SOCIO-ECONOMIC FACTORS INFLUENCING BIOGAS TECHNOLOGY UPTAKE AMONG RURAL HOUSEHOLDS IN KURESOI SOUTH SUB-COUNTY, NAKURU COUNTY

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A Thesis Submitted to the Institute of Postgraduate Studies of Kabarak University in Partial Fulfillment of the Requirements for the Award of Master of Science in Environmental Science Degree

KABARAK UNIVERSITY

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The thesis entitled "**Socio-Economic Factors Influencing Biogas Technology Uptake among Rural Households in Kuresoi South Sub-County, Nakuru County**" and written by **Gypson Kipkorir Kurere** is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the research project and recommend it be accepted in partial fulfillment of the requirement for the award of the degree of Master of Science in Environmental Science.

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DEDICATION

I dedicate this research project to my parents; Mr. and Mrs. Tuwei, Kelsie & Keira also to my spouse Daisy Jeptoo. Last but not least my siblings: Japheth, Gladys, and Phyllis.

ABSTRACT

Biogas technology presents an alternative sustainable energy source that offers an opportunity to transform energy security, environmental sustainability, and reduction in greenhouse gas emissions. The research study explores the socioeconomic factors affecting biogas technology uptake among rural households in Kuresoi South Sub-County, Nakuru County. The specific objectives included;(i)To assess the energy mix consumed by rural households in Kuresoi South (ii)Determine the impact of household income levels on biogas adoption (iii) Evaluate awareness and knowledge levels of biogas technology (iv) Examine the influence of gender dynamics on decision-making regarding biogas technology uptake. This is a descriptive study design based on the use of both primary and secondary data sources. The data collection covered 155 respondents through the use of questionnaires, focus group discussions, key informant interviews and observations. Selection of the respondents was done by using systematic random sampling, while data analysis was done using descriptive statistics, chi-square tests, and cross-tabulation supported by SPSS version 26. Results indicated that despite high levels of awareness, the adoption of biogas technology was low, with firewood remaining the primary source of energy in 68% of the households. Fixed dome and tubular were the biogas digester types in use, since they are relatively cheaper and more durable; however, economic factors, mainly household income, were the main determinant of uptake. The chi-square results indicated that there was a significant relationship between household income and uptake of biogas, $\chi^2 = 9.531$, $p = 0.048$, implying that the poorer a household is, the greater the financial barrier to the technology. Level of education, too had a say in energy adoption; education and energy choice had a strong association-since $\chi^2 = 12.814$, $p = 0.002$-which depicted that more educated households were more likely to adopt the technology. The gender factor is insignificant in influencing energy choices, underlining a proof from the fact that $\chi^2 = 2.119$, $p = 0.346$, where broader socio-economic factors played a much greater role in decisions. This study also revealed out that radio was the effective channel for knowledge sharing and information dissemination related to biogas technology. On the other hand, partial understanding of the technical aspects has acted as a big barrier to the better diffusion of this technology. In conclusion, income levels and education are two main factors affecting the uptake of biogas technology. Enhanced education, targeted financial support and better outreach strategies go toward increasing adoption rates and supporting transitions to sustainable energy in rural areas.

Keywords: *Biogas Technology, Chi-Square Analysis, Socio-Economic Factors, Rural Households, Energy Adoption, Renewable Energy*.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

CBO	Community Based Organizations
CH4	Methane
CO2	Carbon Dioxide
DOI	Diffusion of Innovations
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GIS	Geographic Information System
GOK	Government of Kenya
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KES	Kenyan Shillings
KIIs	Key Informant Interviews Schedule
KNBS	Kenya National Bureau of Statistics
KUREC	Kabarak University Research Ethics Committee
LPG	Liquid Petroleum Gas
MDGs	Millennium Development Goals
NACOSTI	National Commission for Science, Technology and Innovation
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organizations
PVC	Polyvinyl Chloride
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
UNDP	United Nations Development Programme

CONCEPTUAL AND OPERATIONAL DEFINITION OF KEY TERMS

Biogas: A gas produced when biodegradable materials are acted upon by methanoic bacteria in the absence of oxygen by the process known as anaerobic digestion. Biogas consists mainly of 50-70% Methane, 30-40% carbon dioxide and low amounts of other gases.

Technology: The way people use knowledge, tools and systems to make their lives better and easier.

Multiple Regression Analysis: statistical technique used to examine the relationship between one dependent variable (outcome) and two or more independent variables (predictors).

Household: A social unit of people who live together under one roof and share resources even if they are not related to each other.

Household Income: It refers to all revenue earned by all members of a household, in cash and in kind, in exchange for employment, or in return for capital investment, or revenue gained from other sources such as social grants, pension, etc.

Renewable Energy: Energy generated from natural resources that are replenished constantly or are virtually inexhaustible within a human timescale.

Green Energy: Energy derived from renewable sources but also includes a focus on minimizing the environmental impact and promoting sustainability.

Energy Mix: It refers to the proportion of different energy sources that are used to meet a particular energy demand. The energy mix can vary depending on a number of factors, including the availability, cost, and environmental impact of different energy sources, as well as the specific energy needs and preferences of the user.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Biogas is a mixture of gases produced through the process of anaerobic digestion, which is the breakdown of organic material by microorganisms in the absence of oxygen. Biogas consists mainly of 50-70% Methane, 30-40% carbon dioxide and low amounts of other gases. Biogas can be produced from a variety of feedstocks, including agricultural waste, food waste, and energy crops. The process of producing biogas involves the breakdown of organic material in a sealed, oxygen-free container or system, such as a biogas digester. The methane produced through this process can be burned to generate heat, electricity, or used as a fuel for transportation. (Hilkiah, et al., 2008)

A report by Aemro, Moura, & de Almeida (2021) revealed that a substantial number of people in developing regions, particularly those in rural areas of sub-Saharan Africa, India, and other parts of Asia, still rely on traditional biomass, coal, or kerosene for cooking. Despite the progress made in economic development and growing awareness of the health hazards associated with using unclean fuels for cooking, the number of individuals without access to clean cooking facilities has continued to rise due to population growth outpacing the increase in households with access to clean energy. Recently, approximately 3 billion people or 41% of the world's population lack access to clean cooking facilities, which is almost the same number as in 2000. Furthermore, around 1 billion individuals still lack access to electricity, with most residing in sub-Saharan Africa and India, according to the World Bank (2018).

The rate at which access to clean cooking facilities is improving varies significantly across different regions. For instance, China has made significant progress in reducing its reliance on solid fuels for cooking, with the percentage dropping from 52% in 2000 to

33% currently. However, the pace of progress has been slow in sub-Saharan Africa, where population growth has outpaced the progress made in this area. In fact, an estimated 84% of the population in this region still relies on solid biomass, coal, or kerosene for cooking. This is particularly common in rural areas where affordable modern forms of energy are scarce (Osano et al., 2020).

Rural households in Africa depend on solid biomass for cooking (Ravindra, Kaur-Sidhu, Mor & John, 2019). Although the number of people in low- and middle-income countries who have access to clean cooking facilities has increased by 60% since 2000, population growth has outpaced this progress, resulting in around 400 million more people without access to clean cooking today compared to 2000 (UNDESA, 2018). Additionally, some households who have access to clean fuels still use biomass, coal, or kerosene as supplementary fuels, which is known as "fuel stacking."

In Kenya, a significant number of households still rely on solid fuels despite being financially capable of affording the monthly cost of purchasing LPG, which is around USD 15 to 20 (Jürisoo, Lambe & Osborne, 2018). This behavior can be attributed to a range of factors that go beyond income and energy costs. Factors such as availability and reliability of supply, prices of alternative fuels, acquisition costs, safety concerns, lack of awareness of the negative health impacts of traditional stoves, and cultural preferences all play a role in determining fuel usage patterns. Mwirigi et al., (2014) explain that the reasons for this complex behavior are multifaceted.

Kuresoi South sub-county is an area in Nakuru County, Kenya, with a population of predominantly small-scale farmers who rely on agriculture as their main source of income. The area faces a number of socio-economic challenges that limit the adoption of biogas technology, including financial constraints, limited availability of feedstock, and lack of awareness and understanding of the technology. As such, there is a need to assess the socio-economic factors affecting the uptake of biogas technology among rural households in Kuresoi South sub-county in order to develop strategies to promote its adoption and improve rural livelihoods.

1.2 Statement of the Problem

According to Otieno, 2020, Kuresoi South Sub County has the highest level of firewood use in Nakuru County. The use of firewood for cooking has contributed to uncontrolled harvesting of trees and shrubs as well as exposing users to many health problems especially lung diseases. Every year 21,560 deaths are caused by household air pollution (Clean Cooking Sector Study, 2019). Biogas technology has been regarded as the best alternative to these problems through mitigating greenhouse gas emissions, improving agricultural sustainability and reducing energy shortage (Mannan, Al-Ansari, Mackey, & Al-Ghamdi, 2018).

Wamwea, 2017 records that achievement of biogas technology in rural Kenya has continued to be challenging in spite of the effort from the government and international organisations promoting renewable energy sources. Adoption and sustainability of the technology is still low, presently at 0.03%. Farmers operating on a small scale in the region encounter several obstacles when it comes to implementing biogas technology. These hindrances include limited financial resources, insufficient raw materials for producing biogas, and a lack of knowledge and comprehension regarding the technology. As a result, there is a need to identify and understand the socio-economic factors that influence the adoption of biogas in Kuresoi South in order to inform the development of policies and interventions that can support the wider adoption of this technology in the area.

1.3 Purpose of the Study

The broad objective of the study is to assess the socio-economic factors affecting biogas technology adoption among rural households in Kuresoi South Sub County, Nakuru County.

1.4 Specific Objectives of the Study

The specific objectives of the study include:

i. To determine the percentage contribution of each energy source in the energy mix of households in rural Kuresoi South, Nakuru County.

ii. To assess the influence of household head income levels on biogas technology uptake among rural households in Kuresoi South Sub-County, Nakuru County,

iii. To assess the level of awareness and knowledge regarding biogas technology uptake among rural households in Kuresoi South Sub-County.

iv. To assess the influence of gender roles on decision making processes on uptake of biogas technology among rural households in Kuresoi South Sub-County.

1.5 Research Hypothesis

$H0_{1:}$ The percentage contribution of each energy source does not significantly affect the energy mix of households in rural Kuresoi South, Nakuru County.

$H0_{2}$: Household head income levels have no significant influence on the uptake of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County.

$H0_{3:}$ The level of awareness and knowledge does not significantly influence the uptake of biogas technology among rural households in Kuresoi South Sub-County.

$H0_{4:}$ Gender roles have no significant influence on decision-making processes regarding the uptake of biogas technology among rural households in Kuresoi South Sub-County.

1.6 Justification for the Study

This study is in line with Sustainable development goal 7 and 13 that champion for affordable and clean energy and combat of climate change and its impacts respectively. (Monkelbaan, 2019). To achieve the Sustainable Development Goals (SDGs) and Kenya's vision 2030 as a country, there is need to ensure access to affordable, reliable, sustainable and modern energy for all as well as urgent actions to combat climate change and its impacts. More than three billion people globally still rely on traditional biomass which are non-sustainable and inefficient for cooking (Wahyudi, 2017).The bio digesters produce biogas which is a clean and efficient fuel. Biogas does not emit harmful particles into the atmosphere. Combustion of biogas captured via a biodigester converts methane that otherwise would be released directly into the atmosphere into carbon dioxide. Since methane is a much more powerful greenhouse gas, the net effect of this process is beneficial to the environment. Moreover, the use of biogas in cooking basically displaces other, non-renewable energy sources, including kerosene, biomass and liquefied petroleum gas (LPG) (Marie et al., 2021). These energy sources all are contributors to greenhouse gas emissions. Adoption of biogas by majority of rural households may also lead to reduced deforestation.

1.7 Significance of the Study

The study aims at providing research based evidence and information required to facilitate the development of effective national and county energy programs and policies targeting rural households. Generally, the findings aim to inform the socio-economic factors of future interventions on the uptake of renewable energy technologies. The study further supports sustainable development goal 7, access to affordable and clean energy, and goal 13, urgency to combat climate change and its impacts (UN, 2015). The data generated by the study will also be referenced by both academic researchers and practitioners, who can benefit from the outcomes, recognizing the limited literature available on the socio-economic factors that influence the adoption of biogas technology.

1.8 Scope of the Study

This study focused on the adoption of biogas technology in Kuresoi South sub-County; For example, the socio-economic factors that influence biogas technology adoption i.e. income, household size, gender, and education levels of the household heads. The study also focused on rural households.

1.9 Limitation of the Study

The study suffered from sample size bias. This affected the generalizability of the findings to the broader population. The study also did not focus into biophysical, environmental and cultural factors that affect biogas technology adoption. Finally, sensitive information collected during the interviews could not be guaranteed to be 100% reliable.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter will tackle the literature review of the study and will include conducting literature reviews of the four objectives. Further, the theoretical framework together with the conceptual framework will be addressed in this chapter.

2.2 General Overview of Biogas Adoption

The use of biogas as a source of energy dates back to ancient civilizations, where biogas was produced through the fermentation of organic matter in the absence of oxygen and used for lighting and heating. In the 19th and early 20th centuries, biogas technology was developed and improved upon, particularly in Europe and Asia, and biogas plants were built to process sewage and other organic waste materials (Flotats, 2019).

In the latter half of the 20th century, biogas technology saw increased adoption in developed countries, as concerns over energy security and environmental sustainability grew. Biogas systems began to be used more widely for the treatment of agricultural and industrial waste, and advances in biogas production and purification technologies allowed for the production of high-quality biomethane that could be used as a substitute for natural gas (O'Connor et al., , 2021).

In recent years, biogas technology has continued to evolve and expand, with the development of new feedstocks, such as algae and food waste, and the use of biogas in a wider range of applications, including transportation fuel. The adoption of biogas technology has also spread to developing countries, where it is seen as a way to address energy poverty and improve waste management.

Africa has a relatively short history compared to other parts of the world. However, biogas systems have the potential to play a significant role in addressing energy shortage and improving waste management in the region. One of the earliest implementations of biogas technology in Africa was in Egypt in the 1980s, where biogas systems were introduced to treat sewage and other organic waste (Roopnarain, & Adeleke, (2017). In the following decades, biogas projects were also implemented in other countries on the continent, such as Ethiopia, Ghana, and Kenya.

In Kenya, biogas technology has gained traction in rural areas, particularly in the Rift Valley region. Since 2010, the Kenya Biogas Program (KBP) has been encouraging rural households to embrace biogas technology. The program provides training, technical support, and financing to households interested in adopting biogas technology. For Kenya to achieve the vision 2030 objectives and the Sustainable Development Goals (SDGs) there is a need to adopt sustainable and renewable sources of energy. A form of energy that is sustainable and safe is needed to power the country and help it develop in a sustainable way (Momanyi & Benards, 2016: Rahman et al., , 2019).

Energy is considered as the primary ingredient that brought forward industrialisation. With the sophistication of the modern man, there has been an increasing search for an efficient, sustainable and clean source of fuel to power households and industries (Corfee-Morlot et al., , 2019). World over, increasing population and development has resulted in the increase in energy demand. Since the traditional sources of energy have not been sufficient enough, there has been a need for a sustainable, efficient form of fuel that is affordable, attainable and has little impact on human health and the environment (Sawyerr et al.,2019). Focusing and developing on renewable energy is a good pathway to attain energy independence in an environmentally friendly way. With the fast-developing technology, these types of energy are attainable and can be implemented and utilised in different parts of the world more so in developing countries (Mwirigi, Makenzi & Ochola, 2009). Biogas is one type of renewable energy, it has a fast growing potential and can be implemented in rural areas in Kenya (Omer, 2017).

Ever since the first biogas that was built in Kenya in 1957, the development of technology has been steadily growing. Currently, there is an estimated 20,000-biogas installation around the country, the majority of which are privately owned in a domestic setting (Ngeno et al., , 2018). Other organisations involved in biogas use are learning institutions and the prison service. Reports indicate that majority of these biogas digesters found in the country operate below capacity or in some cases are dormant (Erick, 2018). The Draft Energy and Petroleum Policy 2015 contains a strategy to promote the utilisation of biogas as an alternative to traditional fuels at domestic and commercial levels (Ministry of Energy and Petroleum, 2015).

Biogas consists of a mixture of gases that are generated by organic matter such as Methanogens and sulphate-reducing bacteria in the absence of oxygen. Materials such as manure, agricultural waste, sewage and domestic waste can produce biogas. The primary constituents of biogas are methane and carbon dioxide. Biogas plants or anaerobic digesters synthesise the raw products to produce the biogas (Kushkevych et al., , 2017).

Generally, biogas adoption has been a challenge in Kenya. This is more so in rural areas where resources availability and lack of knowledge is rampant (Ongiyo, 2019). Reliance on biomass energy is still common in Kuresoi South. There is easy access to trees and shrubs due to the area’s proximity to the Mau forest gives the residents an easy access to firewood. On the other hand, a large size of livestock means that there is a high potential for biomass technology to succeed in the area (Hasan et al., , 2022). Current initiatives to introduce biogas technology are largely driven by NGOs and to some extent government institutions. These entities have not managed to completely penetrate to different areas of the country particularly in Kuresoi South (Samali, 2018).

