College of Science and Technology

Master's program

TITLE OF THE PROJECT: "IMPACT ASSESSMENT OF EXISTING BIOGAS PLANTS IN RWANDA." CASE STUDY: KAYONZA DISTRICT.

A Dissertation submitted to the African Center of Excellence in Energy for Sustainable development (ACE-ESD)

In Partial fulfillment of the requirement for the degree of masters of science in Electrical Power System

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DECLARATION

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

Names: UWAMAHORO Denise _____

Date of Submission: 17/11/2021

This Dissertation has been submitted for examination with my approval as a university advisor.

Dr. Ernest Mazimpaka, Supervisor _____ ____

DEDICATION

This dissertation is dedicated to almighty God, my beloved parents, brothers, sisters and friends, my supervisor and classmates, thank you to all for your ending encouragement and support, without you, this Dissertation would not have been possible

AKNOWLEGEMENT

First of all, I wish to take this opportunity to express my appreciation to individuals or groups who have contributed on achievement of this project. I sincerely thank Dr. Ernest MAZIMPAKA, my supervisor in this project, for his constant support through the course and for providing necessary facilities to carry out this project work, and also all lectures for their guidance and comfort that was given to me while conducting my Master's courses and Dissertation. We thank also the administration of UR for their support, especially post graduate department for suggestions and constructive recommendations during this project. Finally, I send thanks to my relatives, especially parents for their sacrifice in my education, brothers, sisters, friends and all my classmates for their beneficial interventions.

ABSTRACT

There are challenges registered in recent years due to the energy industry growth [1]. The elaboration of several technologies have been improved aiming to address this types of challenges. Among numerous technologies that have been improved, biogas technology shown a high potential to be likely to drive the energy revolution [2]. By the way, energy is crucial in the increase of countries economy and development as reveled in several studies mentioned in the literature. The Biogas figures among relevant options that has been adopted to solve energy availability issues for household in rural area of Rwanda. Nevertheless, from the biogas plants implemented in Rwanda, most of them are not operating. This dissertation addresses the impact assessment of existing biogas plant in Rwanda specifically, in KAYONZA district and the objectives are to assess the economic, social and environment impact of biogas in rural area, to examine the root causes of biogas failure in rural area, to establish the role of community in using the Biogas in their household and to review biogas sustainability and environmental protection. The study was conducted on 134 respondents calculated. In the reference [3] a representative sample of at least 10% or 20% of the inhabitant can be applied. For that reason, 20% of the population was considered. The analysis shows that biogas is more important in country development especially in rural area but the issue is that existing biogas are not followed up as required which make more household to abandon it.

ABREATION

1. DDP: District Development Plan
2. PTD: Plastic Tubular Digester
3. NEA: National Energy Action
4. EU: European Union
5. WWTPS: Waste Water Treatment Plant
6. US: United State
7. USEPA: United States Environmental Protection Agency
8. GHG: Green House Gas
9. PADEC: Projet d'Appui au Développement Communautaire
10. BORDA: Bremen Overseas Research & Development Association
11. EDPRS: Economic development poverty reduction strategy
12. AD: Anaerobic digestion

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CHAP 1: INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Rwanda is a landlocked country with few natural energy resources implemented. However, it is drawing it attention on carrying out alternative renewable energy technologies to reinforce power supply throughout the country. Electrical power is incontestably the core for local industrial development as well as for driving numerous activities within the country. By the way, energy has not only a huge impact on sustainable development but also it plays an essential role to mitigating poverty. Somme studies show that more than 86% of the energy used in Rwanda comes from traditional Biomass energy mainly firewood, charcoal and agriculture residues [4]. The dependence on biomass energy source however, affects not only global climate change but also the environmental degradation as well as human health [5]. The biogas is one of the viable options to figure out environment friendly energy production. In this perspective, the government of Rwanda targets the decentralization strategies for bio-digester implementation for both residential and facilities with a large population such as hospitals, schools and prisons among others [6]. This policy aims at deploying biogas plants in order to mitigate the use of traditional energy technologies that affect negatively the forests and human being health due to indoor air pollution and smoke “the killer in the kitchen” from wood and fuels burning.

In line with the mentioned factors, this dissertation work envisioned the assessment of impact of the biogas plants implemented in Rwanda in such a way to contribute to their optimization strategies. This work put it focus on Kayonza districted since it is one of the districts with significant number of cattle. Kayonza district has 1954km^2 with 346751 populations but also its economy is mostly dependent on agriculture and livestock. Relevant development projects bave been launched throughout Kayonza district mostly in livestock enhancement in order to level up the living conditions of its habitants thereby mitigating poverty. In fact, 2.1% beneficed cattle from the cow per Poor Family Initiative (Girinka) and 6.1% from NGO. In sum, 3924 cows were inseminated by crossing over to improve milk production. Besides, the same report reveals that the rate of charcoal and firewood utilization as primary heating fuels in Kayonza district is 95% resulting in serious threat to the environment and having human health negative impacts caused by lethal carbon gases emission. These reasons have been such a great motive to the district to go

for the use of biogas. So far 670 biogas digesters have been installed [7]. The present study puts a particular focus on assessing existing biogas plant in the district of Kayonza to evaluate strength, weakness, opportunities and threats in the biogas value chains to enhance biogas utilization.

1.2. Problem Statement

Some of installed biogas plants were abandoned and the steps in new one are very slow, people abandoned the biogas energy usage due to biogas system fail and lack of on time maintenance support. This causes the rural citizens to fail in the "Death Valley" reversing the energy ladder back to wood fuels for cooking and paraffin for lighting with associated environmental and health threats.

1.3. Main Objective

This dissertation aims to assess the performance of the existing biogas plants in terms of reliability and failure after their implementation associated to economic, social and environmental impacts.

1.3.1. Specific Objectives

In particular, aspects, this study intends to:

1. Assess the economic, social and environment impact of biogas in Kayonza district.
2. Examine the root causes of biogas failure in Kayonza.
3. Establish the role of community in using the Biogas in their household
4. Review on biogas sustainability and environmental protection in Kayonza.

1.4. Research questions

In order to fulfil the objective of this study, following are the questions that guided the assessment:

1. What is the economic impact of biogas in rural area?
2. What is the social and environmental impact of biogas in rural area?
3. What is the role of Community involvement in using biogas?
4. What is the biogas energy sustainability in the district?

1.5. Scope of the work

This research proposal is limited to economic, social and environment impacts of non-functionalities of biogas plants in rural area of Rwanda, specifically for the case of Kayonza district located at the East Province of Republic of Rwanda. In addition to this, it presents and discusses the future improvements and techniques that can upgrade biogas plant's efficiency.

1.6. Significance of the Study

The importance of this work is to assure the effectiveness and efficiency of the biogas usage as primary energy in rural area. In acceptance of the proposal implementation, clean energy will be used and save forest by reducing wood fuel consumption. This research project will help to improve the biogas production and secure future sustainability of biogas usage. The outcome of the study herein will provide relevant inputs to the country development policy as well as to household's standard of living but also for the future biogas projects implementation.

The biogas usage has several advantages such as:

a. it is not pollutant
b. Reduce the energy burden of households
c. Contribute to agriculture productivity from slurry manure, west management and sanitation
d. It's a simple and low-cost technology

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

The content of this chapter includes previous important findings in line with biogas technology. It is divided in the following sub-sections: situational overview on biogas; biogas composition, biogas production, biogas digesters types, biogas system components, functioning and efficiency; problems and their causes that may occur in biogas plant; biogas economic and financial assessment, health impacts of biogas use, the failure of biogas plant, roles of local community and authorities.

2.2. Situation perspectives of biogas production in Africa

In some African countries Biogas still unknown as source of energy, even if some countries tried to use it many years ago, also it was not part of their economic and social cultural context [8]. The effort has been made to improve biogas production in Africa. An African initiative was started in 2007 to install biogas digesters in at least 2 million households by 2020 [9]. As result to this, the number of biogas plants implementation increased by the year 2010. For a particular instance of Tanzania which installed approximately 4000 units [10]. However, only about 60% of these plants operated properly while the rest of them could not operate at a satisfactory level. This failure is associated with the reasons such as planning and construction errors, poor awareness of the community and lack of culture of maintenance among others [10]. Furthermore, Composite digesters material are relatively new in African countries [11].

2.2.1. An example of Biogas situation in Kenya

Biogas technology was introduced in Kenya in 1954 by the white settlers [12]. However, the mass diversification began in 1980s when 150 units were constructed. The number increased to 800 plants by 2004 [13]. There was a programmer to promote domestic biogas development targeting to install 8000 domestic biogas plants in the rural areas by 2013 [14]. At a social aspect, the widespread of the biogas technology faced a challenge associated with lower awareness of its

benefits and the investment cost for its implementation [15]. Technically, failure to achieve the targeted number of the initial systems were identified as the result of several factors such as scum forming in the digesters, low mastery of bio-digester maintenance as well as its working principles, bad feeding of the digesters and incorrect water and dung mixture proportion. Any single or a combination of these factors affect gas production [12].

In Kenya, there are three types of biogas digesters that have been introduced in the market. They are the Indian floating-drum, the Chinese fixed-dome and the Plastic tubular digesters (PTD). However, in the recent past, the most adopted types in Kenya are the tubular and the fixed dome digesters [16].

2.3. Situation perspectives of biogas production in Asia

The Republic of China has largely participated in the utilization and development of biogas plants. At the end of the 19th Century, simple biogas plants were introduced in the seaside territory of South China. Next, it happened in late 1920s the introduction of the first biogas plant that employs water pressure in Taiwan [17]. In the 1970s, the Chinese government started to deploy thousands of biogas plants throughout the country to assure the usage of biogas and thereby mitigating energy shortages in rural areas. In late 1980s, the federal government included the biogas development into China's national stable program [18]. The opened policy applied after the 1990s participated in the increase of employment in China and speeded up its industrialization. Therefore, China has occupied the second position with the largest economy and high rate of energy consumption, according to the reference [19].

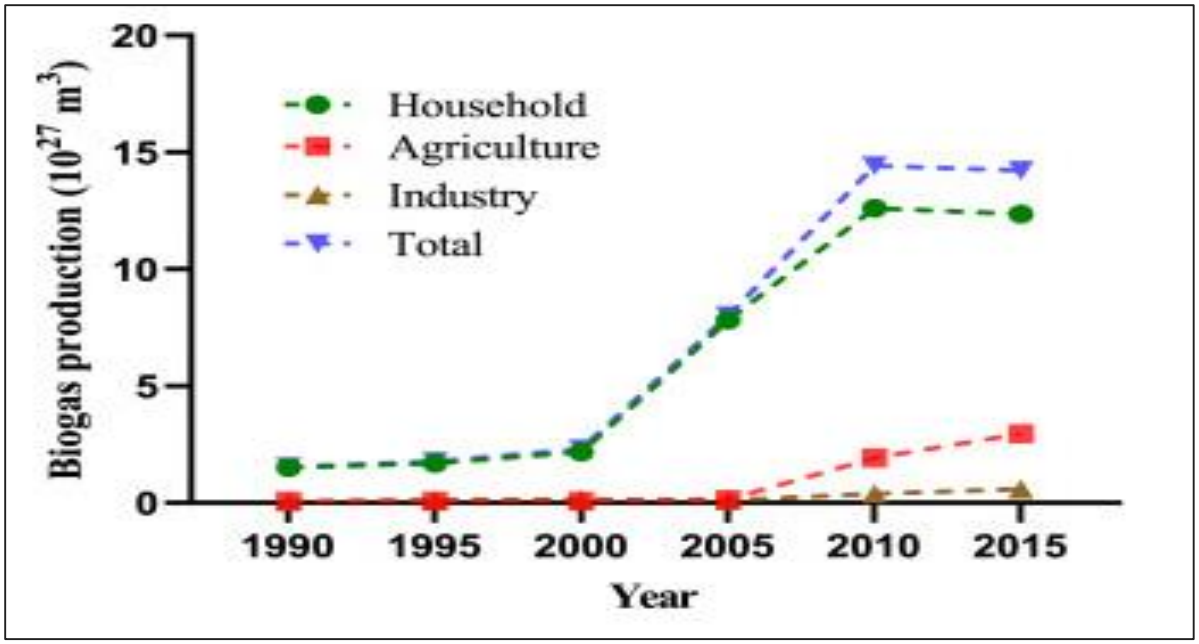

Figure 1:Biogas production of different sectors in China 1990-2018

Source NEA, 2017.

2.4. Situation perspectives of biogas production in Europe

There is still insufficient energy production from renewable energies in Europe. Nevertheless, some political plans aim at the integration of renewable energy in future power supply projects especially for the elaboration of biogas energy production. In the year 2013, the entire biogas plants installed in Europe reached about 14,572. Germany is the most developed country with 9,035 biogas plants in functioning, in other words Germany by itself has 62% of the total number of plants installed. Next, comes Italy with 1,391 plants; followed by Switzerland, which has 620 plants and then comes France with 610 plants [20]. Throughout the European Union, the exploitation of renewable energy reached 17% in the gross final energy consumption in 2015. However, the projections show that it surpassed the target of 20% by the year 2020. Despite the significant part played by other renewable energy, the Bioenergy is likely to preserve its major role as renewable energy in the EU future. By the way, the bioenergy's contribution in the gross final energy consumption increased from 5.0% in 2005, to 9.6% in 2015 and reached about 12% in 2020 [21].

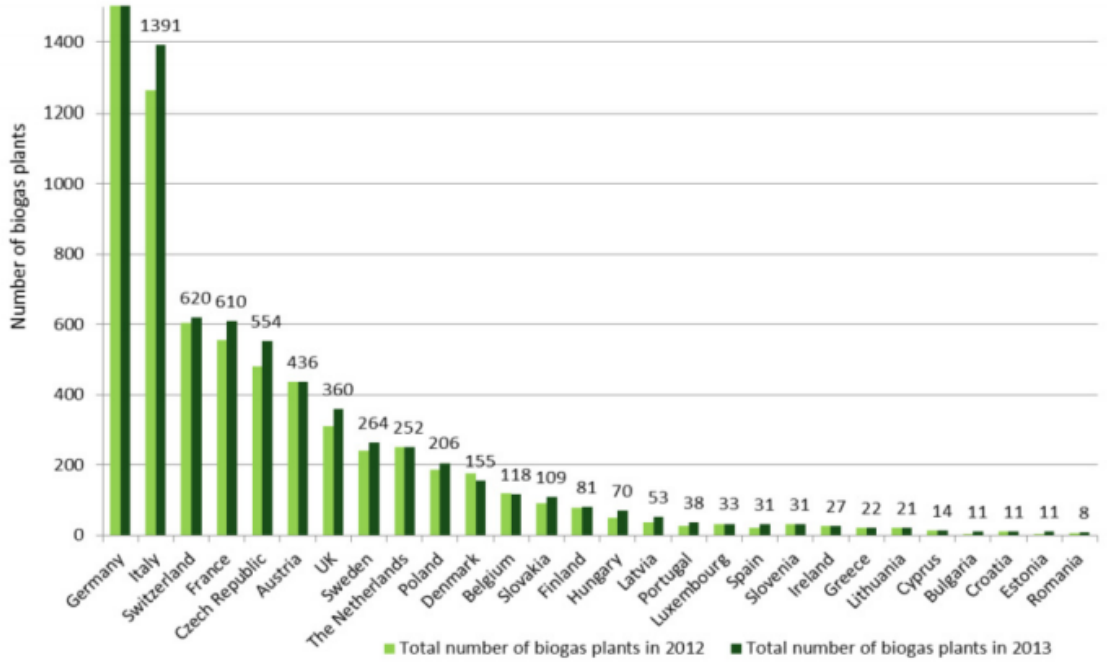

Figure 2:The biogas plants in Europe in 2012 and 2013, Biogas Report 2018 (EBA, 2018)

2.5. Situation perspectives of biogas production the USA

The development of the biogas in the USA is lower as compare to other resources. Several surveys have demonstrated the existence of a high potential of bioenergy feedstock supply but also organic material in landfills, agricultural operations, and municipal wastewater treatment plants (WWTPs) that might also be widely available. Nevertheless, the exploitation of the biogas is still only 16 % of the identified potential locations. Hence, the development of biogas production in the EU is higher in comparison to what the quantity of biogas produced in the US yet the US biogas potential could contribute to the GHG mitigation perspectives. Furthermore, the USA was the world second largest GHG emitter in 2015.

