



UNIVERSITY of
RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY



AFRICAN CENTER OF
EXCELLENCE IN ENERGY FOR
SUSTAINABLE DEVELOPMENT



UNIVERSITY of
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AFRICAN CENTER OF
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SUSTAINABLE DEVELOPMENT

Master's Thesis

Analysis of Biogas Failure

Case Study: Eastern Province, (Rwanda)

Thesis Number: ACEESD/REE/20/10

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A dissertation submitted to the African center of excellence in energy for sustainable
development

College of Science and Technology

University of Rwanda in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE IN RENEWABLE ENERGY

Supervisor: Dr. Venant KAYIBANDA

2020

Kigali-Rwanda



CERTIFICATION

This is to certify that the master's thesis entitled “**Analysis of Biogas Failure: Case Study of Eastern Province, Rwanda**” is a record of the original work done by Mr. NSEKAMBABAYE Theoneste in partial fulfillment of the requirement for the Award of Master of Science Degree in Renewable Energy Engineering at the University of Rwanda, College of Science and Technology.



DECLARATION

I, **Theoneste NSEKAMBABAYE**, hereby declare that this Thesis entitled “**Analysis of Biogas Failure: Case study of Eastern Province, Rwanda**” is my original work, and has not been presented for a degree in University of Rwanda or any other universities. This work is my contribution to the best of my knowledge under supervision of Dr. Venant KAYIBANDA and all sources of materials used for this thesis work has been fully acknowledged.

Theoneste NSEKAMBABAYE

Submission date: **22nd/10/2020**

This thesis has been submitted for examination with my approval as the University Advisor.

Dr. Venant KAYIBANDA

Thesis Advisor

Date: **October 22nd, 2020**

University of Rwanda



DEDICATION

This master's thesis is highly dedicated to Almighty God, my beloved parents, brothers, sisters and friends, my supervisor and classmates, Thanks to all for your ending encouragement and supports.



ABSTRACT

The majority of population in Rwanda lacks access of sustainable energy, and many of countries in African depend on traded energy. Energy is a backbone for economic development globally as well as in Rwanda. Low access to the reliable energy resources for Rwandans is a crucial challenge that needs more efforts to be resolved.

Biogas technology showed area linking all components cited above, Rwanda has the same problems with others African countries where people from rural areas do not have enough energy access in ever day activities and depend much on biomass such as firewood, solid waste, agricultural products, wastes from animal... in order to fulfil energy demand for cooking, and other purpose on daily life activities. and there are many disadvantages of these traditional fuels as they release harmful gases, deforestation and it is difficult to manage their heat released.

Biogas technology is one of the solutions to those issues above because it is non-conventional sources of energy at which can employed on responding to the low level income and rural area energy need also it used to combat fossil fuel combustion health effects and environmental aspects at a low cost Rwanda develop many programs and projects with aim of increasing the quality of life of all Rwandans and accelerated poverty reduction programs. which make easy and feasible the project of biogas technology.

This research entitled analysis of biogas failure drive on how the efficiency production of energy with biogas digesters and introduces, discusses various potential tools of this biogas failure and feasibility studies that this biogas technology can fit well with mitigate those failure of biogas programs in Rwanda specifically in Eastern province and will focus on sites statistical data through which will shows the real situation based on making discussions and survey on different people involved in biogas sector and biogas households to assist in finding the solutions to Rwandan energy sector as well as Rwanda vision through the renewable energy by discussion the knowledge and skills on biogas technology, in design, sites allocation and maintenance, for achieving the high efficiency of biogas, the rural energy reduction and environmental protection by using biogas energy.



ACKNOWLEDGEMENTS

This is my highly wish opportunity to express my sincere thankfully to individuals or groups who have contributed on my achievement of this project. Therefore, I would first like to thank Almighty God for his unceasing love and blessings that is always sufficient to me. I sincerely thank Dr. Venant KAYIBANDA, my project supervisor, for his constant support through the course and for providing necessary facilities to carry out this thesis work, and also all lecturers for their guidance and comfort that was given to me while conducting master's courses and thesis.

I thank the administration of University of Rwanda-College of Science and Technology, Especially the African Center of Excellence in Energy Studies for Sustainable Development (ACE-ESD) under world bank for their support, for suggestions and constructive recommendations during my studies and thesis work.

I also give my sincere thanks to my relatives, especially parents for their supports in my education, brothers, sisters, friends and all my classmates for their beneficial interventions, may God bless you all!



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LIST OF ABBREVIATIONS

UR: University of Rwanda

CST: College of Science and Technology

ACE-ESD: African center of excellence in energy sustainable development

AD: Anaerobic Digestion

EDPRS: Economic Development and Poverty Reduction Strategy

RT: Retention Time

MINIFRA: Ministry of Infrastructure

NDBP: National Domestic Biogas Program

REG: Rwanda Energy Group

SNV: Stichting Nederlandse Vrijwilligers (Netherlands Development Organization)

SACCO: Saving and Credit Cooperative

EDCL: Energy Development Corporation Limited

BGT: Biogas Technology

LPG: Liquefied Petroleum Gas

FIDA: International federation of women lawyers (IFWL), in Spanish Federacion Internacional de Abogadas (FIDA)

NISR: National Institute of Statistics of Rwanda

BD: Bio-Digester

FAO: Food and Agriculture Organization

GHG: Greenhouse gas

NPK: Nitrogen, Phosphorus and Potassium

VFA: Volatile Fatty Acids

KVIC: Khadi Village and Industrial Commission



LIST OF NOMENCLATURES

CH₄: Methane

CO₂: Carbon dioxide

NH₃: Ammonia

SO₂: sulfur dioxide

H₂S: hydrogen sulfide

H₂: hydrogen gas

N₂: Nitrogen gas

H₂O: Water vapor

O₂: Oxygen

Kcal/m³: kilocalorie /cubic meter

°C: Degree Celcius

Km²: square kilometre

Sq. mi: Square mile

CHAPTER ONE: GENERAL INTRODUCTION

1.1. Introduction

Landlocked country like Rwanda with minor industries sector and few other natural resources, seeking the way of improving the energy sector; the alternatives of sources of energy to improve the energy power of the country. The renewable energies are the most important parts to the global economy and prosperity, in the recently the fossil fuel was the primary energy source with the impacts on the global climate changes, environmental impacts and human health circumstances[1]. According to the world globally efforts on displacing the fossil fuels used for energy production and the necessity of finding environmentally sustainable solutions for the treatment and recycling of animal manure and organic wastes. Rwanda chooses renewable energy as the solution, the biogas plant or latrine when successful is an appropriate and sustainable method to deal with human or animal waste. Rwanda has the same problems with others African countries where people from rural areas do not have enough energy access in ever day activities and depend much on biomass such as firewood, solid waste, agricultural products, wastes from animal... in order to fulfil energy demand for cooking, and other purpose on daily life activities. and there are many disadvantages of these traditional fuels as they release harmful gases, deforestation and it is difficult to manage their heat released, the biogas plants energies came to solve this problem of energy sector duplicity.

