.1.4 Factors influencing the adoption of cook stoves for low-Income households

Low-income households determined on the basis of monthly expenses on food, education, health, transport and electricity. Due to the low Income households in Rwanda Government create different categories called Ubudehe. The first category includes households with low income compared to others (Nizeyimana, Pacifique, Kee-Won Lee, and Songyong Sim, 2018).

in Rwanda Government create different categories called Ubudehe. The first category includes households with low income compared to others (Nizeyimana, Pacifique, Kee-Won Lee, and Songyong Sim, 2018). So the price is main factor for low-income households in addition with above others. Price variables include the price of improved cook stoves, the price of fuel-wood, the price of kerosene, charcoal etc. (Grant Axén, Johanna, 2012) for example argues that the price of improved cook stoves and household's perception on the price have effect on the probability of the household's adoption (Benson, 2018).

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2.1.3.2 Benefit of adoption of improved cook stove

In developing countries, traditional fuels 'account for as much as 90% of total energy use, while in most developing countries. Therefore, the massive dissemination of ICSs was expected to have a significant positive impact on the fuel wood supply/demand imbalance, environmental benefits such as the slowing of erosion, siltation, desertification, and the deprivation of soils of valuable nutrients and organic conditioning material as people turn to animal wastes and crop residues for fuel when wood supplies become exhausted (Manibog, Fernando R, 1984). And also health benefit, change of meal per day, ICS is safety than traditional, reduce indoor pollution (Kuhnhenn, 2003).

For fuel wood shortages at the regional or community level, diffusion of ICSs was seen as a way to reduce the rapid rate of increase in fuel wood prices and the magnitude of the difficult, costly, and time-consuming task of rural afforestation.

Considering all the promised benefits, and perceiving cooking fuel as a basic need like food itself, numerous local and international groups embarked on various pilot ICS programs. (Manibog, Fernando R, 1984).

2.2 Empirical Review

According to Jan on what makes people adopt improved stoves? The study based on primary data collected from 100 randomly selected household in two villages of northwest Pakistan Show that large dependence of the World population on biomass fuel for domestic energy consumption is one of major cause of deforestation worldwide. In his research he provides empirical evidence of individual, household, and community level variable that play a vital role in the adoption of improved cooking stoves. The study conclude that rate of adoption could be improved if government and non-government organization(NGOs) play a greater role in overcoming the Social, economic, political, and institutional barriers to adopt improved cooking technologies (Jan,Inayatullah, 2012).

(Dadzie, 2018) , Assessed the adoption of improved cook stoves in kwabenya in the Ghana east municipality. Findings from the study indicated that 41.2% of households interviewed had adopted the improved cook stoves. Among the adopters, 50.4% used their technological stoves frequently. They recommended that the increased awareness of their benefits and affordable price of the devices and energy/fuels including options such as financing or subsidies by major stakeholders and the government (Benson, 2018).

Caroline and others, while conducting research on comparison of fuel use between a low costs, Improved wood stove and traditional three-stone stove using both cross-sectional and longitudinal, conducted two-day kitchen performance tests in 145 households and 37 households, respectively. Fuel consumption was 5.4 kg d_1 in the rocket stove group and 6.7 kg d_1 in the Three stone stoves group.

According to Philbert Nkurunziza, Green Amayaga Project Coordinator, at least 60,000 households in the Districts of Nyanza, Gisagara, Kamonyi and Ruhango are provided improved and energy-efficient cooking stoves with capacity to reduce firewood wood by more than 50% compared to traditional stoves. In total, 11,000 improved cook stoves distributed in four sectors of Kamonyi District under the 2020/2021 financial year namely Mugina, Nyamiyaga,

Nyarubaka, and Rugarika. These cook stoves will also contribute to socio-economic development of beneficiaries, since thanks to their efficiency to save energy and time. REMA says, the distribution of 60,000 improved cook stoves will contribute to reduce about five million tons of greenhouse gas emissions meaning 15 million tons in the next 20 years compared to the air pollutants currently being experienced in Rwanda Studies show that, between 1990 and 2010, Rwanda lost 37 per cent of its forest cover due to forest degradation (Michel, 2021).

1.2.1 Critical review and Research gap identification

In this research, the gaps have been identified; different discussions and dissertations did not fill these gaps. Some researchers focused on different technology for cooking, others consider the factors for adoption but did not take into consideration the low-income households. Therefore, this research will contribute to fill the gap on factors influencing adoption of cook stoves for low-income households.

Other researchers may also use the finding of this study in relation to factors influencing the adoption of improved cooking technology in rural areas in Rwanda and may contribute to empirical literatures on factors that determine household's choice of adoption of cook stove in most developing countries.

1.2.2 Theoretical and Conceptual Framework

The Energy Stacking and Diffusion of Innovation Theories are among the most referenced theories in household energy studies (Sahin, Ismail, 2016). The theoretical and conceptual framework of this study is, therefore, based on the assumptions of these theories and findings from the literature.

2.2.2.1 The Energy Stacking Theory

This theory is based on the fact that, there are multiple interactive socio-economic, cultural and environmental factors that determines the adoption and use of household cooking stoves and related energy (Ruiz-Mercado, Ilse, Omar Masera, Hilda Zamora, and Kirk R. Smith, 2011). The theory explains that households may adopt multiple cooking stoves, often traditional and a modern type for reasons including occasional shortage of modern fuel, expensive modern stoves, and preference.

Sometimes households who can afford expensively, cleaner energy and stove sources opt to maintain or rely on improved or traditional stoves for reasons such as taste, texture, and technique available to the use of the traditional stoves (Heltberg Rasmus. 2003). Due to this reason, the theory has gained popularity in cook stove studies (Hosier and Kipondya 1993; Davis, 1998; Kowsari and Zerriffi, 2011; Masera et al. 2000). The theory in practice implies that in addition to increase in income that empowers households to afford modern and more efficient cook stoves such as electric and gas stoves, households also adopt ICS and or traditional cook stoves for various other reasons.

2.2.2.2 Diffusion of Innovation Theory

The Diffusion of Innovation theory was developed by Rogers in 1962. The theory explains how the adoption or rejection of an idea, technology or a product spread (diffuses) through a given population or a social system over a period of time. Diffusion researchers argue that factors such as availability (of a technology), economic status of individuals in a population, influence from early adopters and other social factors promote the adoption or rejection of the technology (Sahin, Ismail, 2016).

Base on this theory, for ICS to gain a high adoption rate in a given social system, its perceived characteristics must well be communicated to the intended users. Early adopters over a period of time will also persuade others to adopt the stove thereby spreading the adoption base in the population (Sahin, Ismail, 2016).

2.2.2.3 Conceptual Framework

The conceptual framework explains the processes leading to the adoption of cook stove based on the Diffusion of Innovation theory. According to Rogers, (1995, 2003) certain drivers (independent variables) positively or negatively influence the adoption (dependent variable) of ICSs by providing information (Knowledge) and also persuading potential consumers to influence their decision to adopt or reject the technology through communication over a period of time (Dadzie, 2018).

According to Rogers (2003), the adoptions decision process begins with an individual having a felt need for the technological cook stove. The potential adopter then depends on an information

gathering and early adopter persuasions to drive his or her adoption decision process. This process according to Rogers occurs along communication channels such as the mass media and personal communication with social associations. The theory postulates some factors that influence the adoption and use of an innovation. These include the relative advantages derived from the use of the innovation, the compatibility of the innovation to the everyday life of its adopters and the simplicity and ease of use as some of the characteristics of influential innovations.

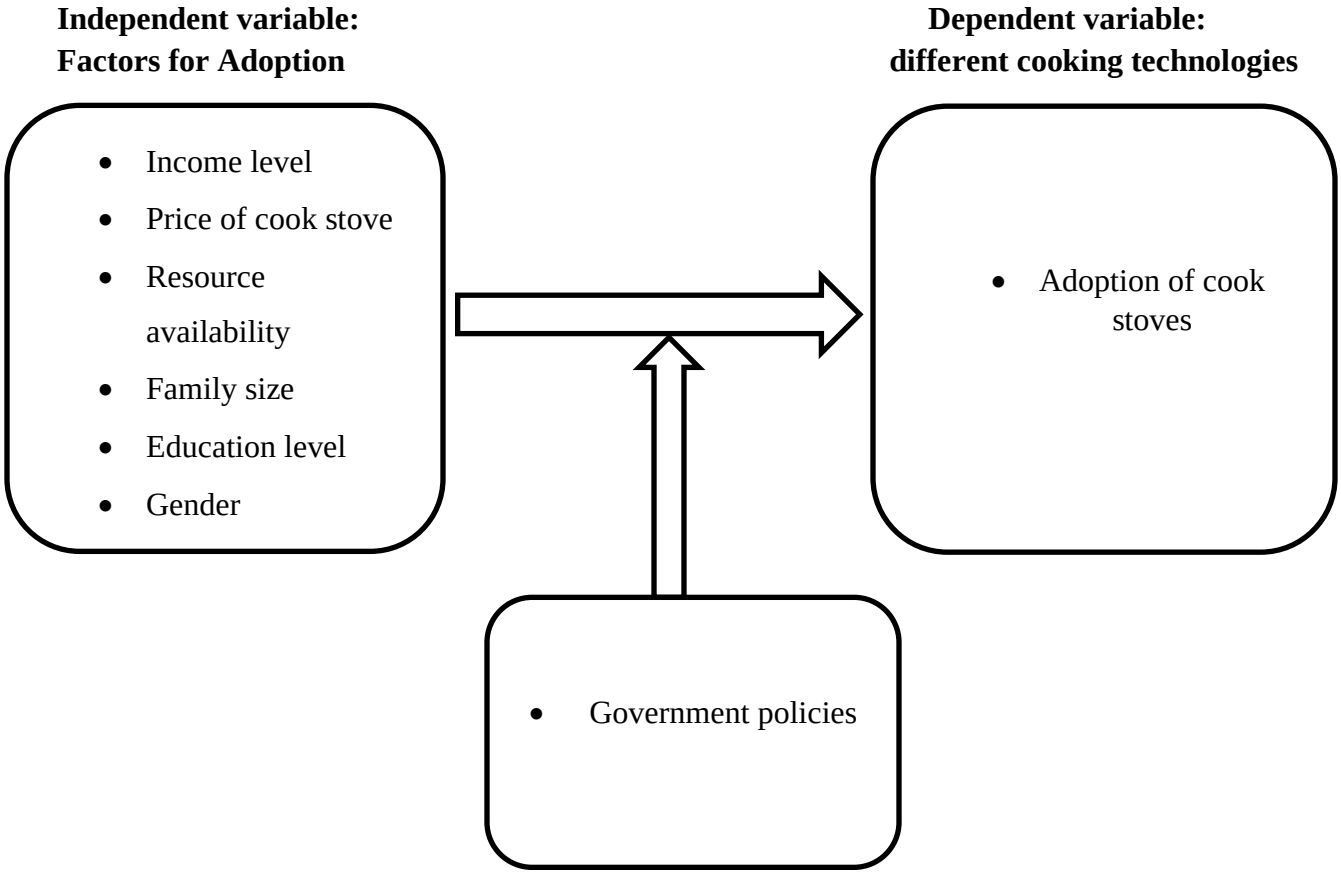

Figure 2: Conceptual framework

The literature shows that the global community is kin in mitigating the adverse effects (health, social, economic, and environmental) associated with the use of biomass fuel and traditional cook stoves. However, the adoption of improved cook stoves for the purpose of reducing these

adverse effects is faced with hindrances. Literature shows several socio-economic factors such as educational level of household head, sex, household size, preference, income etc. of a household influence their chances of adopting and using ICS.