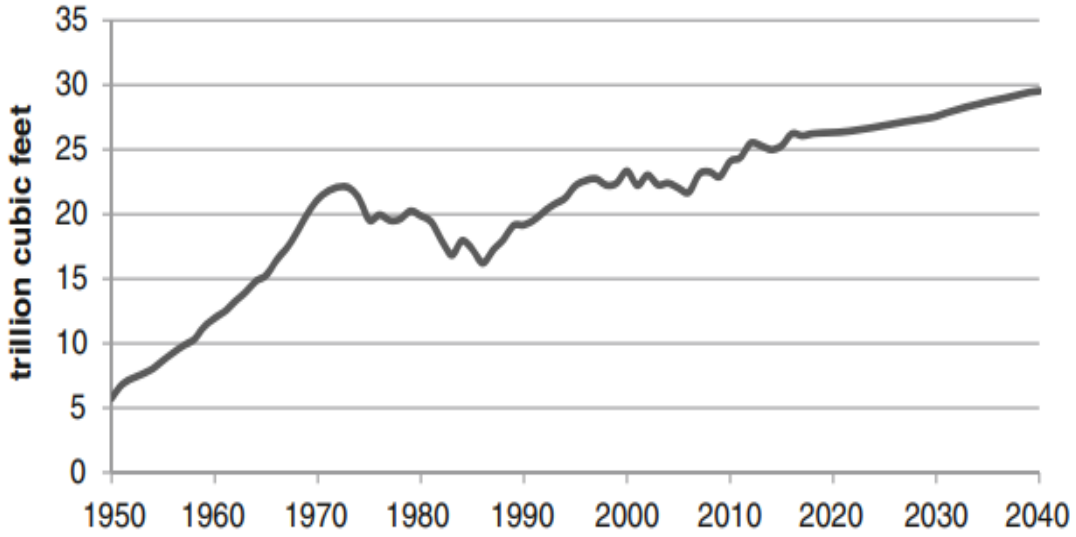

Figure 3:US NG consumption: actual and projected, 1950–2040

2.6. Situation perspectives of biogas production in Rwanda

In 1982, the biogas consultant from Nepal have constructed the four first biogas plants of capacity from 8 m3 to 20 m3 at Kabuye (Kigali City) and initiated trainings relatively. Next, the construction of other biogas plants took place at Rwesero in the North Province and at Murambi in the East Province through PADEC project under SNV Rwanda's supervision. However, they could not last for long because that program failed. The implementation of biogas plants of the fixed dome type occurred at the end of 1990 according to an international biogas survey found in the reference [22]. Next, the construction of a biogas plant for a prison took place for the first time in 2001. This was implemented by the technicians from KIST whose ones expended the project of biogas plants implementation throughout the prisons. This project has participated a lot in solving the problem of cutting trees for the use of wood charcoals [23]. In 2006, the Ministry of Infrastructure in cooperation with the SNV Rwanda project launched the promotion of biogas. The year 2006 took off the run in the first phase until the year 2010 revealed the same source. In addition to this, the construction plan targeted to implement about 15000 biogas plants by the year 2012 [24].

According to National Domestic Biogas Program, there is domestic biogas in Rwanda that generate from the cow dung of at least 2 cows. These could save to reduce the wood consumption,

which is 2,348kg firewood per year. From about 99% of households using firewood as cooking fuel, 99% have a latrine or toilet; 89% are willing to use energy generated from animal and humans waste for lighting and cooking purposes, and 90% would use the bio-slurry produced from animal and toilet waste as fertilizer on their fields although they are not yet used to it. 56% experience negative effects from in-door air pollution due to smoke from firewood and kerosene.

2.7. Biogas Production

Biogas come from biomass and waste being converted to CH4, CO2 and water in anaerobic conditions by micro-organisms. Biogas produced under anaerobic digestion of manure and bio-waste is used for generating heat and electricity. Besides, its transformation into bio methane may be improved to enable it usage for fuel in transportation or fed into a natural gas grid [25]. The use of biogas technology presents an important potential for both rural as well as urban energy supply. Therefore, the energy can be generated by ‘‘biogas plant’’ or ‘‘biogas digester” in which anaerobic digestion (AD) of organic waste occurs causing the production biogas as shown in the Figure 4.

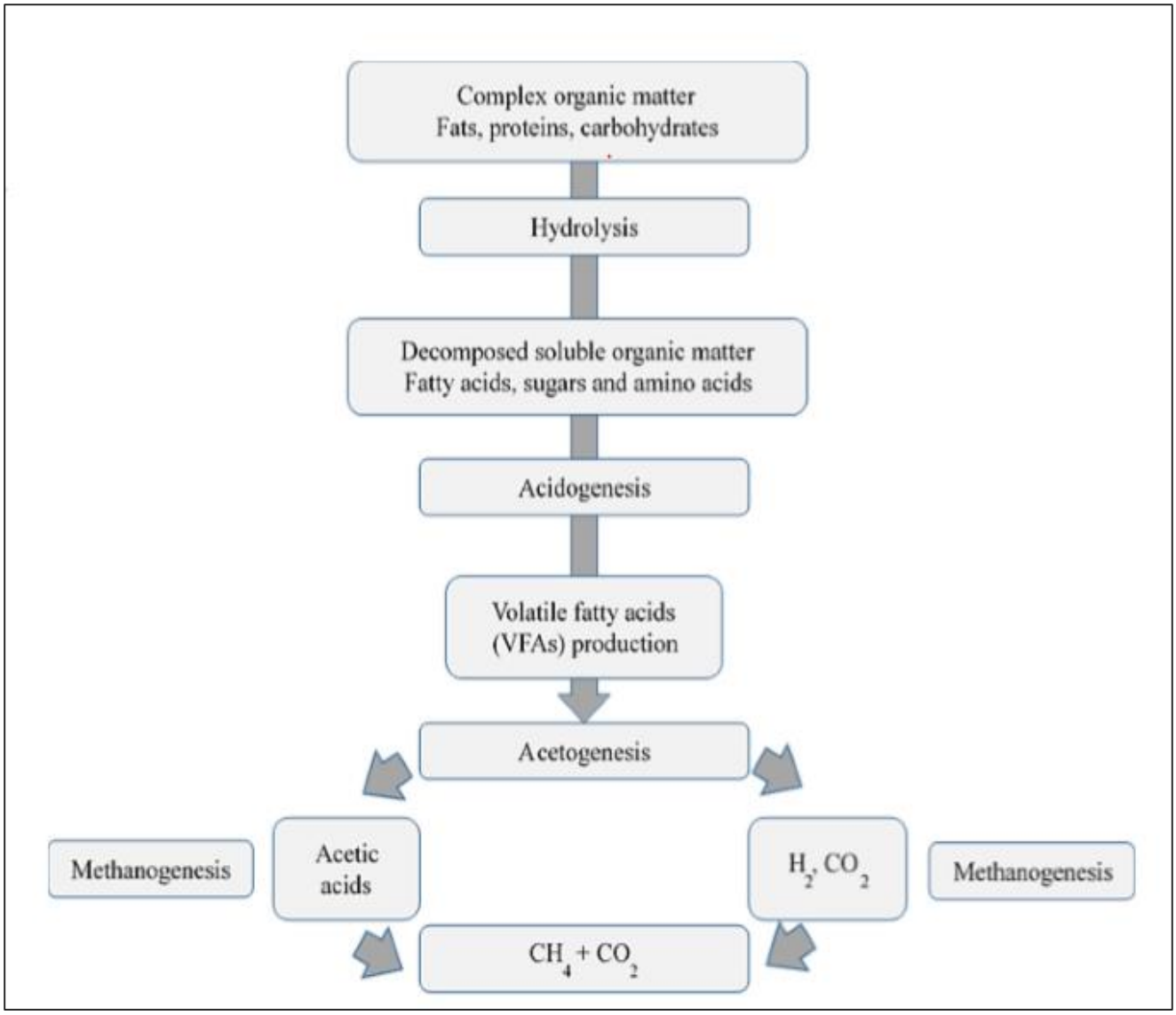

Figure 4:Schematic of the anaerobic digestion process

Source:Afridi, Zohaib Ur Rehman; Qammar, Naseha Wafa ,2020

- Hydrolysis: In the first step (hydrolysis), the original organic matter containing carbohydrates, fats and complex organic compounds is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of microorganisms and then they are split up into simpler organic compounds due to bacteria [26].

❖ Acidification The micro-organisms of anaerobic and facultative groups (i.e. bacteria that can grow under acid conditions) involved in the second step, produce fermentation and hydrolysis to form volatile liquids and solids of simpler organic nature and acids such as acetic acid (CH3COOH) [26]. In this acid formation phase, hydrogen (H2) and carbon dioxide (CO2) are also released. The oxygen and carbon is needed in acetic acid formation.

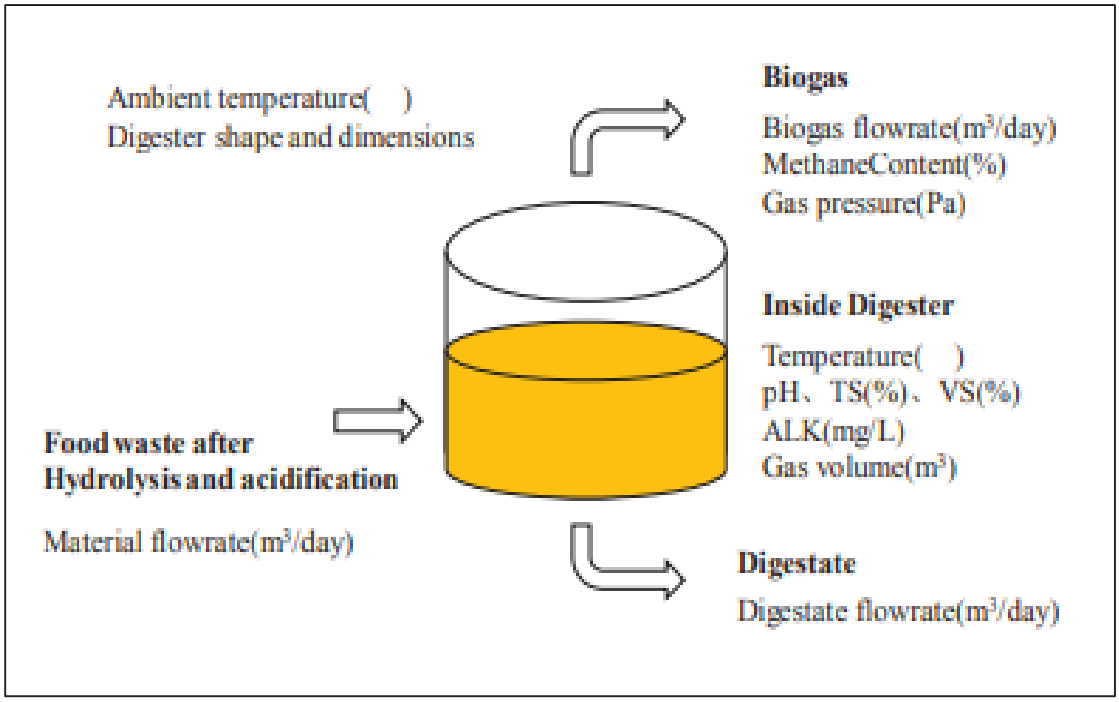

Figure 5:Illustration of an anaerobic digestion reactor and the process variables that are typically measured

Source: Anthony Wu, David Lovett, Matthew McEwan, 2016

2.8. **Biogas composition**

Biogas is composed of the following components as shown in the table below:

Table 1: Biogas Component

COMPONENTS	CHEMICAL FORMULA	RANGE	NORMAL
Methane	CH4	55 - 85%	70%
Carbone dioxide	CO2	14 - 44%	29%
Nitrogen	N2	Trace	Trace
Hydrogen	H2	Trace	Trace
Hydrogen sulphide	H2S	Trace	Trace
Vapour of water	H2O	Trace	Trace

Source: Hailun Huang; Zheng Yan ,2010.

2.9. **Types of biogas digester**

Biogas digester has different types

1. Fixed dome
2. Floating drum
3. Tubular design
4. Plastic containers

The table below is the types of biogas digester comparison

Table 2: comparison of different types of biogas digesters.

Factors	**Fixed dome**	**Floating drum**	**Tubular design**	**Plastic containers**
Gas storage	Internal Gas storage up to 20 m^3 (large)	Internal Gas storage drum size (small)	Internal eventually external plastic bags	Internal Gas storage drum sizes (small)
Gas pressure	Between 60 and 120 mbar	Up to 20 mbar	Low, around 2 mbar	Low around 2mbar
Skills of contractor	High; masonry, plumbing	High; masonry, plumbing, welding	Medium; plumbing	Low; plumbing
Availability of Material	yes	yes	yes	yes
Durability	Very high >20 years	High; drum is weakness	Medium; Depending on chosen liner	Medium
Agitation	Self-agitated by Biogas pressure	Manual steering	Not possible; plug flow type	Extl Manual steering
Sizing	6 to 124 m^3 digester vol	Up to 20 m^3	Combination possible	Up to 6 m^3 digester vol
Methane emission	High	Medium	Low	Medium

2.10. Biogas System Components, Functioning and Efficiency

According to Stephen Ngugi Waimea in his paper published in December 2017 [27], defaults occurring within the biogas systems result from the following five major subsystems:

i. Structural components,
ii. Biogas utilization equipment,
iii. Piping system,
iv. Biogas production and
v. Effluent disposal system.

Subsequent study has given recommendations on how these subsystem faults can be rectified.

The table below further explains the main failures and inefficiency indicators of biogas technology subsystems.

Table 3: Failure in biogas Plants

Subsystem	Failure and inefficiency indicators
Structural components	1. Inconvenient position of plant components. Relative positioning of plant components is not appropriate, e.g., plant is too far from animal shed; inlet tank is too high for feeding; outlet tank is too remote to be reached 2. Unsuitable inlet pipe slope. Cleaning the inlet pipe with a long stick is impossible when the inlet pipe is blocked during feeding because the long stick will be hindered by the wall 3. Broken/missing mixing device. In such case, the dilution of raw materials is difficult, therefore feeding is difficult 4. Cracks in structural components. Big crack(s) on the wall of the inlet tank or outlet chamber because the construction quality is poor or the chamber is damaged by natural disasters such as floods
Biogas utilization equipment	1. Malfunction of biogas stove. Flame pedestal is broken; gas tap is broken; air injection ring is rusty or broken; air injection hole is blocked or too big to adjust gas consumption or flame.

Subsystem	2. Inoperative biogas lamp
Piping system	1. Leakage of piping system. The valve is defective. The valve is a water valve instead of a gas valve. The connections between the valve and the pipe, or between the pipe and the nipple, are not fixed. The gas pipeline is corroded after a long time. The clamp for fixing the connection is missing 2. Blockage of piping system. If the biogas pipeline is too long or overhanging, and if no water trap is available, then water may be condensed within the pipe
Biogas production	When daily biogas production is less than half of the designed standard capacity, failure is taken into consideration 1. Leakage of biogas in digester due to pressure inside the digester. 2. Thick scum layer on the surface prevents biogas from escaping 3. Breakdown of anaerobic digestion process. Several parameters affect normal anaerobic digestion process, such as unbalanced carbon to nitrogen ratio, too-high or too-low pH value, low temperature, less feedstock, and existence of inhibitor 4. Not enough feedstock.
Effluent disposal system	1. The outlet pipe is blocked. 2. Biogas slurry is discharged without environmental control, e.g., into a body of water without any disposal treatment 3. Unsuitable effluent disposal. The slurry is only stored as waste without being reuse as organic fertilizer. Slurry is applied onto farmlands directly without composting or stabilization

Source: 3: Stephen Ngugi Wamwea, 2017

2.11. Benefits of biogas

Biogas benefits include saving money and time, reduced workload, health and quality of life. Women are the main beneficiaries within a family [28]. In the rural areas, 90% of energy is used for cooking. When rural households use biogas, firewood consumption decreases on average by 53% [28]. The figure below shows the nexus between women and biogas in a rural household setting.