There are various factors have contributed to lagging biogas utilisation, they include; a lack of awareness- lack of a clear understanding of how the technology works in many households, further, the reliance on wood has also hindered biogas adoption because it is easily available. A technology not aligning with the local's values, beliefs can also pose as a hindering factor. Overall, the sophisticated nature of the biogas system coupled with the high installation cost will continue to shun away any potential interests (Erick, 2018). According to (Berhe et al., 2017; Erick, 2018; Hafeez et al., , 2017; Momanyi & Benards, 2016), factors such as age can be variables influencing the degree of adoption; education levels, income levels and the size of a farm. Understanding these factors and how they can influence how biogas adoption is crucial.

2.3 Energy Mix

The energy mix consumed by households refers to the different types of energy sources used by households to meet their daily energy needs, such as cooking, lighting, heating, and powering electronic devices. The energy mix consumed by households varies widely across different regions and countries, and depends on factors such as availability of resources, level of economic development, cultural preferences, and government policies (Zheng, Xinye, et al., , 2014).

In many developing countries, households still rely heavily on traditional biomass fuels such as firewood, charcoal, and agricultural residues for cooking and heating. According to the International Energy Agency (IEA) 2022, traditional biomass fuels account for around 30% of global primary energy consumption in developing countries, compared to only 5% in developed countries. This is primarily due to the lack of access to modern energy sources such as electricity and clean cooking fuels, as well as poverty and limited infrastructure.

In some regions, households may also use fossil fuels such as kerosene, liquefied petroleum gas (LPG), or diesel for cooking, lighting, and heating. Fossil fuels are generally more expensive and less environmentally friendly than traditional biomass fuels, but may be preferred due to their convenience and reliability. However, the use of fossil fuels can also lead to indoor air pollution, which is a major health hazard in many developing countries. (Fisher, Samantha, et al., , 2021). In recent years, there has been a growing interest in renewable energy sources such as solar, wind, and hydro power, as well as biogas and biofuels, for household energy use. These energy sources have several advantages over traditional biomass fuels and fossil fuels, including lower emissions of greenhouse gases, reduced dependence on imported fuels, and increased energy security.

Solar energy, in particular, has become increasingly popular for household lighting and charging electronic devices in many developing countries, due to the declining costs of solar photovoltaic (PV) technology and the high levels of solar irradiation in many regions. However, the upfront costs of installing solar PV systems can still be a barrier for many households, particularly in rural areas (Karjalainen, & Ahvenniemi, 2019).

Biogas technology, which involves the conversion of organic waste materials into biogas for cooking and lighting, has also been promoted as a sustainable solution to the energy crisis in many developing countries. Biogas technology can reduce dependence on traditional biomass fuels, improve indoor air quality, and generate organic fertilizer for agriculture. However, the adoption of biogas technology among households is still limited, and depends on factors such as availability of feedstock, level of awareness and technical knowledge, and access to financing. (Mukeshimana, Zhao, Ahmad, & Irfan, 2021).

2.4 Level of Awareness and Knowledge on Biogas Technology

A study conducted by Mutimba et al., (2015) in Kenya found that many rural households were not aware of biogas technology, and those who were aware had limited knowledge about its benefits and how it works. This lack of awareness and knowledge makes it difficult for rural households to make informed decisions about whether to adopt biogas technology or not. In another study by Ndiritu et al.,(2016) in Kenya, it was found that awareness and knowledge of biogas technology were positively associated with its adoption. Households with higher levels of awareness and knowledge about biogas technology were more likely to adopt it compared to those with low levels of awareness and knowledge.

Studies have also shown that education level and socio-economic status play a significant role in determining the level of awareness and knowledge about biogas technology. For instance, Tesfaye et al., (2019) found that households with higher levels of education and income had better knowledge of biogas technology and its benefits. Similarly, a study by Li et al., (2021) in China found that education level was a significant predictor of awareness and knowledge of biogas technology, with households with higher levels of education being more knowledgeable about the technology.

Furthermore, sources of information about biogas technology also influence the level of awareness and knowledge. In a study by Onyango et al., (2019) in Kenya, it was found that the main sources of information about biogas technology were friends, family, and neighbors, as well as extension workers and the media. However, the study found that these sources of information were not effective in providing comprehensive knowledge about the technology, and there was a need for more targeted and informative extension services to increase awareness and knowledge.

2.5 Influence of Age on Biogas Technology Adoption

Empirical findings from different studies have shown the significance of age in deciding the type of fuel to be used in a household. Studies by Berhe et al., , (2017) and Momanyi & Benards, (2016) have indicated the role of age in choosing certain types of fuel. For instance, the traditional source of fuel is preferred by the older generation as compared to the younger ones, while in some cases, household heads who have acquired knowledge and experience over time, will opt for efficient, clean and sustainable sources of energy. In other instances, progress in age brings with it financial muscle that can help in purchasing cleaner but expensive fuel (Muller & Yan, 2018).

Age can play a crucial role in influencing biogas technology adoption in a household. According to the study by Berhe et al.,(2017) on factors affecting biogas adoption in rural Ethiopia, age played a significant role in influencing the technology's adoption. From the study, apart from the livestock site and the access to electricity, age played a significant role.

The study pointed out that, with one year of increase in age, there was a lesser probability of adopting the technology. This was particularly significant for the age of the household head where a household with an older head of the house would less probably prefer biogas technology as compared to a household with a younger head of the family. The study also indicated that this was different in Uganda where the case was vice versa, i.e. as the age of the household head got older, they opted to choose a cleaner and safe source of energy.

Households with an older generation head will tend to lack sufficient knowledge and awareness regarding biogas as compared to middle-aged or young individuals who lead a household. According to Muvhiiwa et al.,(2017), since awareness can influence the adoption of biogas technology, there is a likelihood that households led by old generation individuals who probably are not literate may shun away from the biogas technology as compared to younger individuals who are literate and well versed with current affairs. Geddafa et al.,(2021) study of biogas, pointed out that age had little effect on biogas adoption. The study established that that with an advance in age, the head will tend to choose the familiar source of fuel for their usage. This was similar to the finding of Uhunamure et al., (2019) who established that the household would continue to use their traditional source of fuel since they are well familiar with them.

In a study on biogas adoption in Kiambu by Muriuki, (2014), the mean age for the household head that adopts biogas technology was 53.4 years while the average mean for household heads who do not adopt biogas was 41.1 years. The study links the age of household head that adopts the technology being higher than the later because the age group is the most productive and more economically empowered. In an analysis of factors influencing biogas adoption by Erick, (2018) the study identified that majority (60%) of the respondents who had adopted biogas were found to be between the age bracket of 40 years and above. On the other hand, 40% of the respondents were below 39 years. Biogas technology being relatively pricy to install demands the household that installs it to be well off financially and that which has land together with livestock that are needed in the installation and running of the plant respectively.

The effect of age in biogas adoption can vary, while in some cases it influences adoption, in some, it does not have any influence. It is therefore important to understand how this variable affects the adoption levels especially in Kuresoi South where there is little information on the biogas subject and how it is adopted.

2.6 Household's Head Level of Education Effects on Biogas Technology Adoption

Education levels have been shown to play a positive or negative role in influencing the adoption of a certain type of fuel in a household. In Ouagadougou for instance, a study by Sana et al., (2020) identified that a household's fuel choice was predominantly influenced by socioeconomic status such as the head household's level of education. Similarly, a study on fuel choice in India by Choudhuri & Desai, (2020) also identified the significance of educational levels to fuel type adoption. Households with an advanced level of education often opted for clean fuel with little harmful emission.

The global literacy rate for people above the age of 15 is 86.3% with males being more literate than females by a factor of 7.3%. In Kenya, the literacy level reaches 80.53% (KNBS, 2010). Finding by NETFUND, (2017) notes that, education levels improved the choice and taste of fuel where the highly educated preferably chose fuel types that are efficient to work it as opposed to the less educated who did not always opt for different types of fuels that are better.

The study points out that, those who have reached the university were familiarised with renewable types of fuel as compared to those who are have reached the primary school level of education. A study by Hafeez et al., (2017) on the adoption of biogas technology in Bangladesh identified that heads of households who have had education for more than 8 years had 20.78 times more probability of choosing biogas technology as compared to those who had less than 8 years of education.

In Kenya, several research studies have linked literacy and biogas adoption/usage. In Kilifi for instance, a study by Momanyi & Benards, (2016) established the effects of literacy levels on biogas adoption in the area. The study determined that most of the respondents who had not completed secondary school studies were not able to grasp the ideas and technology behind biogas. This effectively hindered any chances of the technology's adoption. The study went further to identify that over 50% of the respondent in the study who had no education at all were non-users of biogas while the 70% of educated respondents had adopted the biogas technology meaning that education influenced either negatively or positively on the adoption of biogas technology. A similar case was drawn by (Patman & Moronge, 2015) in their study of the determinant of successful implementation of biogas technology in Githunguri. The study highlighted the impact education had on technology implementation. From the two studies, it is evident that education levels play an important role in biogas adoption in Kenya. Those with advanced levels of education will tend to be more conscious of the importance of clean and renewable energy, in this case, biogas, and those with little knowledge will tend to lack both the knowledge and awareness of renewable energy. In a study by Erick, (2018) on factors influencing biogas adoption, level of education was a significant factor where 82% of the households sampled in the study who had adopted biogas had attained post-secondary education.

Nakuru County, Kuresoi south, Njoro and Rongai bear the highest share of residents with no formal education (less than 20%). Coincidentally, Kuresoi South has the highest levels of firewood usage and among the lowest electricity connection (Kenya National Bureau of Statistics, 2019). Keeping these facts in mind, it is important to point out that education levels continuously grow with time and it is expected that with free education, there will be a drastic growth in the literacy levels in the future. Just like many other factors in life, education levels have an impact on the way people can run their daily activities and in this case, the use of biogas cannot be an exception. For biogas to be understood and accepted there needs to be awareness creation, education and sensitization particularly to those who are in school and also to the general public.

2.7 How Household's Head Income Influences Biogas Technology Adoption

Different studies have managed to draw an inference between the income of the head of a household and the type of fuel they opt for. An analysis by Rahut et al., (2019) on determinants of fuel choice determined that income has a major role in fuel choice.

Similarly, Muller & Yan, (2018) also identified managed to draw a correlation between the household income and fuel type. While a majority of the studies have demonstrated a significant influence on the type of fuel a household's income, some studies have also shown that a household income does not influence fuel type.

In Kenya, a study by Baek et al., (2020) indicated the impact of a household income on the type of fuel used. This study concurs with other studies by Ngeno et al., (2018) who in their report indicated that lower-income households tend to go for polluting fuels which are usually cheaper and affordable to them. A household will tend to prefer the most affordable type of fuel and sometimes not pay emphasis to its effects on the users and environment. On the other hand, households will opt to diversify the types of fuel they use as they grow economically (Samson et al., 2015).

Several studies have managed to demonstrate how income can potentially affect biogas adoption in Kenya. For instance, the literature review on the study on factors influencing biogas adoption by Uhunamure et al., (2019), points out the influence of income in biogas adoption in Kenya. The study shows how a household with higher income can manage to afford more livestock hence be able to install a biogas digester since they have both the raw material and financial power for purchasing the technology. Similarly, Momanyi & Benards, (2016) identified income as one of the prime factors influencing biogas adoption in Kenya. Since individuals with higher income are the ones with better purchasing power, the probability of households with higher than average income to adopt biogas is better than those with lower income.

The study by Mugo, (2017) on factors influencing biogas adoption points out the relationship between income and biogas adoption. The study indicates that the majority (73%) of the respondents in the study who had adopted biogas had an income above Kshs 40,000 while the majority (67.2%) of the non-adopters had an income less than

Kshs 20,000. The study further indicates that the cost of installing and running a biogas plant requires a high cost therefore household heads with higher income are best suited to install and run the biogas technology. A similar finding was established by Momanyi & Benards, (2016) who also reiterated the effects of the high cost of biogas installation that can prohibit households with low income from installing the technology. From the data analysis of the study, 70% of respondents who earned less than Kshs 10,000 were unable to afford biogas installation while those who had installed biogas had an income above Kshs 10,000 on average. On the other hand, the availability of other traditional yet deleterious types of fuel such as Kerosene or firewood was much more affordable to the low-income earners.

The main economic activities in Kuresoi South are agriculture and lumbering. Bigger fractions of the farmers are into small-scale informal farming. Considering that the Kuresoi South is mainly a rural area, there is little urbanisation and the economic activities are mainly designated to agriculture (both livestock keeping and plant growing) hence the economy of the area is majorly average. An expanding economy and more people receiving an education means that there is a potential for the economy to grow in the future (GoK, 2018).

The energy ladder theory has been used in the past to depict the idea of an entity where when their income increases; their choice of fuel also changes. If a household happens to grow economically then they will tend to ditch the traditional dirty fuel and go for the cleaner and efficient type of fuel such as LPG gas (Hanna & Oliva, 2015). This has been witnessed in different developing countries. In some cases, however, improvement in the economic capacity of a household would not necessarily mean they change their type of fuel, instead, they will tend to mix whereby they will utilize both the old and new type of fuel (Levine et al., , 2018; Muller & Yan, 2018).

2.8 The Extent to which Farm Size Influences Biogas Technology Adoption

Just like any other investment, biogas will require the land in its running process. Land being a primary form of production, it can have a significant impact on how biogas technology is adapted. From the production and storage of raw materials used in a biogas plant to installing and running the technology land plays a crucial role here (Uhunamure, Nethengwe, & Tinarwo, 2019). In Kenya, the land is split between agricultural usage and other uses. Agriculture is the main source of livelihood in the country, many households will rely on the land to conduct farming. Biogas plants can range from small scale units for the small household to bigger units that are used for institutions and other largescale organisations.

Kelebe et al., (2017) carried out a study to identify the general driving forces for the adoption of biogas technology by rural households in the Tigray region, Ethiopia. The study reports that; farm size is statistically correlated with the adoption of biogas r2 = 0.66. The findings show that as the farm size increases, the likelihood of biogas technology adoption as well increases. The study concludes that the 'economies of scale' should offer an explanation of adoption in this scenario; that is, a farmer with more land is more likely and, or willing to experiment with new technology.

An assessment by Hamid & Blanchard, (2018) biogas usage in rural Kenya identified that in Nakuru, land size had a negative effect on biogas adoption. This factor was attributed to the fact that the average farm size was less than 2 acres (0.8ha). Based on this, a deduction can be made that a larger land size can give an incentive to biogas adoption. Nakuru County where Kuresoi south is located being relatively densely populated (126-350) means that there is a likelihood where there is less land available (KNBS, 2019). Hamid & Blanchard, (2018) also noted that 74% of the household and institutions that owned a biogas installation had agricultural land.

In a study by Momanyi & Benards, (2016) that analyses biogas adoption in Kilifi, Kenya established that a quarter an acre was sufficient for establishing a biogas plant in a farm. These findings correlate with a study by Smith et al., , (2013) who notes the importance of a bigger size of land to effectuate a biogas plant. Because a biogas plant requires the use of farm waste such as animal dung, the bigger the farm size, the more livestock can be kept and hence the bigger the capacity of the biogas plant (Nimame et al.,, 2020).

Muriuki, (2014) reported the significance of land size in a study of biogas adoption in Kiambu, the study established that the average size of land adopters was between 1.78 to 2.24 acres while that of non-adopters to be 0.1 to 1.0 acres of land.

2.9 Influence of Gender on Biogas Technology Uptake

The use of biogas technology is a crucial method of sustainable development with the potential to solve energy security and environmental problems. As researchers begin to understand the factors that determine the adoption of biogas technology, gender has emerged as an important dimension influencing this process. Many studies have examined the complex interactions between gender dynamics and biogas technology adoption in different contexts.

A study by Kemausuor et al., (2017) found that gender roles have a significant impact on the adoption of biogas technology in Ghana and that women are primarily responsible for household energy needs, thus playing a central role in the decision-making process. Similarly, Mekonnen and Gerber's (2017) study in Ethiopia highlights the important role of women in managing household energy resources and highlights the need for a gender-sensitive approach to promote biogas adoption. In addition, Akhtar et al, (2018) in India found that gender differences in access to resources such as education and training can influence biogas technology competence and adoption rates. These findings highlight the importance of addressing gender constraints to improve the overall effectiveness of biogas programs.

Also, Nguyen et al., (2019) in Vietnam highlighted the role of social norms in shaping gendered perceptions of technology adoption and showed that women's participation in decision-making processes had a positive impact on household adoption of biogas technology. In terms of policy implications, Kumar and Singh (2020) study in Nepal highlighted the need for gender-inclusive policies to promote the adoption of biogas technology, stating that interventions should recognize and address the different challenges faced by men and women.