Biogas is a combustible/flammable gas produced from several organic wastes like agricultural, animal, domestic and industrial (except wood) through anaerobic digestion, during an anaerobic digestion (absence of oxygen) inside a tank called Biogas plant through bacteria action, the Biogas plants are considered to be the cheap sources of energy in rural areas.

Using biogas for cooking and lighting reduces the strain on the environment by decreasing the use of biomass and the production of greenhouse gases (as methane that is produced normally from manure is now captured and used). The biogas technology was launched in Rwanda at the end of 1990s in search of an alternative energy for cooking and lighting and as an environment conservation strategy.

1.2. Background of the study

The government of Rwanda through its Ministry of Infrastructure (MININFRA), the authority in charge of energy has initiated different initiatives aimed at finding long term solutions to energy shortage in the country where no investment has been done the last 20 years in electricity generation. Amongst these solutions, biogas has been identified as one of the sectors to develop[3].

The feasibility study of biogas technology has been carried out with the help of the Netherlands Development Organization (SNV), to see the viability of a biogas program. There are many findings include more than 100 000 potential households meeting technical requirements to get a biogas plant, government enthusiast and commitment to such a program and financial capacity & willingness for farmers to invest in biogas. After this feasibility study, the ministry has set up a national domestic biogas program with clear objectives of building 15,000 family sized and the quality biogas plants by the end of 2011 (the first phase of 4 years). But even there is those project of biogas construction in Rwanda they occurs many failure of those projects, this is what my research will focused to analyze this failure by looking the main causes of those different failure of biogas projects in Rwanda generally[4].

1.3. Statement of the problem

Energy sector has become big issue for the economic development for many countries. Rwanda also is facing a serious energy crisis, which can be continuous growing. Hence, the government of Rwanda through its ministry of infrastructure in charge of energy has initiated different initiatives aimed at finding long term solutions to energy shortage in Rwanda where investment has been done in electricity generation. In order to find different solutions, Rwanda chooses renewable energy especially the biogas energy has been identified as the one of sector to develop and after this feasibility study, the ministry of infrastructure has set up a national domestic biogas program with clear main objectives. But even there is those projects of biogas construction in Rwanda many failures of those projects happened, this is why this research is conducted for analyzing the failure of those biogas plants in eastern Province.

This research entitled “**Analysis of Biogas Failure** ”provide solution to those failures of biogas to strengthen in security of construction projects skills, design and maintenance for improving its comfortable and reducing the low performances caused by those failures.

1.4. Research objectives

1.4.1. Major Objectives

The major objectives of the research study “**Analysis of Biogas Failure in Eastern Province, (Rwanda)**” is to improve the sustainability of biogas plant projects and uphold the maintenance of biogas plants for making them comfortable. and provides high performances by improving the knowledges, technical skills of biogas holders, biogas users and technicians with indicating the measures to mitigate the biogas projects failure in eastern province and in Rwanda generally.

1.4.2. The specific objectives

The specific objectives of this research study are:

- To analyze the biogas failure by providing the causes of this failure in biogas construction projects
- To analyze the biogas failure by providing the causes of this failure of biogas in design skills
- To analyze the biogas failure by providing the causes of in biogas maintenance and biogas feeding
- To reduce low performance of the biogas by providing the causes of this low performance and how to mitigate in order to achieve efficiency performances of biogas projects in eastern province.
- To provide the measures must be followed to mitigate the biogas failure in Rwanda.

1.5. Scope of the study

The scope of this research project performed in Rwanda, specifically in Eastern Province because obviously it is where huge number projects of biogas plants are found as indicated by the Ministry of Infrastructure (MININFRA).

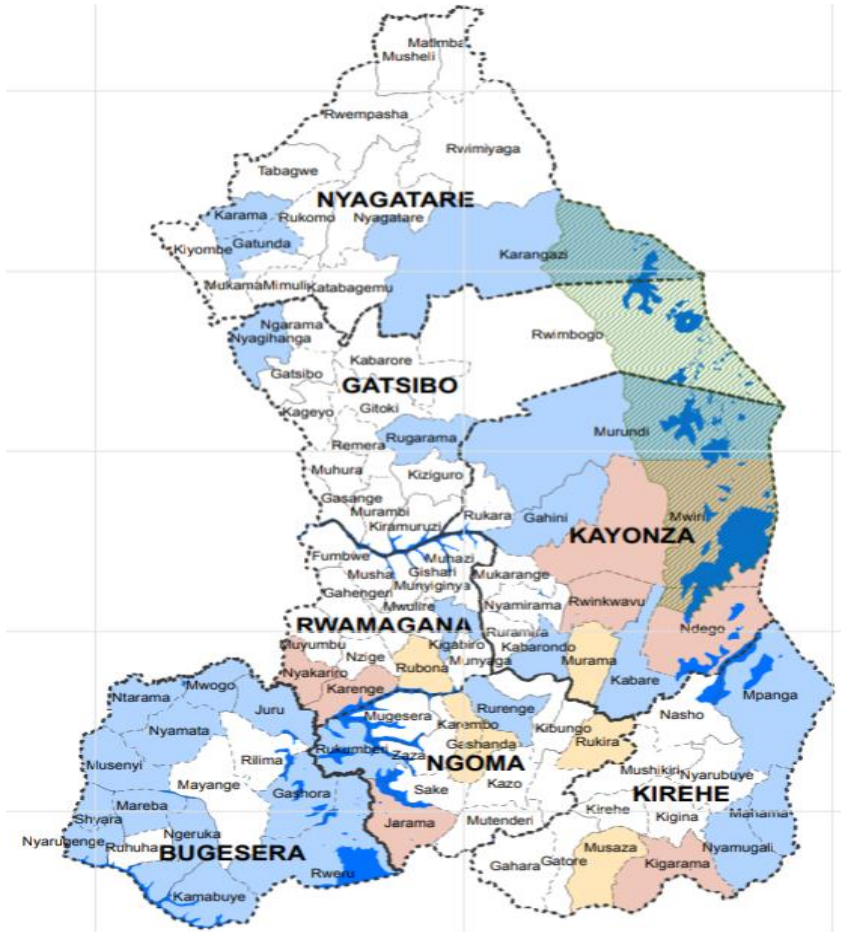


Figure 1: Eastern province districts map (data source: MINALOC 2014/2015)

Eastern province of Rwanda is the largest, the most populous and the least densely populated province of Rwanda with seven districts: Kayonza, Bugesera, Gatsibo, Ngoma, Kirehe, Nyagatare and Rwamagana. The capital city of the eastern province is Rwamagana.

The eastern province of Rwanda has total area of 9,813km² (3,789 sq. mi) and the population around 2,660,814 with density of 275/km² (710/ sq. mi)

1.6. Expected Outcomes and Significance of the Study

1.6.1. Expected Outcome of the Study

This research project will give outcomes impacts in different sectors of renewable energy resources, especially in biogas by proving the causes of failure of biogas at the end this research project will help in improving the technical skills of biogas construction strategies in order to mitigate this failure, improving the maintenance of biogas plants by achieving sufficiency performances and findings the long-term solution to energy shortage in Rwanda by using biogas as energy resources particularly.