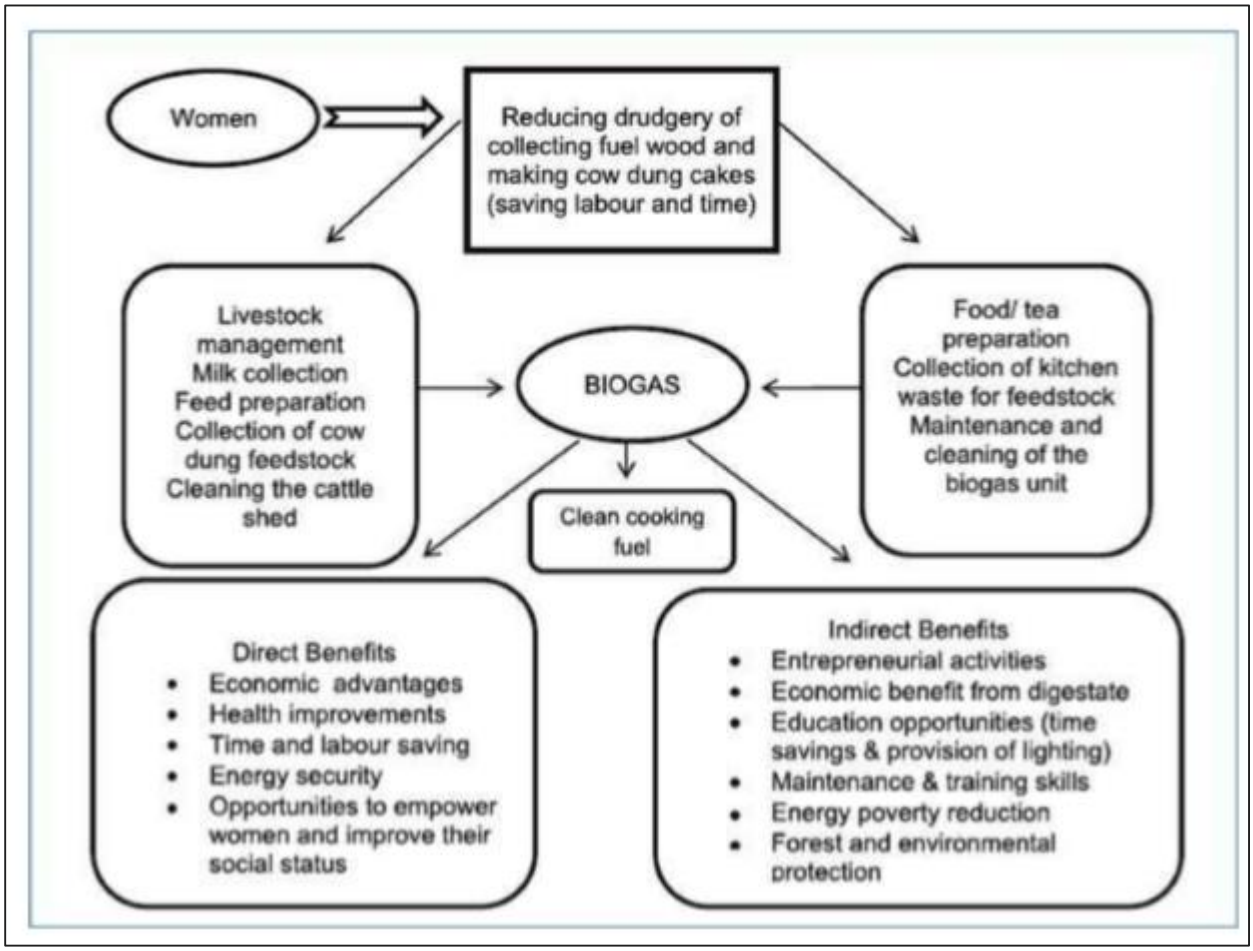

Figure 6:Role of women in feeding, maintaining and usage of household biogas systems

Source: Rowse ,2011

2.12. Health impacts of biogas use

According to Alison, biomass fuels usage yields adverse health effects. However, the utilization of biogas enables to avoid these negative impacts. Whether or not people had previously used wood or charcoal inside the home, they felt that their homes were cleaner as a result of less smoke. One woman who previously cook with wood, and charcoal felt that there was far less smoke in her home since using biogas which were causing her a headache when cooking [29].

2.13. Problems and causes that may occur in biogas plant

The Table 4 shows the problems and its causes that may happen in biogas digester and suggested recommendation have been mentioned.

Table 4: biogas-plant-troubleshooting

Problems	Most likely causes	Recommended action
Gas yield has dropped	Drop in quality of substrates Drop of temperature Compounds inhibition Non-homogenous substrates Drop of methanogenic bacteria	Assure substrates mixing and quality Check heating system Check level of potential inhibitor compounds Add digestate from another digester if the methanogenic bacteria as drop
Methane concentration dropped	Drop in quality of substrates Drop of temperature Compounds inhibition	Assure substrates mixing and quality Check heating system Check level of potential inhibitor compounds
Foaming problem	A new substrate with high protein content has been added Air is introduced in the digestion Temperature is changing	Reduce or stop feeding Analyze substrates Reduce air introduction
pH dropped	Feeding rate is too high or variable Operating temperature have changed Agitation is not working	Reduce substrates until system returns to normal Use only manure until system returns to normal
FOS/TAC ratio has increased	• VFA rate is too high • Change in feedstock • Lack of buffer • Compounds inhibition	Reduce OLR Use more manure in the mixte

Source: https://www.biogasworld.com/biogas-plant-troubleshooting/ [30]

2.14. Important of addressing the failure of biogas

The discussion on biogas plants failure in developing countries is very important
According to Chanakya, it might be caused by the fact that plants could probably have poor inspection and maintenance, abandoned, or could no longer generate biogas. The biogas industry is in its starting stages, it is required to observe the status of biogas in other developing countries so as to learn from others' experience [31].

For example, in Kenya, the authors provide a short evaluation of biogas in sub-Saharan Africa. From Kenya report, estimated 850 plants installed in Kenya as of 1995, 25% were working which resulted in a negative view of biogas in the country.

However, in considering the histories of biogas in other nations, it is evident that the biogas industry in Rwanda faces many challenges in terms of sustainable development.

2.15. Economic assessment of biogas in use

The economic assessment is done by assessing the overall costs and benefits for the wider society from adopting the biogas technology. Economic benefits are not necessarily equivalent to financial benefits. The economic benefits of biogas are cleaner environment, increased food production, reduced carbon emissions/global warming, conservation of forests ,improved health, economic growth, poverty alleviation, increased employment opportunities, more free time for women, increased happiness due to better lifestyle and food security [32].

The figure below shows the environmental and social benefits derived from using biogas.

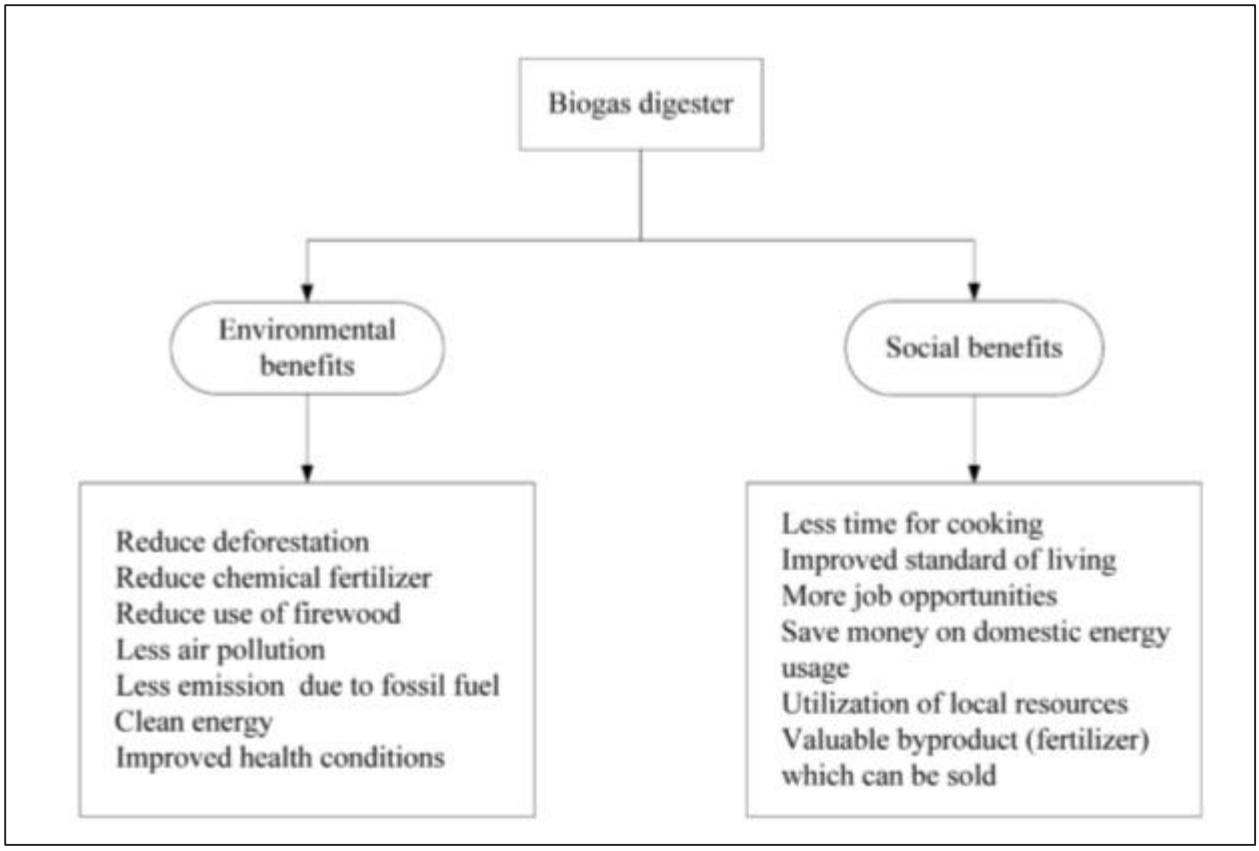

Figure 7:Environmental and social benefits of using biogas

Source: Rajendran et al., 2012.

2.16. Roles of local community and authorities

The local community and authorities have roles and responsibilities for managing, use of space and the economic development of the existing biogas digester and new biogas projects implementation. The skilled projects managers have to coordinate the process of the biogas digester projects.

The governance of the projects and relations in the region will be influenced by parameters such as feasibility, profitability, positive and negative externalities. Therefore, it is necessary for a project manager to be able to facilitate the coordination of the system by controlling, preparing and following up the projects. The government plays a role of intermediary and facilitator of welcoming biogas digester projects in the region. The local authorities and households have obligations of participating on sustainability development of the biogas digester in the regional. They are able to make anaerobic digestion management projects successful. The government

represented by Local authorities is able to connect stakeholders with local communities for making easier communication with each other, facilitate the spreading of information on how to use and maintain biogas digester and set up support mechanisms for the development of the projects. The local authorities and households are responsible for the managing, maintaining, feeding the existing biogas to the maximum production. The role of intermediary can also include selecting and introducing partners likely to provide both knowledge and resources that do not exist in a given region [33].

According to Tatiana, the biogas plants production depends on the experience, skilled staff, and well-trained personnel of the operators. A less number of qualified companies, construction businesses, qualified specialists and technologists specializing in designing, constructing, and exploiting agricultural biogas plants is a challenging task for the adoption of biogas technologies. Farmers should therefore be educated in the proper use of biogas, for example, animal manure for producing biogas and biofertiliser [34].

2.5. Research Gap

Most of the studies reviewed identify and prioritize impact through empirical research in order to suggest mitigating measures. Although a few studies introduced framework of impact management of biogas digester. Therefore, this study seeks to fill the existing research gap by determining the impact assessment on biogas fail usage in Kayonza district of Rwanda.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

The research proposal adopts descriptive research designs. It has given more details on adopted method for the research proposal implementation. The methodology includes study population, sample size and techniques, data collection, data analysis and processing.

3.2. Study Population

The study conducted 134 inhabitants of Kayonza district who use Biogas energy. The interview was made to the household representative as beneficiaries. this was because they are all responsible in management of the biogas plants and understand the project impact on their daily life.

3.3. Sampling Frame

The study adopts sampling technique to represent the target population. The study focused on any households who owned the biogas digester and who are involved in its production process to ensure proper performance in Kayonza district, thus it will help in recognizing different risks that affect the biogas digester performance.

3.4. Sample Size and Technique

The representative sample is one which is at least 10% or 20% of the population, thus we chose to use 20% of the biogas household in this study [3]. The research targets 134 households who own biogas digester and who play vital roles in its operations thus forming the sampling size of the study. Subsequently, the study investigated from them on what kind of challenges they have experienced during biogas digester construction and its operations and how they have managed the situation. The study therefore sought to identify from the respondents what causes of non-functionalities of biogas digester and how should be managed in its properly functionalities.

3.5. Data Collection

The research used both primary and secondary data. Primary data was collected using a semi structured self- administered questionnaire, interviews and observation. Secondary data sources come from desk researches. These are the main sources of actual data that was analyzed to enable the researcher make conclusions on the research study. The result helped the researcher to correct inconsistencies arising from the instruments to ensure the instrument measured what was intended to measure. Reliability obtained by frequencies and percentages.

3.6. Data processing and analysis

Primary data was converted into significant statement by means of various SPSS software for data processing and analysis.

4.CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter emphases on data collected analysis of 134 households in Kayonza District. All data are displayed in chats with analysis. The survey has been divided into five different parts. Number one is related to general information of respondents, second deal with economic, social and environment impact of biogas in rural area, the third is concerning about the root causes of biogas failure in rural area, the fourth is the role of community in using biogas in their household and the fifth is the review on biogas sustainability and environmental protection.

4.1 Respondents demographic characteristics

The respondent demographic characteristics include age, gender, marital status, income, education background and employment of the respondent. Information related to economic, social and environment impact of biogas, root causes of biogas failure, community in using biogas in their household and the review on biogas sustainability and environmental protection have been provided in the interviews. Also the information comes from the Rwanda Energy Group as the intuition which is in charge of Biogas program implementation and others from the department in charge of biogas in Kayonza district where all biogas digesters of the study are is installed.

4.1.1. Age of respondents

From the figure 8, among the sampled population it shows that under 30 years represents were 14.2% while 20.1% were aged between 31 – 40 and 29.9% were aged between 41 – 50. Only 35.8% of respondents were aged above 51 years. The below figure shows the distribution of household by age.

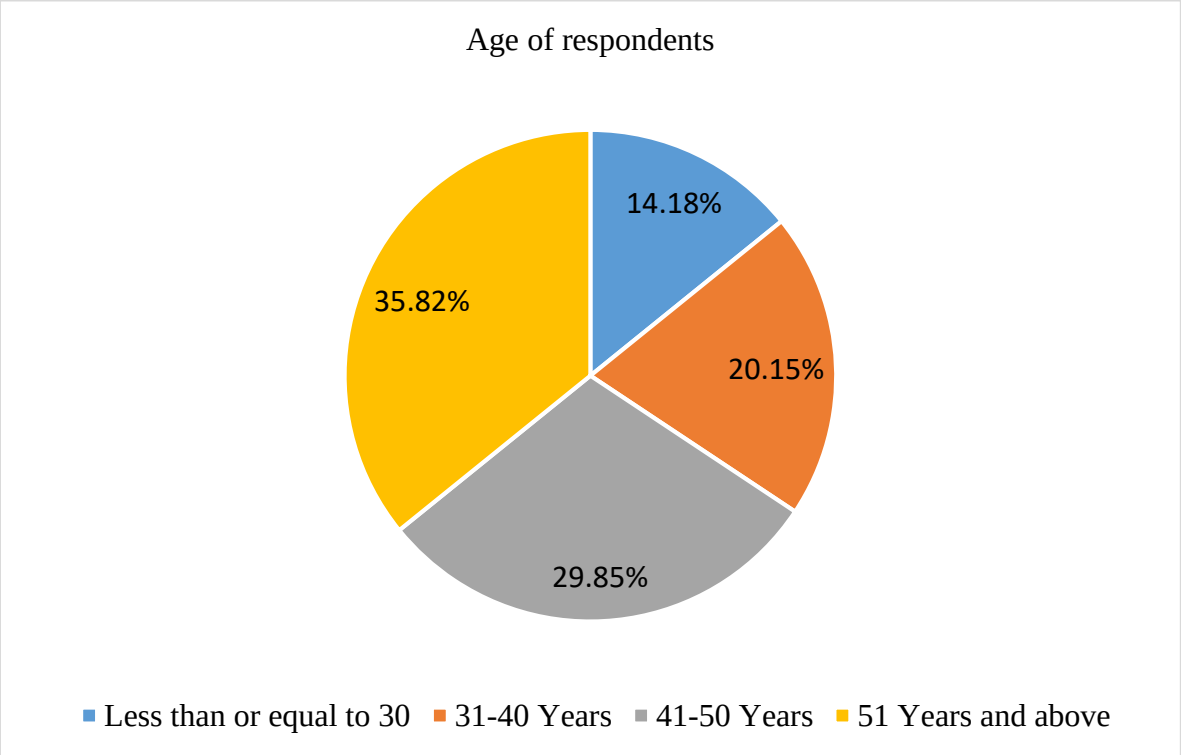

Figure 8:Distribution of respondents by age

Source: Primary data ,2021

4.1.2. Gender

From the information provided by figure 9, the results of the study revealed that the participant on the survey were mainly male 52.2% compared to the female that were only 47.8% this was due to the fact that some respondents were head of families. See the figure below for gender distribution.