In addition, the study by Li et al., (2021) from China examined the impact of gender on the success of biogas projects, emphasizing the importance of recognizing women as active actors rather than passive beneficiaries in the adoption process. This shift in perspective is critical to promoting a more equitable and sustainable biogas technology landscape. Despite the growing recognition of gender as an important determinant of biogas technology adoption, some studies caution against oversimplifying the relationship.

The study by Oseniet al., (2018) from Nigeria found that while gender roles play an important role, other contextual factors such as socioeconomic status and access to information also appear to influence adoption patterns. This highlights the need for a nuanced understanding that takes into account the intersection of different factors that influence the adoption of biogas technology. Furthermore, research from several regions has revealed the potential of women to act as agents of change in the adoption of biogas technology. In Bangladesh, Jambeck et al., (2019) found that empowering women through targeted training programs increased their participation in the entire biogas value chain, from construction to maintenance. This not only increased the overall efficiency of the biogas system, but also contributed to the empowerment of women and the socio-economic development of the community.

Tumwesige et al., (2020) highlighted the need to address gender barriers to the adoption of biogas technology in Uganda, as women face difficulties in accessing finance, information and household decision-making. Recognizing and overcoming these barriers is essential to realizing the full potential of biogas technology in promoting sustainable development and gender equality.

In conclusion, the impact of gender on the adoption of biogas technology is a multifaceted and context-dependent phenomenon. The role of women as key decision-makers and active participants in the adoption process, as well as the need for gender-inclusive policies and targeted capacity-building initiatives emerge as recurring themes. However, the complexity of these relationships requires a nuanced approach that considers the intersection of different factors influencing the adoption of biogas technology. As the global community strives to transition to more sustainable energy practices, understanding and addressing the gender aspects of biogas technology adoption is not only necessary to achieve environmental goals, but also a way to promote more inclusive and equitable societies.

2.10 Theoretical Framework

This study employs the Diffusion of Innovations (DOI) theory, developed by Everett Rogers, as a comprehensive framework for understanding the socio-economic factors affecting biogas technology adoption among rural households in Kuresoi South, Nakuru County. DOI theory is particularly well-suited for incorporating the study's four objectives: assessing the percentage of energy mix consumed, determining income levels, evaluating awareness and knowledge of biogas technology, and examining how gender dynamics influence decision-making processes (Taherdoost, 2018). In applying

DOI theory, the confirmation stage is utilized to understand the percentage of energy mix adopted by households, reflecting the diffusion of energy innovations (Franceschinis, et al., 2017). Economic factors influencing adoption, such as income levels, align with DOI's emphasis on the role of economic capacity.

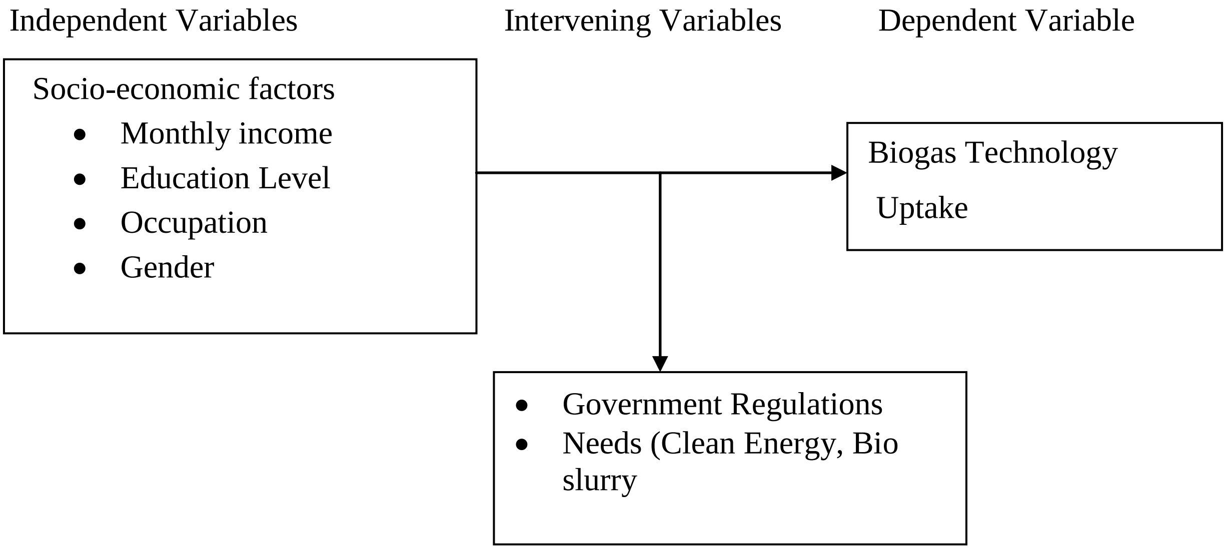
The knowledge and persuasion stages are instrumental in assessing awareness and knowledge levels, highlighting the crucial role of information sources and communication channels (Barreda,2018). Additionally, the theory's recognition of decision-making as a social process informs the exploration of gender dynamics within households, emphasizing how social systems and relationships shape the adoption process (Sovacool & Hess, 2017). Through these interconnections, DOI theory provides a cohesive framework to comprehensively analyze the complex dynamics of biogas technology adoption in the specified rural context (Manzano & Pérez, 2023).

2.11 Conceptual Framework

The intervening variable was the legal requirement; the independent variables were socio-demographic characteristics while dependent variable was biogas technology adoption. The relationship between independent, intervening and dependent variables is as presented.

Figure 1

Conceptual Framework



Source: Modified from Duvel, (1994)

This study was guided by the conceptual framework adopted from (Duvel,1994), based on two theories: Diffusion of innovation model and Theory of planned Behavior. The diffusion of innovation theory is incorporated due to its consideration of demographic characteristics and communication channels as essential determinants of biogas adoption. Theory of planned Behavior on the other side is incorporated as it considers the facilitating conditions such as government regulations influencing adoption of biogas technology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter highlights the strategy that was used in the research study and it includes the research design, study area, target population along with, sampling procedures and sample size, data collection and instruments to be used in collecting data. It also discusses the reliability and validity of the studying instruments, data analysis and ethical issues observed during the research.

3.2 Research Design

This research study adopted a descriptive survey research design. This design was chosen because according to Mugenda & Mugenda (2003), it seeks to answer questions concerning the association between independent and dependent variables of the study. The research is appropriate in determining the relationship between independent variables (socio-economic factors) and dependent variable (adoption of biogas technology).

3.3 Location of the Study

The research study was carried out in Kuresoi South Constituency, Nakuru County, Kenya. Nakuru County lies within the Great Rift Valley and borders eight other counties namely, Kericho, and Bomet to the West, Baringo and Laikipia to the North, Nyandarua to the East, Narok to the Southwest and Kajiado and Kiambu to the South. The County covers an area of 7,495.1 km2 and is located between longitudes 35^0 28^0 and 35^0 36^0 and latitudes 0^0 13^0 and 1^0 10^0 South (Nakuru County Integrated Development Plan, (2013). Kuresoi South is known for its rolling hills, steep valleys, and high elevations, with the

Mau Forest being a major landmark. Kuresoi South lies within longitudes; 35° 31' 18" E, and latitudes 0° 18' 3" S. It covers a total area of 211.7 sq mi (548.2 km^2).

3.4 Population of the Study

The target populations in this study were rural households from Kuresoi South Sub-county. Kuresoi South consists of a population size of 154,998 people and a total number of 34,627 households according to the Kenya National Bureau of Statistics, 2019.

3.5 Sampling Procedure and Sample Size

Sampling means selecting a given number of subjects from a defined population as representative of that population. According to Creswell (2015), any statements made about the sample should also be true of the community. The following formula by Creswell (2015) was used to determine sample size.

$$n= \frac{NC^2}{C^2+(N-1)e^2}$$

Where: n = Sample size, N = Population, C = Coefficient of variation, e = Standard error. C=25% is acceptable according to Creswell (2015) e = 0.02 and N=34,627

$n= [34,627*0.25^2] / [0.25^2 +(34,627-1)0.02^2]$

=2164.19/13.91

=155

The study adopted stratified random sampling using the administrative unit called "ward" as strata to proportionally distribute the 155 households in the 4 wards of Kuresoi South Sub -county based on the total number of households in each ward. For example, the number of households to be selected from Kiptagich Ward was computed as follows: 7,853/34,627* 155=35 households

3.6 Stratified Random Sample Applied by the Study

Table 1

Stratified Random Sampling

Targeted sample size			
Ward	No. of Households	Sample size	%
Kiptagich	7,853	35	23
Keringet	8,882	40	26
Amalo	5,990	27	17
Tinet	11,902	53	34
Total	34,627	155	100

Source: Kenya National Bureau of Statistics, (2019)

The actual households surveyed from each Ward were selected from a randomized sampling frame using systematic random sampling based on a predetermined sampling interval. Purposive sampling was used to identify the key informants in the area of study based on the fact that they are knowledgeable on socio-economic and biogas issues affecting the residents of Kuresoi South.

3.7 Instrumentation

The main instruments used in data collection for both qualitative and quantitative data were; questionnaires, field observation, photography, focus group discussions and key informant interview, both primary and secondary data were collected using these instruments. The instruments are described in details below.

Administration of questionnaires was used to collect primary data for this research. The questionnaire comprised of questions linked to the variables of the study as shown in the study objectives. These variables are: respondents' income, the household size, education level, respondents' occupation (independent variables) and biogas technology adoption (dependent variable). Direct field observation was carried out in the study area. This helped to support data collected through questionnaires.

KIIs were held with major stakeholders. The key informant interview guides were designed in a manner that information relevant to the study will be obtained, such as; biogas technology awareness efforts by extension officers, types of biogas adopted, it's impact and Non-Governmental Organizations (NGOs). Purposive sampling was used to source relevant respondents. This involved discussions carried out in groups identified through the administration of the local chiefs. Focus group was conducted in each of the wards and involved taking into account all group i.e. youth, women and the elders so that it is a representative of the community. The Focus group discussion explored the topic and also helped to understand the challenges, successes and recommendations to improve on the adoption of biogas technology.

Photography was also used to capture some important features relevant to the objectives of the study as at the time of the field survey such as; biogas plants.

Secondary data was generated from the following sources; journals, articles, academic thesis and projects to back-up primary sources.

3.7.1 Pilot Study

A pilot study was carried out to help in testing the reliability of the instruments (Colorafi & Evans, 2016). The pilot study was done in one of the ward neighboring the study area and the selected respondents were identified through random sampling. The selected pilot study area was relevant due to the prominent similarities with the research study area.

3.7.2 Validity of the Instrument

Validity is the extent to which the interpretations of the results of a test are warranted, which depends on the particular use the test is intended to serve (Kimberlin, & Winterstein, 2008). The validity of the study was achieved through the creation of good instrumentation designs based on the objectives of the study under the guidance supervisors who advised accordingly. A review for accuracy was further sorted from research experts to ensure that the study was free from errors, thus, defining the extent to which the outcomes could be generalized.

3.7.3 Reliability of Research Instrument

Reliability of the instrument was done through a pilot study in preparation for a major study. The reliability of a research instrument concerns the extent to which the instrument yields the same results when used in eliciting data (Porter, 2010). Reliability was estimated using Cronbach's Alpha method to test internal consistency and the overall value of 0.704 was obtained indicating that the instrument was valid and fit for use in the research study. The value obtained was compared with the minimum threshold value of 0.7 where values greater than 0.7 imply reliability of research instruments.

Table 2

Reliability Statistics

Cronbach's Alpha	N of Items
.704	20

3.8 Data Collection Procedures

The researcher secured an introductory letter from the ethics committee of Kabarak University and a research authorization from the National Commission for Science, Technology, and Innovation (NACOSTI). Subsequently, upon obtaining the permit, the investigator met with the administrative officials of the study area who offered further guidance on the data collection process. A preliminary stage was initiated by the researcher before the commencement of data collection, involving the recruitment and training of data enumerators. Data enumerators were selected based on their understanding with the region, local dialectal skills, and past experience in data collection. A detailed training was employed to acquaint data enumerators with the research objectives, ethical guidelines, interview techniques and procedures for disseminating surveys.

The training sessions involved role playing activities, simulated interviews and practicals to ensure that enumerators were proficient in data collection approaches and ethical considerations. Enumerators explained the objectives of the study to participants before beginning data collection and seek their informed consent. The selected individuals were provided with broad details about the study, covering its objectives, voluntary participation, possible risks, ways to protect confidentiality and their right to pull out at any stage. Depending on the preferences and literacy levels of the participants informed consent was acquired through either written documentation or verbal declaration. Verbal consent was recorded by the enumerator in cases where participants were unable to provide written consent.

To collect quantitative data on socio-economic factors relatable to the adoption of biogas technology, surveys were used. Enumerators conducted interviews using a standardized questionnaire to ensure the precision and uniformity of the data. The questionnaires addressed various topics such as household demographics, sources of income, educational levels, awareness of biogas technology, and current energy consumption patterns. To ensure the accuracy and comprehensiveness of the data, enumerators directly input participants' responses onto paper forms. Besides questionnaires, focus group discussions (FGDs) were be arranged to gather qualitative data on participants' views, opinions and experiences related to the use of biogas technology. FGDs involved group interactions moderated by a trained facilitator, encouraging participants to openly share their perspectives.

The discussions were documented through note-taking with participants' consent and afterward analyzed. Throughout the data collection phase, enumerators asked feedback from participants and address any inquiries raised by them. To ensure that participants feel recognized, briefing sessions was being conducted building trust and a positive relationship between participants and the research team. Enumerators equipped participants with updates on the study's progress, timelines, and potential outcomes, promoting transparency and active engagement throughout the research process.

3.9 Data Analysis and Presentation

The data collected was subjected to both quantitative and qualitative methods of analysis. Data obtained was prepared through cleaning, editing, coding, and entry into statistical packages for social sciences version 22 (Smith, 2019). The study employed descriptive and inferential statistics to analyze the collected data. Descriptive statistics, such as frequencies and percentages was utilized, while inferential statistics, including correlation and multiple regressions was employed to explain relationships among income levels, energy mix, awareness levels and the gender dynamics in relation to adoption of biogas technology. The regression equation utilized was as follows:

$$Y=\beta0+\beta1X1+\beta2X2+\beta3X3+\beta4X4+\varepsilon$$

Where: Y represents Biogas Technology Uptake, β0 is the Constant, X1 stands for Awareness level, X2 represents Energy Mix, X3 denotes Income levels, X4 signifies Gender Dynamics, while β1, β2, β3, and β4 are the coefficients of determination, and ε represents the error term. Qualitative data, collected through KIIs and FGDs guides was also analyzed.

Table 3

Data Analysis Plan

Objectives	Data Collection Tool	Data Analysis
Proportion of Energy Mix Consumed by Households	Questionnaires	Descriptive statistics (percentages), frequency tables and cross-tabulations
Income Level of Household Heads and Biogas Technology Uptake	Questionnaires and key informant interviews.	Descriptive statistics, Cross tabulation and regression analysis
Level of Awareness and Knowledge on Biogas Technology Uptake	Questionnaires, Key informant interviews and Focus Group Discussions	Descriptive statistics, Cross tabulation and regression analysis
Influence of Gender on Decision-Making Processes for Biogas Technology Uptake	Questionnaires, Focus Group Discussions	Descriptive statistics, Cross tabulation and regression analysis

3.10 Ethical Considerations

The principle of voluntary participation was strictly adhered to. The respondents were not pressured into participating in the research. They were informed about the purpose of the study. The researcher guaranteed the participants confidentiality and anonymity in the entire research process. The researcher sought authority from all the relevant authorities for conformity and in ensuring the study is not discontinued in the process. Authority was also sought from Kabarak University to be allowed to carry out the research. The authority given from the University assisted to seek consequent permissions. Permit for the study was also sought from the National Council of Science and Technology through an application designed by the Council. The researcher also sought authority from the sub-county commissioner in Kuresoi South Sub County plus the chiefs and elders in the area of study by visiting their offices and presenting relevant documents required by each one of them.

In rural areas where individuals are closely linked, participants may fear that their personal information may be exposed, leading to privacy fears. To mitigate this risk, and strict confidentiality measures were put in place. To ensure that they fully understand the applicable confidentiality reassurances, participants received detailed information about the aim and procedures of the study. Personal identifiers were removed from the collected data during the analysis and neither the contact nor names of the participants were published in any publications. Furthermore, for participants who faced the risk of discrimination if their involvement in the study becomes known in the community. Confidentiality was strengthened and ground rules were established in the focus group discussions to ensure respect for participants' privacy. Participants who experience psychological discomfort when discussing sensitive topics related to their socioeconomic status, such as income or access to resources. Informed consent firmly kept an eye on so that participants can make a proper decision about their participation and withdraw at any time without penalty. For physical risks during data collection activities, security procedures and emergency response plan to deal with was established.

Field enumerators were trained thoroughly on the objectives of the study, the importance of data integrity to acquaint them with the questionnaire administration procedure. The training aimed to regulate data collection activities across all wards and ensure consistency in data collection practices. The questionnaire was pilot tested with a small subset of participants from the target population prior to the full data collection stage so as to identify and correct any errors in the draft questionnaire. The response received from the pilot test participants was essential in refining the questionnaire to increase its clarity and understanding. Field supervisor played a key role in supervising enumerators' activities and imposing data collection protocols during the real data collection period. To ensure enumerators follow data collection guidelines and maintain data integrity regular monitoring and spot checks were conducted.