1.6.2. Significant of the Study

This project research will help to improve the knowledge and skills to the renewable energy especially in biogas energy sector to achieve the efficiency performance of biogas plants by indicating the causes of biogas failure in Rwanda, such causes can be found in design of the biogas plants, improving the skills and knowledge of technicians for maintenance and construction purpose of biogas and improving the knowledge in site allocations of biogas plants in Eastern Province (Rwanda).

1.7. Limitation of study

There are the challenges associated with this research study, such as quantification of the exact daily human manure and animal wastes as primary data were constrained by time limit, monthly money spend on maintenance of your biogas systems as time frame for this research was not sufficient enough to record such kind of primary data. Therefore, this study relied on both primary and secondary data from different literatures. It was not easy to get quality data since the study relied on use of questionnaire, respondent might not have been honest with the answers given or be biased and give information out of context of the situation.

1.8.Thesis structure

The thesis work began with introduction remarks, which covers briefly the general global renewable energy, especially the biogas energy situation in Rwanda; background of the study that emphasized on key information about biogas in Rwanda; the statement of the problem; the main and specific objectives of this research study; expected outcomes with this study, significance from this research; the scope of the study that includes both geographic; and content scope; and hence limitations of the study.

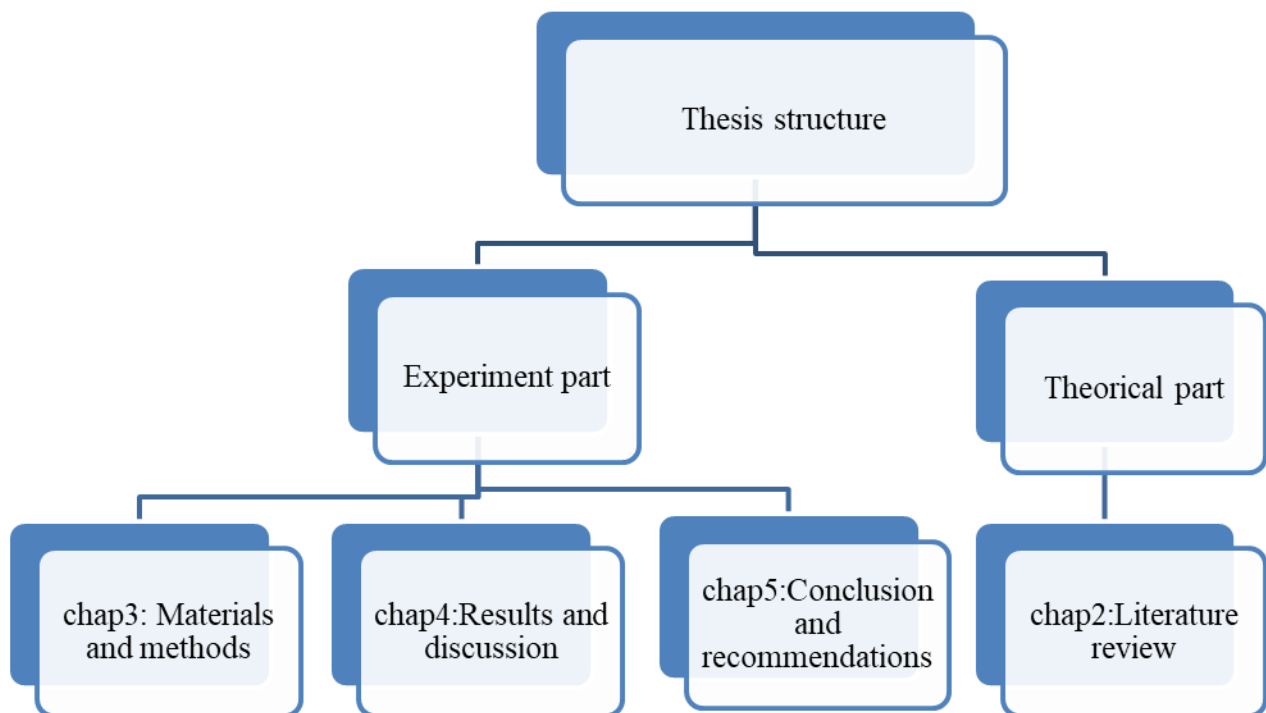


Table 1: Thesis structure

Chapter two: Literature review, in this chapter includes:

- ✓ The Research in the areas related to the study topic, case studies on biogas production technologies
- ✓ Theory and research literature relative to the topic:
 - Biogas production process, designs of biogas plants or types of biogas plants, ...

Chapter three: Materials and methods, in this chapter includes:

- ✓ Description of geographic scope; target population; sampling procedure and sample size; and research instrument.

Chapter four: Results and discussion, in this chapter includes:

Family Size from survey, Estimation of the plant's money spend on maintenance, households' trainings and workshops on the use of biogas plants data, mostly relevant causes of biogas failure, mitigation parameters for biogas failure.

Chapter five: conclusion and recommendations; in this chapter includes:

- ✓ Research findings in summary or brief and remarks.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The fossil fuel as primary energy source has led to global climate change, environmental degradation and human health problems the government of Rwanda is increasingly looking at alternative sources of energy to power the country given the energy deficit, Renewable energy is one of the most important factors to global prosperity. Rwanda chooses renewable energy as the solution, a biogas plant or latrine when successful is an appropriate and sustainable method to deal with human or animal waste.

The costs of biogas system are particularly high compared to rural household incomes and it is representing the main barriers to the adoption of the biogas technology at household level. To help overcome these barriers, the national domestic program provides a subsidy to each system installed, the farmers being expected to finance the rest of the upfront costs with possible credit to the banks or savings and credit cooperative. The subsidy approval scheme has evolved since the inception of national domestic biogas program, in the initial form of the national domestic biogas program authorized biogas company for final approval by the Rwanda energy group [7].

2.2. Related studies

2.2.1. Biogas energy

The biogas energy is generated by Biogas plants systems. Biogas is a clean fuel produced through anaerobic digestion of several organic wastes like agricultural, animal, domestic and industrial. Biogas made from organic waste matter after it is decomposed, biogas is tremendously used as fuel. The feed material is mixed with water in the influent collecting tank. The fermentation slurry flows through the inlet into the digester. The bacteria from the fermentation slurry are intended to produce biogas in the digester. For this purpose, they need time to multiply and to spread throughout the slurry. The digester must be designed in a way that only fully digested slurry can leave it. The bacteria are distributed in the slurry by stirring with a stick or stirring facilities[1]. The fully digested slurry leaves the digester through the outlet into the slurry storage. The biogas is collected and stored until the time of consumption in the gasholder. The gas pipe carries the biogas to the place where it

is consumed by gas appliances. Condensation collecting in the gas pipe is removed by a water trap[10].