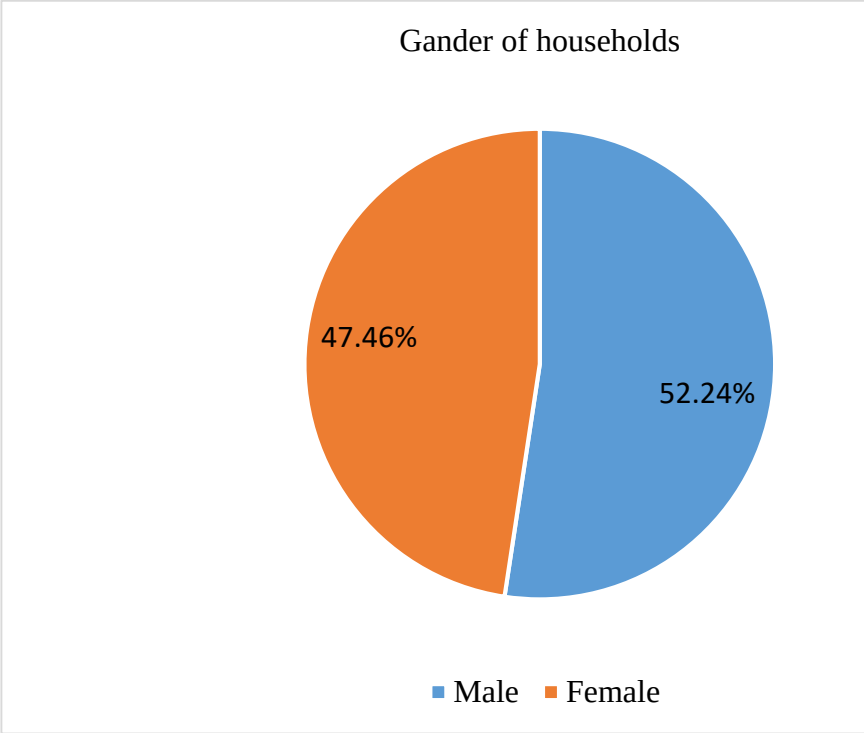

Figure 9:Gender distribution of household

Source: primary data ,2021

4.2.3. Level of education of respondents

From the figure 10, the unschooled level was too high at 40,30%, primary school 14,93%, secondary school 26.87%, 8.2% had diploma and bachelor degree holder were at be 5.97%. Only 3.73% of respondents were qualified with master's degree or above. The figure below shows the education level of respondent.

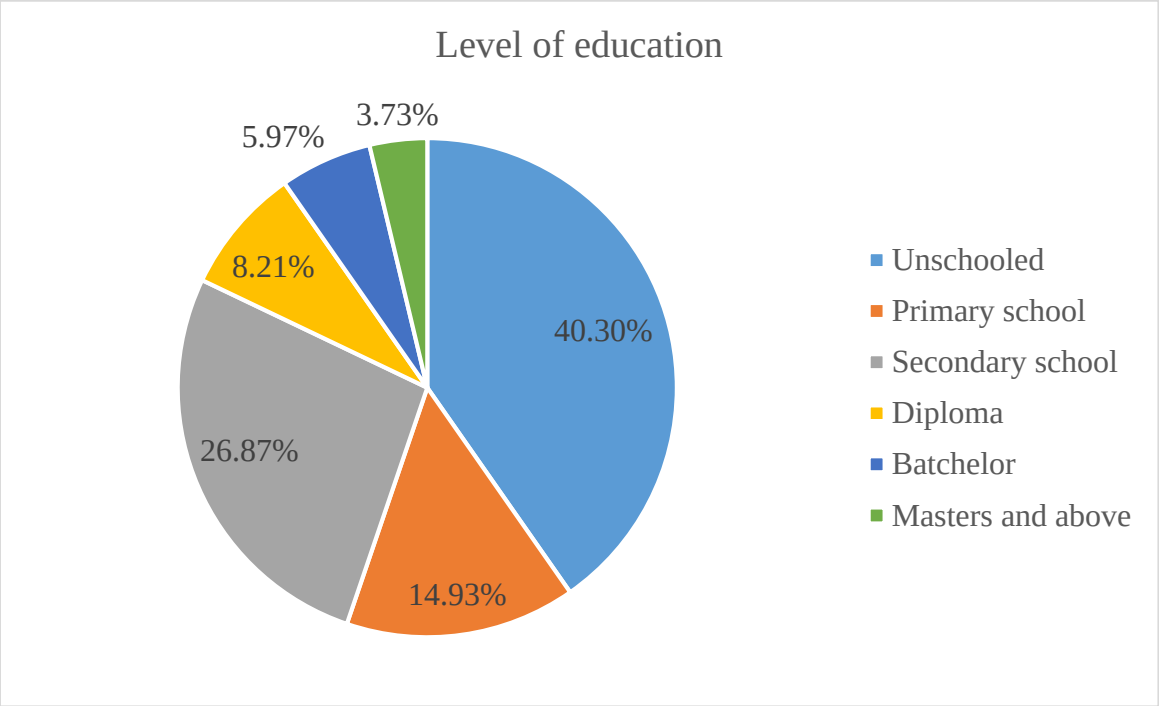

Figure 10:Education level

Source: Primary data ,2021

4.1.4. Source of energy used for cooking

The information from figure 11 shows that 41% use biogas while 31.6% of respondents use firewood. 20.9% use charcoal while 6.4% use Liquid Petroleum Gas (LPG). The figure below shows the distribution of source of energy.

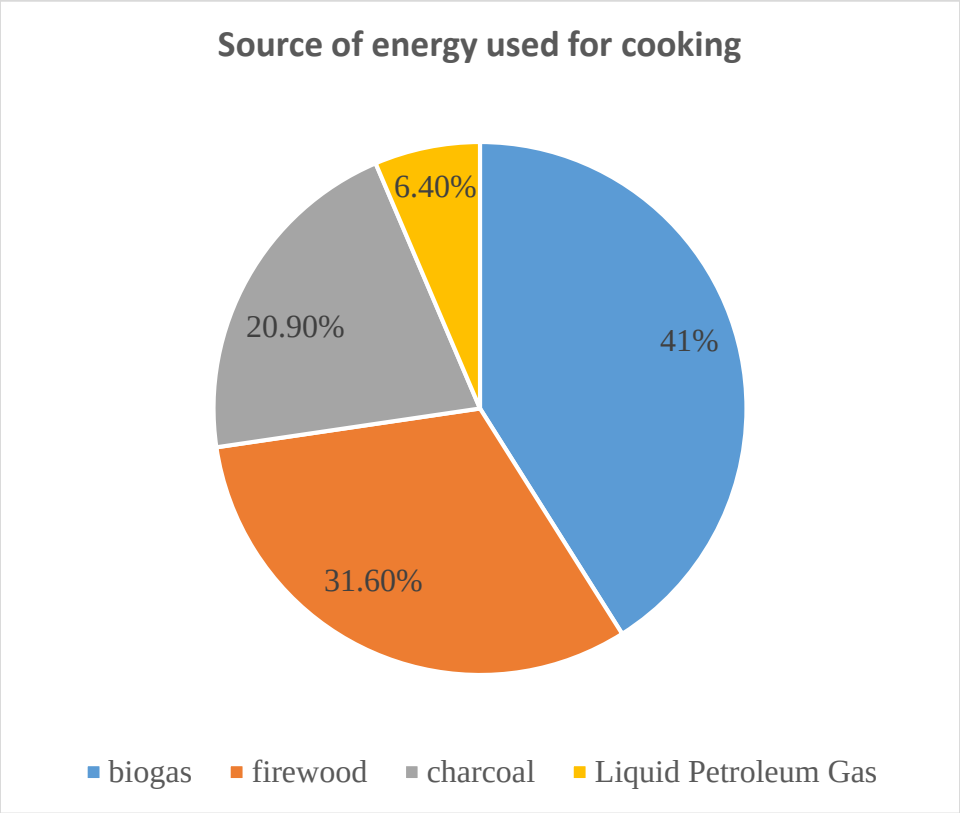

Figure 11:Education level

Source: Primary data ,2021

4.1.5 Biogas sustainability

The information from the figure 12 shows that the interviewers from selected household, the results shows that 49.3% abandoned biogas while 50.7% of respondents still interested in using biogas. The figure below shows the biogas sustainability.

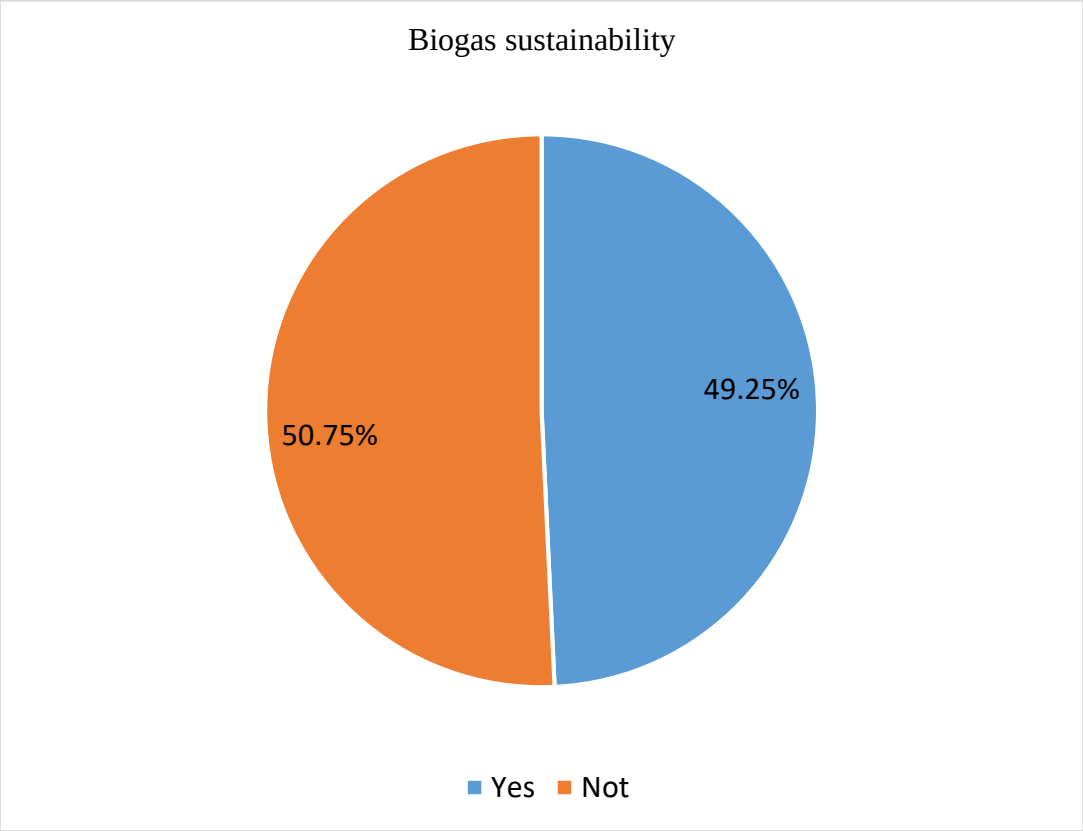

Figure 12:Biogas sustainability

4.2. ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACT OF BIOGAS IN RURAL AREA

4.2.1. Source of income

The details provided in the figure 13 shows the household source of income is Salaries at 13.88%, while 68.51% of respondents shows that their source of income is farming and 17.61% get their income from different source like businesses.

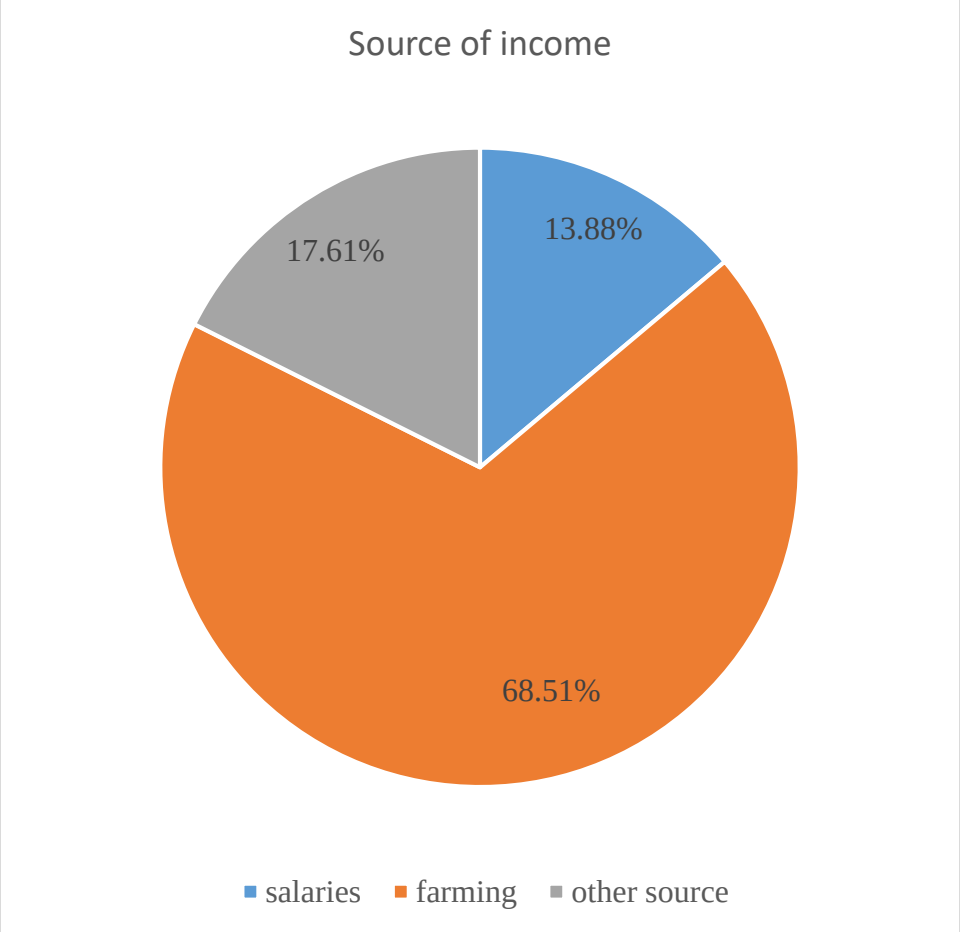

Figure 13:Source of income

Source: primary data ,2021

4.2.2. Biogas use and life change

From the figure 14, The results of the study show the status of household life after using biogas is good at 52.24% while 42.54% said the life is better. Only 5.22% Respondents said that the life is worse. The figure below shows the biogas use and life change

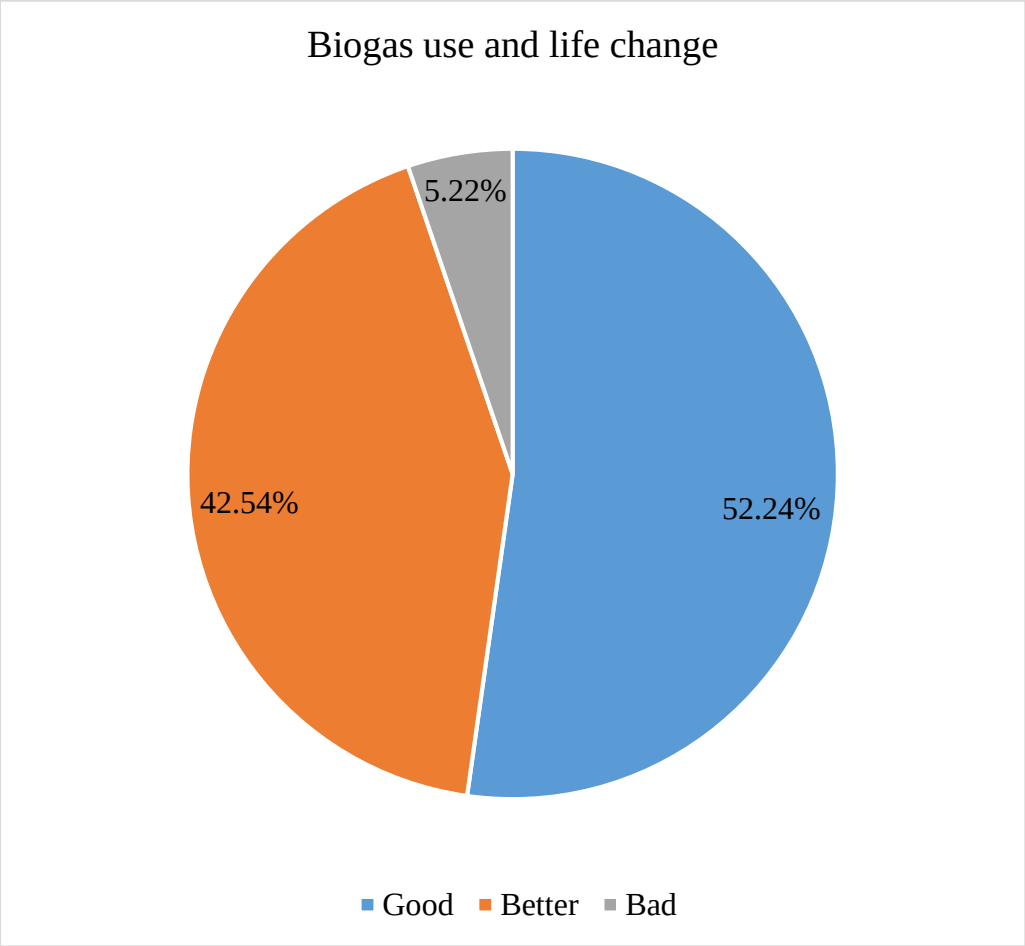

Figure 14:Biogas use and life change

Source: Primary data ,2021

4.2.3. Cost of biogas digester

From the figure 15, the result revealed that the biogas plant has low cost (33.58%) of construction while 40.3% cost medium. Only 26.12 consider the cost as high. The figure below shows the understanding on cost of biogas digester.