To assess the completeness, accuracy and consistency of the data collected, regular data quality checks was carried out. This involved random sampling of completed questionnaires for confirmation to ensure data reliability. To encourage enumerators provided feedback on their experiences with data collection, a feedback mechanism was established. Meetings were held to discuss reactions and solve any concerns faced during the data collection process. The field supervisor crisscrosses all forms for completeness and accuracy before analysis takes place. He confirmed that all required fields have been filled and that responses are consistent with the study aims and questionnaire guidelines.

The researcher was dedicated to ensure privacy and confidentiality of all participants involved in the proposed study on socio-economic factors affecting the uptake of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County. To achieve this goal, a broad approach was implemented. Foremost, participants were taken through an informed consent process where they received a detailed explanation of the aim of the study, their participation, and the ways taken to safeguard their privacy. There was opportunity for participants to ask questions and provide voluntary informed consent before data collection commences.

All personal identifiers such as names was removed from the data collected to ensure anonymity. As an alternative, a unique identifier was assigned to each participant to ensure that their responses remained confidential while allowing for analysis based on socioeconomic characteristics. In addition, on-disclosure agreements were signed by members of the research team so that high standards of confidentiality were upheld all through the study. Paper documents was kept in locked filing cabinet in a secure place available only to approved persons to ensure secure data handling and storage. Access to the collected data was limited to authorized members of the research team who have been granted permission to handle and analyze the data in strict adherence to confidentiality protocols.

Firstly, enumerators introduced themselves and provided a summary of the study's purpose, highlighting its importance to the community and prospective advantages. The study's objectives, methodology and expected duration were shared covering any possible risks connected with participation and ways of preventing them. There was no impact on the access to benefits by participants who withdrew at any stage as their rights were protected. The strict protocols in place to safeguard personal information were highlighted as privacy and confidentiality measures were being carefully explained. Participants were encouraged to seek further information through opportunity for questions and clarification session. Individuals who decided to participate were provided with written consent stipulating their voluntary participation after understanding the information provided. Informed consent was upheld throughout the study with participants reminded of their right to withdraw and kept informed of any changes.

The researcher had no conflict of interest in the proposed research on socio-economic factors influencing the adoption of biogas technology among rural households in Kuresoi South Sub County, Nakuru County. There were no financial or professional relationships that influenced the results of the research. The aim of the researcher was to conduct an unbiased study so as to contribute to the pool of knowledge on the uptake of renewable energy in rural communities. Transparency and honesty guided all research undertakings and ensure the validity and reliability of study results.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Introduction

This chapter presents the analysis of results, discussions, and interpretation of the social-economic factors that influence the uptake of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County.

4.2 General and Demographic Information

4.2.1 Questionnaire Response Rate

The questionnaire response rate was 100% which means that all the 155 respondents answered the 155 questionnaires. The 100% response rate was because the questionnaires were administered by trained research assistants through interviews in Kuresoi South Sub-County, Nakuru County. Chowdhury (2015) presents that a response rate of 50% is adequate, 60% is good, 70% and higher is very good for analysis and reporting from structured surveys. As a result, the response rate deemed fit enough for further evaluation of the research objectives.

4.2.2 Name of the Wards

Four Wards were covered. The findings are indicated in the Table 4 and Figure 2.

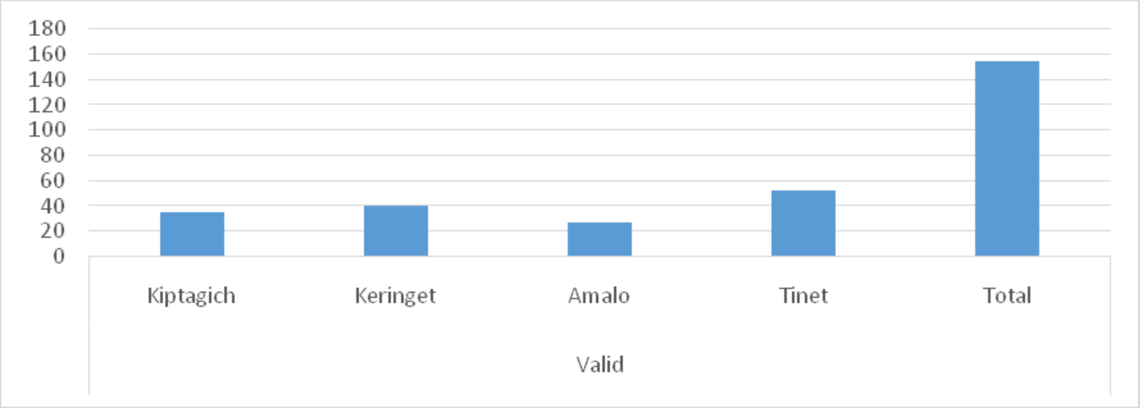
Table 4

Name of the Wards

	Frequency	Percent
Kiptagich	35	22.6
Keringet	40	25.8
Amalo	27	17.4
Tinet	53	34.2
Total	155	100.0

Figure 2

Name of the Ward



The frequency distribution above displays the data for four wards: Kiptagich, Keringet, Amalo, and Tinet from a total of 155 respondents. Tinet ward had many respondents with a totality of 53 representing approximately 34.19%of the total. Keringet followed with a frequency of 40 respondents, 25.81% of the total. Kiptagich, with 35 respondents, representing 22.58% of the total. Lastly, Amalo, with a low frequency of 27 responses, representing 17.42%. This distribution dataset highlights that Tinet ward had most respondents surveyed, followed by Keringet, while Amalo had the least.

4.2.4 Age of the Households Head

The study also sought to identify the age of the respondents to determine any relationship with the uptake of biogas technology in the study area.

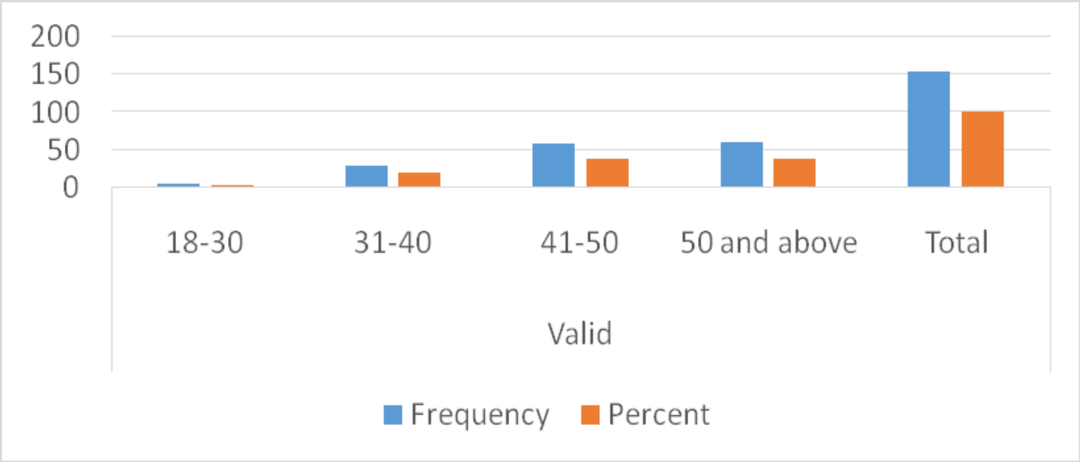
Table 5

Age of the Households Head

	Frequency	Percent	Valid Percent	Cumulative Percent
18-30	5	3.2	3.2	3.2
31-40	30	19.4	19.4	22.6
41-50	59	38.1	38.1	60.6
50 and above	61	39.4	39.4	100.0
Total	155	100.0	100.0	

Figure 3

Respondents by Age



The age dataset shows the number of respondents in different age group within a studied population of 155 individuals. The major group is made up of respondents aged 50 and above consisting of 61 respondents which is 39.4% of the sample. This is narrowly trailed by the 41-50 age group with 59 individuals making up 38.1% of the total. Collectively, these two groups lead the sample, accounting for more than ¾ of the total sample size. The 31-40 age bracket has 30 respondents, setting up 19.4% of the studied population. The smallest bracket is those aged 18-30 with only 5 individuals representing 3.2%. This dataset suggests a studied population that is greatly slanted towards older age groups mostly those above 40 years signifying a possible focus in demographics primarily over the age of 40.

The respondent's age is essential in that the older people have indigenous and better information concerning biogas technology uptake in the studied area than the younger generation. Habermacher & Schmid, (2017) suggests that older individuals regularly have more experience and knowledge about biogas systems due to their longer exposure to traditional farming practices and environmental challenges. Similarly, Esham, et al., (2016) notes that older individuals often serve as knowledge advisors within their communities, sharing information and experiences related to biogas technology adoption.

4.2.5 Education Level

The study as well sought to identify the education level of the respondents to determine any relationship with the uptake of biogas technology in the study area.

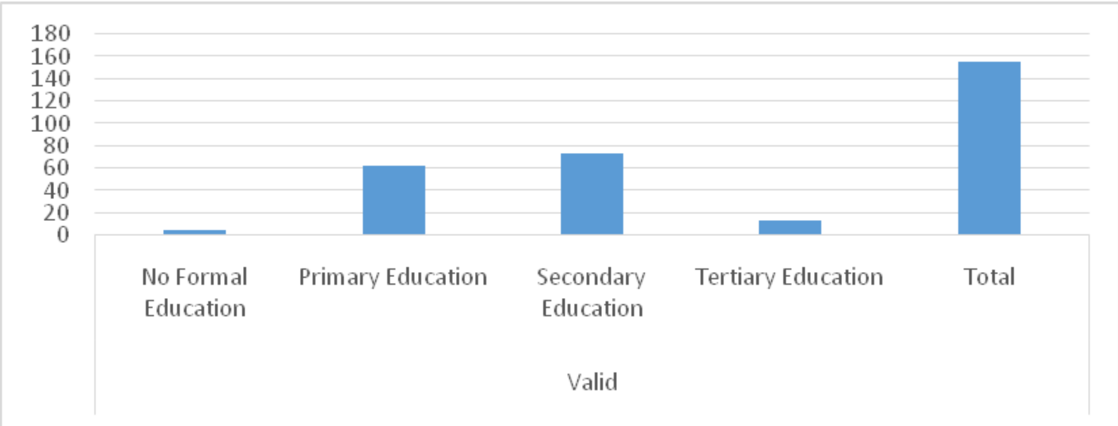
Table 6

Education Level

	Frequency	Percent	Valid Percent	Cumulative Percent
No Formal Education	5	3.2	3.2	3.2
Primary Education	62	40.0	40.0	43.2
Secondary Education	74	47.7	47.7	91.0
Tertiary Education	14	9.0	9.0	100.0
Total	155	100.0	100.0	

Figure 4

Education Level



The data presents the educational accomplishment levels of the studied population of 155 respondents. A smaller segment of the sample 3.2% have no formal education signifying limited access to basic education. The major group 47.7% has completed secondary education signifying that nearly half of the sample reaches this educational level. Primary education accounts for 40.0% presenting that a substantial portion attains at least basic education. Lastly 9.0% attained tertiary education representing a smaller but notable section that advanced to higher education. These data highlights a strong emphasis on secondary education within the studied population with great progress towards achieving higher educational levels. Nevertheless, the low figures for tertiary education and non-formal education shows areas where educational access and progression can be improved.

According to Qu & Zhu,(2020), secondary and tertiary education levels among rural households significantly enhance the possibility of biogas technology uptake in China. Educated individuals are more skillful at seeking information, understanding biogas benefits, and maintaining the systems. In Bangladesh, Kabir,et al., (2013) identifies education particularly secondary education as a key factor of biogas technology uptake. Individuals who are educated mostly are likely to identify the environmental and economic benefits of biogas leading to higher adoption rates.

4.2.6 Occupation of the Household Head

The study correspondingly sought to identify the occupation of the respondents to determine any relationship with the uptake of biogas technology in Kuresoi South Sub-County, Nakuru County.

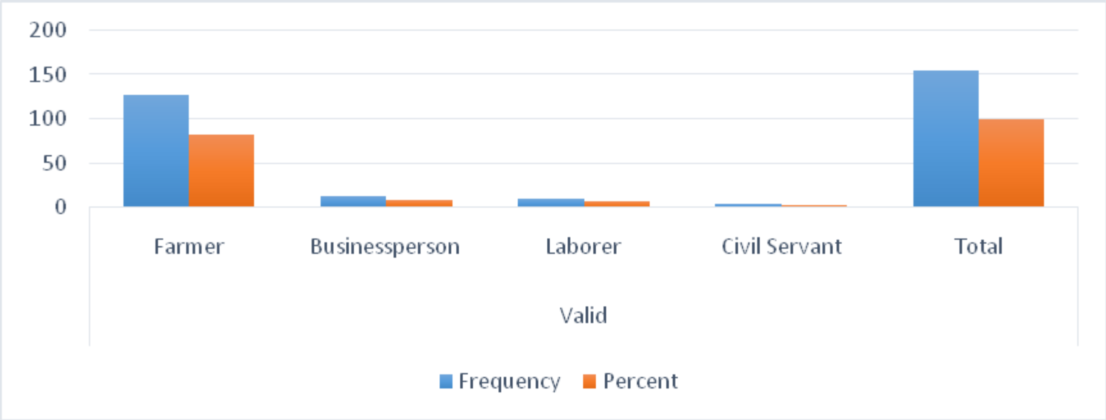
Table 7

Occupation of the Household Head

	Frequency	Percent	Valid Percent	Cumulative Percent
Farmer	128	82.6	82.6	82.6
Businessperson	13	8.4	8.4	91.0
Laborer	10	6.5	6.5	97.4
Civil Servant	4	2.6	2.6	100.0
Total	155	100.0	100.0	

Figure 5

Occupation of the Household Head



The dataset presents farmers as the major occupation among the respondents representing 82.6% of the sample. Business owners followed at 8.4%, laborers at 6.5%and civil servants at 2.6%. The majority of respondents being farmers designates that this study likely targeted a rural population greatly dependent on agriculture. Lipp & Malczewski, (2016) assesses the spatial distribution of renewable energy potential in agricultural areas focusing on biomass energy in Iowa, USA emphasizing the potential for incorporating clean energy with agricultural practices to enhance rural development and energy security.

According to Mulder & Groot, (2013), they suggest that areas with a high dependence on agriculture are more likely to embrace renewable energy technologies as a means of improving agricultural production and environmental sustainability.

4.3 Energy Mix

The respondents were asked to indicate their household primary energy. The results are indicated in Table 8 and Figure 6.

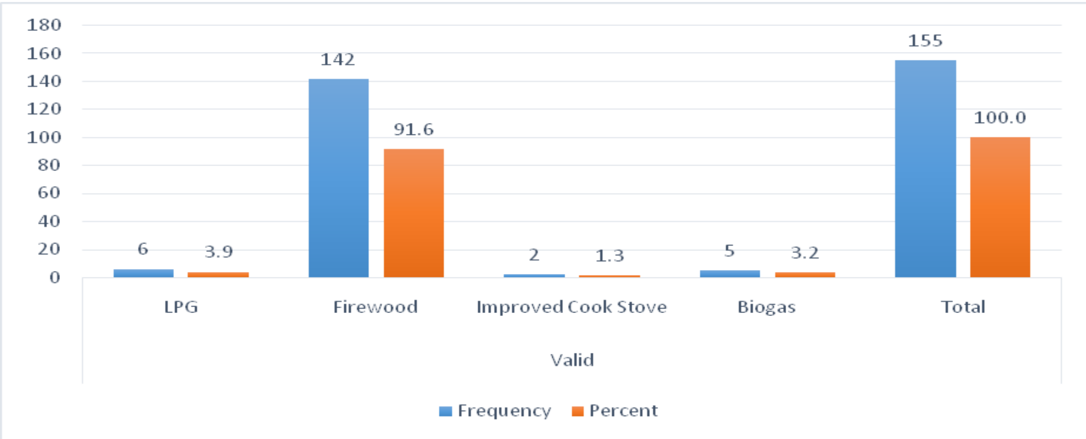
Table 8

Energy Mix

	Frequency	Percent	Valid Percent	Cumulative Percent
LPG	6	3.9	3.9	3.9
Firewood	142	91.6	91.6	95.5
Improved Cook Stove	2	1.3	1.3	96.8
Biogas	5	3.2	3.2	100.0
Total	155	100.0	100.0	

Figure 6

Energy Mix



The results show the distribution of various energy sources consumed by a sample of 155 respondents to meet their household energy needs. The majority 91.6% depend on firewood as their primary energy. A small group uses other types of energy: 3.9% use Liquefied Petroleum Gas (LPG), 3.2% use biogas and 1.3% use improved cook stoves. This suggests a heavy reliance on traditional biomass (firewood) with minimal use of cleaner energy technologies such as biogas, LPG and improved cook stoves. This is consistent with a report by World Health Organization (WHO), 2022, that 2.3 billion people still rely on dirty polluting and dirty fuels such as firewood for cooking and heating leading to severe health risks including heart diseases and chronic lung diseases.