2.2.2. Biogas production process

The Biogas is a methane rich gas, which results from anaerobic digestion that breakdown the organic materials with the absence or with the presence of oxygen in the system. The anaerobic digestion process converts the energy stored in organic materials present in organic matter into biogas. When converted, biogas can either be used directly for cooking through biogas stoves. Biogas can be used to generate electricity from thermo- electric power plants through generating steams that run the steam turbines. Biogas can also undergo further purification and upgrade processes to generate diesel that is used in the vehicles. Biogas digestate constitute a very good fertilizers (NPK) that is useful for crops (Abbas.T, et al., 2012). The use of anaerobic digestion (AD) technology has been expanded in recent times following the widespread concerns of researchers for the use of sustainable renewable energies. Due to several effects of greenhouse gas (GHG) on climate change as a result of fossil fuel consumption has led to the growing interest in biogas production to curb the situation (Akoore. A.,2018). The production processes of organic materials take place in four (4) main phases as follows:

➤ hydrolysis

During this process, the complex polymers such as carbohydrates, proteins, fats are degraded into the sugars, amino-acids and long-chain fatty acids respectively. This stage plays an important role in ensuring that enough chemical reaction is taken place to prepare the soluble content to the next chemical stage. The hydrolysis steps consist of unique procedures such as enzyme reaction, adsorption, and diffusion (Cirne et al,2007). Substantially, all chemical enhancements assist in smooth and higher methane production. However, the challenge associated with hydrolysis is commonly found in organic waste but most can be composed by reagent chemical application (Vavilin et al, 1997).

➤ Fermentation or Acidogenesis

The acidogenesis step is operationalized by a microbial process known as acid forming fermentation. It is the second step in bacteria consortia of anaerobic process. The microorganism in acidogenesis stage further transform the hydrolyzed content into small organic acids. The nutrients ratio of carbon dioxide and hydrogen is categorized into 70% of volatile fatty acids (VFA), 30% of alcohols (Al Sead et al.,2012). The organic acids are converted into acetic acids and hydrogen with acetogenic bacteria. The reflective conversion factors in acidogenic phase are mostly glucose to ethanol and glucose to propionate (Ostrem & Themelis,2004).

➤ Acetogenesis

In this stage, the fermentation products such as alcohols and organic acid are digested by acetogenic bacteria to produce acetic acids alongside with hydrogen and carbon dioxide. The critical element in acetogenesis is hydrogen, and this is because without the presence of H₂ concentration no chemical reaction could take place (Ray et al.,2013). The temperature in acetogenesis is quite an important parameter since it affects the thermodynamics of acetogenic reactions (De Bok et al 2004). The interspecies electron transfers in methanogenic propionate degrading groups is influenced by the chemical reactions at the previous steps. Formation of hydrogen from organic acids becomes stronger at higher temperatures whereas, in methanogens phase, H₂ consumption becomes less energetic (Akoore, A.,2018)

➤ Methanogenesis

The methanogenesis phase is the last step and is the most crucial stage in the anaerobic digestion processes. This stage is regarded as the slowest biochemical reaction process when compared to others. This depends on the processes condition like feedstock composition, P^H, temperature and the retention time cannot be underemphasized. The methanogenesis is the sensitive and the critical stage in anaerobic digestion process during methane production with less substrate content (Al Seadi et al.,2008).

Those main phases of organic matter transformation processes are presented in diagram below:

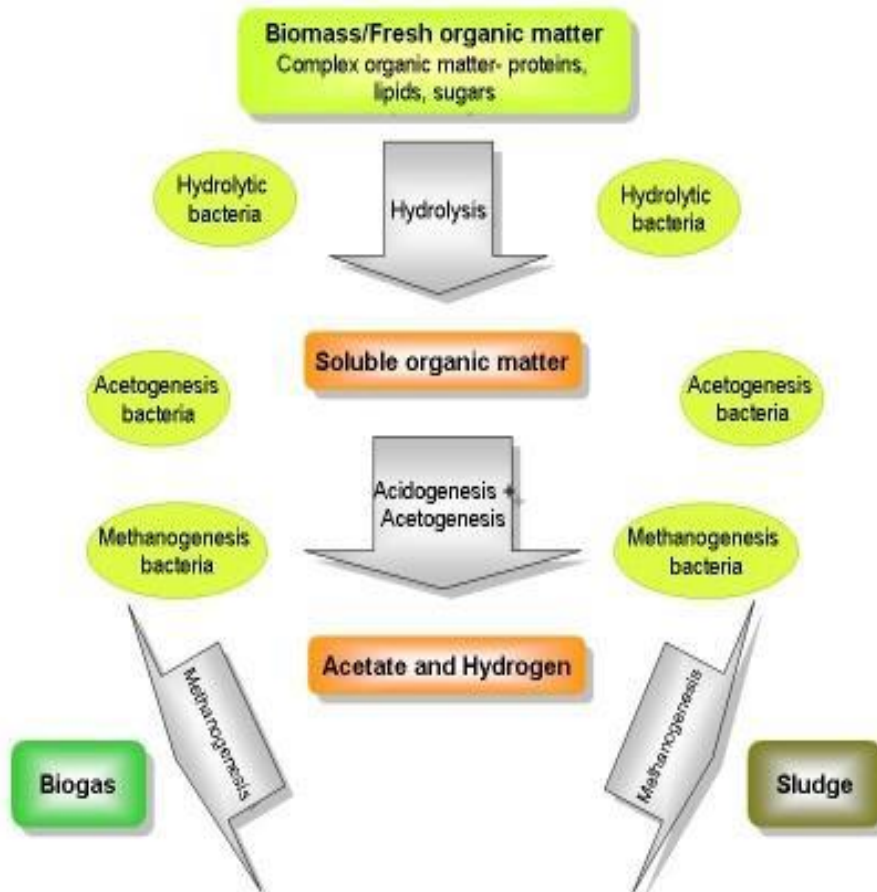


Figure 2: Anaerobic digestion diagram ("Biogas composition", 2017)

2.2.3. Products of anaerobic digestion process

The biogas is relatively clean burning, colorless, and odorless gas. The biogas is composed by methane (CH₄), carbon dioxide (CO₂), some traces of nitrogen, ammonia (NH₃), sulfur dioxide (SO₂), hydrogen sulfide and hydrogen depending on the feeding materials used. Generally, the gas produce from anaerobic digestion consists of methane, carbon dioxide with other small quantities like Nitrogen, Hydrogen. And the biogas composition varies depending on the origin of anaerobic digestion process [8], the table below presents the composition of biogas as indicated in above .

Matter	Chemical symbol	Percentage (%)
Methane	CH ₄	55-75
Carbon dioxide	CO ₂	30-45
Nitrogen	N ₂	1-2
Hydrogen	H ₂	3-10
Hydrogen sulfide	H ₂ S	0-3
Oxygen	O ₂	1-2
Water vapor	H ₂ O	0.3

Table 2: Products of anaerobic digestion process[8].

This table shows that the methane as one products of anaerobic digestion has huge amount in percentage on biogas composition, when biogas is in functionality you have also to consider the feeding materials which are being used because will have mainly role on sufficient biogas which might be produced.

In table below indicates how methane percentage containing in biogas will be produced according to the feed stock in biodigesters. The percentage of methane contains in biogas produced from various feedstock is presented in the following table:

S/N	Feed stock (feeding materials)	Content of Methane in Biogas in Percentage %
1	Cattle manure	54-56
2	Pig manure	57
3	Poultry manure	55

4	Farm yard manure	55
5	Straw	55
6	Leaves	58
7	Grass	60
8	Kitchen waste	50-52
9	Human excreta	60

Table 3: Methane content in biogas produced from different feedstock [8].