Developing countries has seen a notable increase in the proportion of the population with cleaner stoves and fuel over the past 2 decades (WHO, 2018).

However, the literature shows well over half of the population still rely on biomass fuel and traditional cook stoves. The Diffusion of Innovation and Energy Stacking theories were therefore engaged to identify the barriers to adoption of ICSs and the possible remedies to increase its uptake.

“Numerous recent assessments of the fuel wood supply and demand situation and outlook in developing countries have confirmed earlier evidence of the extent and severity of the fuel wood crisis. According to the UN Food and Agriculture Organization (FAO), nearly half of the world's present population lives in areas of acute fuel wood scarcity or deficit. The fuel wood crisis, unlike the oil crisis, has shown no signs of easing in recent years.

However, national and international awareness of the fuel wood situation has improved significantly. Many governments and virtually all aid donors have been seeking to step up their involvement in addressing this problem. Demand management activities have been sorely lacking and have received attention only recently through attempts at promoting more energy-efficient cooking stoves in the domestic sector. (Manibog, 1984).

The East African Community (EAC) recognizes the energy access gaps among East African Countries (Tanzania, Kenya, Rwanda, Uganda and Burundi). Currently 81 % of East African population lack of access to modern energy services thus poses a challenge to achieve the Millennium Development Goals by 2015 (Bwenge, 2011).

CHAPTER THREE: RESEARCH METHOLOGY

3.0 Introduction

In social science, research methodology is a process designed and used in the generation and analysis of gathered data. Essentially, the procedures by which researchers go about their work of describing, explaining and predicting phenomena are called research methodology. This chapter explains how this was achieved. This chapter focused on the research designs, sources of data, the instruments utilized in the data collection process, the sampling procedure as well as how the data was analyzed.

3.1 Research Design

This study adopted the mixed method approach in the data gathering process. Mixed methods research can be described as a model of inquiry that combines qualitative and quantitative models of research so that evidence may be mixed and findings derived in a more meaningful manner than either approach could achieve alone. Qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to interpret phenomena in terms of the actual meanings. This methodology usually investigates the "what, why, where and when" of the phenomena understudy to make a decision (Dadzie, 2018).

Quantitative research is based on the measurement of quantity or amount. Quantitative research conversely is concerned with quantities and measurements aimed at making scientific generalizations and predictions in a research activity (Biggar, 2008). This methodology allows the researcher to observe the relationship between a dependent and independent variables and identify cause and affect relationships (Creswell, J.W, 2013).

The results derived from the findings are usually presented in tables and graphs. In order to satisfy the objective of the dissertation, of identifying different cooking stove technologies and find the appropriate technology for low income households, assessing the adoption of improved cook stoves by considering economic, And environmental aspects of Rwandan's life by improving the appropriate cooking energy access, socio-economic development as well as environmental protection a mixed research method of qualitative and quantitate research method will be used.

Mixed research methodology recognizes the value of knowledge as constructed through qualitative means such as perceptions, as well as experience based on the factual aspects of the world in which people live. Another key characteristic of the mixed-method research approach is that it rejects the dualism that sets qualitative or fact-based and quantitative or subjectively based methodologies as having value only in exclusivity from each other by comparing Quantitative, Qualitative methods versus mixed method research (Bamundekere, 2019).

i. Quantitative methods: This method it is pre-determined, instrument-based questionnaire, performance attitude, observation and census data, statistical analysis and interpretations.
ii. Qualitative methods: Emerging methods, open-ended questions, document and audio-visual data, text and image analysis, theme and patterns interpretation.
iii. Mixed methods: Pre-determined and emerging methods, Both open- and closed-ended Questions, Multiple forms of data drawing on all possibilities, statistical and text analysis , a cross database interpretations

The mixed method study is more complex than a purely quantitative or qualitative study because it requires ‘‘knowledge of both,’’ (Petticrew, Mark, Eva Rehfuess, Jane Noyes, Julian PT Higgins, Alain Mayhew, Tomas Pantoja, Ian Shemilt, and Amanda Sowden, 2013).The main characteristic of qualitative research is that it is most appropriate for small samples, while its outcomes are not measurable and quantifiable. It offers also a complete description and analysis of research subject, without limiting the scope of the research and the nature of the participant’s responses while the quantitative research focus on using numbers as its basis for making generalizations about a phenomenon. It is also concerned with analyzing statistical, mathematical and numerical data through polls, questionnaires and surveys (Langkos, Spyros, 2014).

The reasons for using the mixed method research approach was that it takes into account the context where qualitative and quantitative research methods are not sufficient to be used alone, because of the inherent weaknesses of each approach. For instance, quantitative research does not adequately investigate personal stories and meanings or deeply investigate the perspective of individuals. While qualitative research does not enable to generalize from a small group of people to a large population, it does not precisely measure what people in general feel (Creswell, J.W, 2013).

3.2 Research approach design

In this study, numerical figures and descriptive information obtained, given it both a quantitative and qualitative research dimension. The study hence will use both qualitative and quantitative approaches in data collection and analysis. This mixed research methodology used involves qualitative and quantitative data collected and analyzed concurrently to answer a certain research question beginning with specific observations which are used to produce generalized theories and conclusions (Creswell, 2013). In this work, we need to understand the reasons behind the adoption of appropriate Improved Cook stoves (ICSs) for low income household and the country as a whole.

This study will help us see the correlation between people's motives to adopt Improved Cook stoves and the impact of appropriate stoves in their daily life. We used both qualitative and quantitative research methods to know people's perspectives, stories, and feelings and to be able to quantify the importance of Improved Cook stoves to Rwandans.

3.3 Sample Size and Sampling Procedures

The study conducted in Rwanda Gisagara which located in south region of Rwanda. The choice of Gisagara as the area was motivated by the limited research studies conducted on cook stove adoption among households in the area. This was followed by the familiarization of the geographical boundaries of the area by the researcher. It will be important in ensuring the sampling technique which will effectively employed within the boundaries of the study area. Also, the study completed within the limited time and resources at the researcher's disposal; therefore the population size and the subsequent sample size of the area influenced its selection as the study area.

Gisagara is one of the province and densely populated area in Rwanda with a population size of 322,506, comprising of 150,455 males and 172,051 females (NISR, 2012). The average household size in Gisagara district is 4.2 persons, at the Sector level, household size varies between 4 and 4.4 persons. The community also has 77,259 households. The study area is largely residential with limited commercial activities in the form of retailing in shops along the principal streets in the town (NISR, 2012).

To make a generalization about a population, the sample size and procedures used and must be truly representative of the population (Israel, Glenn D, 2017). This means that in determining the sample size and sampling procedures, factors like the population of the study area, settlement, and homogeneity of household socio-economic characteristics considered. A smaller sample size is found to be representative enough in a homogeneous population (Israel, Glenn D, 2017).

The 2012 population and housing census estimated the household population size of Gisagara to be 77,259 households. The Taro Yamane formula is one of the most used formulas for calculating the sample size of a given population. It is considered appropriate when the population size is known and finite (Raimi, Morufu Olalekan, 2018). This study, therefore, employed the Yamane's formula in estimating the sample size.

The sample size n is given as $n = \frac{N}{1+N(e)^2}$

Where n=Sample size, N=total population, e = margin of error (0.05)

77,259 households = 398 sample size

This sample will be used in data collection by different Sectors of Gisagara, It is made of **13** Sectors.

3.4 Type and Sources of Data

Two major sources of data collection employed in this study, namely primary and secondary data. Primary data refers to a first-hand data source that the researcher collects for the purpose of answering research questions and the study objectives. This can be obtained through a survey, interview, focus group discussion, observation or experiment (Salkind, Neil J., ed, 2010). Secondary data, on the other hand, are data sources that already exist and can be used by others other than the original collector and for a purpose other than it was originally intended. These can be assessed in books, journals, newspapers and online sources (Salkind, Neil J., ed, 2010).

For this study, the primary data collected from field interviews conducted and questionnaires the researcher administered. The secondary sources were gathered from books, journals, articles and other online sources. The Library, Institute of Statistical, Social and Economic Research and Regional Institute of Population Studies Library of the University of Rwanda as well as other electronic sources including Jstor, Sage, and Google Scholar were used.

The unit of analysis for the study was household heads. Household heads often make the major decisions concerning home keeping which include the decision to adopt a particular cooking stove or combination of stoves. However, the other knowledgeable household member with eighteen years and older qualified to answer the questionnaire in the absence of the household head.