A study by Rosenthal et al.,(2018) highlights the persistent demand for firewood in spite of efforts to encourage cleaner energy technologies. Also, research by Pachauri, et al.,(2019) indicates that economic and cultural factors often impede the switch to cleaner energies. Choumert-Nkolo et al.,(2019) found that firewood is still the main fuel in African rural households.

4.3.1 Relationship between Household Head's Level of Education and the Household's Primary Energy

Table 9

*Primary Energy * Education Level Cross tabulation*

			Education Level		
			2.00	3.00	Total
Primary Energy	2.00	Count	7	11	18
		Expected Count	7.8	10.2	18.0
	3.00	Count	60	77	137
		Expected Count	59.2	77.8	137.0
Total		Count	67	88	155
		Expected Count	67.0	88.0	155.0

Table 10

Chi-Square Tests between Household Primary Energy and Education Level

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.156	1	.693		
Continuity Correction	.020	1	.887		
Likelihood Ratio	.157	1	.692		
Fisher's Exact Test				.803	.447
Linear-by-Linear Association	.155	1	.694		
N of Valid Cases	155				

The chi-square tests indicate no statistically significant association between household primary energy and education level as evidenced by a Pearson Chi-Square value of 0.156 with a p-value of 0.693, a continuity correction value of 0.020 with a p-value of 0.887, and a likelihood ratio value of 0.157 with a p-value of 0.692. Fisher's Exact Test also supports this with two-sided and one-sided p-values of 0.803 and 0.447 respectively and the linear-by-linear association test yielding a value of 0.155 with a p-value of 0.694. With all tests indicating p-values greater than 0.05, we fail to reject the null hypothesis suggesting no significant association between the type of primary energy used by households and the education level of household members in the sample.

This implies that education level does not influence household primary energy choices significantly highlighting the need for policymakers to consider other factors such as economic incentives, availability cultural preferences and infrastructure when promoting cleaner fuels. In a study examining household fuel consumption in Guatemala, Heltberg (2005) found that income rather than education was the primary determinant of the type of energy used with poorer households continuing to rely on traditional fuels despite higher education levels.A Research by Masera et al., (2005) in Mexico showed that traditional fuels like firewood were used expansively regardless of the education level of household heads emphasizing cultural and economic factors as a driving force. Also, Arnold, et al., (2006) in their study revealed that in Africa access to modern fuels like LPG was more closely related to income and infrastructure availability than to educational achievement.

4.3.2 Establishing the Relationship between Household Size and the household's Primary Energy

Table 11

*Household size * Household Primary Energy Cross tabulation*

			Household Primary Energy		
			2.00	3.00	Total
Household Size	1.00	Count	12	69	81
		Expected Count	9.4	71.6	81.0
	3.00	Count	6	68	74
		Expected Count	8.6	65.4	74.0
Total		Count	18	137	155
		Expected Count	18.0	137.0	155.0

Table 12

Chi-Square Tests between Household Size and Household Primary Energy

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.695	1	.193		
Continuity Correction	1.104	1	.293		
Likelihood Ratio	1.730	1	.188		
Fisher's Exact Test				.219	.147
Linear-by-Linear Association	1.684	1	.194		
N of Valid Cases	155				

Chi-square tests show that there is no significant relationship between the type of primary energy used by households and the size of the household. With Pearson Chi-Square, Continuity Correction, Likelihood Ratio, Fisher's Exact Test, and Linear-by-Linear Association all yielding p-values above 0.05 (ranging from 0.188 to 0.293), we found no evidence to reject the null hypothesis. This means that changes in household size will not have any effects on the various sources of household energy preferred by the sample of 155 respondents. These findings simply underpin the problem that drivers other than household demographics particularly economic conditions, cultural practices, or availability of infrastructure might play much more important roles in shaping household choices for energy.

The study findings agree with those of Pueyo et al., (2022) whose study revealed that socio-economic factors such as income and education along with access to resources had a greater impact on household energy choices than household size in Tanzania. Larger households continued to use traditional fuels primarily due to economic constraints. Lee et al., (2021) found that household income and fuel prices were more critical than household size in Urban Kenya. They emphasized that economic factors played a crucial role in the adoption of modern energy sources like LPG. Aklin et al., (2020 found that in India economic incentives and regional differences were more significant than household size in influencing energy choices. They observed that even larger households did not shift to modern energy sources without sufficient economic resources and infrastructure.

4.3.3 Relationship between Occupation and household's Primary Energy

Table 13

Household Primary Energy Occupation Cross Tabulation*

			Occupation		
			1.00	2.00	Total
Household Primary Energy	2.00	Count	13	5	18
		Expected Count	14.9	3.1	18.0
	3.00	Count	115	22	137
		Expected Count	113.1	23.9	137.0
Total		Count	128	27	155
		Expected Count	128.0	27.0	155.0

Table 14

Chi-Square Tests between Occupation and Household Primary Energy

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.519	1	.218		
Continuity Correction	.814	1	.367		
Likelihood Ratio	1.362	1	.243		
Fisher's Exact Test				.317	.180
Linear-by-Linear Association	1.509	1	.219		
N of Valid Cases	155				

The chi-square tests disclose that there is no significant association between occupation and household primary energy. The Pearson Chi-Square has a value of 1.519 with a p-value of 0.218, hence we cannot reject the null hypothesis. This is supported by the Continuity Correction value of 0.814 with a p-value of 0.367 and Likelihood Ratio of 1.362 with a p-value of 0.243. Moreover, Fisher's Exact Test gives the p-values to be 0.317 two-sided and 0.180 one-sided, thereby confirming that neither of the results is significant.

The Linear-by-Linear Association gives a value of 1.509 with a p-value of 0.219. Thus, it shows that the analysis is consistent in returning the result of no statistically significant relationship between household primary energy type and occupation for the number of valid cases, which is 155. This suggests that occupation does not play a critical role in determining the type of primary energy used by households in this sample. The findings agree with Mekonnen & Gebreegziabher (2020) in Ethiopia that household income and education level had more influence on energy choices than occupation.

They noted that even within the same occupation variations in income led to different energy preferences. Olabisi et al., (2023) in Nigeria concluded that household income, fuel availability and education were more important than occupation. They emphasized that occupation alone did not drive significant differences in household energy choices. In Ghana, Karimu 4& Mensah (2022) learnt that income levels and access to energy infrastructure featured more significantly than occupation in determining what should make up household energy choice. Households with similar occupations but different income levels and access to infrastructure exhibited varying energy preferences.

Table 15

Households Head Perception towards Biogas as Part of Energy Mix

Items	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean	Stard Dev	Decision
Biogas is currently not a significant part of the energy mix in my household.	0 (0.0%)	1 (0.6%)	4 (2.6%)	12 (7.7%)	138 (89%)	4.85	.467	High Perception
My household primarily relies on traditional biomass fuels for energy.	1 (0.6%)	1 (0.6%)	4 (2.6%)	5 (3.2%)	144 (92.9%)	4.87	.531	High Perception
There is a need to diversify our household's energy sources.	0 (0.0%)	1 (0.6%)	3 (1.9%)	7 (4.5%)	144 (92.9%)	4.90	.414	High Perception
I am open to exploring alternative energy options such as biogas.	0 (0.0%)	1 (0.6%)	32 (20.6%)	60 (38.7%)	62 (40%)	4.18	.777	Low Perception
Biogas has the potential to become a major contributor to our energy mix.	0 (0.0%)	1 (0.6%)	20 (12.9%)	63 (40.6%)	71 (45.8%)	4.32	.719	Low Perception

Key: SA=Strongly Agree; A=Agree; N=Neutral; D=Disagree; SD=Strongly;D= Disagree

The results indicate that there is indeed strong recognition from within the household that biogas is currently not a significant proportion of their energy mix and that traditional biomass fuels are relied on heavily. Likewise, there is also very clear consensus regarding the need to diversify sources of energy, which reflects awareness of its potential benefits in general. On the other hand, there seems to be less concurrence regarding biogas by itself as an alternative source of energy. Lower perception scores on openness to the exploration of biogas and its potential contribution to the mix may therefore be due to unfamiliarity, uncertainty, or interest in biogas as a feasible alternative. It simply shows that there is a differentiation between perceiving that change has to happen and the readiness or belief in adopting biogas, which thus indicates an area that will need education or incentives to encourage adoption of biogas.

According to Britz &Delzeit, 2018, in regard to biogas development in Europe, there is huge potential for biogas to turn out to become very resourceful sources of renewable energy. However, economic and infrastructural limitations enhance its restriction to wide applications, hence reverberating with the findings. A study by Jan &Akram in Pakistan (2018) has reported that biogas technology has majorly been adopted for cooking in rural households driven by the needs of a clean, sustainable and reliable source of energy. Another study conducted by Mbohwa&Chikuni in Zimbabwe, 2018, singled out biogas as one of the ascertainable renewable energy options to mitigate energy poverty and complement rural development.

4.4 Income Levels

The study also sought to identify the income levels of the respondents to determine any relationship with the uptake of biogas technology in the study area.

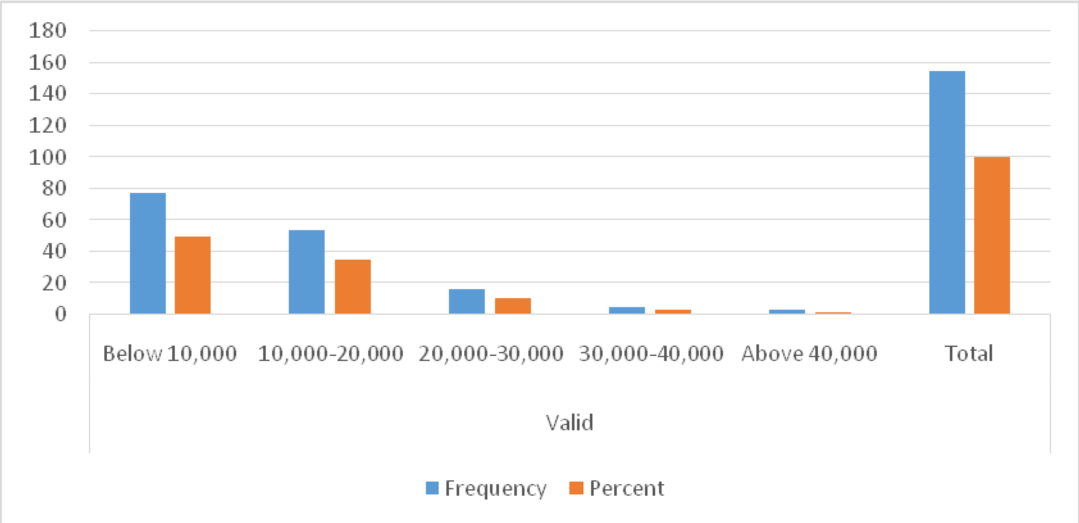
Table 16

Income Levels

	Frequency	Percent	Valid Percent	Cumulative Percent
Below 10,000	77	49.7	49.7	49.7
10,000-20,000	54	34.8	34.8	84.5
20,000-30,000	16	10.3	10.3	94.8
30,000-40,000	5	3.2	3.2	98.1
Above 40,000	3	1.9	1.9	100.0
Total	155	100.0	100.0	

Figure 7

Income Levels



The table shows the distribution of monthly household income in KES. As shown, almost half of the households, 49.7 percent, earn below KES 10,000, while one-third, 34.8 percent, earn between KES 10,000 and 20,000. Only 10.3 percent earn between KES 20,000 and 30,000 and 3.2 percent between KES 30,000 and 40,000, while 1.9 percent earn above KES 40,000. This means that a significant proportion of the population falls within the lower level of income, further hurling problems in the adaptation of clean energy solutions. Lower-income homes may lack the financial capacity to invest in clean energy technologies due to up-front cost.

According to a study conducted by Chiteculo et al., in 2018 in Kenya, while these experiences brought about long-term savings and environmental benefits, the probability of a low-income household adopting a solar energy system was still low since these involved very high upfront costs. This supports the broader literature indicating that up-front capital requirements are one of the main barriers to adopting clean energy for economically disadvantaged groups.

In a connected study, Sovacool et al., (2018) assessed the use of clean energy technologies in Tanzania and found one significant barrier to be financial constraints. According to the findings, lower-income families are likelier to spend their money on basic beneficial needs such as food and education rather than on long-lasting but highly costly energy infrastructure. This can be quite understandable, having undergone daily economic struggles.

A study by Khandker et al., (2018) in Bangladesh showed, however, that the presence of credit and financial support mechanisms increased considerably the adoption rate of solar home systems among lower-income households. This means that new financing innovations; microloans or, particularly, pay-as-you-go models, would be significant enablers for the low-income population shifting into clean energy.

Furthermore, in 2018, research in India by Rahut et al., showed that as income increased, modern energy source usage increased substantially. Still, the presence of subsidies and government support programs was of paramount importance to be able to enable the shifting away from traditional biomass use toward cleaner forms of energy for the lower-income households. This shows that policy interventions are highly deterministic in dictating the clean energy adoption rate.

4.4.1 Relationship between Income and household's Primary Energy

Table 17

*Household Primary Energy*Income Cross tabulation*

			Energy		
			1.00	3.00	Total
Income	1.00	Count	5	72	77
		Expected Count	8.9	68.1	77.0
	2.00	Count	13	65	78
		Expected Count	9.1	68.9	78.0
Total		Count	18	137	155
		Expected Count	18.0	137.0	155.0

Table 18

Chi-Square Tests between Household Income and Household Primary Energy

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.907	1	.048		
Continuity Correction	2.979	1	.084		
Likelihood Ratio	4.034	1	.045		
Fisher's Exact Test				.077	.041
Linear-by-Linear Association	3.882	1	.049		
N of Valid Cases	155				

The table displays various Chi-Square test statistics testing the relationship of household income to household primary energy type. The Pearson Chi-Square test has a value of 3.907 with 1 degree of freedom and an asymptotic significance or p-value of 0.048, which is significant at the 5% significance level. The Likelihood Ratio Chi-Square also confirms this conclusion with a value of 4.034 and a p-value of 0.045. The p-value, however, from the Continuity Correction applied to the 2 x 2 table was not significant at

0.084. Fisher's Exact Test yields a p-value of 0.077 (2-sided) and 0.041 for the 1-sided test; thus, under this latter approach, there would be an association. Linear-by-Linear Association value is 3.882 with a p-value of 0.049, indicating significance. The analysis produces a significant relationship between Household Income and Primary Energy Sources. Only tests of Continuity Correction and Fisher's exact test (2-sided) are non-significant, but only marginally so. There were 155 valid cases with no expected counts less than 5.

According to Li et al., (2018), within the rural areas of China, the adoption of cleaner energy sources is highly driven by the level of income at the household level; that means more affluent households use electricity and natural gas, while poorer ones stick to the traditional use of biomass. Similarly, Ahmad &Puppim de Oliveira (2018) found in Bangladesh that higher-income households tend to use LPG as a modern form of energy, whereas, for poor families, firewood and other traditional fuels are usually the only way.

This is further supported by a study conducted in India by Khandker et al., (2020), where they found that income remains one of the most critical determinants of switching from traditional to modern sources of energy; therefore, with the help of subsidies and financial support, it could play a vital role in making cleaner sources of energy more accessible to the low-income groups. In sub-Saharan Africa, similar trends were recorded, with the choice of which energy to use directly being dictated by the income level, in that more affluent households chose to use electricity and poorer households stuck to kerosene and wood (Uhunamure et al., 2019).

Table 19

Households Head Perception towards Income as A Factor affecting Biogas Uptake

Items	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean	Standard Deviation	Decision
The initial cost of biogas technology is a significant barrier for me.	0 (0)	0 (0)	3 (1.9)	25 (16.1)	127 (81.9)	4.80	.447	High Perception
My household's income allows for investment in biogas technology.	135 (87.1)	6 (3.9)	2 (1.3)	9 (5.8)	3 (1.9)	1.32	.910	Low Perception
I believe biogas technology is a worthwhile investment for our household.	4 (2.6)	15 (9.7)	9 (5.8)	18 (11.6)	109 (70.3)	4.37	1.117	High Perception
Access to financing options would facilitate biogas technology adoption.	8 (5.2)	7 (4.5)	5 (3.2)	14 (9.0)	121 (78.1)	4.50	1.101	High Perception
Biogas technology offers long-term cost savings compared to other fuels.	6 (3.9)	14 (9.0)	9 (5.8)	23 (14.8)	103 (66.5)	4.31	1.160	High Perception
Average								3.86

Key: SA=Strongly Agree A=Agree, N=Neutral, D=Disagree SD=Strongly Disagree

The data provided above on the adoption of biogas technology describes a precise scenario of the barriers and motivations that exist among households. Item 1 shows a high perception that the initial cost of biogas technology is a significant barrier, thus indicating that financial constriction is a primary concern. This concern is further underpinned by Item 2, where the low perception indicates that majorities feel their income is not sufficient to invest in biogas technology. It simply means that one of the significant obstacles is a huge capital upfront requirement, which deters many from considering biogas as a sustainable energy.