2.2.4. Description of biogas plant

A Biogas plant is an airtight tank in which organic wastes mixed with water can be digested/fermented through anaerobic bacteria action and Biogas is generated. The biogas plant is composed by the following components:

Inlet tank/ mixing tank: Part where mixture of organic material and water pass to enter into the tank body,

Outlet tank/ Expansion tank/ Compensating chamber: Part where bio effluent is stored

Man hole/Neck: Part where builders can pass during the construction of the Biogas plant. It is where Removable lid is put after first feeding of the biogas plant. Level indicating pressure of gas in the dome, Scum: Floating organic materials, Settlement of mad, Settlement of sand and soil, Reference level: Low limit of empty space

Inlet pipe: Pipe connecting the inlet tank and the digester/ tank body in which mixture or raw material and Water pass by gravity,

Overflow: Pipe taking bio effluent outside the outlet tank (It is at 15 cm from the top of the outlet tank.

Mixing tank: is where the feeding materials; dung, human excreta ...are gathered and mixed together with water. The water must be sufficient and the mixture has to be homogeneous slurry.

Digester: is the component of biogas plant where the slurry is fermented and the biogas is produced through the bacteria action.

Gas holder or gas storage dome: The biogas thus formed gets collected in the gas holder. It holds the gas till the time it is transported for consumption.

- **Outlet pipe:** The slurry is discharged into the outlet tank. This is done through the outlet pipe or the opening in the digester.
- **Gas Pipeline:** The gas pipeline carries the gas to the utilization point like a stove or lamp[11].

2.3. Types of biogas digester

The biogas digesters can be categorized in two categories: **Batch** and **Continuous digesters**.in two main categories which are **batch** and **continuous digesters**. The main difference of these two is that the batch digester is filled and operates for a longtime whereas the continuous digester is filled regularly, the batch digesters should have the higher volume than a continuous to digest the same amount of feedstock.

The digester size is defined as the total volume or size of biogas unit; includes the effective size of volume occupied by fermented materials and volume of gas storage. the following formulas are used for different parameters in designing of the biogas plant where the size of biogas plant digester is calculated by the following formula:

$$V_T = V_D + V_d + V_b \text{ (m}^3\text{)} \quad (1)$$

Where:

$$V_D = \frac{\pi \times D^2 \times H_D}{4} = \pi R^2 H_D \text{ (m}^3\text{)} \text{ or } V_D = DFM \times RT \text{ (L or m}^3\text{)} \quad (2)$$

$$V_d = \pi H_d^2 \left(R_d - \frac{H_d}{3} \right) \text{ (m}^3\text{)} \quad (3)$$

$$V_b = \pi H_b^2 \left(R_b - \frac{H_b}{3} \right) \text{ (m}^3\text{)} \quad (4)$$

$$DFM = \frac{V_D}{RT} \text{ (L/day)} \quad (5)$$

$$RT = \frac{V_D}{DFM} \quad (\text{days}) \quad (6)$$

Where

- V_T : Total volume of digester
- V_D : volume of digester
- V_d : volume of dome
- V_b : Volume of the bottom
- **DFM**: daily feeding materials
- **RT**: Retention time
- H_D : Height of digester
- **D**: diameter of digester
- H_b : height of bottom
- R_d : radius of dome
- R_b : radius of bottom
- H_d : height of the dome

2.3.1. Types of continuous digester plants

2.3.1.1. Fixed dome plant

The fixed dome biogas plants are mostly ancient type, the most known and used type of digesters plants in the world, and the first fixed dome digesters has been launched in china in 1936 ("Fixed dome digester - Appropedia: The sustainability wiki", 2017). It is composed by the mixing tank constructed above the ground, inlet with outlet ports and overflow tank, the inside of the dome there is fixed gas holder which holds the produced biogas. The main advantages of fixed dome digesters are cheap in construction because requires cheap technology with low budget for the initial investment with low costs in construction and long lifespan which can reach over 20 years (working of biogas plants, n.d., 2003).

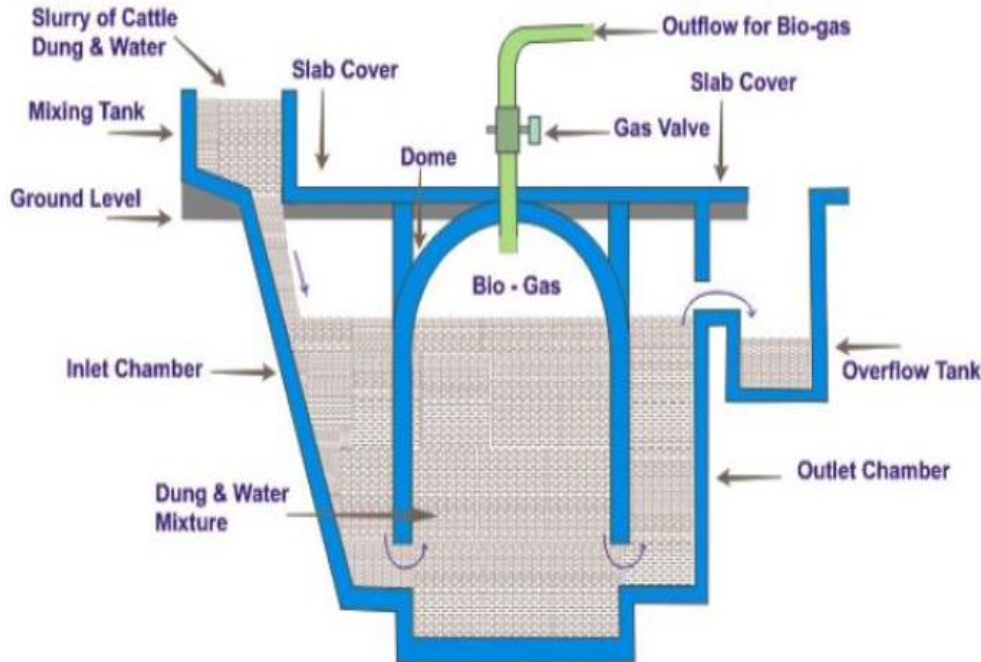


Figure 3: fixed dome-type, biogas plant (Florentino, 2003)

Types of fixed-dome plants

- **Chinese fixed-dome plant** is the archetype of all fixed dome plants. Several million have been constructed in China. The digester consists of a cylinder with round bottom and top.