3.5 Data Collection Instruments

In order to obtain an in-depth understanding of the topic, a qualitative phenomenological approach employed. Semi-structured interviews used to elicit the qualitative data because it allows for significant and elaborative probing through a two-way communication those results in in-depth descriptions of the topic being discussed. These interviews lasted approximately between 15 to 20 minutes. Questionnaires also administer to respondents to obtain the quantitative data. The questionnaire captured user information such as the perceived benefits of ICS, the frequency of use, its price competitiveness among others. The questionnaire also use to elicit information that can interpret why certain people do not use the technology.

3.6 Data Analysis

The qualitative interviews conducted analyzed through a content analysis technique. This done after the interviews transcribed into a text form using Microsoft Word into a more formal written style. The content analysis activities as explained by Weber (1990) include translating the verbal audio data into text and classifying the dominate words into similar meaningful themes that represent explicit or inferred communication.

Also, the quantitative data collected analyzed using the Statistical Package for Social Sciences (SPSS) Program. Descriptive statistics such as frequencies and percentages will presented in bar and pie charts and in tables. Cross-tabulations will also performed to test the association between the dependent variable (adoption of ICS) and the independent variables (level of education of household head, sex of household head, availability of ICS, the price of alternative cook stoves and low public information).

3.7 Ethical Consideration

Ethics play an important role in any scientific research in ensuring that the privacy, confidentiality and other rights of all participants are respected. To do this without peril, participants were aware of their right to refuse to participate; assured of confidentiality and the potential uses of the information which was collected (Corti, Louise, Annette Day, and Gill Backhouse, 2000). The respondents was assured and reassured of their confidentiality, that none of their personal information or locations would be disclosed. To address ethical consideration, the assurance of anonymity, and informed consent of all participants took care of in a bid to repose trust in the researcher.

Introductory letter seeking consent for participation from institutions of concern was also delivered in advance. Also Validity and Reliability test was used: In this study face validity and concurrent validity techniques were used. In order to ensure validity of the experiment the following approaches were undertaken: Sample was collected using stratified random sampling technique; the numbers of samples greater than 30 are taken to ensure Normal Distribution; closed and open ended questionnaire design to avoid ambiguity in response; and due importance was given to the frequency of occurrences.

The internal consistency aspect was used in this study. The reliability was assessed by the statistical significance tests; the Spearman's Correlation test was used was used to show the degree of agreement between the different parties. The correlation coefficient varies between +1 and −1, where +1 implies a perfect positive relationship (agreement), while −1 results from a perfect negative relationship (disagreement). It might be said then that sample estimates of correlation close to unity in magnitude imply good correlation, while values near zero indicate little or no correlation. It helped in identifying a set of independent factors causing delays in government construction projects.

CHAPTER FOUR: RESEARCH FINDINGS AND DISCUSSION

4.0 Introduction

This chapter presents the results on information of households, the cooking technologies used, factors affecting adoption of cook stove and benefits of adopting and using cook stove among low income household of Gisagara which made of 13 Sectors which are Gikonko, Gishubi, Kansi, Kibilizi, Kigembe, Mamba, Muganza, Mugombwa, Mukindo, Musha, Ndora, Nyanza and Save.

4.1 Household Characteristics

The data collection covered 13 sectors with the numbers and frequencies for each village (Table2).

Table 2: Respondents per Sector

Name of Sector	Frequency	Percentage
Gikonko	30	7.53
Gishubi	31	7.8
Kansi	26	6.6
Kibilizi	32	8.04
Kigembe	34	8.54
Mamba	29	7.29
Muganza	28	7.04
Mugombwa	27	6.77
Mukindo	30	7.54
Musha	46	11.5
Ndora	33	8.29
Nyanza	29	7.29
Save	23	5.77
TOTAL	**398**	100.0

Sources: Researcher, 2022

4.1.1 Position of respondents in the household and household size

Among the respondent, 78% were women in the homestead with men making 12% while daughters, son, relatives, grandmother and granddaughters account for 10%. The size of the households ranged between of 1-2 at 24%, with most of households at 66% having between of 3-5 individuals while few households had 6-8 individuals (8.9%).

This study concurs with the findings that family size of 1-3 and 4-6 people served to have adopted more energy saving cooking technologies as compared to a family of size of 7-9 and 10-12 individuals. The results showed that households of between 3-5 members adopted the use of improved cook stoves at 67% followed by those of between 1-2 members at 25% for their cooking (Table 3).

Table 3: Position of the respondents in the household size

Household head	**Frequency**	**Percentage**
Men	48	12.5
Women	312	78
Daughter	10	2.5
Son	16	4.0
Relative/Guadian	8	2.0
Grandmother	4	1.0
Total	398	100.0

Source: Researcher, 2022

Table 4: Cross tabulation of type of cooking technologies used and household size

Type of cooking technology used	House hold size			Total
	1-2	3-5	6-8	
Traditional three stones	23	32	8	63
Metal stove	28	21	2	51
Multi-purpose-stove wood/charcoal	3	3		6
biogas		4	1	5
ICS/rondereza	36	194	24	254
Electric		1		1
LPG	8	6	1	15
Non response		3		3
Total	**98**	**264**	**36**	**398**

Source: Researcher, 2022

4.1.2 Age of respondent

The results indicated that majority of the respondents surveyed were female (84.2%) while males were 15.8%. on age variation, 27.7% of the respondents were aged between 50-59 years, 30-39 years and above 70 years were 22.8% indicating that women are more involved in cooking and cooking technologies affairs in the family (table 5).

Table 5: Age of respondent

Age bracket of respondents	Frequency	Percentage
20-29	20	5.0
30-39	91	22.8
40-49	56	13.9
50-59	108	27.7
60-69	32	7.9
Above 70	91	22.8
Total	**398**	**100.0**

Source: Researcher, 2022

4.1.3 Education level and household type

Technologies are knowledge intensive and require considerable management input (Chaudhuri, 2003). According to the results, those who had higher education level and undergraduate had adopted new technologies were 8% whereas those with lower education level were the majority of 75%. This is tallying with (Barnes, 2010) who postulated in his research that education is negatively related to adoption of improved cook stoves (table 6).

Table 6: Cross tabulation of type of cooking technologies used and education

Type of cooking technology used	Education level of respondents					Total
	Primary level	Secondary level	College diploma	Undergraduate degree	none	
Traditional three stones	35	41	2	1	26	105
Metal stove	17		10	1	8	36
Multi-purpose-stove wood/charcoal		1	8		1	10
biogas		3				3
ICS/Rondereza	74	109	4		36	223
Electric		1				1
LPG		7		1		8
Non response	8		4			12
Total	**134**	**162**	**28**	**3**	**71**	**398**

Source: Researcher, 2022

4.1.4 Nature of land holdings

The results indicate that 97% of the respondents owned family inherited land, 2% bought private and 1% rented household land for their dwellings and use (figure 3).

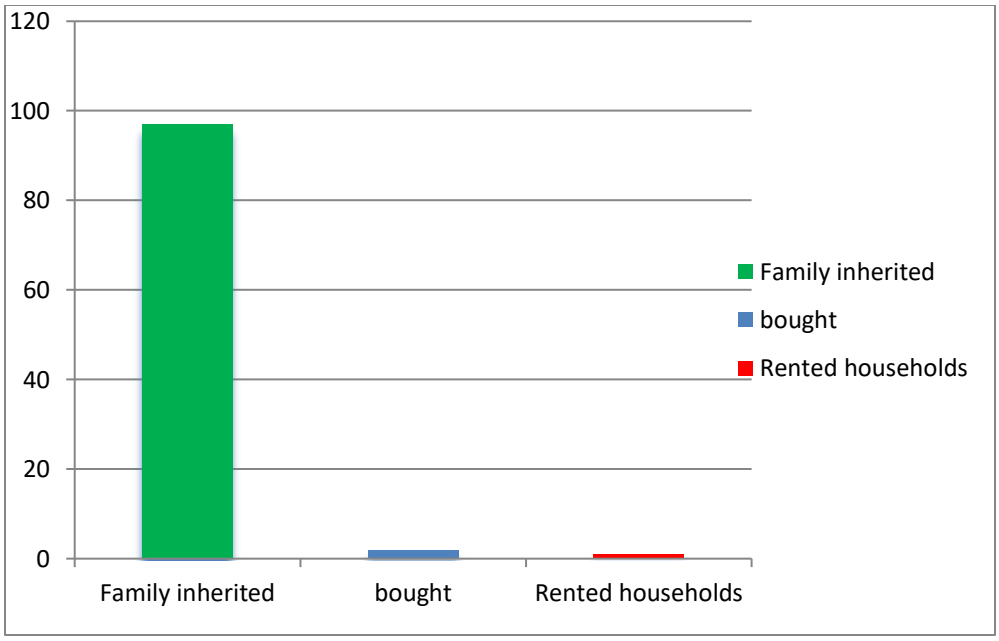

Figure 3: Nature of land holdings

4.2 Type of cooking technologies and fuel sources

Different cooking technologies were observed among the households in Gisagara including traditional three stone, firewood stove and charcoal, metal cook stove, LPG gas, biogas, electric and ICS stove as major cooking devices.

Among the 398 households surveyed, majority acknowledged having improved cooking stove mainly known as Cana make and Rondereza at 56.5% while those still having traditional three stones at 22.8%, followed closely by biogas, metal stove, multi-purpose firewood/charcoal stove at 4% each(Table 7).

Table 7: Type of cooking technologies

Type of cooking technology used	Frequency	Percentage
Traditional three stones	63	15.8
Metal stove	51	12.8
Multi-purpose-stove wood/charcoal	6	1.5
biogas	5	1.35
ICS/rondereza/canamake	254	63.8
Electric	1	0.3
LPG	15	3.8
Not applicable	3	0.65
Total	**398**	**100.0**

Source: Researcher, 2022

4.2.1 Type of cooking technology used

According to (Benson, 2018), several types of cook stoves are used by household and these stoves are often associated with specific energy types. Traditional three stone, simple non-traditional for example clay pot-style, charcoal and some ICSs use solid fuels which are common in rural areas of most developing countries. In contrast, more modern cooking stoves, such as LPG, natural gas and electric stove are common in urban areas of both developing and developed countries.

In this study seven different cooking technologies were identified in the study area (see appendix) these were: traditional three stone, multi-purpose cooking stove, wood/charcoal and improved three stones being the most common accounting for 26.7%, 22.8% and 20.8% respectively, as most commonly used cooking devices in rural Gisagara(figure 4).