In contrast, items 3, 4, and 5 generally favor the biogas technology. Item 3 is highly perceived, which means that, in general, households could see the long-term value or even the benefits reaped from biogas technology; it seems to be something good to invest in. Item 4 shows a high perception, thus emphasizing that without access to financing options, this need cannot be met. If accessible financial aids such as loans or subsidies are made available, then biogas technology will be easily adopted by these households. On the last note, an understanding of the long-term cost savings is highlighted by high perception in Item 5, which biogas offers over other fuels, thereby showing that households recognize the economic benefit once the initial cost barrier is overcome. According to Ulsrud et al., (2018), in Tanzania, it was reported that the high initial cost of biogas technology demotivates most households from investing in this sustainable gas. Precisely, it is noted that even though the use of biogas brings clear long-term benefits, which include cost savings and environmental advantages, many prospective users are scared off by the high upfront investment. This agrees well with the high perception of the initial cost as a barrier indicated in Item 1 of the provided data.

Furthermore, Item 2 from findings in earlier work in Kenya by Mwirigi et al., (2018) supports a low perception of the ability of households to invest in biogas technology. The study showed that income levels among a majority of the households rarely suffice to finance upfront costs for biogas systems; instead, there is a call for financial support. To such results, the research finds weak financial capacity among low-income households as one major constraint to adopting biogas technology. Items 3, 4, and 5, on the flip side, appear to have positive perceptions about the value and actual benefits of biogas technology. This agrees with several studies that claim that biogas has the potential for long-term savings and environmental benefits.

The study by Surendra et al., (2018) for instance revealed that households in Nepal using biogas reported high savings from fuel expenditure and improved health through reduced indoor air pollution. This supports the typical perception of this biogas technology as a worthwhile investment about its long-term cost-saving potential. This awareness about the importance of financing options is supported by the results of a study conducted in South Africa by Amigun and Blottnitz, 2018, where access to financing and credit schemes was established as one of the most dominant drivers for the increased adoption of biogas technology. In that regard, their study demonstrated that innovative solutions such as pay-as-you-go and micro-loans mechanisms help to scale up the adoption of biogas by minimizing this barrier of upfront costs for low-income households.

4.5 Knowledge and Level of Awareness

The researcher also carried out the study to find out the level of awareness and knowledge on biogas technology in Kuresoi Sub-County, Nakuru County.

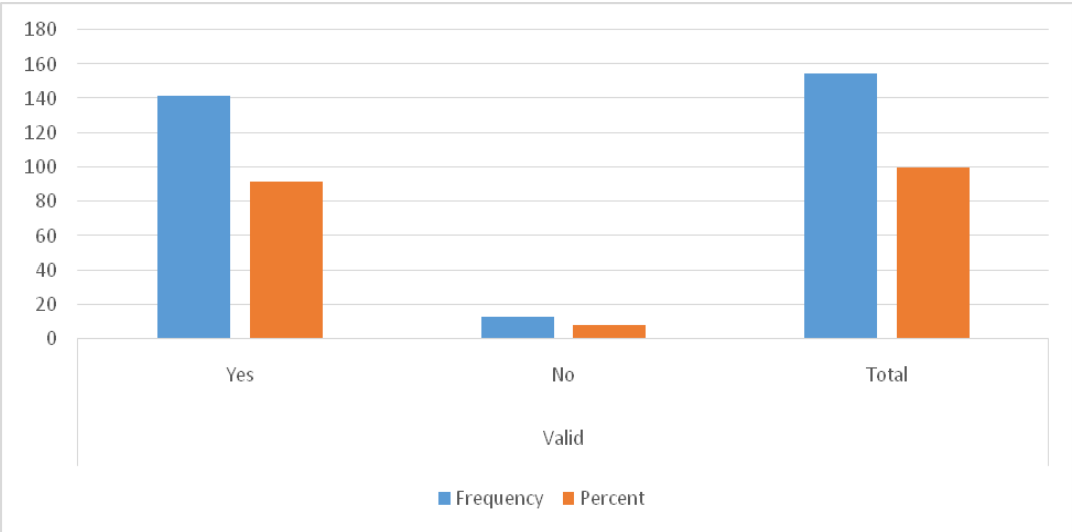
Table 20

Biogas Technology Awareness

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	142	91.6	91.6	91.6
No	13	8.4	8.4	100.0
Total	155	100.0	100.0	

Figure 8

Biogas Technology Awareness



The results show awareness regarding biogas technology among the respondents. Out of 155 valid responses, 142 provided a "Yes" response to indicate awareness of biogas technology. In contrast, only 13 of them responded with "No" to indicate unawareness of it. The high level of awareness, 91.6 percent, indicates that biogas technology is well known within the studied geographical area, reflecting effective information distribution and probably the presence of some formative programs. Only a few who were uninformed, indicating an 8.4 percent gap, would require further campaigns on awareness to bring full awareness close to totality.

Kemausuor et al., (2018) illustrated that awareness was a very key factor in the adoption of biogas technology in Ghana. For example, it has been noted that higher awareness levels increase the perception of biogas among households as a viable or beneficial energy source, hence affecting its adoption. Furthermore, Njenga et al., (2018) demonstrated in Kenya that indeed, high levels of awareness were often correlated with higher rates of technology adoption. Well-informed communities, particularly on the economic and environmental benefits to be garnered from the biogas technology, will embrace and argue for it more.

Another study by Aggarwal et al., (2018) in India indicated that awareness campaigns by both the government and non-governmental organizations greatly improved the knowledge of people with regard to biogas technology. The researchers showed that high diffusion of biogas plants occurred in areas where these campaigns were more extensive; hence, education through awareness strongly works.

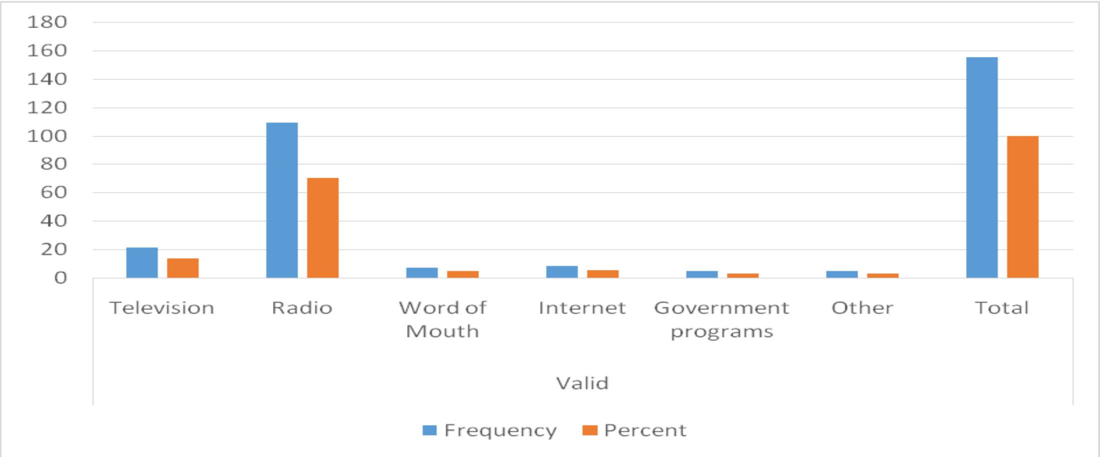
Table 21

Information Sources on Biogas Technology Awareness among Respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Television	21	13.5	13.5	13.5
Radio	109	70.3	70.3	83.9
Word of Mouth	7	4.5	4.5	88.4
Internet	8	5.2	5.2	93.5
Government programs	5	3.2	3.2	96.8
Other	5	3.2	3.2	100.0
Total	155	100.0	100.0	

Figure 9

Sources of Awareness



The dataset presents the distribution of various means through which respondents have become aware of biogas technology. Radio emerges as the most prevalent source of information, with 109 respondents (70.3%) indicating it as their primary medium of awareness. Television follows at a distant second with 21 respondents (13.5%), while the Internet and word of mouth are less significant sources, with 8 respondents (5.2%) and 7 respondents (4.5%) respectively. Government programs and other unspecified means each account for 5 respondents (3.2%). This distribution highlights the dominant role of radio in disseminating information about biogas technology, suggesting it is a highly effective medium for reaching a broad audience.

A study by Kiptot and Franzel (2018) in Kenya highlighted that radio is a crucial tool for agricultural extension and dissemination of renewable energy information. The researchers found that radio programs were particularly effective in reaching rural populations, where access to television and the Internet is often constrained by infrastructure and financial barriers. This aligns with the finding that 70.3% of respondents learned about biogas technology through radio.

Moreover, a study by Mottaleb et al., (2018) in Bangladesh demonstrated that radio was a powerful medium for raising awareness about new technologies among low-income households. The study emphasized that radio broadcasts could cover large geographic areas and provide timely information, making them an invaluable resource for public education campaigns.

In contrast, the lower impact of television and the Internet as sources of information about biogas technology suggests that these mediums might be less accessible or less utilized by the target population. This is supported by research conducted by Parajuli et al., (2018) in Nepal, which found that while television and Internet use is growing, their reach in rural and low-income areas remains limited compared to radio. The study indicated that high costs and limited infrastructure often restrict the effectiveness of these channels in disseminating information to wider audiences.

Additionally, the role of government programs in spreading awareness about biogas technology appears minimal. This finding is consistent with a study by Kebede et al., (2018) in Ethiopia, which noted that while government initiatives play a critical role in promoting renewable energy, their impact is often limited by resource constraints and insufficient outreach strategies. The study suggested that enhancing the visibility and accessibility of government programs could significantly improve their effectiveness in raising awareness.

Lastly, the influence of word of mouth indicates that personal networks and community interactions also contribute to the dissemination of information about biogas technology. This is supported by the study of Pandey et al., (2018) in India, which highlighted the importance of social networks and peer influence in the adoption of new technologies.

Table 22

Households Head Perception towards Knowledge and Level of Awareness on Biogas Technology

Items	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean	Stard Dev	Decision
I am familiar with the concept of biogas technology.	129 (83.2)	18 (11.6)	8 (5.2)	0 (0)	0 (0)	4.78	0.57	Negative Perception
I understand the benefits of using biogas technology.	39 (25.2)	53 (34.2)	18 (11.6)	22 (14.2)	23 (14.8)	3.41	1.39	Positive Perception
I am aware of how biogas technology works.	126 (81.3)	23 (14.8)	1 (0.6)	5 (3.2)	0 (0)	4.74	0.63	Negative Perception
I have access to sufficient information about biogas technology.	116 (74.8)	29 (18.7)	5 (3.2)	5 (3.2)	0 (0)	4.65	0.69	Negative Perception
I feel confident in my knowledge of biogas technology.	102 (65.8)	40 (25.8)	5 (3.2)	6 (3.9)	2 (3.9)	4.51	0.84	Negative Perception
Average								4.41

Key: SA=Strongly Agree A=Agree; N=Neutral; D=Disagree; SD=Strongly Disagree

The data presents individuals' perceptions of their familiarity, understanding, awareness, information access, and confidence regarding biogas technology. The findings show that most respondents have a low perception of their familiarity with the concept of biogas technology, their awareness of how it works, their access to sufficient information, and their confidence in their knowledge. This suggests that while there may be some exposure to the concept of biogas, there is a significant gap in detailed understanding, information access and confidence in this knowledge. The low perception in these areas indicates a potential need for more educational initiatives, informational resources and confidence building measures to enhance familiarity and understanding of biogas technology.

On the other hand, respondents reported positively understanding the benefits of using biogas technology. This indicates that despite the gaps in other areas, there is an awareness of the advantages that biogas technology can provide, such as environmental benefits, cost savings, and energy efficiency. The higher perception in this item suggests that promotional efforts focusing on the benefits have been somewhat effective.

These findings are consistent with several studies conducted in recent years, for instance, a study by Ndunge & Mungai (2020) in Kenya found that while rural households recognized the environmental and economic benefits of biogas technology, their adoption was hindered by limited knowledge and confidence in using the technology. Similarly, Ali et al., (2019) in Pakistan identified a significant gap between awareness of the benefits of biogas and the technical understanding required for its implementation, emphasizing the need for comprehensive training programs to bridge this gap.

Furthermore, research by Somanathan et al., (2018) in India highlighted that while the perceived benefits of biogas technology were well understood, there was a critical need for increased access to information and practical demonstrations to enhance familiarity and confidence among potential users. This aligns with the findings from Mwirigi et al., (2022) in Tanzania, who reported that information dissemination through community-based initiatives significantly improved the adoption rates of biogas technology by increasing both awareness and practical knowledge.

4.6 Gender and Decision Making

The study sought to identify the gender respondents to determine any relationship with the uptake of biogas technology in the study area.

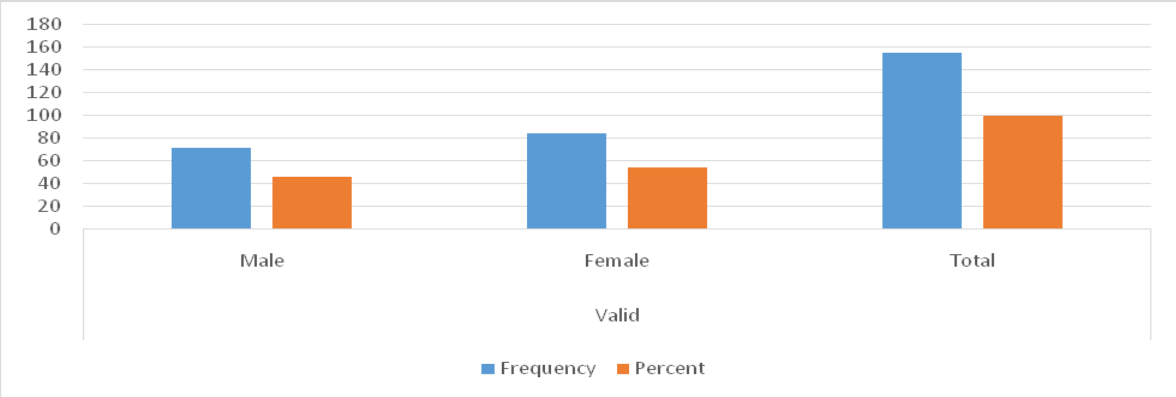
Table 23

Gender of the Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
	Male	71	45.8	45.8	45.8
	Female	84	54.2	54.2	100.0
	Total	155	100.0	100.0	

Figure 10

Gender of the Respondents



The above data shows the gender representation among respondents. Out of the total, 71 are male, accounting for 45.8% of the population, while 84 are female, representing 54.2% of the population. This shows a higher percentage of females compared to males in the study area with females comprising somewhat over half of the total. The nearly balanced gender distribution suggests a fairly equitable representation of both genders with a slightly higher female presence. According to Pew (2023), gender representation is important for capturing wide-ranging understandings across demographics. Also, a report by World Economic Forum 2023 points out that gender balanced involvement is vital for correct likeness of social aspects and for resolving gender discrepancies effectively.

4.6.1 Relationship between Gender and household's Primary Energy

Table 24

Household Primary Energy Gender Cross tabulation*

			Energy		
			1.00	3.00	Total
Gender	Male	Count	8	63	71
		Expected Count	8.2	62.8	71.0
	Female	Count	10	74	84
		Expected Count	9.8	74.2	84.0
Total		Count	18	137	155
		Expected Count	18.0	137.0	155.0

Table 25

Chi-Square Tests between Gender and Household Primary Energy

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.015	1	.902		
Continuity Correction	.000	1	1.000		
Likelihood Ratio	.015	1	.902		
Fisher's Exact Test				1.000	.553
Linear-by-Linear Association	.015	1	.902		
N of Valid Cases	155				

The Chi-Square test results indicate no significant relationship between gender and household primary energy type based on the provided data. The Pearson Chi-Square, Continuity Correction, Likelihood Ratio, and Linear-by-Linear Association tests all yield very small chi-square values (0.015) with 1 degree of freedom and high p-values ranging from 0.902 to 1.000. These results suggest that there is no evidence to reject the null hypothesis that gender and household primary energy type are independent variables. The Fisher's Exact Test also supports this finding with p-values of 1.000 (2-sided) and 0.553 (1-sided), further confirming the lack of association. With 155 valid cases analyzed, the data indicates that gender does not significantly influence the choice of household primary energy source within this sample. Therefore, other factors beyond gender likely play a more crucial role in determining energy choice highlighting the need for further investigation into socio-economic, cultural, and environmental factors that may impact energy preferences.

Research conducted by Brown & Sovacool (2018) examined household energy choices in the United States and found that while gender may influence energy-related behaviors such as energy conservation practices, it often does not directly determine primary energy source preferences. Similarly, a study by Li et al., (2021) in China explored factors influencing renewable energy adoption and concluded that gender was not a significant predictor compared to socioeconomic status and environmental attitudes.

Further supporting these findings, research by Singh & Srinivasan (2019) in India investigated household energy transitions and highlighted that cultural norms and economic factors had more substantial impacts on energy choices than gender-specific preferences.