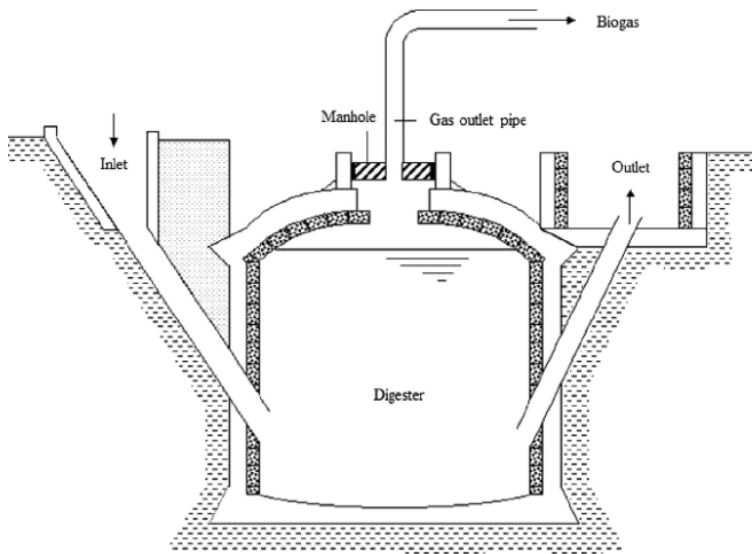


Figure 4: Fixed dome digester (Chinese type), source: <https://www.researchgate.net/> visited on 10 October 2020

- **Janata model** was the first fixed-dome design in India, as a response to the Chinese fixed dome plant. It is not constructed anymore. The mode of construction leads to cracks in the gasholder - very few of this plant had been gas-tight.

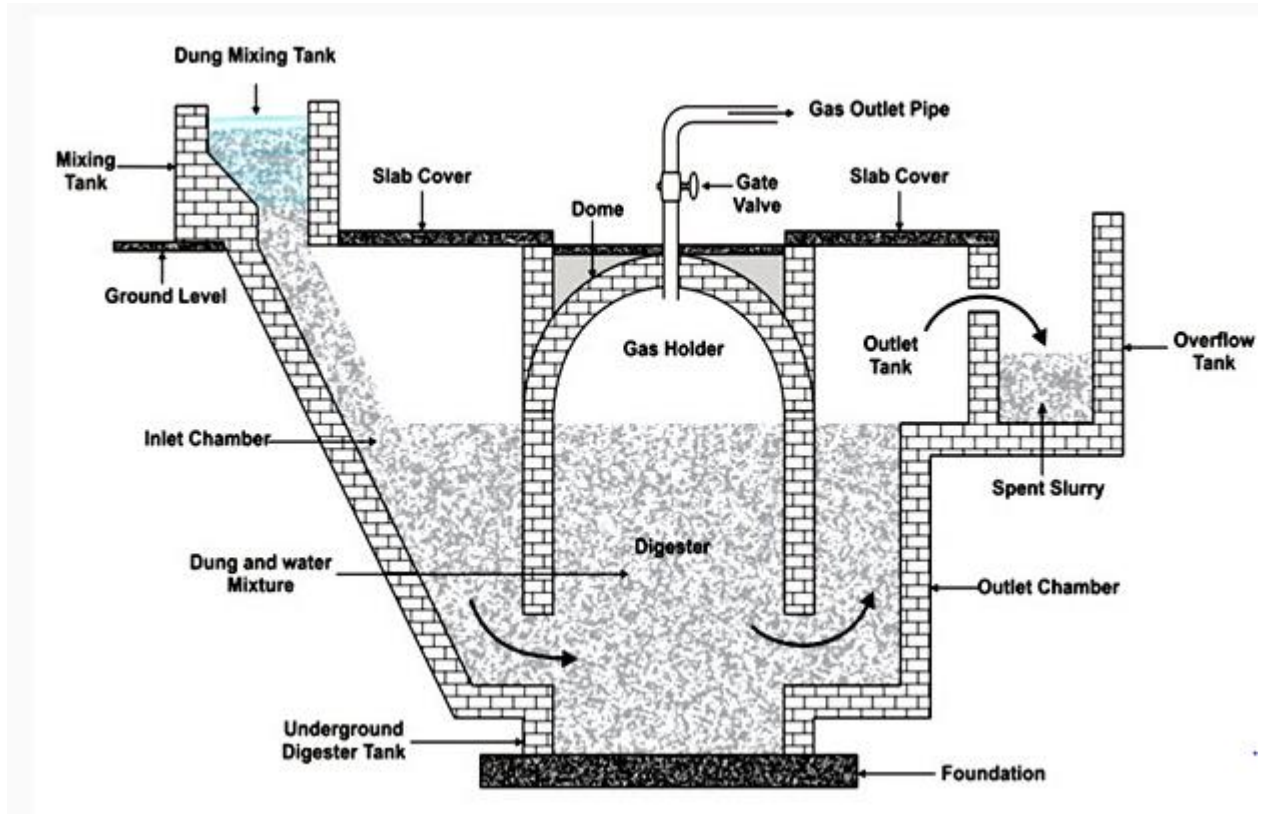


Figure 5: Fixed dome biogas plant (Janata Model), source: <http://mechanicalinventions.blogspot.com/2014/06/>

- **Deenbandhu**, this is the successor of the Janata plant in India, with improved design, was more crack-proof and consumed less building material than the Janata plant. with a hemisphere digester.

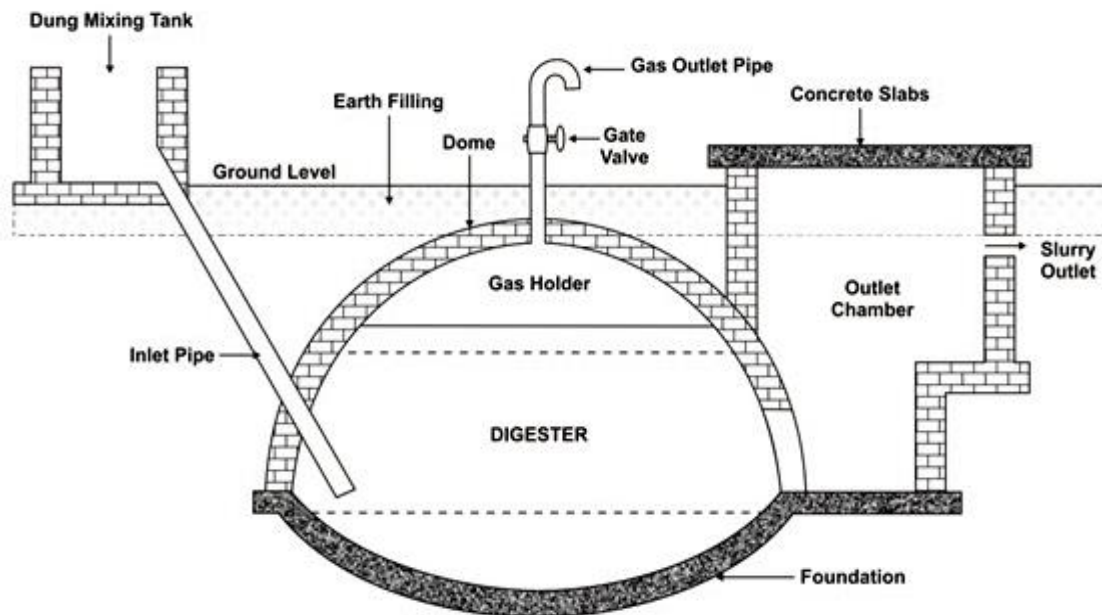


Figure 6: Deenbandhu Model biogas plant source: <https://energypedia.info/> visited on 09 October 16, 2020

- **CAMARTEC model**, this has simplified structure of hemispherical dome shell with a rigid foundation ring and calculated joints of fraction and it was developed in the late of 80s in Tanzania. In full words, CAMARTEC is the Centre for Agricultural Mechanization and Rural Technologies.