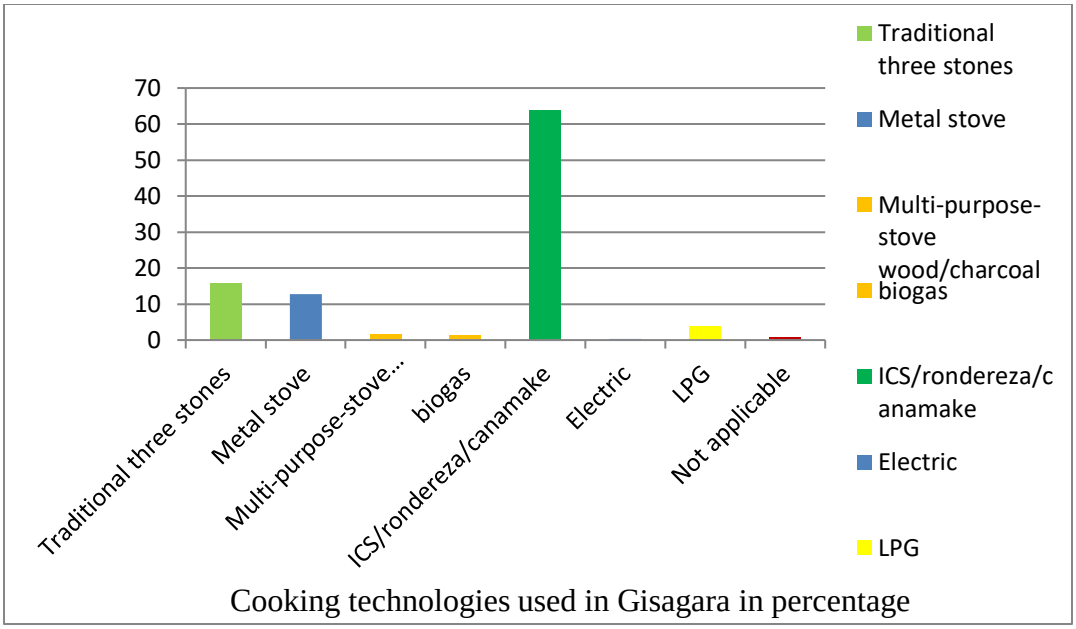

Figure 4: Type of cooking technologies used in Gisagara

4.2.2 Cooking dynamics in Gisagara

The results showed that major changes in cooking technologies switch occurred between 2006 and 2015 where adoption of improved cook stove (Rondereza, Cana make, cana rumwe), metal stove, LPG gas and Multi-purpose/ wood/charcoal, electric stove were realized (71.5%). The result further showed positive changes before 2000 to 2007 (23%). While above 2017, further switch of about 6% was realized. Before years of 2000 households were using tradition mud stove.

But around 1998 – 2000 households' shift to improved stoves which use the stone and try to reduce inefficiency instead of mud which seems to be great achievement this count to 15% of total changes of cooking. From 2010 to 2015 different project started which contribute to 48.5% of total percentage contributed as household start using metal stoves, LPG gas, ICSs like (Rondereza, Cana make, Can rumwe) which were strategies to reduce deforestation.

2015 to 2020 the trends keep being positives reach to71.5% and due to different strategies and projects like Amayaga Green Project which launched December 17, 2020 the distribution of 60,000 improved cook stoves will contribute to reduce about five million tons of greenhouse gas emissions meaning 15 million tons (15Mtoe of CO_2) in the next 20 years compared to the air pollutants currently being experienced in Rwanda.

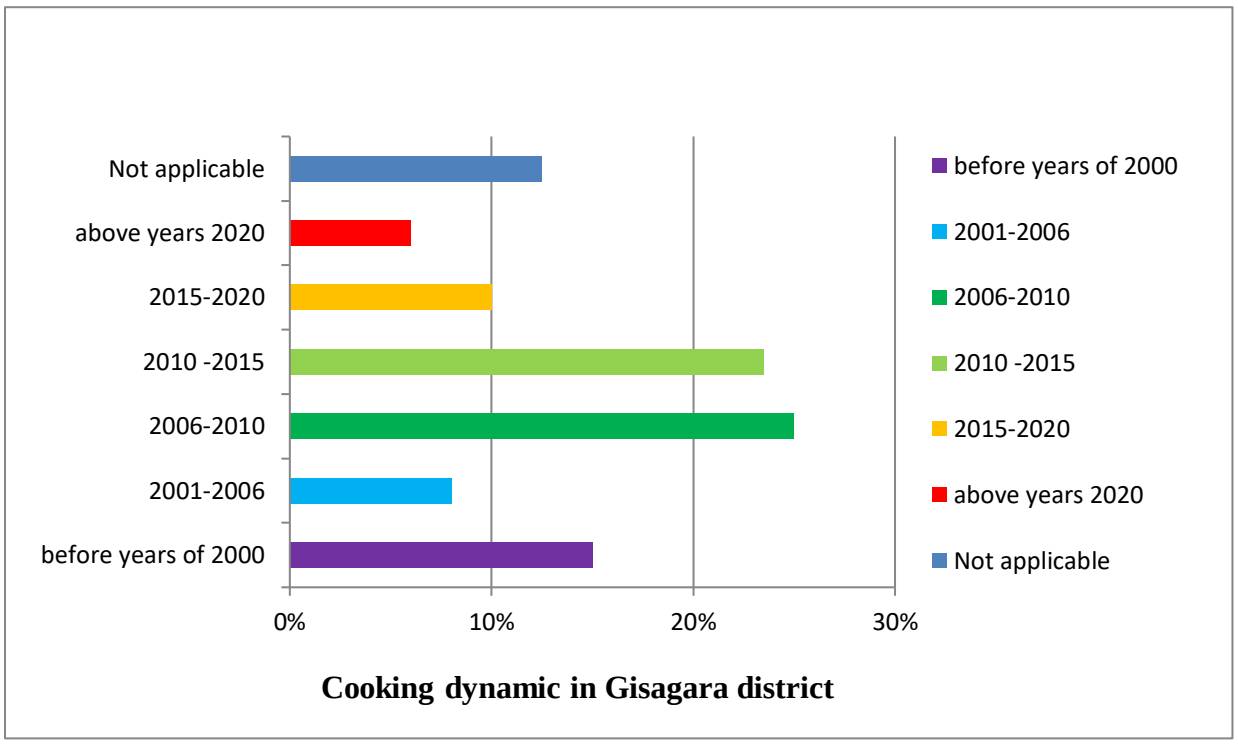

Figure 5: Cooking dynamic in Gisagara Districts

4.2.3 Sources of Cooking technologies and its influence on cook stove adoption

The results shows that about 37.6% of respondents indicated that the cook stoves were made at home, 16.7% from nearest Centre – Ndora market shopping Centre and 12.9% got their cook stoves from nearby small shopping centre –Rugogwe and Nyaruteja markets. This shows that the local households preferred the devices they are sourcing locally. This was facilitated by the availability of various dealers which are able to construct ICSs like Rondereza, and metal made stove which are sold in different market of Gisagara districts.

According to the results, about 17.6% of ICS in Gisagara town and side area got the stove from DelAgua Company. And the Amayaga Green Projects also gives stoves to Gisagara's households counted to 11.4% (figure 6).

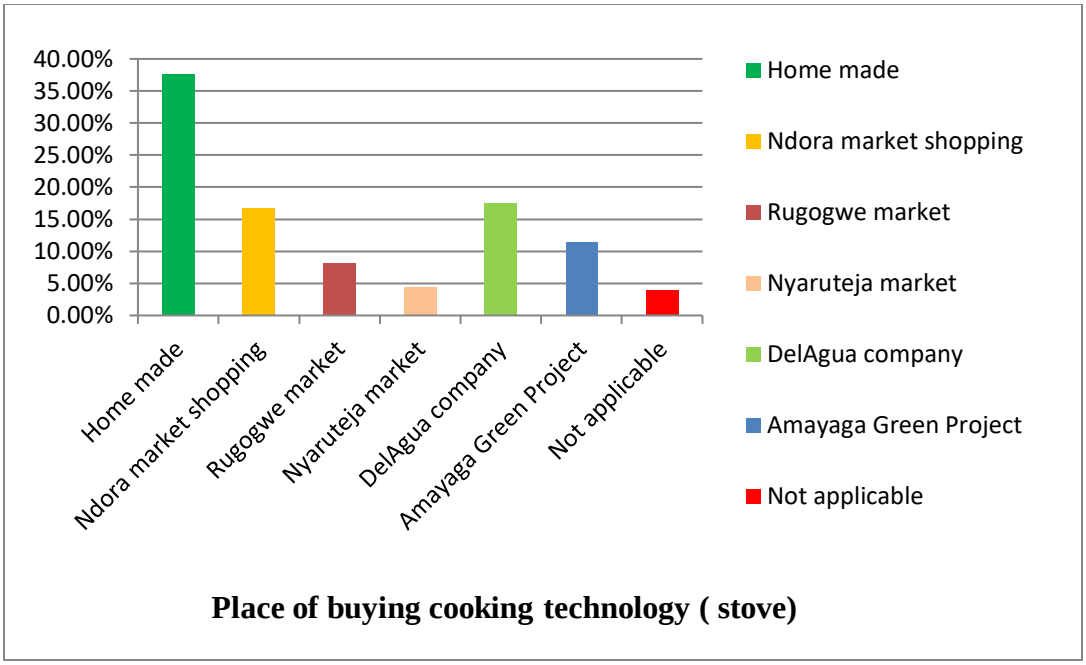

Figure 6: Place of buying cook stove and Price influence on stove adoption

The analysis on the prices of cooking devices revealed that those whose prices were less than 2000 Frw were 29%, those priced between 5000 Frw – 10000 Frw were 43%. The study revealed similar findings by (Benson, 2018) that found price is one determinant factor that influences improved cook stoves adoption among the households (Figure 7)