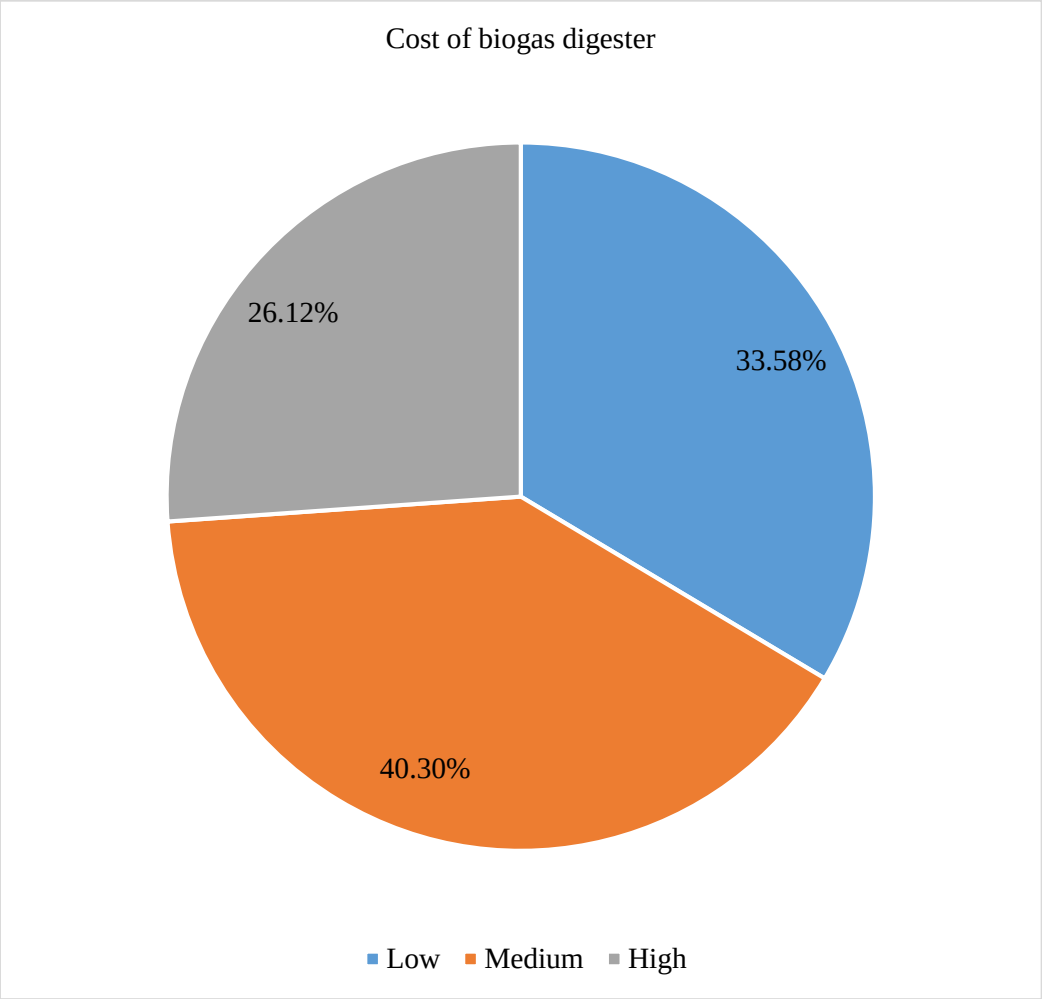

Figure 15:cost of biogas digester

Source: primary data ,2021

4.2.4. Biogas use and wellbeing

The detail from figure 16, the results shows that the biogas gas has reduced poverty at 14.93% of the sampled households and its contribution to environment protection was expressed by 25.37%, Its contribution as fertilizer was at 28.36% and 31.34% estimated its role in reducing wood collection. The figure below shows the biogas use and wellbeing.

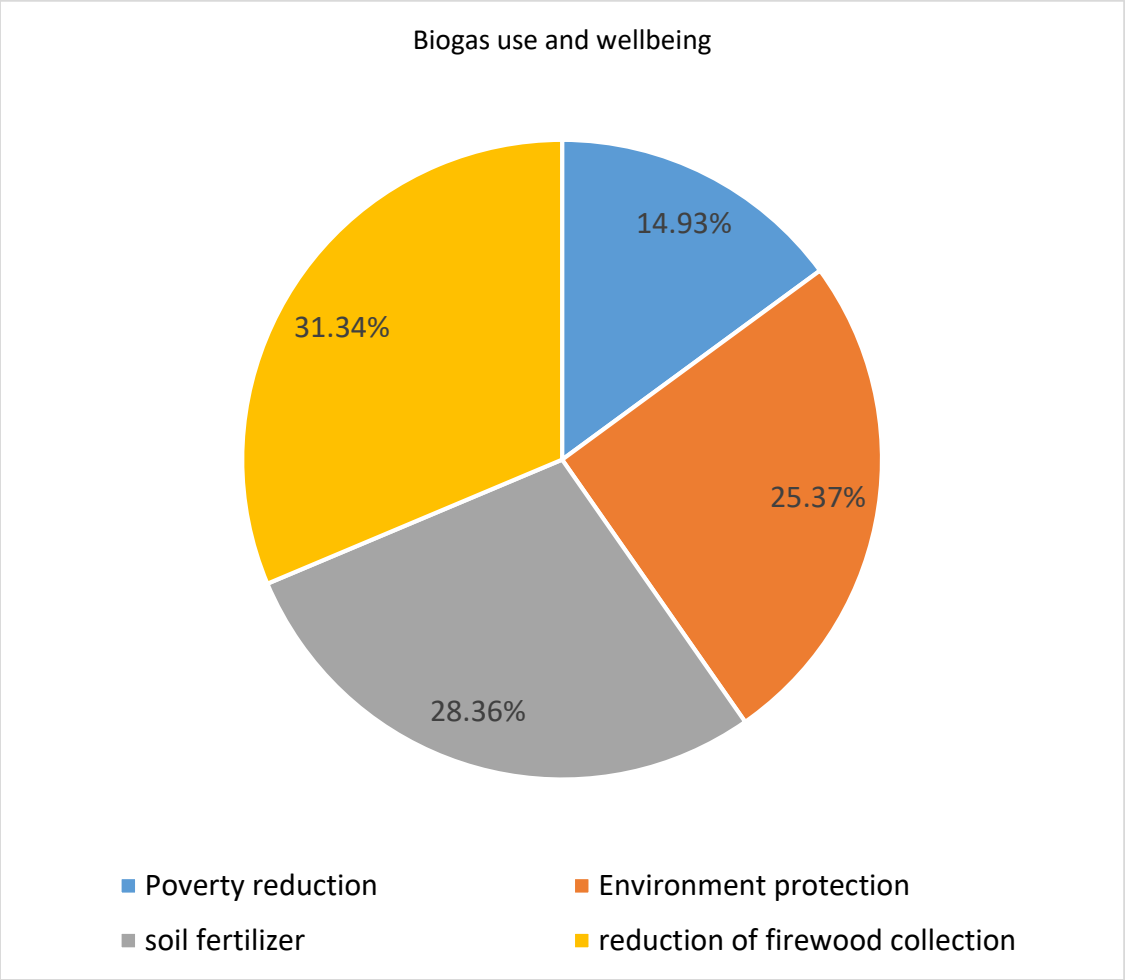

Figure 16:Biogas use and wellbeing

Source: primary data ,2021

4.2.5. Biogas cooking time

From the figure 17, the results show that the biogas save time at 79.85% and only 20.15% disagreed. the figure below illustrates the biogas cooking time

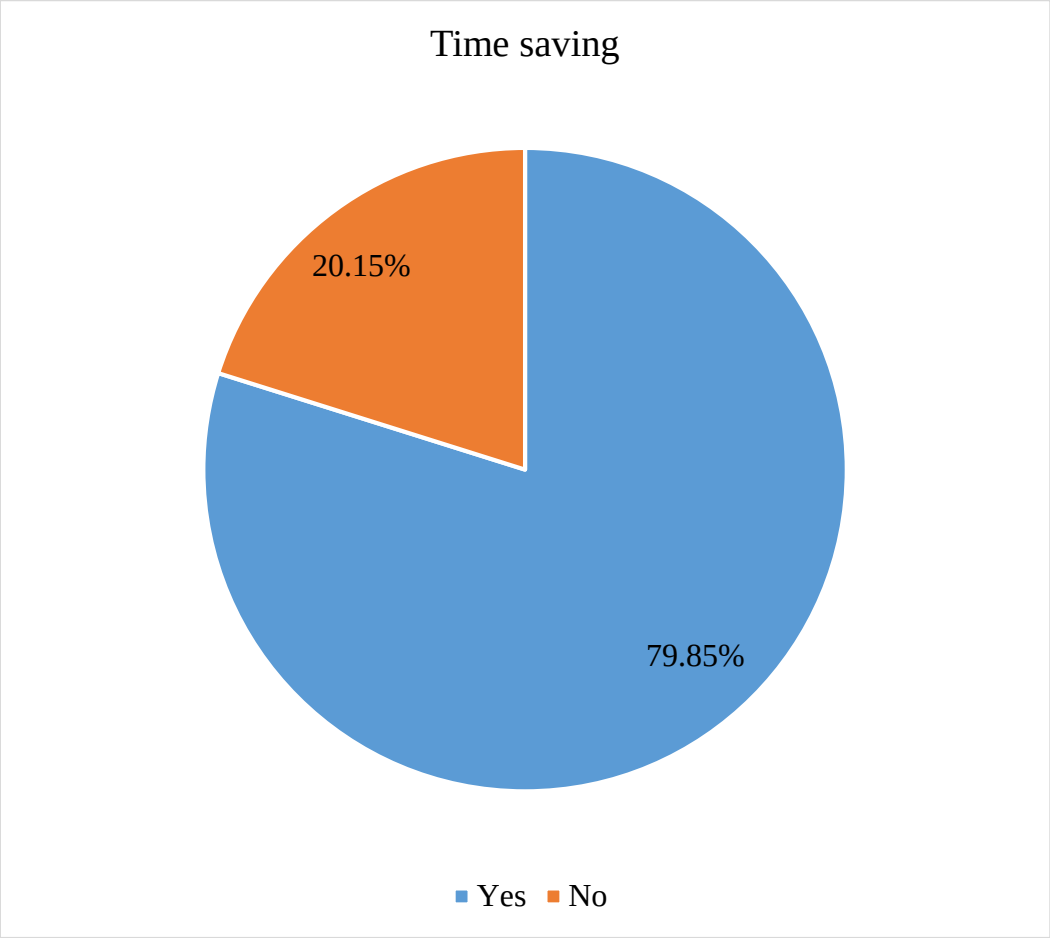

Figure 17:Biogas cooking time

Source: primary data ,2021

4.2.6. The reduction of smoke in the kitchen

From the figure 18, The household contacted confirmed that biogas reduce smoke by 92.54% while 7.46% disagreed.

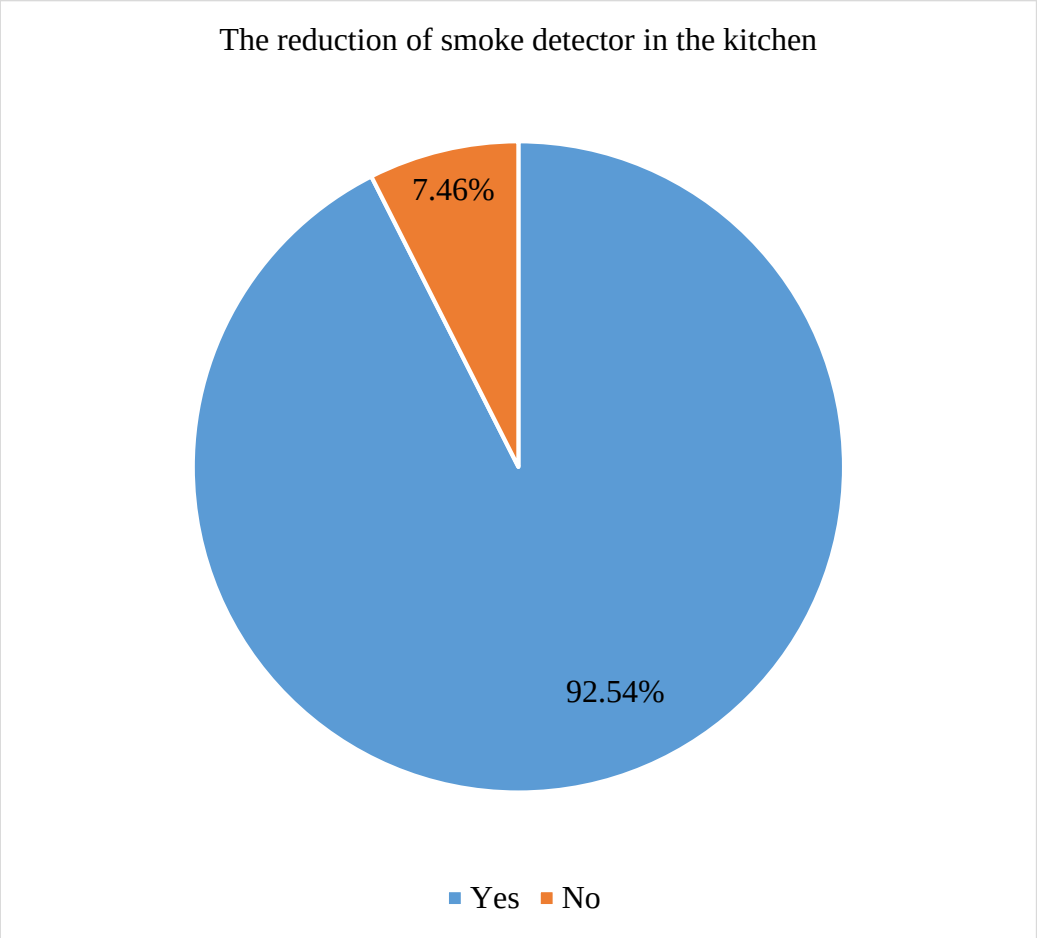

Figure 18: Reduction of smoke in kitchen

Source: primary data ,2021

4.2.7. Biogas plant funding

The information from the figure 19, the household contacted shows that 12.09% are self-sponsored, 11.19% sponsored by government. And 16.42% said the biogas digester have been constructed by loan. Also 60.30 % said they are partial sponsored by government. The figure below shows the biogas plant funding

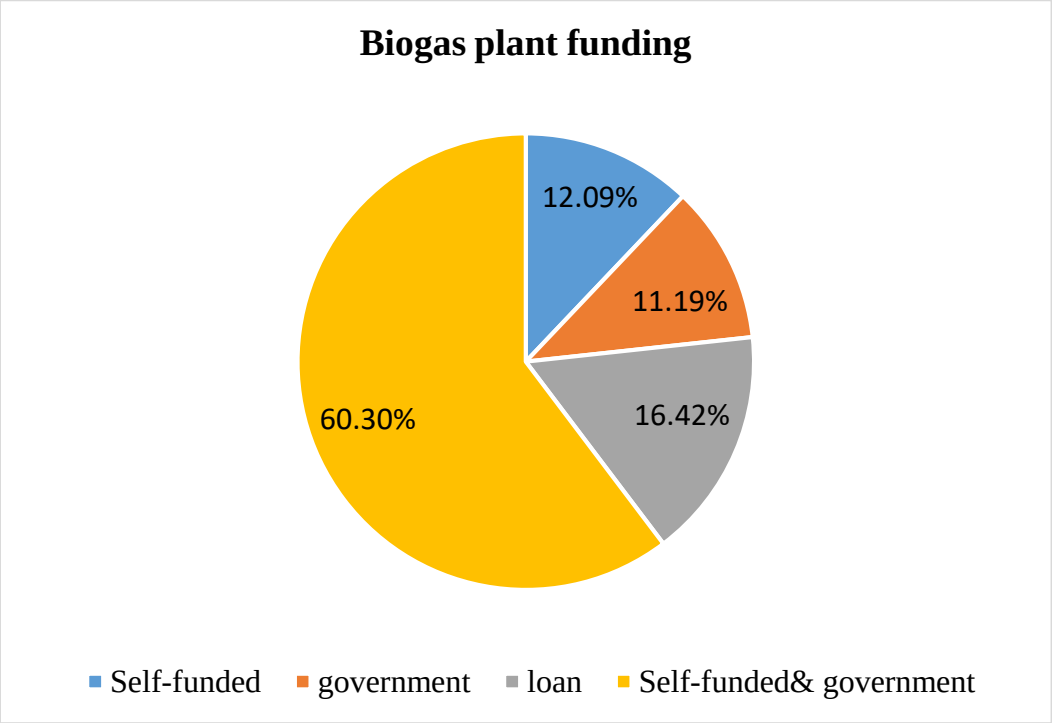

Figure 19:Biogas plant fund

Source: primary data ,2021

4.3.THE ROOT CAUSES OF BIOGAS FAILURE IN RURAL AREA

4.3.1. The feeding material

From the table 20, The household contacted shows that 9% use human waste for feeding digester, 90.3% use animal waste and 0.7% said that the digester fed by other waste. This is shown in the figure below.