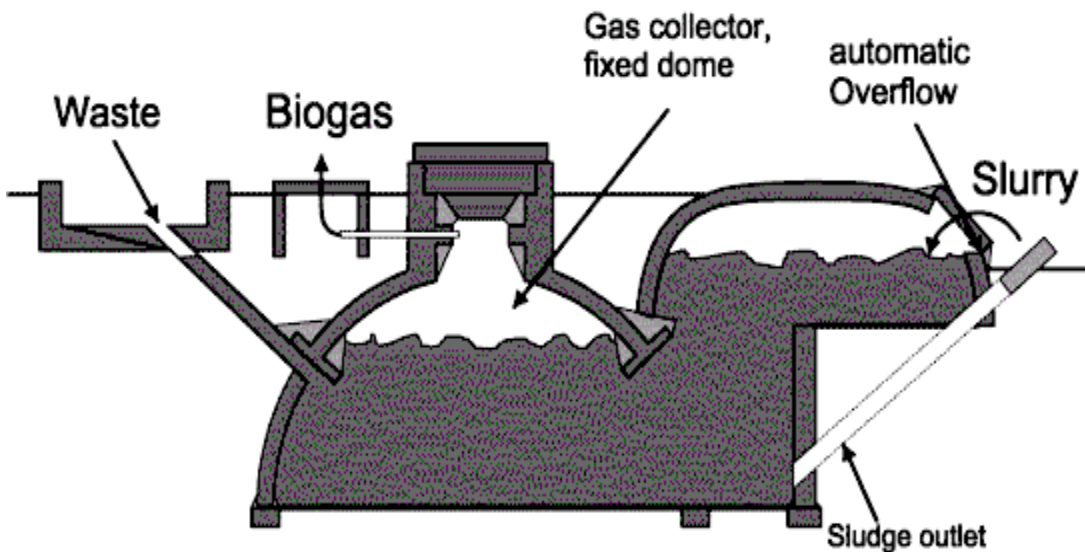


Figure 7: Fixed dome digester (CAMARTEC Model), source: <https://energypedia.info/> visited on 09 October 16, 2020

2.3.1.2. Floating drum plant

The floating biogas plant are commonly called Indian type of digesters, it was introduced in Indian in 1962 by khadi and village industry. This type of digesters is polyvalent because it can be used in small scale purposes for farmers and can be used for larger scales such as agro-industries. The floating drum digesters are mainly composed of different components similarly to the fixed dome digesters but the floating digesters have a dome shape at the top which is the main difference between fixed dome digesters and floating drum plants, the figure below represents the floating drum plant.

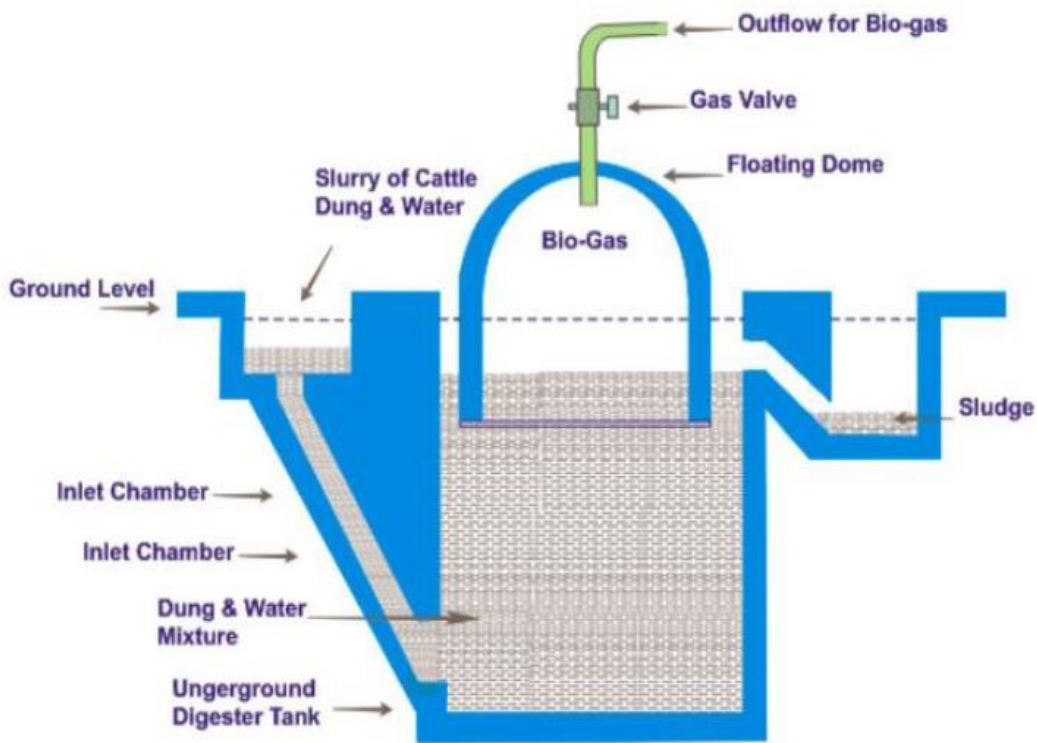


Figure 8: Floating dome-type biogas plant (Florentino, 2003)

2.3.1.3. Balloon biogas plant

The balloon biogas plants are also called tube digesters or ball type digesters; are the digesters plants which consists with the long tube made in plastic generally and are very popular and widely used around the world because of cheapest costs than other and easy in construction. The innovative technology of balloon biogas plant was launched in African regions in 1993 “throughout a technical cooperation program conducted by the FAO (Food and Agriculture Organization of the United Nations) in Tanzania. This program aimed to transfer and adapt technologies that had been previously validated in other tropical developing countries”