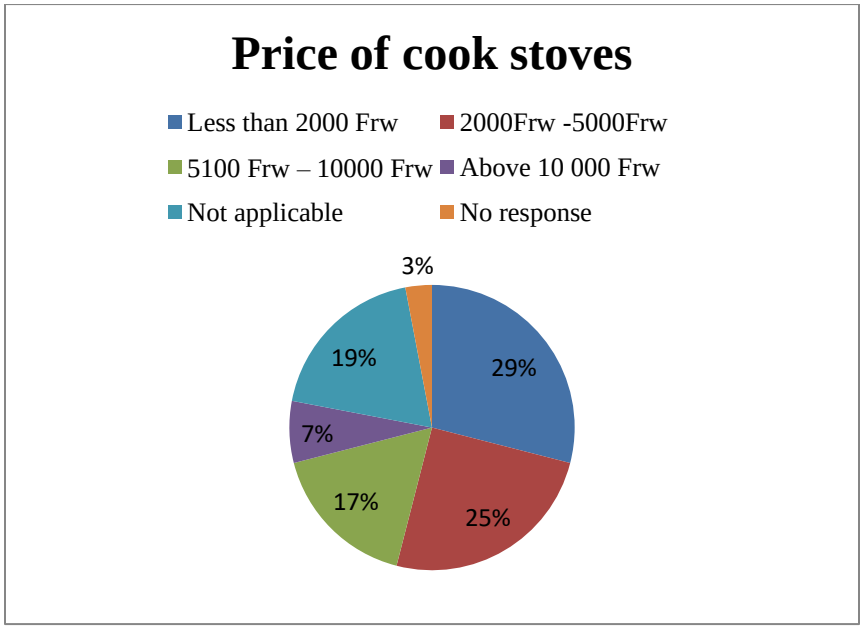

Figure 7: Price of cooking technologies

4.2.4 Type of cooking energy/ fuels

Among the 398 households surveyed, 43.6% indicated that they use firewood from own farm and 21.8% from own farm and firewood purchased for their cooking. For the quantity of cooking energy used per week, majority of the households use between 0-5 kg per week (72.3%) and 51-100kg per week (13.9%). On the price, respondents indicated the use of energy/fuel monthly less than 2000 Frw (56.4%) followed by between 2000 Frw -5000 Frw (18.8%) while on distance covered to get cooking energy/fuels and preferred uses, the results showed that most of the respondents walk between 1 to 2 km (77.2%) and 70.3 % of the households, preferred use of fuels for cooking and warning (Table 8).

Table 8: Type of cooking energy/fuels used

Types of Cooking Fuels/energy Used	Frequency	Percentage
Firewood from own farm	79	19.8
Firewood collected	178	44.7
Firewood collected and from farm	98	24.8
LPG Gas	7	1.7
charcoal	19	4.8
Farm residues-Maize stalks, Dry leaves, Maize cobs	4	1.0
Others (electricity,biogas etc...)	3	0.7
Decline to answer the question	10	2.5
Total	**398**	**100.0**

Sources: Researcher, 2022

4.3 Factors influencing choice of cooking technologies

The results indicate that among the respondents surveyed on the factors influencing their choice of cooking devices/technologies, 30.7% indicate the cooking technologies as economical, fuel, saving at 18% and being able to cook faster and therefore save time while cooking at 17.8% and 11.9% indicated the availability of fuel wood as a factor influencing choice of cooking devices among the households.

(Dadzie, 2018) Alluded that "advancement towards the provision of greater access to modern energy services has been slow, due to a combination of interrelated circumstances" These include low income levels among the unnerved population, lack of financial resources for services providers to build the necessary infrastructure and reduce the first cost barriers to access, weak institutional, Financial, Legal structures and government involvement.

Improved cook stoves are more attractive in those households that experience a scarcity in wood fuel resources since they will benefit significantly from the performance of the stoves (Table 9)

Table 9: Factors influencing choice of cooking technologies

Factor that influences choice of cooking technologies	Frequency	Percentage
Lack of finance	8	2.0
Traditional method	12	3.0
Fast in cooking	71	17.8
Fast and fuel saving	12	3.0
Economically	122	30.7
Fuel saving	75	18.8
Lack of alternative	19	5.0
Less smoke produced	8	2.0
Easy to use	12	3.0
Availability of fuel use	47	11.9
Decline to answer the question	12	3.0
Total	398	100.0

Source: Researcher, 2022

4.3.1 Special occasions for cooking technologies

A research conducted in Ghana pointed that open fires are needed in fish-smoking process. So the failure to effectively address issues like ability to use cooking device for special cooking ensure that new cook stove will be adopted or not (Benson, 2018).

The study shows that 22.8% of the households indicated that it was economical to cook large quantity of food for visitors followed by 5.9% able to prepare food that take longer time example like beans, etc... The results support similar studies conducted in Guatemala by Hertzberg 2005, postulates that traditional cooking practice and food tastes might make households prefer fuel-wood, even in circumstance where fuel-wood used is compared to other efficient cooking devices. (Benson, 2018) Found that people in rural Mexico continue to use fuel-wood even when they could afford to use cleaner and modern cooking devices and fuels due to the cost and availability of wood-fuel (Table 10).

Table 10: Special occasions for cooking technologies

Reason for special cooking	Frequency	Percentage
Economical while cooking large quantity of food for visitors	91	22.8
To prepare food that take longer time e.g. Beans	23	5.9
Warming during cold weather	20	5.0
When there is scarcity of fuel	4	1.0
Not applicable	4	1.0
Decline to answer the question	256	64.4
Total	**398**	**100.0**

Source: Researcher, 2022

4.3.2 Cooking fuels and rainy period

The results showed that majority of the respondents surveyed, use firewood and charcoal for their cooking during rainy periods at 9% declined (Figure11).

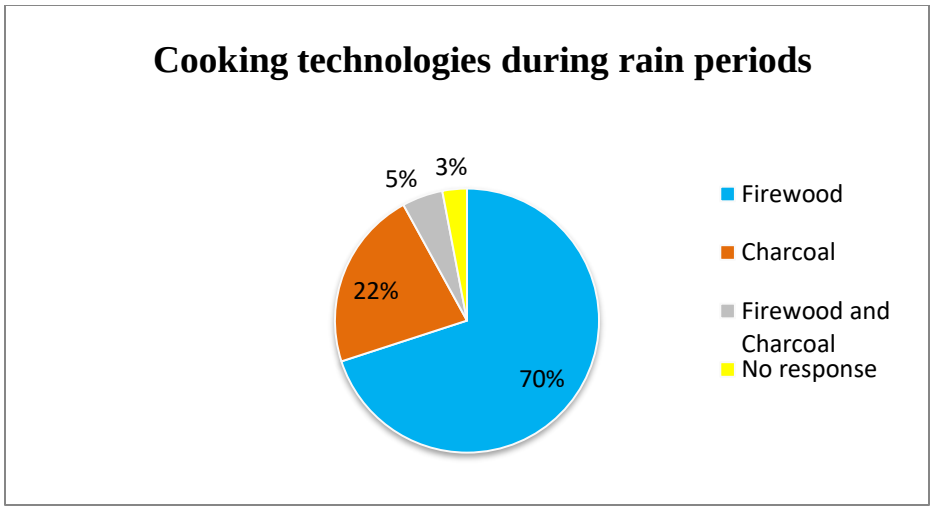

Table 11: Cooking devices used during rain period

According to the results majority of the residents used the above cooking fuel due to the provision of enough warmth, for being economical, readily available and scarcity of dry firewood (42%, 19%, 15%, and 10%) respectively. About 11% of the respondents indicated lack of alternative source of fuel, portability, and multipurpose for use as other reasons (Figure 12).

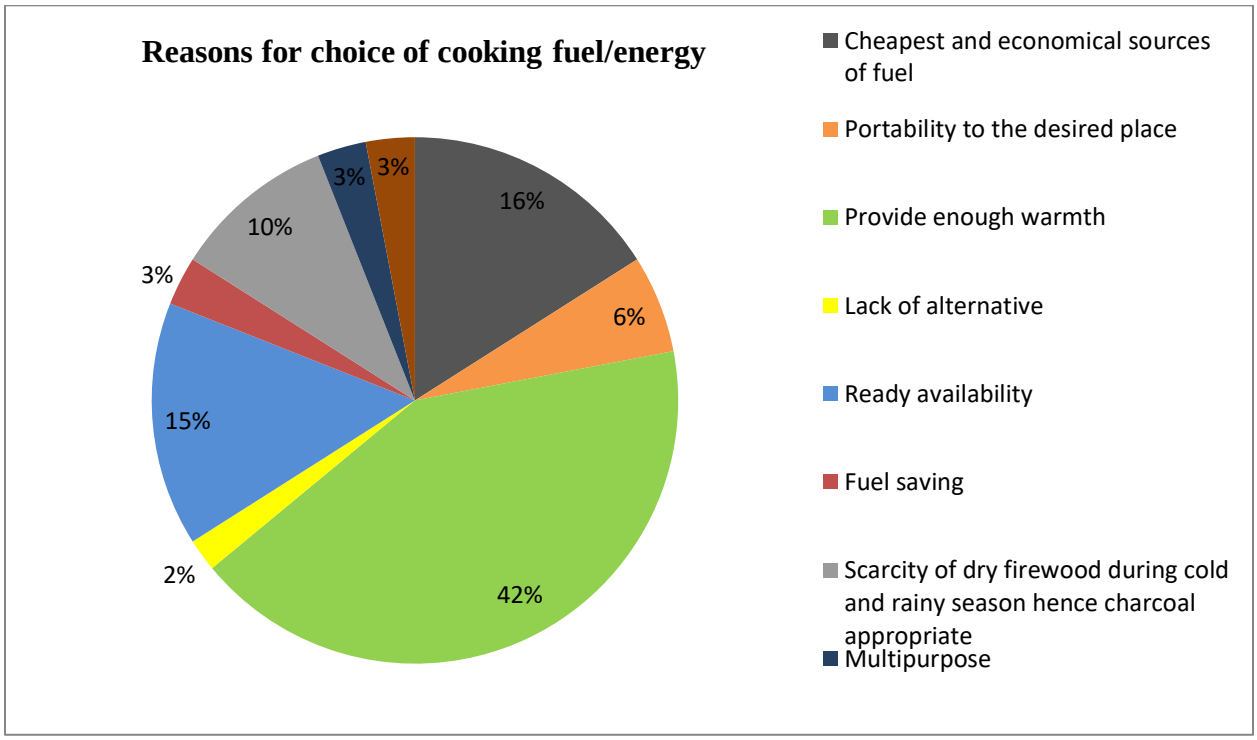

Table 12: Reasons for choice of cooking fuel/energy

4.3.3 Challenges in getting cooking energy/fuels

The results indicated inadequate, unavailability of firewood and heavy to transport for long distance at 20% and 19% respectively followed closely by high price of firewood at 12.9% as major challenges in getting cooking fuels among the households (Table 13).