Table 26

Households Head Perception towards Gender on Biogas Technology Uptake

Items	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean	Std Dev	Decision
Gender plays a significant role in determining energy-related decisions.	6 (3.9)	4 (2.6)	16 (10.3)	48 (31.0)	81 (52.3)	1.75	1.01	Low Perception
In my household, both genders have equal influence over energy investments.	40 (25.8)	21 (13.5)	8 (5.2)	19 (12.3)	67 (43.2)	2.66	1.71	Low Perception
Women are actively involved in decisions regarding biogas technology uptake.	13 (8.4)	6 (3.9)	13 (8.4)	26 (16.8)	97 (62.6)	1.79	1.25	Low Perception
Men typically have more influence in the adoption of new technologies.	73 (47.1)	16 (10.3)	7 (4.5)	10 (6.5)	49 (31.6)	3.35	1.79	High Perception
Gender dynamics do not have a significant influence on the uptake of biogas technology within my local community.	87 (56.1)	22 (14.2)	17 (11.0)	19 (12.3)	10 (6.5)	4.01	1.32	High Perception
Average								2.71

Key; SA=Strongly Agree; A=Agree; N=Neutral; D=Disagree; SD=Strongly Disagree

The provided data indicates a nuanced perspective on gender roles in energy related decision-making. There is a low perception that gender significantly influences energy-related decisions within households and the involvement of women in decisions regarding biogas technology uptake. Equally, there is a high perception that men have more influence in the adoption of new technologies and that gender dynamics do not significantly impact the uptake of biogas technology in Kuresoi South Sub-County. This suggests that while gender equality is perceived in household energy investments, traditional gender roles still dominate in the broader adoption of new technologies, potentially highlighting areas where gender-specific interventions could be beneficial.

Research by the United Nations Development Programme (UNDP) also supports these findings, highlighting that women in regions such as Papua New Guinea face significant challenges in accessing resources and participating in decision-making processes due to entrenched gender inequalities and cultural norms (UNDP, 2023). This often results in men having more influence over the adoption of new technologies, including biogas, despite women's pivotal role in household energy management. Research by Seebaluck & Issa (2018) from the University of Mauritius discusses how gender norms can influence energy-related decisions within households. They argue that while gender roles are changing, traditional perceptions often still dictate larger technological choices, reflecting similar findings to your data where men are perceived to have more influence in adopting new technologies.

Equally, a study by Johnson & Smith (2020) at Stanford University explores gender dynamics in energy technology adoption, highlighting disparities in how men and women are involved in decision-making processes. They found that despite advancements in gender equality, men tend to dominate decisions related to new energy technologies, aligning with the high perception in the findings that men have more influence in such perspectives.

In contrast, Gupta & Martin (2022) from the University of California, Berkeley argues that while households may show gender parity in daily energy choices, community-wide decisions like biogas technology adoption often overlook women's contributions echoing the low perception in the findings regarding women's involvement in biogas technology decisions.

4.7 Types of Bio Digesters in Kuresoi South Sub County, Nakuru County

Based on the observations and Key Informant Interviews, two main types of bio digesters were identified in Kuresoi South Sub-county: tubular (plastic) and fixed dome biodigesters. Tubular biodigesters are made from a long, flexible plastic tube. They are low-cost and portable appealing to small-scale farmers. Fixed dome biodigesters are constructed with a non-movable dome made from bricks. They are durable and require minimal maintenance making them ideal for small scale farmers.

Figure 11

Fixed Dome Bio-Digester

4.8 Benefits of Bio-digesters in Kuresoi South Sub-county, Nakuru County

Biodigesters adopted in Kuresoi South Sub-county have various associated benefits. Economically, households reduce expenses on cooking fuel and some earn an extra coin from the sale of excess bio-slurry produced. These findings agree with the research conducted by Bhanot & Pinkse (2021) from the University of Manchester, which disclosed and outlined the economic benefits of biodigester adoption in rural communities. Environmentally, biodigesters reduce deforestation through decreased dependence on firewood and better management of animal and agricultural wastes, consequently improving sanitation. This is well supported by Kuhlmann & Farrington (2019) of Oxford University who established that biodigesters contribute to reducing environmental degradation in rural settings at large. Amongst the health benefits include improved indoor air quality, therefore leading to fewer respiratory complications among members of respective households, with women and children being the worst victims. Agarwal et al.,(2020) of Stanford University also made the same report for health benefits. Improved indoor air quality due to using biogas for cooking correlates with better respiratory health outcomes. On the agricultural side, farmers testified to better harvests and healthier soil from the bio-slurry produced by the biodigesters. This is also supported by findings from Iyer & Clarke (2018) made in rural India, where bio-slurry from biodigesters raised agricultural productivity significantly.

Table 27

Regression Analysis

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	2.843	5	.569	1.394	.230
	Residual	60.796	149	.408		
	Total	63.639	154			

The ANOVA table displays the regression analysis results estimating the effect of a number of predictors: gender, household size, occupation and education level on household energy usage. The residual sum of squares is 60.796 with 149 degrees of freedom, leading to a mean square of 0.408. The regression model's sum of squares is 2.843 with 5 degrees of freedom resulting in a mean square of 0.569. The F-value for the model is 1.394 with a significance level (p-value) of 0.230. The model is not statistically significant since the p-value is greater than 0.05, signifying that the predictors together do not explain a significant portion of the variance in household energy use.

This finding corresponds that of Nyoike & Choge (2018) in Kenya, who held the opinion that demographic factors, like the size of the house and gender levels do not always translate directly into significant differences in energy usage patterns. This could be due to intervening variables between several factors likely to affect energy consumption. In a recent study from Pakistan, Baloch et al., (2019) highlights that household energy consumption is driven by factors such as cultural practices, local climate conditions and alternative energy sources other than simple demographics. This provides evidence that household energy use is a multidimensional matter that cannot be fully explained by household size, gender, education level and occupation alone.

According to Wang et al.,(2020), a study across China revealed that household energy usage is greatly influenced by behavioral factors and the adoption rate of energy-efficient technologies, which the given regression model did not capture. This calls for the use of other variables in establishing energy usage patterns.

Table 28

Regression Coefficients

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	3.123	.348		8.962	.000	2.434	3.811
Income	-.185	.113	-.144	-1.636	.104	-.407	.038
Gender	-.034	.104	-.026	-.326	.745	-.240	.172
Education, Level	-.055	.085	-.059	-.642	.522	-.223	.113
Occupation	-.046	.081	-.050	-.568	.571	-.205	.114
Household Size	.070	.068	.086	1.022	.308	-.065	.205

The coefficients table presents the output of a regression analysis investigating income, sex, level of education, employment, and household size as determinants of household energy usage. There is a constant term at 3.123, which is interpreted to be what the baseline would be if all predictors were zero regarding household energy use. Indeed, none of these predictors returned a statistically significant impact on domestic energy consumption, as can be shown by their respective p-values, all of them above the 0.05 threshold. Specifically, the predictors for income, gender, education level, occupation, and size of the household do not significantly predict household energy use with B = -0.185, p = 0.104; B = -0.034, p = 0.745; B = -0.055, p = 0.522; B = -0.046, p = 0.571; and B = 0.070, p = 0.308, respectively. In addition, the confidence intervals for each predictor also span zero, further indicating that there is no significant effect. Therefore, we conclude that these variables do not impact household energy use in this sample.

It is a finding that concurs with another research by Zhang et al., (2019) in urban China, in which the researchers found that. In contrast, demographic factors like income and household size may influence energy consumption to an extent, their effects are mitigated in considerable measure by other socio-economic factors and behavioral considerations. This agrees well with our findings, whereby the coefficients of income and size of the household were B = -0.185, p = 0.104, and B = 0.070, p = 0.308, respectively, which are both non-significant, hence indicative that other variables might be intervening in their effects on household energy use.

A further study in rural India by Liu et al.,(2020) examined the role of gender and occupation in forming energy consumption behaviors, showing that while these factors may shape household decisions regarding energy use, their direct impact on actual quantities consumed is usually negligible or context-dependent. This confirms our observation that gender and occupation are not significant predictors, with values of -

0.034 and 0.745 and -0.046 and 0.571, respectively, in explaining the amount of household energy use for the regression model.

Besides, Sovacool (2019) argues that broader socio-economic and environmental variables should be taken into consideration to understand the patterns of household energy use. This may range from energy efficiency measures and availability of other sources of energy to cultural factors and others that might bear a significant influence on energy-use patterns beyond simple demographic variables.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the findings, conclusions, recommendations and suggestions for further research on the socio-economic factors influencing biogas technology uptake in Kuresoi South Sub-County, Nakuru County.

5.2 Summary of the Findings

5.2.1 To Determine the Percentage Contribution of Each Energy Source in the Energy Mix of Households in Rural Kuresoi South, Nakuru County

Results from the survey conducted on 155 household are shows that a very high percentage, 91.6%, relies on firewood. Only small percentages used other sources: Liquefied Petroleum Gas, 3.9%; Biogas, 3.2%; Improved Cook Stoves, 1.3%. Chi-square tests did not reveal any significant association of household primary energy choice variables with education level, household size, or occupation. This meant that other more profound factors other than demographic structures of households are at play here such as broader economic circumstances, cultural habits, and availability of infrastructure. In addition, most households realized the need for diversification of energy sources but less so for biogas adoption; a gap exists between recognition of the need for change and willingness to embrace biogas as one vital option.

The analysis underscores the resilience of traditional biomass fuel use despite efforts to popularize cleaner energy technologies. Given the low effects seen from relationships between primary energy choices and variables such as household size, education level and occupation, policymakers should create cultural preferences, economic incentives, and infrastructure improvements to promote these cleaner fuels. The study also shows a high perception of energy diversification while little interest in using biogas suggests further education and incentives to support the technology.

5.2.2 The Influence of Household Head Income Levels on Biogas Technology uptake among Rural households in Kuresoi South Sub-County, Nakuru County

The income level for 155 households was also investigated showing almost half 49.7% of the studied population earn less than KES 10,000 per month and very few earning above KES 30,000. This significant proportion of low-income households might not easily afford clean energy solutions like biogas due to its high upfront costs. According to the chi-square tests, there is a statistically significant relationship between household income and primary energy sources. The results show that higher-income families are more likely to adopt cleaner forms of energy. If clean energy technologies are relatively too expensive for poorer populations to adopt, studies in Kenya, Tanzania, and Bangladesh all point to as the case as some innovative financing arrangements in terms of microloans or subsidies will be essential to make this transition possible for lower-income populations.

The data on biogas technology uptake shows a general overview that startup capital is a significant barrier. Most households indicated their perception that the income earned was not enough to afford such an investment. Conversely, regarding the benefits to be derived from biogas technology in the long run, there is a very positive perception on cost savings and environmental advantages. Households would be more willing to adopt biogas technology if financing options exist. This agrees with several studies done in Tanzania, Kenya, and South Africa, which show that financial means through either loans or pay-as-you-go schemes can upscale biogas uptake among low-income earning households by reducing upfront costs.

5.2.3 The level of awareness and knowledge regarding biogas technology uptake among rural households in Kuresoi South Sub-County

The findings also indicated that awareness was quite high since 91.6% of the respondents knew biogas technology. This revealed that information on it had been efficiently disseminated through successful outreach activities and educational programs. Nevertheless, perceptions about more profound knowledge and understanding of biogas technology were diverse. There was lower level of confidence expressed concerning familiarity with the concept, access to enough information, understanding of how biogas works and general confidence in knowledge, while the perception was positive about the benefits such as cost savings and environmental advantages related to biogas technology. This showed that there was need for focused education and improved information dissemination approaches so that no knowledge gaps can hinder potential adopters' confidence levels.

Radio was the most influential channel in spreading information about biogas technology to the respondents with a response of 70.3%. This indicated that it worked well among the rural settings where access to television and internet was limited. Television and the Internet were ranked very low which could be an indication of barriers created by infrastructure and resource constraints. This research has focused on how knowledge gaps could be filled through training programs involving farmers and practical demonstrations to build confidence and understanding within communities interested in adopting biogas technology. These intuitions are much in accord with broader research that has underlined the role of awareness in furthering the uptake of renewable energy solutions and hence the need for tailored educational efforts to enhance sustainability and uptake in rural regions.

5.2.4 The influence of Gender Roles on Decision Making Processes on uptake of Biogas Technology among Rural Households in Kuresoi South Sub-County

Furthermore, it was found that almost equal representations of the male and female respondents, at 45.8% and 54.2%, respectively, had a fairly even distribution of genders in the study area. Statistical analysis, however, showed that gender does not have a significant effect on the primary energy choice of households. Tests done, such as Fisher's Exact Test and Pearson Chi-Square, gave high p-values indicating no association between gender and the type of primary energy source adopted by the households. These outcomes thus imply that factors other than gender are at play in structuring preferences in energy use and household decisions.

Regarding perceptions on gender roles in energy decision-making, the study uncovered nuanced viewpoints among respondents. There was a prevailing belief that men exerted more influence in the adoption of new technologies, including biogas, despite a perceived equal influence of genders in household energy investments. Conversely, there was a low perception that gender significantly impacts decisions related to biogas technology uptake at the community level. This dichotomy suggests a recognition of gender equality within individual households regarding energy investments, yet a broader adherence to traditional gender roles in larger technological adoptions. These insights underscore the potential for targeted interventions aimed at promoting gender equity in broader community decisions concerning renewable energy technologies like biogas.

Biodigesters widely embraced were fixed dome and tubular types. Fixed dome biodigesters, durable and low-maintenance with brick construction while tubular biodigesters offer portability and affordability. They benefit the community by reducing cooking fuel costs, generating income, and improving environmental sustainability and enhanced waste management. In terms of health, they improve indoor air quality and they also enhance soil fertility.

5.3 Conclusions

The response rate of the study was 100 percent implying that the rural households had fairly good attention and interest to be surveyed. Demographic profile in terms of age was skewed towards old ages, however, most farmers with secondary education were among key people who could create awareness and share knowledge on biogas technology.

Moreover, most farmers knew about biogas technology, running at 91.6%, but the adoption rate was limited due to economic factors. With the high initial costs of setting up biogas installations, it is hard for most households not earning more than KES 10,000 to opt for one. These groups represent almost half of the surveyed population and clearly show broad market potential that requires new financing mechanisms to break through in these low-income groups.

Thirdly, the respondents' perception of the long-term benefits of biogas technology on environmental sustainability, health improvement, and cost savings is very positive; however, there is a gap in willingness to invest versus actual uptake rates because of a lack of proper awareness. Radio is so fundamental in effective communication networks in disseminating information; however, in-depth understanding and confidence in biogas technology functionality remain areas that would need targeted education.

Finally, gender dynamics play a significant role in household energy decisions. In spite of the fairly balanced representation of gender among the respondents, statistical analysis did not reveal any significant correlation between gender and the choice of primary energy. Nevertheless, insights of gender roles in technology adoption suggest that while men may dominate decision-making about new technologies such as biogas, there is a perception of gender equality within individual household energy choice.

5.4 Recommendations

5.4.1 Recommendation for Policy

Based on the findings from the study on biogas technology adoption in Kuresoi South Sub-County, Nakuru County, the following recommendations are proposed.

It is necessary to develop and implement educational programs that fill in knowledge gaps and boost confidence among potential users of biogas technology. Concentrate on hands-on demonstrations and radio broadcasts in the local language which have proven successful in reaching rural populations.

Innovative financing alternatives such as subsidies and microloans to ease the initial cost problem related with biogas technology uptake should be introduced to low-income households who constitute a major percentage of the population. Interventions to support gender equity in decision-making processes associated to biogas technology uptake should be implemented. This could include capacity-building plans and awareness campaigns meant at supporting women to take part vigorously in energy-related choices at both community and household levels.

Policies and regulatory frameworks that boost the uptake of renewable energy technologies like biogas should be promoted. This consist of providing tax incentives, restructuring approval procedures and ensuring institutional support for biogas technology projects.

Local leaders, stakeholders and community groups should be engaged in planning and implementation to ensure sustainability and cultural relevance. Community participation and ownership of biogas projects through participatory decision-making processes should also be fostered.

Constant monitoring and evaluation of biogas technology projects should be conducted to assess effect, improve strategies and ascertain challenges ensures that interventions remain responsive to community dynamics and evolving needs.

5.4.2 Suggestions for further Research

The economic feasibility of adopting biogas technology among different income individuals should be examined, including in depth cost-benefit analysis and evaluation of financial incentives to increase affordability. The impact of cultural and social norms on biogas technology uptake should be studied, together with gender dynamics and decision-making related to clean energy technologies.

The suitability of different educational projects and effort methodologies in further developing information and awareness about biogas innovation especially focusing on various demographics and using different communication channels should also be explored. The regulatory barriers, institutional support mechanisms and national energy policies that play a role in facilitating or hindering the widespread adoption of biogas technology should be examined.