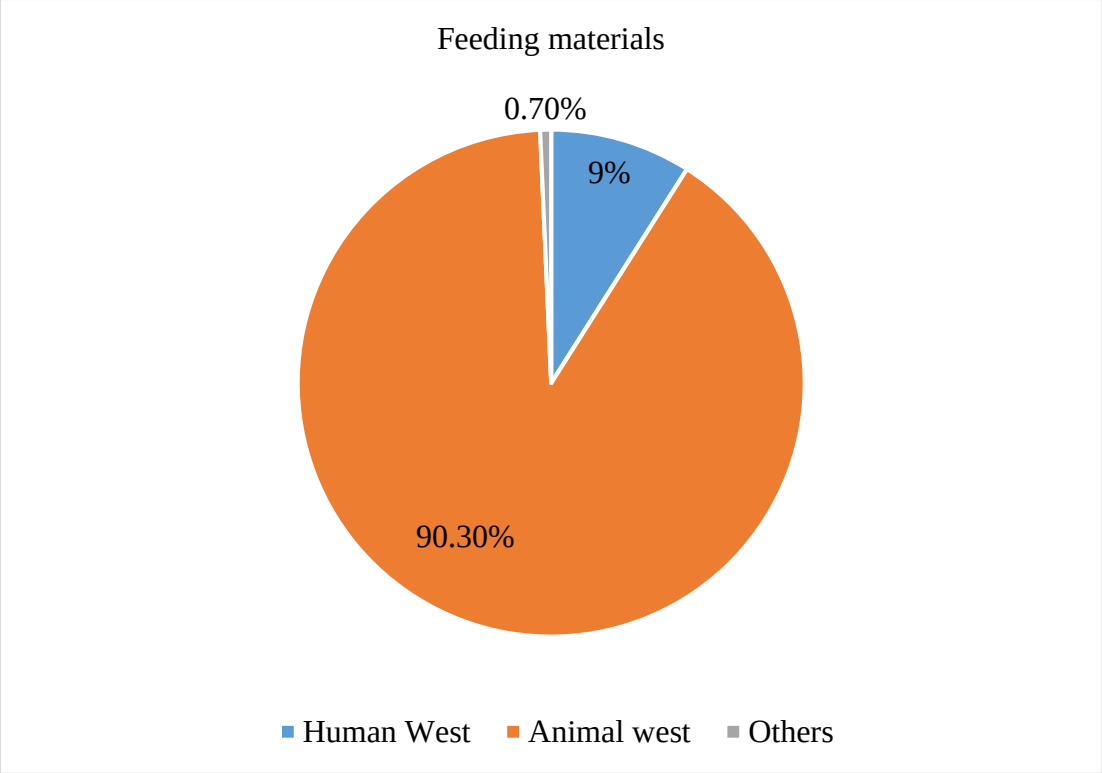

Figure 20:The feeding material

Source: primary data ,2021

4.3.2. Feeding materials availability

The information from the figure 21, The household contacted revealed that there is feeding materials by 47.8% while 52.2% said it is not easy to get feeding materials. See the figure below.

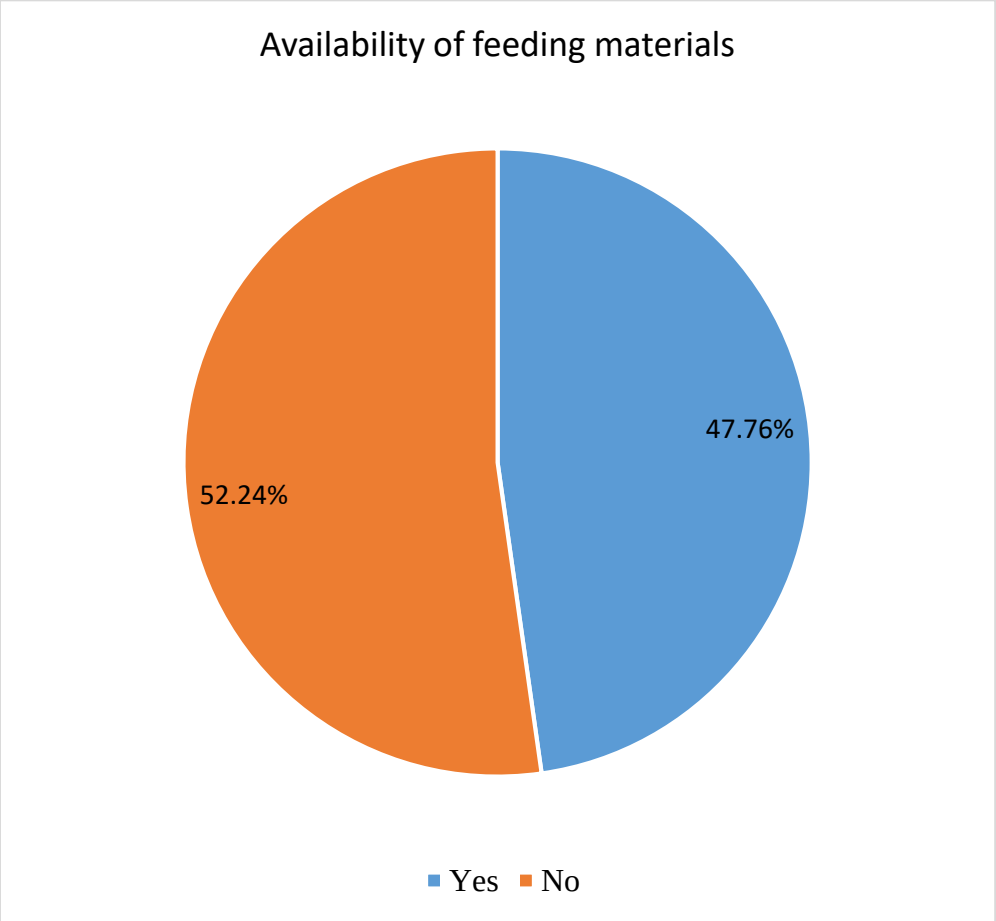

Figure 21:Feeding materials

Source: primary data ,2021

4.3.3. Type of digester used in Kayonza district

From the figure 22, The responded contacted revealed that there are fixed dome digesters at 62.69% while 37.31% of the household have plastic containers. See The figure below showing the type of biogas digester.

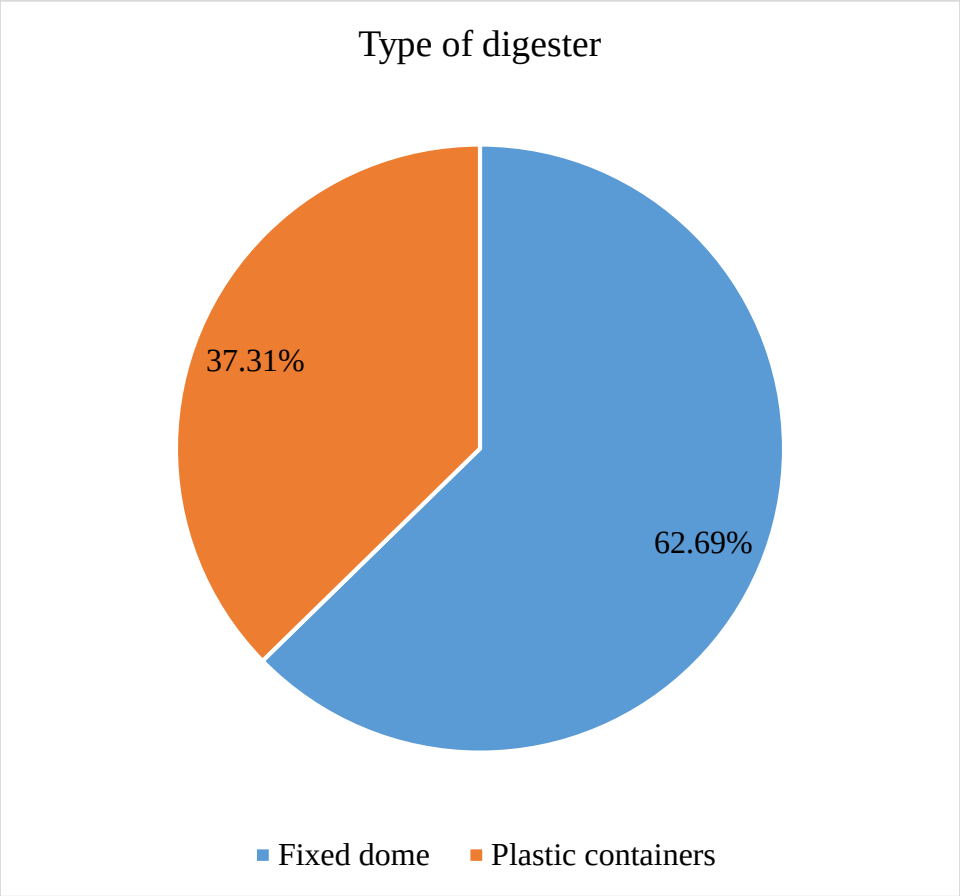

Figure 22:Type of biogas digester

Source: primary data ,2021

4.3.4. Maintenance schedule of biogas Plants.

From the figure 23, the responded contacted revealed that 77.61% don't do maintenance of their biogas plant while only 5.97% do it after a year. In all interviewer's no one said that he/she does weekly maintenance but 4.48% do it quarterly and 11.94% do it monthly. The Figure below shows the percentage of Maintenance schedule of biogas plants.

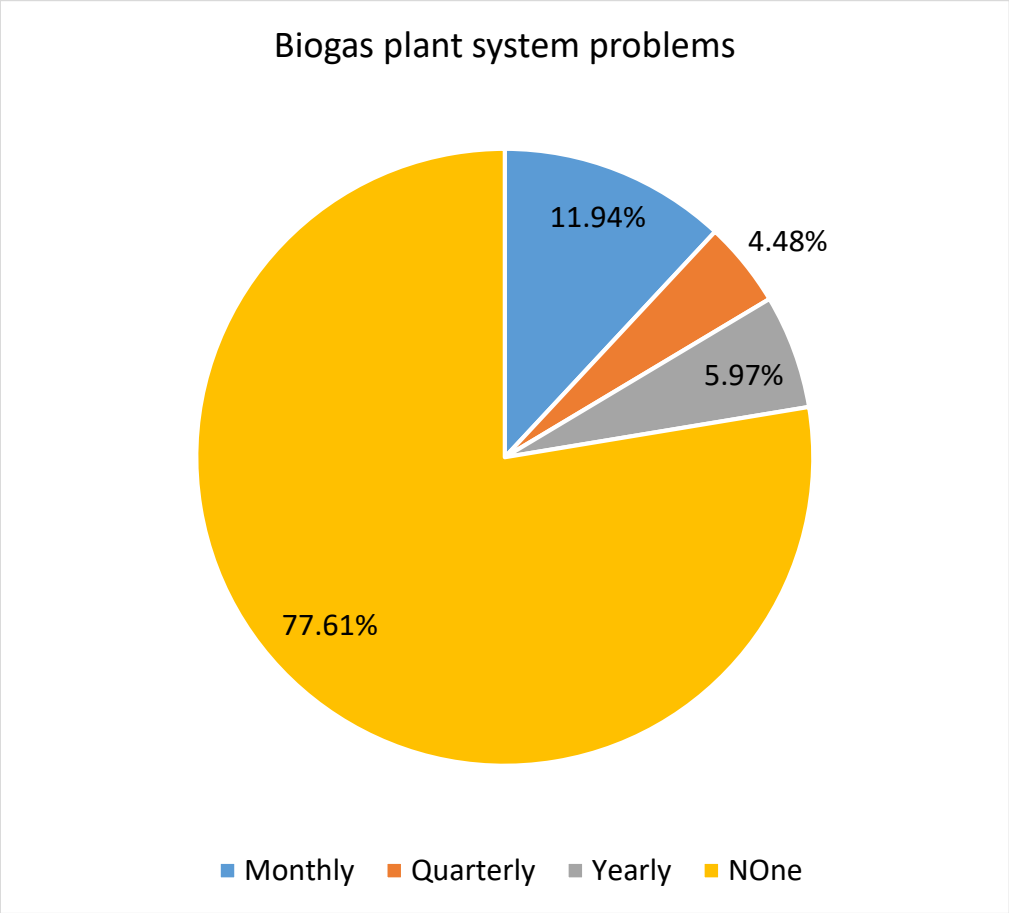

Figure 23:Maintenance schedule

Source: primary data ,2021

4.3.5. Biogas plant maintenance

From the figure 24, The percentages of the results of this study showed that 9.7% of household get support maintenance from the district while 33.6% support themselves. 9% supported by their neighbor and 47.8% do not get support at all. The figure below illustrates the biogas plant maintenance.

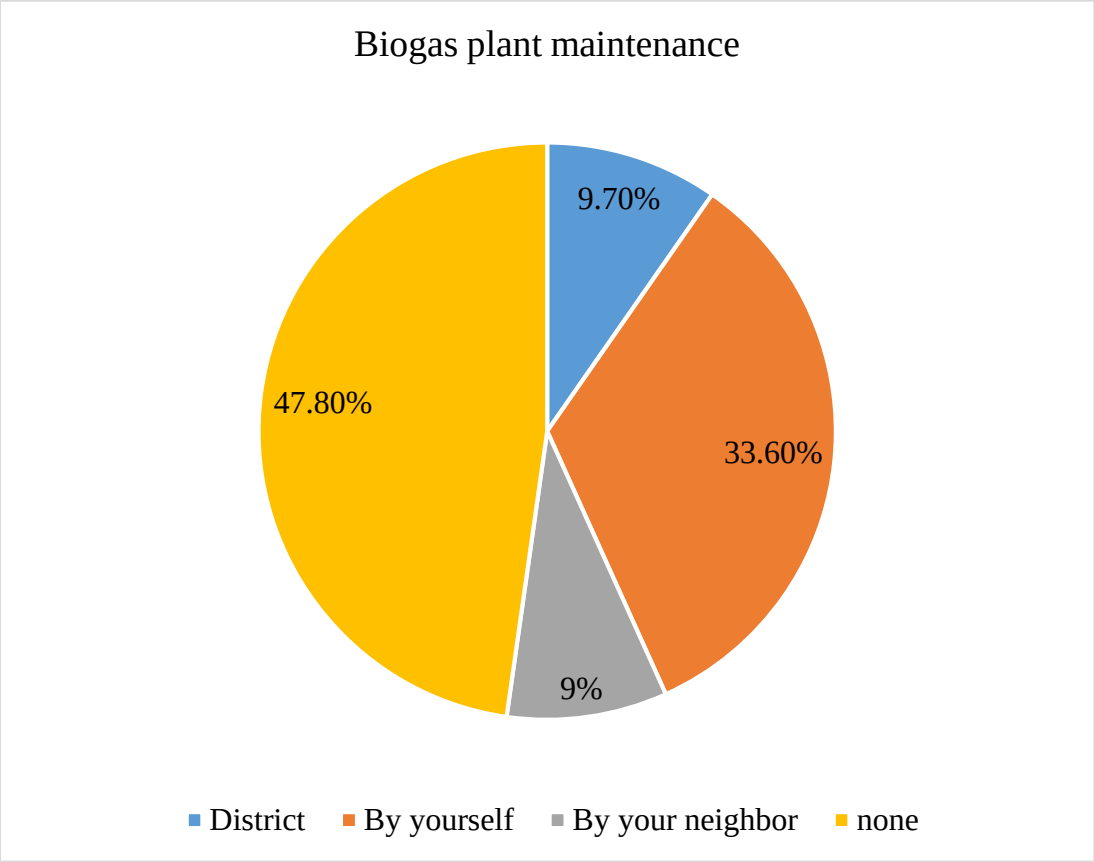

Figure 24:Biogas plant maintenance

Source: primary data ,2021

4.3.5.1. Biogas status in Kayonza district

From the figure 25, Kayonza district report stated that only 6.5% biogas plant has been maintained while 13.5% biogas plant are out of service and the remaining 80% are running well. The figure below illustrates the biogas status in kayonza District.