Table 13: Challenges in getting cooking energy/fuels

Cooking Fuels Challenges	**Frequency**	**Percentage**
High price of firewood	51	12.9
None	83	20.8
Inadequate and unavailability of firewood	79	19.8
Take time to dry during wet season	35	8.9
Process of making biogas requires skilled manpower	4	1.0
Heavy and bulky to transport for long distances	75	18.8
Time consuming to fetch firewood	20	5.0
Lack of labor to fetch firewood	27	6.9
Tedious to split firewood	8	2.0
Requires a lot of firewood to cook	4	1.0
No response	12	3.0
Total	**398**	**100.0**

Source: Researcher, 2022

4.4 Factors influencing adoption of cook stoves for low-income households

On factors influencing adoption of cooking technologies, majority of respondents surveyed in different sectors of Gisagara district indicated that the cost effectiveness 40% and availability of fuel at 27% as the major influencing factors. According to (Benson, 2018)found out that the cost of modern fuels and lack of supply contributes limited adoption of cook stoves in sectors. Use of new technology depends on its efficiency and effectiveness to perform a task. Improve and clean fuels can save time by reducing fuel collection time and through more efficient cooking process.

This aspect is usually highly valued by women and a direct benefit that adopters positively recognize (Table 14).

Table 14: Factors influencing adoption of cook stove

Type of factors	**Frequency**	**Percentage**
Availability of fuel	106	26.7
Lack of alternative	12	3.0
Time effectiveness in cooking	31	7.9
Lack of capital	8	2.0
Cost effectiveness	158	39.6
Durability and design	16	4.0
Level of income	4	1.0
Fuel saving	31	7.9
Reduced smoke	12	3.0
Accessibility	4	1.0
Climate change	4	1.0
No response	12	3.0
Total	**398**	**100.0**

Source: Researcher, 2022

4.4.1 Social – Cultural factor

Out of the 398 households surveyed, the results showed that, 77.2% (308 households) had adopted whereas 22.8 % (90 households) had not adopted. Across cultural study conducted in Guatemala, Uganda, Ghana, illustrated that cultural barrier influences improved cook stove adoption (Bielecki, 2014). The results also showed that an increase in frequency price of cooking in households reduces the likelihood of using fuel wood.

4.4.2 Household income and cook stove adoption

In study findings, 61.4% earn their income from subsistence farming, business 12%, assistance from children 8.9%, employment 7.9%, commercial farming 5.9%, and daily farming 1%, indicating that farming is the main economic activity of Gisagara's households. On animals reared by households, the results indicated that 35.2% keep cows, 14.9% chicken, 41% keep goats, while those who do not keep any animals were 8.9%.

The reason for keeping these animals was given as source of income (89.1%), culture (1%) while those who declined were 9.9%. indicating that this was a big supplement to the other sources of household income mentioned. Further, the results showed that majority of households earns below 30,000 Frw (33.7%), followed by 30,000 Frw- 40,000 Frw at (30.7%), 40,000 Frw-50,000Frw (9.9%) above 50, 000 Frw were (22.8%). This also revealed the relationship between adoptions of clean energy for cooking.

The results showed that those households whose average income was below 30,000 Frw adopted and used improved three stone and traditional three stones cooking technologies, while those with average households income is above 30,000 Frw, adopted and used clean energy like LPG, Biogas, metal stoves, electricity indicate the positive effect on adoption of new and advanced technologies as shown in the cross-tabulation table below.

This study disagrees with (khamati, 2000) findings of rural stoves-device programs in Kenya, that the rural people are generally poor and that children and women collect their fuel for free. According to word bank 2005, household income can be utilized as to determine the available disposable income for use and adoption of new technologies for example the improved cook stoves (Figure 8).

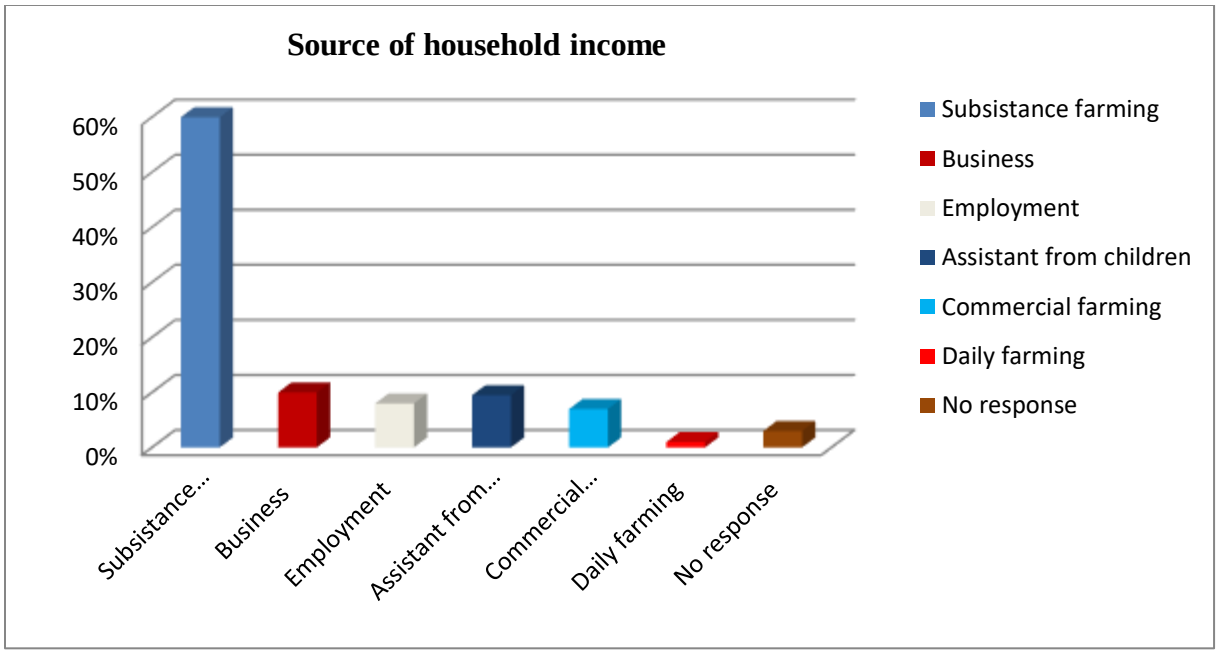

Figure 8: Source of household income

Table 15: Cross tabulation of type of cooking technologies and average household's income

Type of cooking devices used	Below 30,000 Frw	30,000 Frw-40,000 Frw	40,000 Frw-50,000 Frw	Above 50,000 Frw	No response	
Traditional three stones	59	23	4	3		**89**
Metal stove	4	15	7	23		**49**
Multi-purpose-stove wood/charcoal	4	3	1	1		**9**
biogas		2	1			**3**
ICS/rondereza	63	73	23	60		**219**
Electric				1		**1**
LPG	4	6	3	3		**16**
Non response					12	**12**
Total	**134**	**122**	**39**	**91**	**12**	**398**

Source: Researcher, 2022

Table 16: Chi-square test

	value	df	Asymp.sign.(2-Side)
Pearson Chi-square	141.282[a]	44	0.000
Likelihood Ratio	71.163	44	0.005
Linear-by-Linear Association	97.794	1	0.000
N of Valid Cases	398		
53 cells (89.1%) have expected countless than 5. The minimum expected count is 0.3			

Source: Researcher, 20222

4.4.3 Smoke as a factor for adoption of cook stoves

The results showed that respondent's acknowledging that indeed smoke as an issue were at par (45.8% each). When asked to justify why smoke is an issue, about 15% mentioned that smoke causes respiratory problems, discomfort and eye problems at 18%, coughing at 2% and smoke dirtying the house at 1%. Others who declined to answer were 51% Cleary indicating that people adopt improved cook stoves since smoke is not an issue once you adopt new technology (Table 4.17).

According to (Benson, 2018), the use of improved stoves minimize the prevalence of walls and ceiling, clothes and persons, thereby increasing overall health through improved hygiene. (Bwenge, 2011), also find that exposure to smoke from burning biomass fuels for cooking and/or heating is associated with increased risk of chronic obstructive pulmonary diseases(COPD).

Table 17: Types of smoke issues

Type of smoke issues	Frequency	percentage
Causes respiratory problems	59	14.9
Eye problems	34	8.9
coughing	8	2.0
Causes discomfort	34	8.9
Allergies	4	1.0
Not applicable	47	11.9
No response	205	51.5
Smoke will make house dirty	4	1.0
Total	398	100.0

Source: Researcher, 2022

4.4.4 Improved cook stoves development programs in Gisagara

To find out the existence of any development programs on improved coo stoves amongst the household, analysis was done. Out of the 398 households surveyed, 25.8% and 8% indicated DelAgua initiative and Amayaga Green Project (AGP) African company respectively as the major players in southern region of Rwanda. According to (Michel, 2021), targeted village groups through local partners were imperative for acceptance of an improved stove project in northern region including Gisagara.

4.4.5 Benefits of adopting improved stove

Historically, technology has clashed with user habits- how is it that the technology improvement exists as well as the knowledge of the adverse impacts from traditional three stone cooking practices, yet adoption still lags? The missing lies in the overall household's acceptability of a new stove design relative to the traditional methods (Clough, Laura, 2012).

Global Village Energy Partnership international suggests that there are three principal dimensions affecting adoption of any radically new product/service: motivation, affordability and level of engagement required (GVEP, 2009).