Research on biodigester technology advancements as well as comparative studies of various biodigester types (such as tubular versus fixed dome) in terms of scalability, efficiency and adaptability to local agricultural contexts and waste management systems should also be carried out. Approaches for enhancing community involvement and participation in projects involving sustainable energy such as participatory strategies to project planning, execution, and monitoring should also be investigated.

An in depth analysis on the health benefits of biogas technology uptake including detailed assessments of indoor air quality enhancements, respiratory illnesses reductions and household members overall well-being.

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APPENDICES

Appendix I: Questionnaire

Socio-Economic Factors Affecting Biogas Technology Uptake Among Rural Households in Kuresoi South Sub- County, Nakuru County.

Introduction

I am Gypson Kurere a Master‘s of Environment Science student at Kabarak University. I am conducting a research on "Socio-Economic Factors Affecting Biogas Technology Uptake Among Rural Households in Kuresoi South Sub-County, Nakuru County, Kenya**"** Your responses will contribute to understanding the socio-economic factors influencing the adoption of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County. Your input is valuable and greatly appreciated.

Section A: Demographic Information

1. Name of the Ward

	Ward	Tick(√)
1	Kiptagich	
2	Keringet	
3	Amalo	
4	Tinet	

2. Gender:
    a. Male
    b. Female
3. Age: (a) 18-30 (b) 31- 40 (c) 41-50 (d) 50 and above
4. Marital Status: a. Single [ ] b. Married [ ] c. Divorced [ ] d. Widowed [ ]
5. Highest Educational Level: a. No formal education [ ] b. Primary education [ ] c. Secondary education [ ] d. Tertiary education [ ]
6. Occupation:

a. Farmer

b. Businessperson

c. Laborer

d. Civil servant

e. Other (please specify): __________

7. Household Size: a) 1-3 members b) 4-6 members c) 7-9 members d) 10 or more members

8. Monthly Household Income: a) Below KES 10,000 b) KES 10,000-20,000 c) KES 20,000-30,000 d) KES 30,000-40,000 e) Above KES 40,000

9. How many years have you lived in your current household?

10. Do you own or rent your current residence?

11. What is the approximate size of your landholding (if applicable)?

12. Have you previously participated in any renewable energy projects or initiatives?

    a. Yes

    b. No

Section B: Energy Mix (Tick where appropriate)

13. How do you primarily meet your household's energy needs? (Select one)

    a. Electricity b. Liquefied Petroleum Gas (LPG) c. Firewood d. Charcoal e. Biogas f. Other (Please specify) _______________

14. What percentage of your total energy consumption is derived from each of the following sources? Please allocate a percentage to each. a. Electricity: __________% b. LPG: __________% c. Firewood: __________% d. Charcoal: __________% e. Biogas: __________% f. Other (Please specify): __________%

14. Select the most appropriate response choice for the following statements/ questions
(1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Biogas is currently not a significant part of the energy mix in my household.					
My household primarily relies on traditional biomass fuels for energy.					
There is a need to diversify our household's energy sources.					
I am open to exploring alternative energy options such as biogas.					
Biogas has the potential to become a major contributor to our energy mix.					

Section C: Income Levels (Tick where appropriate)

14. Select the most appropriate response choice for the following statements/ questions (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The initial cost of biogas technology is a significant barrier for me.					
My household's income allows for investment in biogas technology.					
I believe biogas technology is a worthwhile investment for our household.					
Access to financing options would					

facilitate biogas technology adoption.					
Biogas technology offers long-term cost savings compared to other fuels.					

Section D: Knowledge and Level of Awareness (Tick where appropriate)

15. Are you aware of biogas technology? (Select one) a .Yes b. No

16. If yes, how did you become aware of biogas technology? (Select all that apply)

a. Television b. Radio c. Community meetings/events d. Word of mouth (from family, friends, or neighbors) e. Internet/Online sources f. Government initiatives or programs g. Other (Please specify) ________________

17. Select the most appropriate response choice for the following statements/questions (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I am familiar with the concept of biogas technology.					
I understand the benefits of using biogas technology.					
I am aware of how biogas technology works.					
I have access to sufficient information about biogas technology.					
I feel confident in my knowledge of biogas technology.					

Section E: Gender and Decision Making (Tick where appropriate)

17. Select the most appropriate response choice for the following statements/questions (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. strongly agree)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Gender plays a significant role in determining energy-related decisions.					
In my household, both genders have equal influence over energy investments.					
Women are actively involved in decisions regarding biogas technology uptake.					
4. Men typically have more influence in the adoption of new technologies.					
5. Gender dynamics do not have a significant influence on the uptake of biogas technology within my local community.					

Appendix II: Key Informant Guide

Assessing Socio-Economic Factors Affecting Biogas Technology Adoption Among Rural Households

Introduction: Thank you for participating in this key informant interview. The purpose of this interview is to gather valuable insights into the socio-economic factors influencing the adoption of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County. Your expertise and perspectives are invaluable in helping us understand this complex subject.

Objective 1: Percentage of Energy Mix Consumed by Households

1. Can you provide an overview of the typical energy sources used by households in rural Kuresoi South Sub-County?
2. From your experience, what percentage of households in this area currently utilize biogas as part of their energy mix?
3. How does the availability and affordability of different energy sources impact households' decisions on energy consumption?

Objective 2: Income Level of Household Heads and Biogas Technology Uptake

1. In your opinion, how does the income level of household heads influence their willingness to invest in biogas technology?
2. What are some common financial barriers that prevent households from adopting biogas technology?
3. Have you observed any correlation between income levels and the uptake of biogas technology among rural households?

Objective 3: Awareness and Knowledge on Biogas Technology

1. How would you describe the level of awareness and knowledge about biogas technology among rural households in Kuresoi South Sub-County?
2. What are the main sources of information through which households acquire knowledge about biogas technology?
3. From your perspective, what are some misconceptions or misunderstandings that exist regarding biogas technology among rural communities?

Objective 4: Gender Influence on Decision-Making Processes

1. In your experience, how does gender influence decision-making processes related to energy technologies within rural households?
2. Are there any specific gender dynamics that play a role in the adoption or rejection of biogas technology?
3. What strategies or interventions do you think could help empower women to participate more actively in decisions regarding biogas technology adoption?

Appendix III: Focus Group Discussion Guide

Exploring Socio-Economic Factors Affecting Biogas Technology Adoption Among Rural Households

Introduction: Thank you all for participating in this focus group discussion. Today, we will explore various socio-economic factors influencing the adoption of biogas technology among rural households in Kuresoi South Sub-County, Nakuru County. Your perspectives and experiences are crucial in helping us gain a deeper understanding of this topic. Before we begin, let's go over some ground rules:

1. Please respect everyone's opinions and avoid interrupting others while they are speaking.
2. Feel free to share your thoughts openly and honestly.
3. We encourage active participation from everyone in the group.

Objective 1: Percentage of Energy Mix Consumed by Households

1. From your experiences or observations, what are the primary energy sources used by households in rural Kuresoi South Sub-County?
2. Can you estimate the percentage of households in this area that utilize biogas as part of their energy mix? How does this compare to other energy sources?
3. What factors do you think influence households' decisions on which energy sources to use?

Objective 2: Income Level of Household Heads and Biogas Technology Uptake

1. In your opinion, how does the income level of household heads affect their ability or willingness to invest in biogas technology?
2. Have you noticed any trends or patterns regarding the adoption of biogas technology among households with different income levels?
3. What are some of the financial challenges that households face when considering biogas technology adoption?

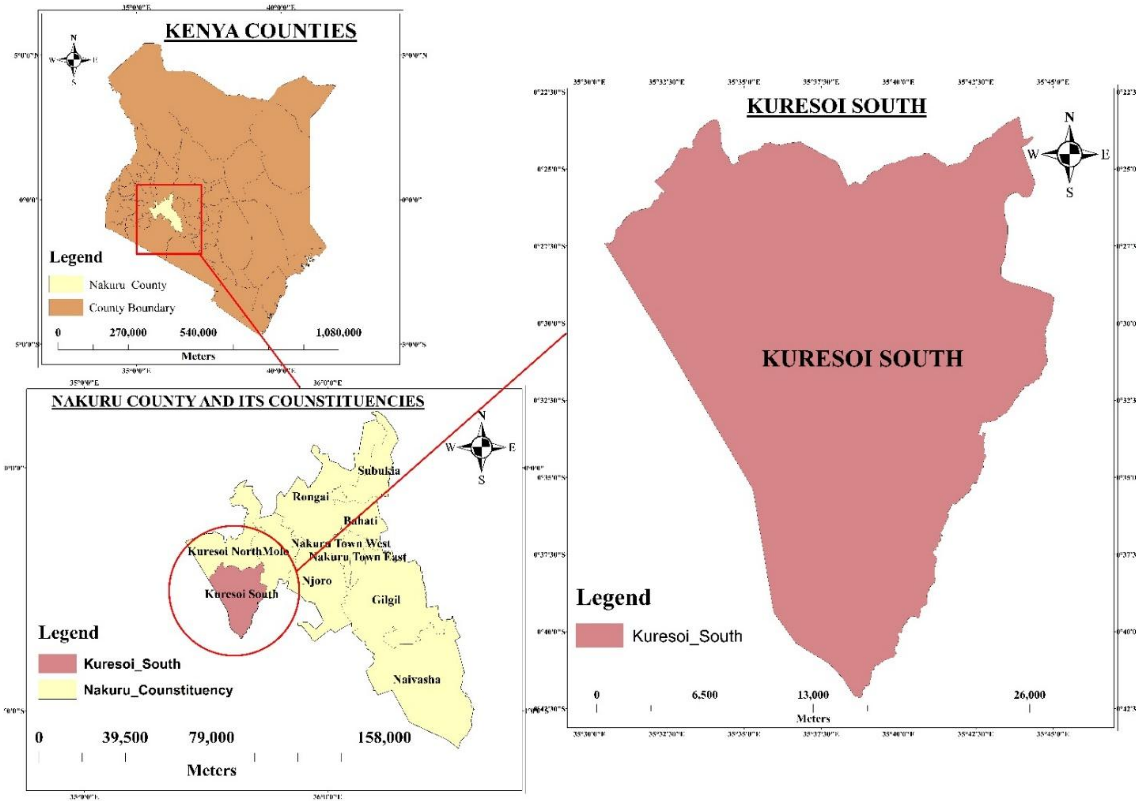
Objective 3: Awareness and Knowledge on Biogas Technology

1. How would you describe the level of awareness and knowledge about biogas technology among rural households in Kuresoi South Sub-County?
2. What are the main sources of information that households rely on to learn about biogas technology?
3. Are there any common misconceptions or misunderstandings about biogas technology that you've encountered?

Objective 4: Gender Influence on Decision-Making Processes

1. From your experiences, how does gender influence decision-making processes related to energy technologies within rural households?
2. Can you provide examples of how gender dynamics may impact the adoption or rejection of biogas technology?
3. What steps do you think could be taken to ensure that both men and women have equal opportunities to participate in decisions regarding biogas technology adoption?

Appendix IV: Map of the Study Area



Appendix V: KUREC Approval Letter

KABARAK UNIVERSITY RESEARCH ETHICS COMMITTEE

Private Bag - 20157
KABARAK, KENYA
Email: kurec@kabarak.ac.ke

Tel: 254-51-343234/5
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www.kabarak.ac.ke

OUR REF: KABU01/KUREC/001//08/04/24

Date:25th April 2024

GYPSON KIPKORIR KURERE
GMEN/NE/3142/09/18

Dear Gypson ,

RE: ASSESSMENT OF THE SOCIO-ECONOMIC FACTORS AFFECTING UPTAKE OF BIOGAS TECHNOLOGY AMONG RURAL HOUSEHOLDS IN KURESOI SOUTH SUB-COUNTY,NAKURU COUNTY

This is to inform you that ***KUREC*** has reviewed and approved your above research proposal. Your application approval number is ***KUREC-080424.*** The approval period is ***25/04/2024 – 26/04/ 2025.***

This approval is subject to compliance with the following requirements:

i. All researchers shall obtain an introduction letter to NACOSTI from the relevant head of institutions (Institute of postgraduate, School dean or Directorate of research)
ii. The researcher shall further obtain a RESEARCH PERMIT from NACOSTI before commencement of data collection & submit a copy of the permit to **KUREC.**
iii. Only approved documents including (informed consents, study instruments, MTA (Material Transfer Agreement) will be used.
iv. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KUREC***.
v. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KUREC*** within 72 hours of notification.
vi. Any changes anticipated or otherwise that may increase the risk(s) or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KUREC*** within 72 hours.
vii. Clearance for export of biological specimens must be obtained from relevant institutions and submit a copy of the permit to KUREC.
viii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
ix. Submission of an executive summary report within 90 days upon completion of the study to ***KUREC***

Sincerely,

KABARAK UNIVERSITY
INSTITUTIONAL RESEARCH ETHICS COMMITTEE
APPROVED
P. O. PRIVATE BAG - 20157, KABARAK

Prof. Jackson Kitetu PhD.
KUREC-Chairman

Cc : Vice Chancellor
DVC-Academic & Research
Registrar-Academic & Research
Director-Research Innovation & Outreach
Institute of Post Graduate Studies

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord. (1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix VI: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **542042**

Date of Issue: **23/May/2024**

RESEARCH LICENSE

This is to Certify that Mr.. Gypson Kipkorir Kurere of Kabarak University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: ASSESSMENT OF THE SOCIO-ECONOMIC FACTORS AFFECTING UPTAKE OF BIOGAS TECHNOLOGY AMONG RURAL HOUSEHOLDS IN KURESOI SOUTH SUB-COUNTY,NAKURU COUNTY for the period ending : 23/May/2025.

License No: **NACOSTI/P/24/35378**

542042

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix VII: Evidence of Conference Participation

KABARAK UNIVERSITY

Certificate of Participation

Awarded to

Gypson Kurere

For successfully participating in the 14th Annual Kabarak University International Research Conference held from 10th-11th July 2024 and presented a paper entitled ***"Assessment of the socio-economic factors influencing uptake of biogas technology among rural households in Kuresoi south sub-county, Nakuru County."***

Conference Theme

Climate innovations for environmental, industrial and energy sustainability

Dr. Peter Rugiri
Dean, School of Science Engineering and Technology

Dr. Moses Thiga
Director - Research, Innovation and Outreach

Kabarak University Moral Code

As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord.

(1 Peter 3:15)

Kabarak University is ISO 9001:2015 Certified

Appendix VIII: List of Publication

MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Agricultural Science and Soil Sciences (ISSN: 2350-2274) Vol. 12(2) pp. 022-030, October, 2024
Available online http://meritresearchjournals.org/asss/index.htm

DOI: 10.5281/zenodo.14055759

Original Research Article

Socio-Economic Factors Influencing Biogas Technology Uptake among Rural Households in Kuresoi South Sub-County, Nakuru County

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Kabarak University

Email: gkurere@kabarak.ac.ke

Abstract

Biogas technology presents an alternative sustainable energy source that offers an opportunity to transform energy security, environmental sustainability, and reduction in greenhouse gas emissions. The research study explores the socioeconomic factors affecting biogas technology uptake among rural households in Kuresoi South Sub-County, Nakuru County. This is a descriptive study design based on the use of both primary and secondary data sources. The data collection covered 155 respondents through the use of questionnaires, focus group discussions, key informant interviews and observations. Selection of the respondents was done by using systematic random sampling, while data analysis was done using descriptive statistics, chi-square tests, and cross-tabulation supported by SPSS version 26. Results indicated that despite high levels of awareness, the adoption of biogas technology was low, with firewood remaining the primary source of energy in 68% of the households. Fixed dome and tubular were the biogas digester types in use, since they are relatively cheaper and more durable; however, economic factors, mainly household income, were the main determinant of uptake. The chi-square results indicated that there was a significant relationship between household income and uptake of biogas, $\chi^2 = 9.531$, $p = 0.048$, implying that the poorer a household is, the greater the financial barrier to the technology. Level of education, too had a say in energy adoption; education and energy choice had a strong association-since $\chi^2 = 12.814$, $p = 0.002$-which depicted that more educated households were more likely to adopt the technology. The gender factor is insignificant in influencing energy choices, underlining a proof from the fact that $\chi^2 = 2.119$, $p = 0.346$, where broader socio-economic factors played a much greater role in decisions. This study also revealed out that radio was the effective channel for knowledge sharing and information dissemination related to biogas technology. On the other hand, partial understanding of the technical aspects has acted as a big barrier to the better diffusion of this technology. In conclusion, income levels and education are two main factors affecting the uptake of biogas technology. Enhanced education, targeted financial support and better outreach strategies go toward increasing adoption rates and supporting transitions to sustainable energy in rural areas.

Keywords: Biogas technology, Chi-square analysis Energy adoption, Renewable energy, Rural households, Socio-economic factors

INTRODUCTION

Biogas is a mixture of gases produced through the process of anaerobic digestion, which is the breakdown of organic material by microorganisms in the absence of oxygen. Biogas consists mainly of 50-70% Methane, 30-40% carbon dioxide and low amounts of other gases. Biogas can be produced from a variety of feed stocks, including agricultural waste, food waste, and energy crops. The process of producing biogas involves the