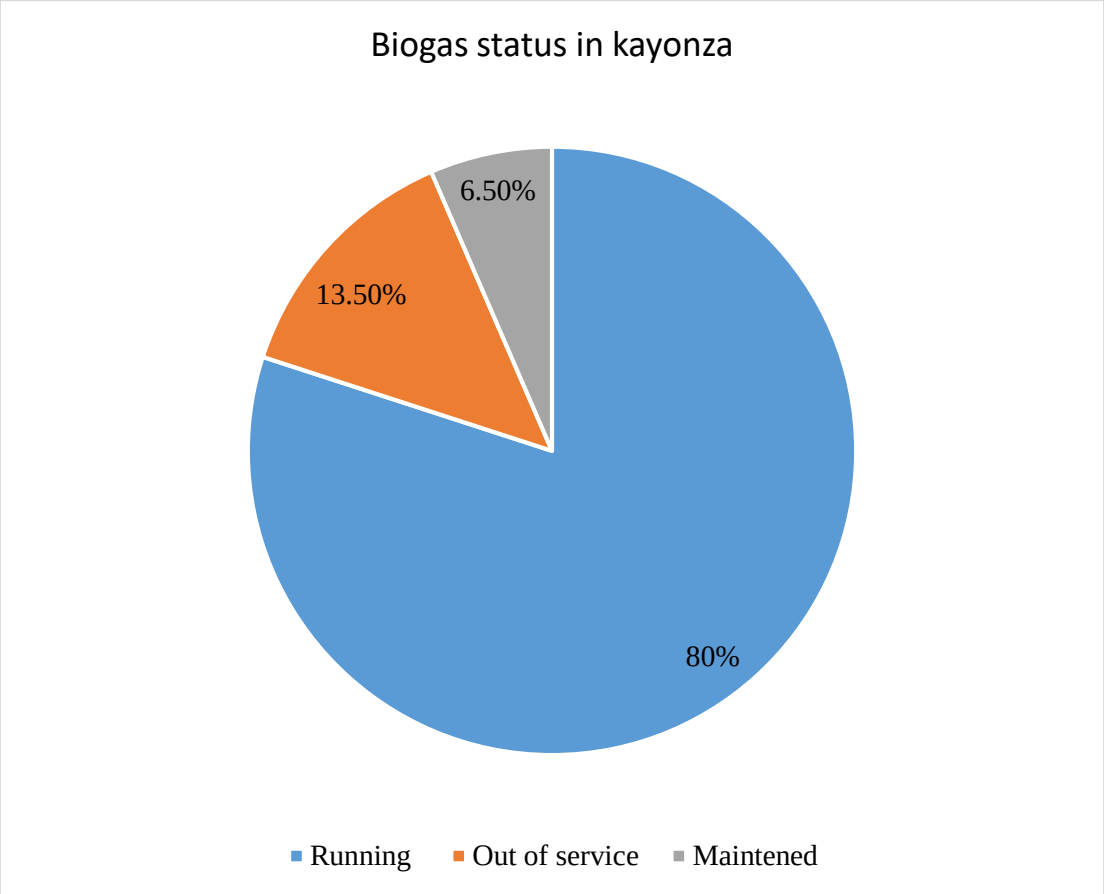

Figure 25:Biogas status in kayonza District

Source: Kayonza District Assessment Report on installed biogas, 2019

4.3.6. Feeding Responsibility

The information from the figure 26 shows that 25.4% of household are parent and 26.9% are children while 46.2% are domestic workers. only 1.2% supported by technicians. The figure below illustrates the feeding responsibility of the biogas plant.

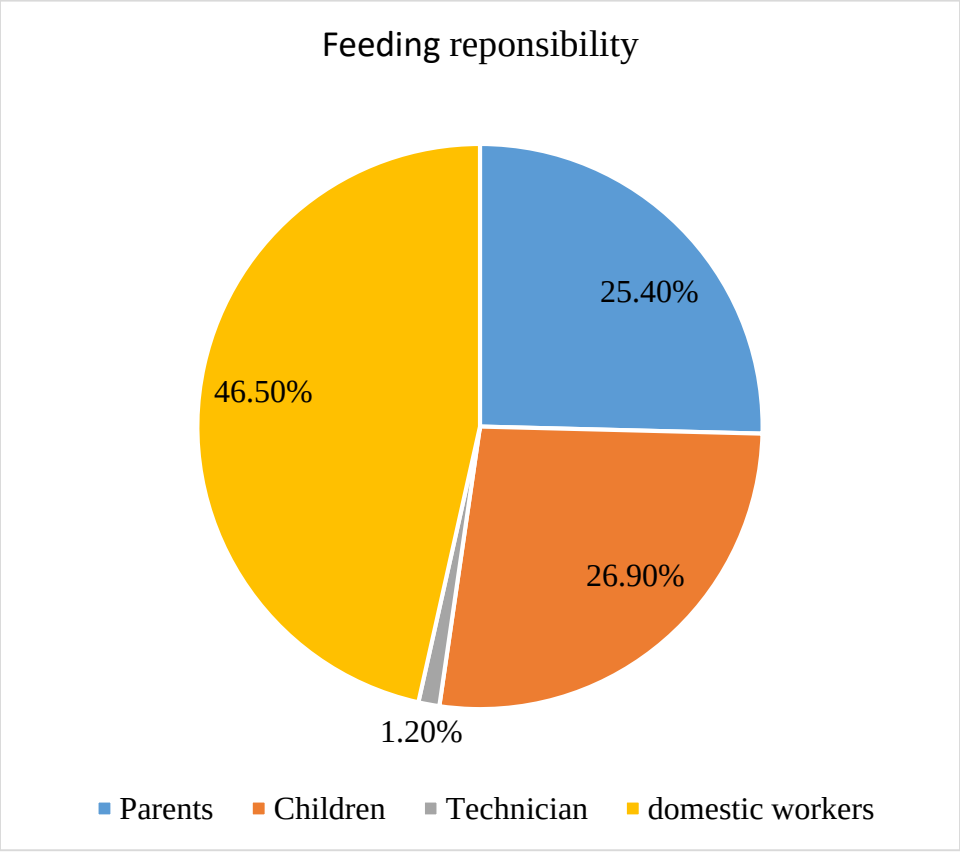

Figure 26:Feeding responsibility

Source: primary data ,2021

4.3.7. Biogas plant system problems

From the figure 27, the results of this study showed that 61.2% have problems while 38.8% has not shown problems. The table below illustrates the problems percentages with biogas plant system.

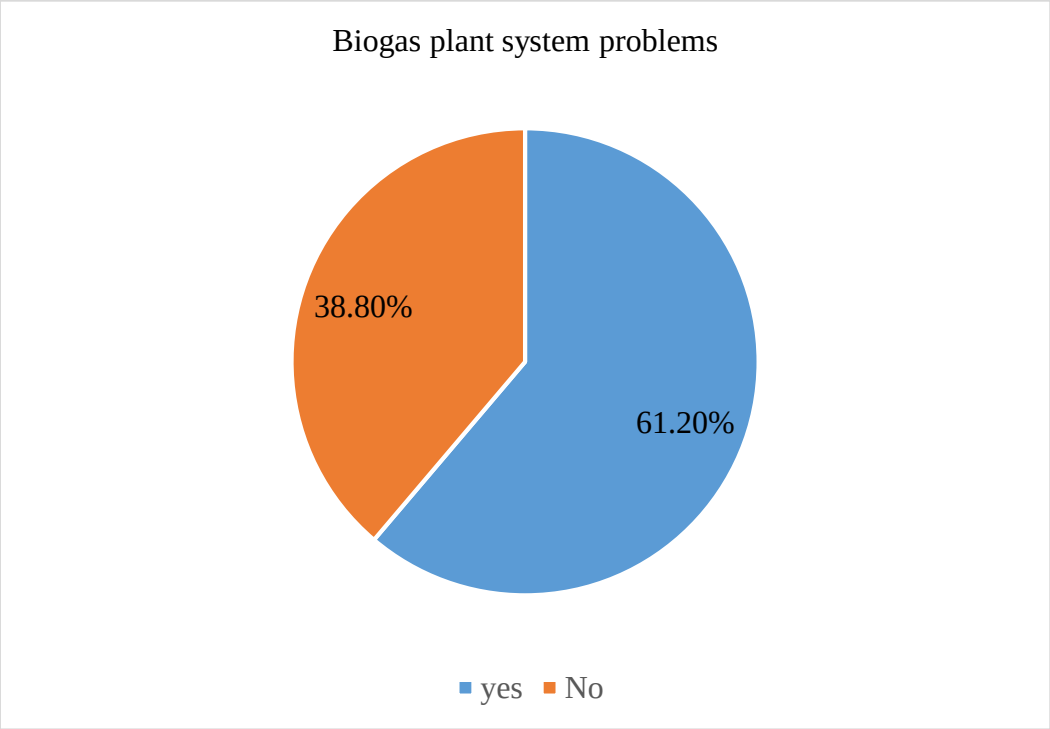

Figure 27:Biogas plant system problems

Source: Primary data ,2021

4.4. THE ROLE OF COMMUNITY IN USING BIOGAS.

4.4.1. Knowledge about biogas production process.

The information from the figure 28 shows showed that 78.4% of household don't have knowledge about biogas production process while 21.6% have knowledge about it. The table below illustrates the knowledge about biogas production process.

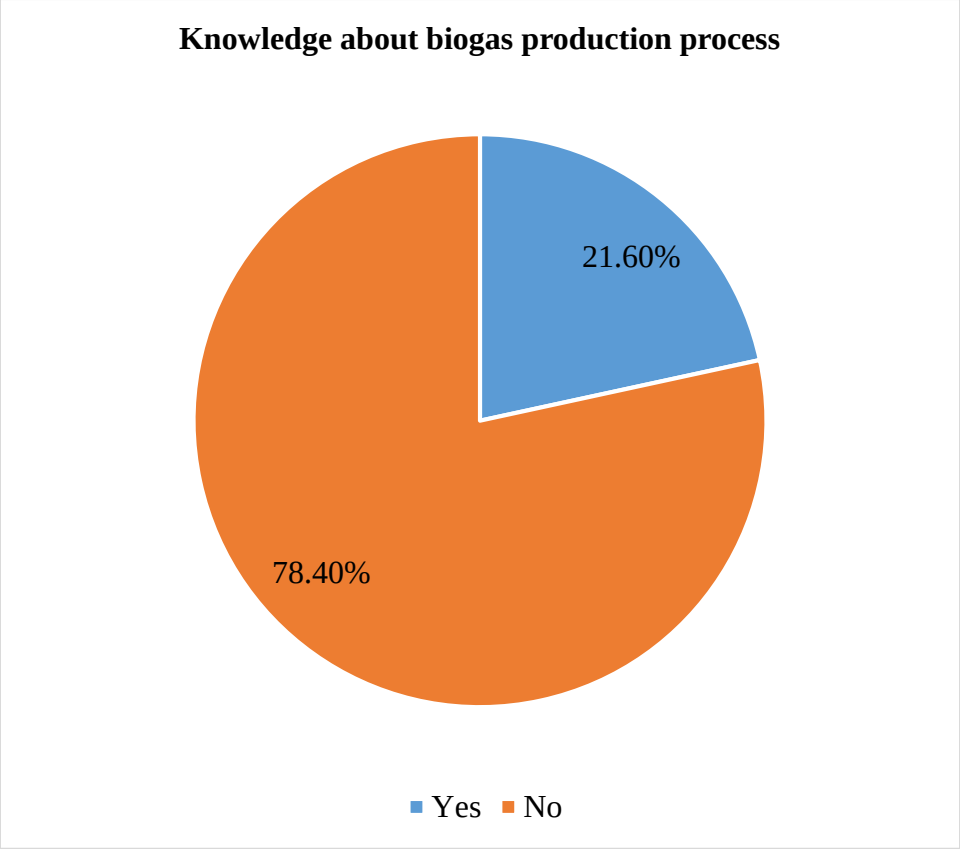

Figure 28:Knowledge about biogas production process

Source: primary data ,2021

4.4.2. Awareness on biogas usage.

From the figure 29, the results showed that 56% of household didn't get awareness about biogas usage while 19.4% get it from their neigbour.12.7% get the awareness from local technicians. Only 11.9% got it from government. The figure below shows the awareness of biogas usage

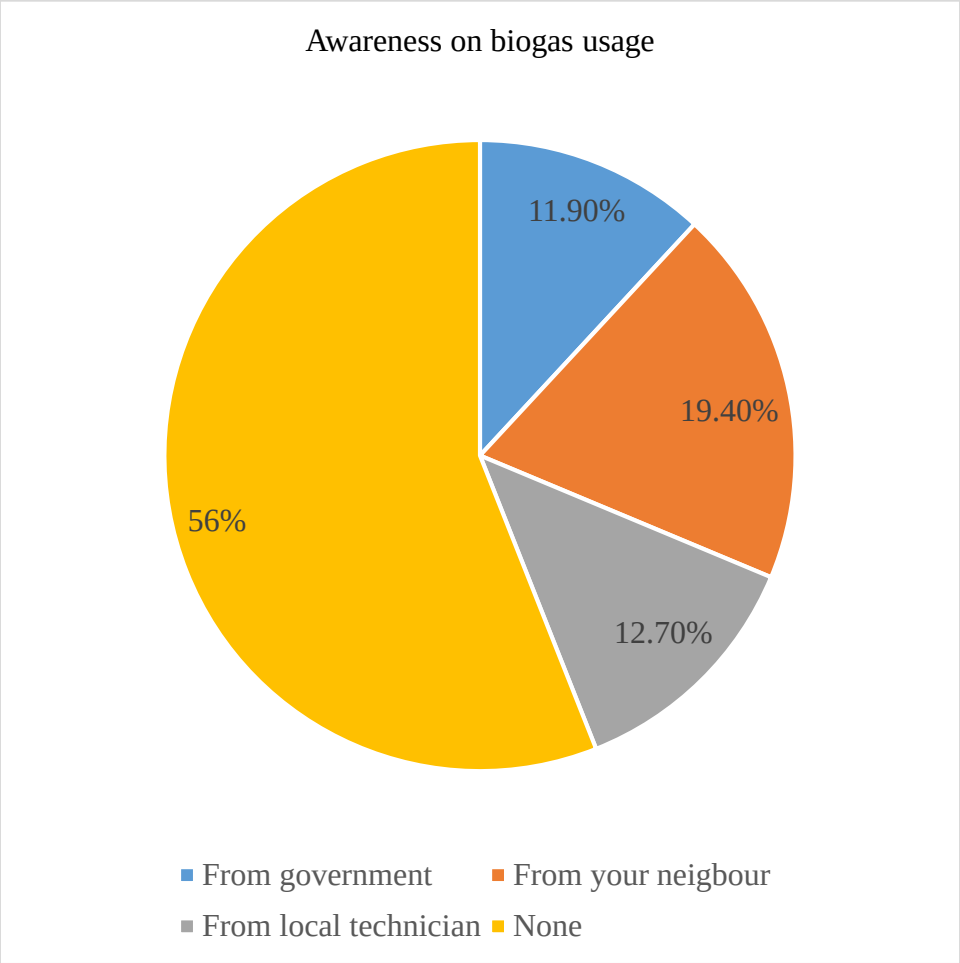

Figure 29:Awareness on biogas usage

Source: primary data ,2021

4.5. REVIEW ON BIOGAS SUSTAINABILITY AND ENVIRONMENTAL PROTECTION

4.5.1. Biogas plant sustainability

The figure 30, the results of this study showed that 59% confirmed that biogas plant is sustainable for longtime while 41% said it is sustainable for short time. The figure below shows the percentage of Biogas sustainability