The global analysis of cook stoves adoption reaffirm that each of the device is utilized for the cooking practices where it fits best-stacking. This concurs with my research in Gisagara Sectors, where the respondents were asked why they bought the improved stoves. The results showed that majority of the respondents (81%) bought them since they are economical and providing warmth, readily available, reduction of smoke at 7%, 4% and 3% respectively (Table18).

Table 18: Benefits of adoption of cook stoves

Types of benefit	**Frequency**	**Percentage**
Fuel saving	**79**	19.8
Fast in cooking hence saves on time	79	19.8
Fast in cooking and fuel saving	102	25.7
Cheap and economical	63	15.8
Reduce smoke	12	3.0
Provide warmth	31	7.9
Readily available	16	4.0
It's durable	4	1.0
No response	12	3.0
Total	398	100.0

Source: Researcher, 2022

4.5 Correlation and coefficient determination

To quantify the relationship and strength of the relationship between variables, the study used Karl Pearson's coefficient of correlation. This is a measure of the strength of a linear association between two variables and is denoted by **r**. which can take a range from **+1** to **-1**.

A value of **0** shows that there is no correlation between the two variables, while a value greater than **0** indicates a positive association or significant (i.e. the value of one variable increase so does the value of the other variable). And a value less than **0**, shows a negative association (i.e. the value of one variable increase as value of other variable decrease).

4.5.1 Cooking technologies and adoption of cook stoves

According to the table below , there is positive relationship between the adoption of type of cooking technologies and gender, average income of household, households size and cost of cooking devices (**r**=0.074,0.989, 0.044) respectively. The results indicate that there is correlation between adoptions of stoves and gender, average of household's income, household's size and cost of stoves in Gisagara sectors.

The despite, all factors had a significant p-value ($p<0.05$) at 95% confidence level. From the Pearson's correlation coefficient, average household income was the most significant determinant where **r** = 0,989.

This findings consist with (Benson, 2018), who find out a significant relationship between average household income and economic status of rural households and adoption of biomass stove. In other hand there was no significant relationship between age of respondents, education level, and land size as of **r** =0.0083, 0.026 showing non-significant (Table 19).

Table 19: Correlation analysis of types of cooking technology and factors for adoption

Variable tested		**Type of cooking technology**
Age bracket	Pearson correlation	-0.083
	Sig.(1-tailed)	0.206
	N	398
Household size	Pearson correlation	0.044
	Sig.(1-tailed)	0.330
	N	398
Gender	Pearson correlation	0.074
	Sig.(1-tailed)	0.230
	N	398
Education level	Pearson correlation	-0.082
	Sig.(1-tailed)	0.207
	N	398
Land size	Pearson correlation	-0.055
	Sig.(1-tailed)	0.293
	N	398
Cost of cook stove	Pearson correlation	0.192*
	Sig.(1-tailed)	0.027
	N	398
Distance covered to buy cooking device	Pearson correlation	-0.026
	Sig.(1-tailed)	0.398
	N	398
Average income of households	Pearson correlation	0.989**
	Sig.(1-tailed)	0.000
	N	398

** Correlation is significant at the 0.01 level (1-tailed).

*correlation is significant at the 0.05 level (1-tailed)

Source: Researcher, 2022

4.5.2 Type of energy/ fuels used for cooking

Table 20: correlation of types of cooking energy/fuels used

Variable tested		Type of cooking energy/fuels used
Type of cooking fuels do you use	Pearson correlation	1
	Sig.(1-tailed)	
	N	398
Household size	Pearson correlation	-0.05
	Sig.(1-tailed)	0.964
	N	398
Gender	Pearson correlation	-0.006
	Sig.(1-tailed)	0.950
	N	398
Age bracket	Pearson correlation	-0.035
	Sig.(1-tailed)	0.725
	N	398
Education level	Pearson correlation	0.023
	Sig.(1-tailed)	0.823
	N	398
Firm size	Pearson correlation	0.043
	Sig.(1-tailed)	0.668
	N	398
Type of cooking technology used for cooking	Pearson correlation	0.457**
	Sig.(1-tailed)	0.000
	N	398
Cost of cooking device (cook stove)	Pearson correlation	-0.273**
	Sig.(1-tailed)	0.006
	N	398
Distance covered to buy cooking device	Pearson correlation	-291**
	Sig.(1-tailed)	0.003
	N	398
Type of cooking fuel used	Pearson correlation	0.077
	Sig.(1-tailed)	0.446
	N	398
Average income of households	Pearson correlation	0.083
	Sig.(1-tailed)	0.408
	N	398

** Correlation is significant at the 0.01 level (2-tailed). , *correlation is significant at the 0.05 level (2-tailed).

Source: Researcher, 2022

The results shows that there is a positive correlation between adoption of cooking fuels with type of cooking technologies used for cooking, education level, farm size and average household income where value of **r** = 0.454, 0.023, 0.043 and 0.083, where all these factors had a 95% confidence level and p value ($p<0.05$). Other factors such as household size, gender, age and cost of cooking technology showed a negative significance indicating that there is no relationship between adoptions of cooking fuels and them as can be seen in the table below where value of **r** = -0.005, -0.006, -0.035 and -0.291, $p>0.005$ respectively(Table 4.20).

CHAPTER FIVE: SUMMARY OF FINDINGS AND RECOMMENDATION

5.0 Introduction

This chapter outlines the discussion of the key data findings, conclusion drawn from the used results and recommendations made there too. These were focused primarily to address the objectives of the study which included, assessing different cooking technologies of cook stoves, examining factors that influencing the adoption of cook stoves for low income household and assessing the advantage of cook stove adoption for low income households in Gisagara.

1.1 Summary of findings

The study assessed factors influencing adoption of cook stove for low income households in different sectors of Gisagara district. Taking 398 households respondents with main three purposes; assessing different cooking technologies of cook stoves, assessing factors that influencing the adoption of cook stoves and examining the foctors influencing adoption of cook stove for low income households in different sectors of Gisagara District which located in southern province of Rwanda.

On the size of the family, the study established that majority of households surveyed were having 3-5 individuals (67% of respondent) followed by those with 1-2 individuals at about 25% while those with 6-8 individuals about 9%. Thereby indicating that these families do not require heavy cooking high rate of adoption can be achieved. This occurs with other researchers who argues that as the family size increases, food amount to be cooked and that also influences an increase in the amount of fuel/energy to be used to prepare the food. Educational level of the households was utilized as a proxy for awareness of the relative threats and benefits of using improved technology for household's fuel purpose.

1.1.1 Objective one: Assessing different cooking technologies

The more aware (educated) respondents were, the more likely they were to use efficient cooking technologies. However, from the results, we can deduce that the level of education might not have been a major factor for adopting new cooking technology in Gisagara districts.

The focus was more on females as they are the ones responsible for collection, choice and use of cooking devices and fuels for the households needs. Further, the results showed 84.2% of respondents interviewed were females, while only 15.8% male concurring with other researchers that females are the victims of the adverse effect of preparing food and fuels/energy collection. On further assessment of the cooking technology owned and used, the results showed the main cooking technology owned were Improved cook stove (Rondereza/ Cana make) about 63.8% followed by tradition three stones at 15.8% . With multi-purpose stove 1.5% respectively.

A further assessment was done to establish, which among the cooking technology owned, which ones are by households for cooking. The results indicated that 15.8% use traditional three stove stoves, multipurpose woo/charcoal at 1.5%, improved stove like rondereza cana make and others count to 63.8% metal stoves 12.8%, LPG at 3.8% and also found that households use electricity for cooking count to 0.3% respectively.

1.1.2 Objective 2: Assessing factors influencing adoption of cook stove

This indicate the positive adoption rate and respondent indicate that as more than 60% use ICSs (DelAgua, Rondereza, Amayaga Green Project stoves) that are efficient cooking technology for low income households due to the following: Concurring with their the reasons for technology choice as use as fast in cooking, fuel saving, more economical for family. The study also found that firewood collected and from farms was major energy used by majority about 68% followed by charcoal with 4.8%. This concurred with the results that indicated that the majority of the respondents use firewood above 70% for their cooking due to the availability of resources in the area, income level of the family, family size etc...

Results also show that there is positive relationship between the adoption of type of cooking technologies and Income of household, households size and cost of cooking devices where Probability value is less than Significance value $P<0.05$; (**r**=0.074, 0.0989, 0.044) respectively.

The results indicate that there is correlation between adoptions of stoves and gender, average of household's income, household's size and cost of stoves

5.1.3 Objective three: Examining factors influencing the adoption of cook stove for low-income households

Further determination of factors influencing adoption of cook stove, the results showed that the cost of cooking technologies was a key in adopting the new cooking technology, with more than 55.3% agreeing and giving lack of finance to purchase the technology as major barrier to adopt new technologies. The correlation result P-Value of 0.027 shows that there is Positive relationship between adoption of stove and Income level of households. This followed by unavailability of new technologies at market and many stove are from different projects like DelAgua and Amayaga Green Project, and created localy like ICSs Rondereza and others.

The study also revealed that majority of the households got information on merit and demerits of improved cook stoves from neighbor, friends and meeting by different program for stove development at 82%, where DelAgua Company has 17.6% and Amayaga Green Project 11.4%
Lastly the study assessed the benefits associated with adoption of cook stoves of which factors such as fuel saving, fast in cooking and saves time, cheap and economical, and reduced smoke while cooking resulted from the survey conducted.

1.2 Conclusions

The study found that the majority of the households in Gisagara sectors had adopted various improved cook stove and a few households still use traditional three stone stove alongside the improved cook stoves. The overall view of existing literature indicates that a number of variables including socio-economic, health, behavior, local environment, technologies, policies, and access to infrastructure affect households cooking technologies and fuel choice towards adoption of cook stove.

However households with higher income and education are more likely to use modern cooking technologies and fuels, their decisions are quite complex and multidimensional for adopt devices and fuels. Deep understanding of these factors is necessary for designing government plans, policies and strategies to improve access to modern fuels and adoption of cook stoves amongst

rural households. For example, cost associated with improved cook stoves outweigh the perceived health benefits by adopting and using ICSs and financial benefits from fuels saving.

1.3 Recommendations

Based on the findings and conclusion drawn above, the study makes the following specific recommendations:

i. Households especially with low income should be empowered financially when it comes to adoption of cook stoves

ii. Dissemination of information on cook stove in terms of benefits need to be improved through neighbor, seminars and meeting.

iii. More research on energy saving cooking technology should be conducted and results implemented for better conservation and environmental sustainability.

iv. The cost of biomass stoves and other clean energy cooking technologies should be affordable to enable low income households to acquire them at low price and to this end the Government of Rwanda, Rwanda Energy Group (REG), and NGOs need to promote interventions that will enable low income earners to use higher-quality technologies and low emission cooking energy/fuels.

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APPENDICES

Appendix 1: Questionaire

HOUSEHOLD QUESTIONAIRE

I am a post graduate student at African Centre of Excellence in Energy for Sustainable Development (ACE-ESD), University of Rwanda. Carrying out, a research on factors influencing the adoption of cook stove for low income households. Your response in this questionnaire will be kept confidential and used for no any other purpose other than for academic purpose.

PART A: HOUSEHOLD CHARACTERESTICS

1. **Way point**

   Location _____

   Sector _____

2. **Position in the Household**

   Mother [ ] Father [ ]

   Daughter [ ] Son [ ]

   Relative /Guardian
   Other specify ----------

3. **What is the total number of household member in your family?**

   1-2 [ ] 3-5 [ ]

   6-8 [ ] Above 8 [ ]

4. **Respondent Gender**

   Male [ ] Female [ ]

5. **Kindly indicate your age blacket**

   10-20 years [ ] 20-30 years [ ]

   30-40 years [ ] 40-50 years [ ]

50-60 years [ ] 60-70 years [ ]
70 years and above [ ]

6. **Household Type**

Male Headed [ ] Single [ ]

Widow [ ] Widower [ ]

7. **Education level**

None [ ] Primary level [ ]

Secondary [ ] College Diploma [ ]

Undergraduate Degree [ ] Maters Degree [ ]

8. **What is the nature of land holdings of your Household?**

Family inherited [ ] Rented Household/land [ ]

Bought Private [ ] Settlement Schemes [ ]

Government land/Household [ ] Trust land [ ]

Other Specify----------

9. **Please indicate the type of house you live in**

Traditional [ ] Semi-Permanent [ ]

Permanent [ ] Others Specify----------

PART B: COOKING DEVICES AND SOURCES OF FUEL

A. Cooking Devices

10. What type of cooking device do you use for cooking? Please list others
11. Why do you use them? Please explain.
12. When approximately did you start using them?
13. What change have occurred with the cooking devices

In 70s_____

In the 80s_____
In 2010 to date_____

14. Where did you buy your cooking device?

15. How much did it cost:

Less than 2000 Frw
2000Frw -5000Frw
5100 Frw – 10000 Frw
Above 10 000 Frw

16. Does the price of cooking device influence your choice?

Yes [ ] No [ ]

17. Are the dealers of improved cook stoves in location?

Yes [ ] No [ ]

18. When did the dealers of improved cookstoves come into Gisagara?

19. Kindly indicate the distance covered to buy your cooking device from:

2-3 km

3-6 km

6-8 km

Above9 kms, indicate how many kms_____

20. Where do you cook?

Outdoor [ ]
Why_____
Indoor [ ]
Why_____

21. Which cooking devices do you use during:

Day time _____
Explain _____
Night time_____
Explain_____

22. Are there occasions that require you special cooking devices?

Explain_____

23. **Do weather characteristics and patterns influence the adoption of improved cookstoves?**
    Explain your answers _____

A. Cooking Devices

Fill in the appropriate column in the table below to the best of your knowledge as per the questions asked.

Types of cooking Devices	Tick the cooking devices you use	Who buy the cooking devices	Price of cooking devices in Frw	What factor influences your choice o cokking devices	How long have you using the cooking device you have ticked
Traditional three stone					
LPG Cookers					
Electric Cookers					
Multipurpose stove-wood/chalcoal					
Any other improved cookstove					
Any other traditional stoves					
Others Specify					

B. Cooking Energy/fuel

Fill in the appropriate column in the table below to the best of your knowledge as per the questions asked.

Cooking Energy/fuel	Tick the cooking energy/fuel you use	Quantify energy used per week.per cokking e.g. kgs, litters?	Price of cooking Energy per month Frw?	Distance covered to get cooking energy/ fuel?	Preferred use e.g. Food/light/ warming of the house etc?
Dry cow dung					
Farm residues – Maize stalks,dry leaves,Maize cobs					
LPG Gas					
Fire wood from own farm					
Fire wood purchased					
charcoal					
Electricity					
Others specify					

24. **Have there been changes in your house holds on the use of domestic energy/fuel Overtime?** If yes, explain_____

25. **During the rainy and cold period in Gisagara area,which cooking fuel are likely to be used in the households?**

    Explain your answer_____

26. **What are the challenges in getting cooking energy/ fuel for your cooking?**
27. **Are there enough suppliers of the cooking fuels?** Yes_____ No_____

28. **If yes which ones**_____
    If No, explain_____

29. Who is responsible for getting the cooking fuel for the family? Does this influence the adoption in the household? _____
    Explain _____

30. What are the challenges experienced in using these fuels?

PART C: FACTORS INFLUENCING ADOPTION OF IMPROVED COOK STOVES

A. Socio – Cultural Factors

31. **Are you using improved cook stove**? Yes _____ No_____

    If yes, which one? _____
    If No, why? _____
    When did you start using it? _____

32. **Does the improved cook stove able to cook all types of food**?

    Yes, Explain_____

    No, Explain _____

33. **Kindly tick what you consider when choosing the type of cook stove for your cooking**

    Type of food to cook [ ] Cost [ ]
    Weather [ ] Availability in Gisagara [ ]
    Other factors [ ]
    Explain your answer _____

34. **Do you have specific food that must be cooked in a special way**? _____
    Explain _____

35. Does your wife/husband/brother/sister/friend encourage you to adopt any improved cookstoves?

Strongly Agree [ ] Agree [ ]

Somehow Agree [ ] Disagree [ ]

Strongly agree [ ]

36. What is the main source of income in the family?

Subsistence farming [ ]
Employment [ ]
Business [ ]
Others specify _____

37. What is average income of your household?

Below 30000 Frw [ ] 30000 Frw – 40000 Frw [ ]
40000 Frw - 50000 Frw [ ] Above 50000 Frw [ ]

38. What animals do you keep in your homestead?

Explain why _____

39. **What is your cultural belief on cooking**? _____

B. Technology

40. Why did you use the improved cook stoves for your cooking?
41. How frequent do you use the improved cook stove for your cooking?
42. Which types of improved cook stove are available within your reach?

Why? _____
Explain _____

43. Where do you get them from?
44. Tick the appropriate characteristics that describe the improved stove you are using for cooking.

Fuel saving [ ] Firewood saving [ ]
Durable and good design [ ] Portable/ Fits my cooking area [ ]
Others, explain _____

45. When looking for an improved cookstoves, is smoke an issue?

46. Is there some health issues related to cooking using improved cook stove? If yes, which ones?
47. Does the issue mention in question 46 above influence adoption of improved cookstoves in your household? If Yes please explain _____

48. Are there people within the locality for repair and maintenance of improved cookstoves? Yes/No
    Explain _____

49. Does this influence the adoption of improved cook stoves? Yes/No

    Explain _____

C. Knowledge and Perception

50. Are you the people of Gisagara aware of improved cook stoves, usage and their benefits?

Strongly Agree	[ ]	Agree	[ ]
Somehow Agree	[ ]	Disagree	[ ]
Strongly disagree	[ ]		

Others (Specify) _____

51. Are you aware of any improved cook stoves development program in Gisagara? If yes, which one?
52. Have you ever received a cooking stove from an improved cook stove development program?

    Yes [ ] No [ ]
    If yes, which one? _____
    Are you using it or not? _____
    Explain _____

53. When did you learn/hear about the improved cookstoves?

Neighbor	[ ]	Spouse	[ ]
Friends	[ ]	Seminal advocacy meetings	[ ]

Others Specify _____

54. Does lack of knowledge about the improved cookstoves affect its adoption in Gisagara?

Yes [ ] No [ ]

55. What is the extent of information dissemination on improved cookstoves influence adoption among household in Gisagara ?

Very low extent	[ ]	Low extent	[ ]
Moderate extent	[ ]	Great extent	[ ]
Very great extent	[ ]		

PART D: BENEFITS ASSOCIATED WITH THE ADOPTION OF IMPROVED COOKSTOVES

A. Cooking devices

56. What are the benefits and factors influencing adoption and usage of the cooking technologies listed in the table below?

Type of cooking technology	**What are the benefits of adoption and usage of the cooking technology you have ticked?**	**What are the factors influencing the adoption and usage of the cooking technology you have ticked?**
Traditional three stone		
LPG Cookers		
Electric Cookers		
Solar cookers		
Multipurpose stove-wood/charcoal		
Any other improved cook stove		
Any other traditional stoves		
Others Specify		

B. Cooking Energy/ Fuels

57. What is your preference for type of fuel? Using likets Scale of 1 – 5 (1 least and 5 most) list is order of preference from Most to least preferred and give reasons for your Rankings.

Cooking Energy/fuel	1	2	3	4	5	Reasons
Dry cow dung						
Farm residues – Maize stalks,dry leaves,Maize cobs						
LPG Gas						
Fire wood from own farm						
Fire wood purchased						
charcoal						
Electricity						
Solar energy						
Others specify						

58. Do the government/ other stakeholders help in Knowledge dissemination concerning improved cookstoves, adoption, uses and benefits to the local villages?
Explain your Answer_____

59. Using likert's scale of 1 – 5 (1 least and 5 most) rate the benefits associated with the adoption of improved cookstoves below. Please indicate appropriately.

Indicators	1	2	3	4	5
a) Less smoke b) Improved health of the family members c) Safety in the kitchen/ cooking place d) Cleanliness and home improvement e) Socio-cultural influence f) Time saved in fetching firewood g) Conservation of environment h) Mother can do more domestic work compared to fuel fetching i) Timely cooking j) Locally available dry farm residues k) Availability of Raw materials for making cookstoves l) Availability of cooking fuels m) Stove design and durability n) Fuel /fire wood savings					

O) Others

Explain _____

_____*Thank you*_____