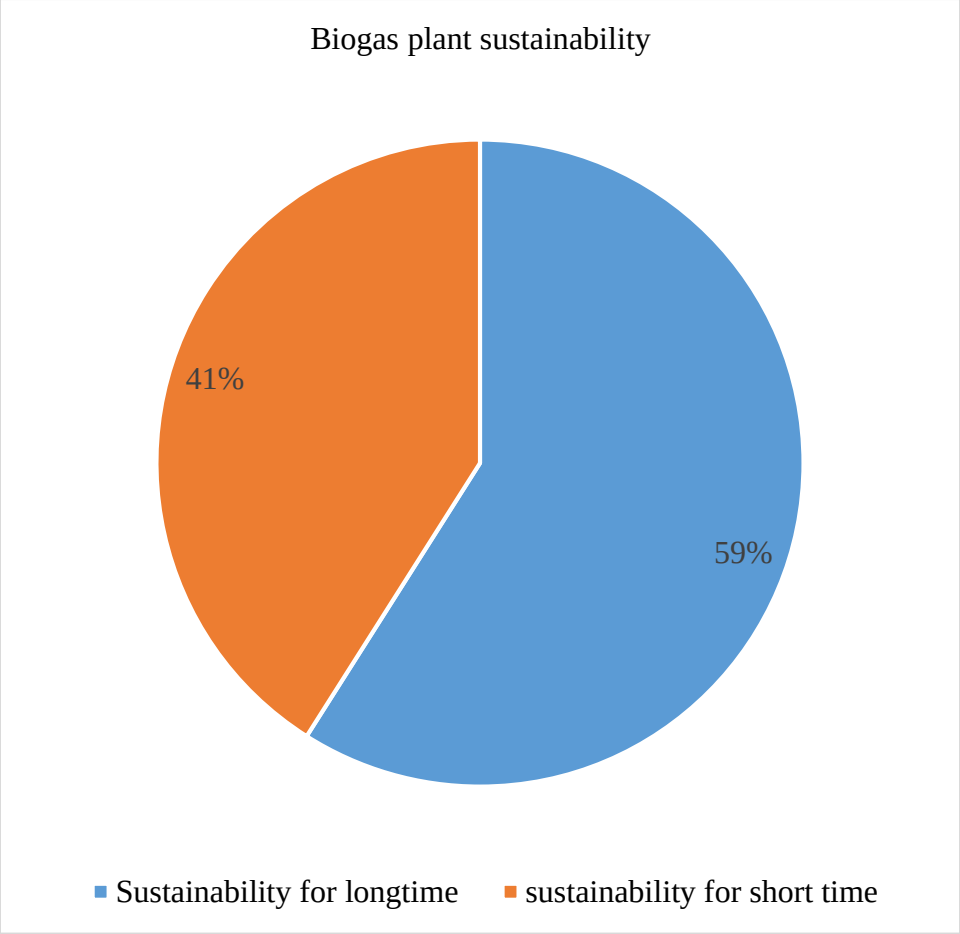

Figure 30:Biogas plant sustainability

Source: primary data ,2021

4.5.2. Advantage of Biogas plant in environmental protection

From the figure 31, the results showed that 95.5% of household said that the biogas plant reduce deforestation while 4.5% said that the biogas digester don't reduce deforestation. The Figure below shows the percentage of deforestation reduction in local community by using biogas.

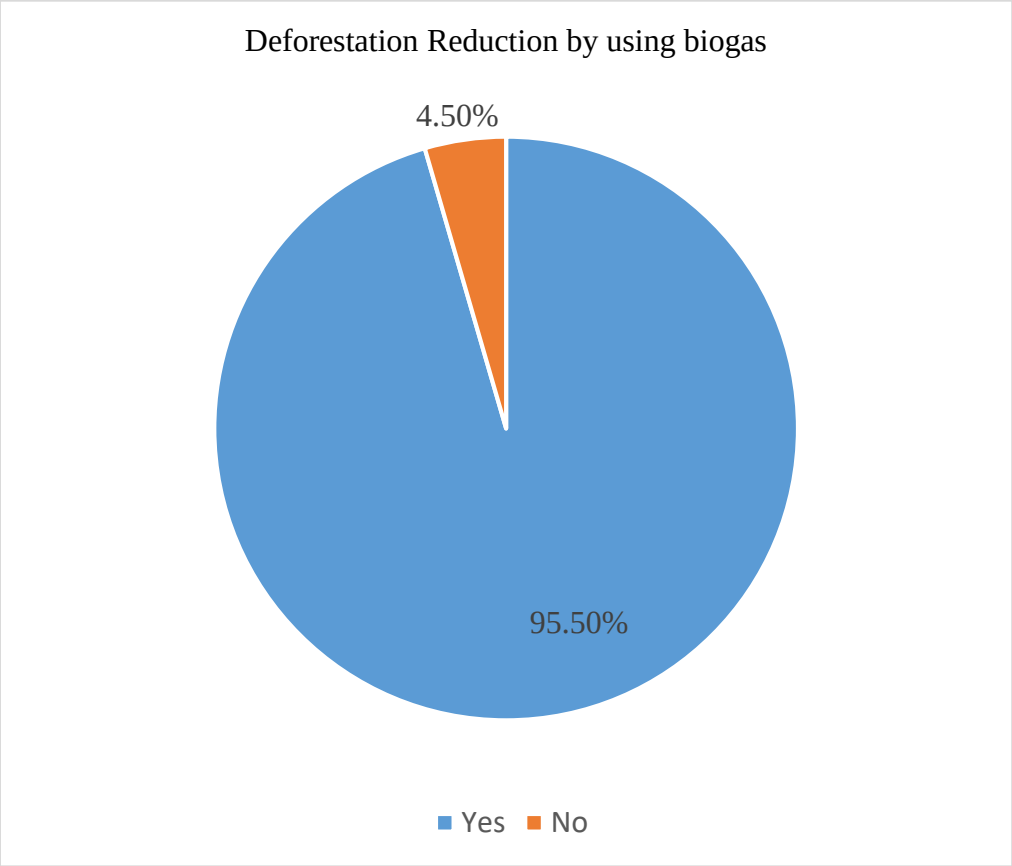

Figure 31Deforestation Reduction by using Biogas

Source: primary data ,2021

4.5.3. The will of using biogas

The figure 32, shows that 70.9% of household still interested in using biogas while 29.1% are not interested at all. The figure below shows the percentage of the household who are willing in using biogas.

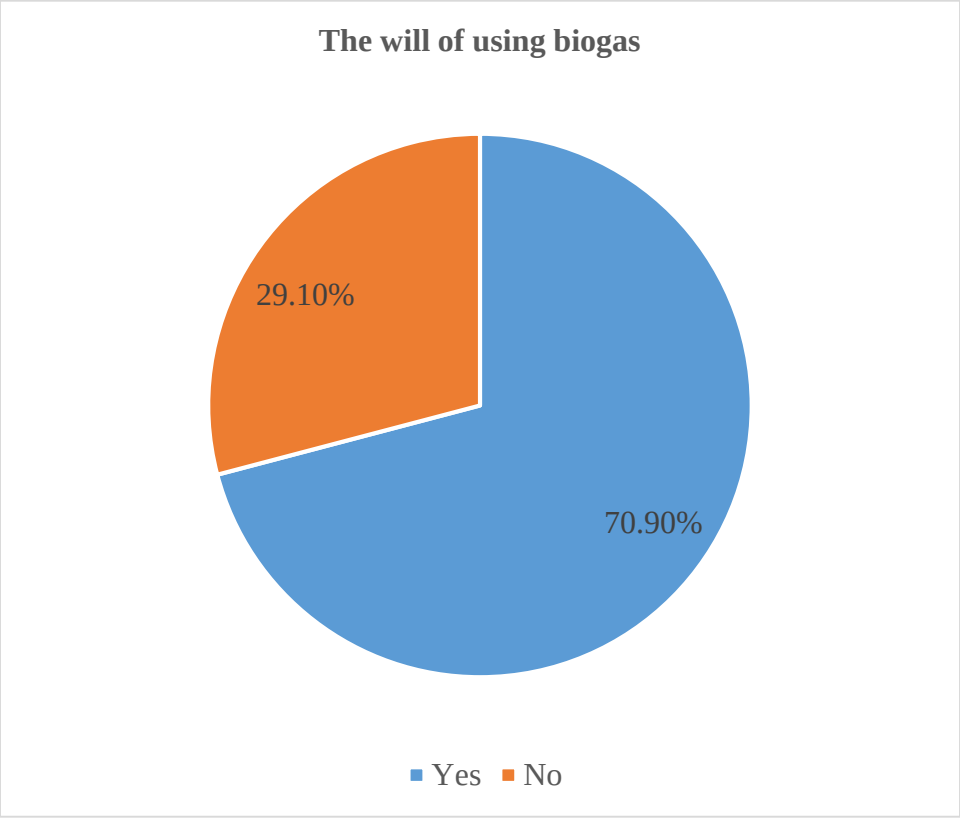

Figure 32:The will of using biogas

Source: Primary data ,2021

4.6. INTERPRETATION OF FINDINGS

From the findings, the result shows that the biogas is used in the household at 41% while 59% use other energy like charcoal, fire wooden and liquid petroleum, this lead the researcher to understand that the percentage of biogas users is not high compared to the others sources. The reason is that some household abandoned biogas plants due to different perspective such as luck of maintenance, damage and feeding materials. The research shows also that the household abandoned at 49.3% while 50.7% of respondents still interested in using biogas. This lead the researcher to understand that the comparison of both abandoned and non-abandoned are quiet almost similar due to some biogas plant that are not making any benefit to their families lives. The findings show that most of the household are farming at 68.51% which is high compare to17.61% salaries and 13.88% of business. This led the researcher to understand that some of respondents were famers that could have capacity to feed the digester. Therefore, this shows that more household can get feeding material and fertilizer. The result from the findings shows 94.78% of household have better life with biogas usage. This led the researcher to understand that the biogas has good impact to the user like saving time of women and children who bearing the burden of collecting firewood. The result shows that the biogas reduce poverty at 14.93%, protect environmental at 25.37%, soil fertilizer at 28.36% and reduction of wood at 31.34%. Therefore, this shows that biogas has many roles in households daily life. The findings show also that the biogas save time at 79.9%. The biogas reduces the smoke at 92.5%, this lead to understand that the biogas is environmental friendly.

From the findings, the result shows that 90.3%use animal west for feeding digester. And this lead the research to understand that the farming is more important in biogas production process. The result shows that the feeding materials is not enough at 52.46%. Therefore, this shows that the biogas plant doesn’t get feeding material as required. The respondents contacted revealed that 77.61% don’t do maintenance of their biogas plant which is the one of the main causes of biogas failure. And 47.8% don’t get support of maintenance at all. The results from findings shows also that the digester feeding responsible are unskilled people at 46.25%. Thus some biogas plant failed due to unskilled domestic workers who usually feed the digesters for example: they don’t know the feeding quantity, feeding mixture, time schedule for feeding, the respondent mentioned that

the biogas system problems are at the rate of 61.2% which also make the biogas digester to fail at any time. After information from the respondents 78.4% of them don't have knowledge about biogas production process. Therefore, the biogas plants got problems due to non-skilled households about the biogas production process. From the findings, the respondents showed that they need different help to have sustainable biogas plant. In that help include 35.8% of household need support in feeding digesters for example to have knowledge about mixing cow dung with water and feed it in proper way, the best hours to feed digesters while 50.7% need technical support like when they face some problem with digesters. After interviewing households raised the problem of not getting awareness from the government because only 11.9% got it, this shows that the big number of household didn't get awareness about the biogas usage. From the result ,95.5% said that the biogas plant reduce deforestation because instead of using wood got from the forest they use gas to cook. The researcher concluded the big numbers of household know the important of biogas in use. The respondent showed that 70.9% of household still interested in using biogas while 29.1% said that they are not interested at all. After observation done by researcher, the big number of household confirmed that they still interested in using biogas since it helps household to be in clean area and protect environment.

5. CHAPETER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In the rural areas, more than 85 % of the population uses firewood as domestic energy source. According to percentages from analysis, different perspectives on Impact assessment of existing biogas plant in Kayonza District have been shown on each particular question. The researcher concluded that the biogas plant is very important to the people who owned the biogas plant because it provide alternative source of energy for communities. Biogas plant improves life of householders in economic, social and Environmental through poverty reduction, production of energy in rural area, environmental protection, saving time for collecting wood, improvement of hygienic conditions, transformation of organic material in high quality fertilizer. Biogas plant technology become solution to the problems in rural area of the country. However, some people abandoned it because some biogas failed to produce biogas as required due to different causes such as: lack of feeding materials, lack of maintenance, less awareness on biogas usage from government or any other expert, lack of skilled people in the village to follow up challenges faced by the users.

5.2 Recommendations

The Government of Rwanda should put into consideration the way of helping householders to get enough feeding materials by reinforcing Girinka Munyarwanda in the Rural Area, as we have seen that there are biogas plants which are not working at the moment due to lack of manure.

The Biogas plants in kayonza were constructed by different companies under supervision of kayonza district, based on our research big number of households are not skilled enough, many of them also are aged above 50 years old, these are the challenges that affect the use of biogas, I give recommendation to the district and their partners to work hand in hand with the local government to allocate the technician on ground for responding to the householder’s problems of lacking required maintenance and train them about biogas production process.

The District should look for the way of communicating and collaborating with householders, this will help them in addressing the problem earlier and helped at a time without abandoning the system. the households should take care of their biogas plant in order to ensure its sustainability.

Based on our research we found that many biogas users (households) don't have knowledge about biogas despite using it only, the researcher recommended that Government of the Republic of Rwanda should help the Biogas users through capacity building so that they can know much about biogas production process, this will help them to use it in proper way and increase its sustainability.

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APPENDIX

RESEARCH QUESTIONNAIRE

This questionnaire is intended to collect data about existing biogas plant installed in Kayonza district.

Target respondents: the owner of biogas plant in kayonza district.

Purpose: the purpose of this questionnaire is to get the information related to biogas status (their performance, durability, efficiency and the problem or obstacles they face) The research is conducted for the completion of masters.

Confidentiality: Please note that the response you provide are completely anonymous and confidential. The research outcome will not include reference to any individuals.

1. To assess the economic, social and environment impact of biogas in rural area
2. To examine the root causes of biogas failure in rural area
3. To establish the role of community in using the Biogas in their household
4. To Review on biogas sustainability and environmental protection

A. GENERAL INFORMATION

1. How old are you? (Please tick.)

   Less than 30 years.

   31 – 40 years 41–50 years

   51 years and above

2. What is your Gender? (Please tick.)

   A) Male

   B) Female

3. Level of education. (Please tick.)

   a) Uneducated

b) Certificate

c) Diploma

d) Bachelor's degree

e) Masters and above

4. Which source of energy do you use for cooking? (Tick where appropriate)

a) Firewood

b) Charcoal

c) Liquid Petroleum Gas

d) Human waste Biogas

e) Electricity

f) Kerosene

B. ECONOMIC, SOCIAL AND ENVIRONMENT IMPACT OF BIOGAS IN RURAL AREA

1. What is the source of your income?

a) Salaries

b) Farming

c) Other source

2. How is your life after using biogas?

a) good

b) Better

c) Bad

3. How much the biogas digester cost you?

a) Low

b) Medium

c) high

C. THE ROOT CAUSES OF BIOGAS FAILURE IN RURAL AREA

1. What is the west do you use to feed the digester?

a) Human west

b) Animal west

c) Others

2. Is the feed materials still enough compare to the beginning?

a) Yes

b) No

3. What are the type of digester do you have?

a) Fixed dome

b) Floating drum

c) Tubular design

d) Plastic containers

4. How do you do maintenance?

a) weekly

b) Monthly

c) Quarterly

d) Yearly

e) None

5. How do you get maintenance?

a) District

b) By yourself,

c) Your neighbor

d) None

6. Who is responsible for feeding the digester?

a) Parents

b) Children

c) Technician

7. Do they find this work to be manageable?

a) Yes

b) Not

8. Are there any improvements you feel could be made to your plant?

a) Yes

b) Not

If yes, describe it

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9. Have you had any problems with the biogas system?

a)Yes

b) not

If yes, what is that?

D) THE ROLE OF COMMUNITY IN USING THE BIOGAS IN THEIR HOUSEHOLD

1. Do you have some knowledge about the biogas production process?

a) Yes

b) No

2. Is there any support you need from the community?

a) Feeding digester

b) Technical support

c) None

E) REVIEW ON BIOGAS SUSTAINABILITY AND ENVIRONMENTAL PROTECTION

1. How do you see the sustainability of your biogas?

a) Sustainability for longtime

b) Sustainability for short time

2. Do you still interested in using biogas?

a) Yes

b) Not

If not, why?

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Thank you for your feedback