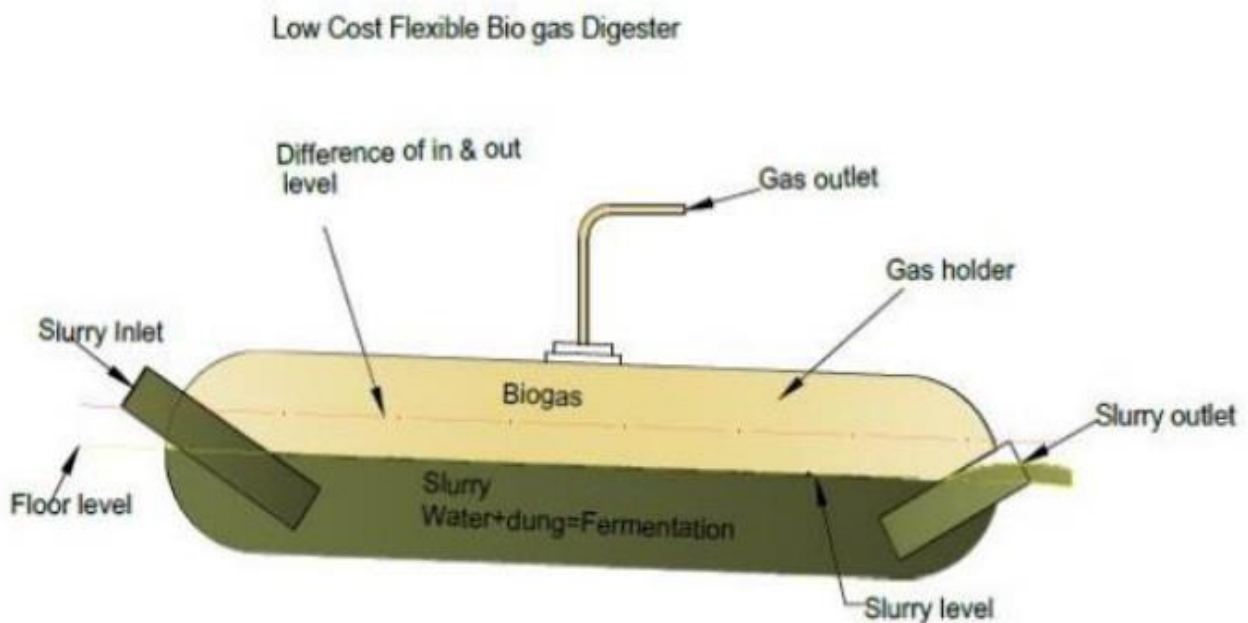


Figure 9: Balloon digester plant (Florentino, 2003)

2.4.1. Biogas failure

The failure of Biogas Technology projects in this research study means no biogas production either immediately or after installation of biodigesters or after using biodigesters for some time period. The research conducted by SNV Rwanda UR-CST on different biogas digester plants, found that the biogas digesters that have been working for at least 5years in good working mode were few. The main reason behind those failure is lack of follow up for technical assistance (Gloria. V, Claude, et al.2015).



Figure 10:Types of biogas digesters found in Rwanda (REG-NDBP,2015)

According to Rwanda Energy Group- National Domestic Biogas Program (REG-NDBP,2015), about 78.3% of fixed dome and 47% fiber biogas digester plants were found in Operation countrywide in 2015.

And in Pakistan, among the first form of failure, many of biodigesters have not started working for the first time of biodigesters operation and consequently were broken by the households, the main reasons of this case were the use of poor quality of construction material and inexperienced masons. Actually the households were expected to buy other construction materials by themselves, with also the problem about its quality and masons without trainings, however, masons were not experienced which explains that FIDA has to provide the training for masons, they did mistakes in measurements of biodigesters design resulted improper biodigesters construction [10].

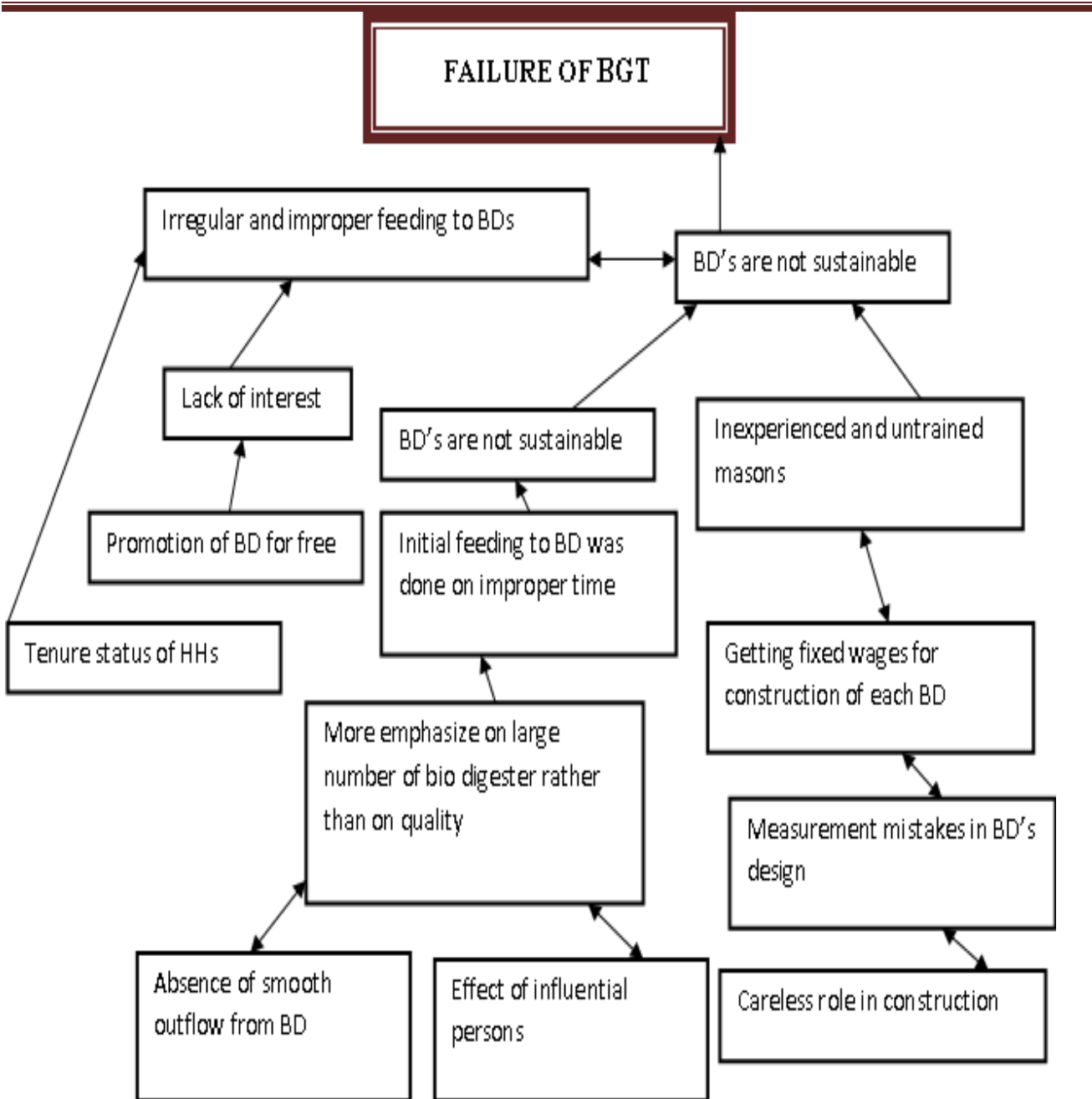


Figure 11: Problem tree analysis diagram on biogas failure[10].

The problem tree analysis above indicated some technical reasons of biogas failure, such as some households claimed that the biodigesters were not working for the last 5-6 months and the problem was when the dungs were fed in the inlet tank, it came out again in inlet tank and the little production of biogas with no outflow slurry.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0. Introduction

This chapter describes the methods were used to conduct this research project including various stages and phases followed in the data collection methods which include personal/face to face interviews, observation method and questionnaire method, and analysis of those data from different sources. In specifically the following subsections included: research design, sampling procedures, target population, sampling procedures, data collection instruments and data collection procedures, regarding this research project.

3.1. Research procedure

This research was conducted in eastern province in various regions to find the real status of biogas failure in this region, to complete and reach the purpose of the study the following procedures were followed;

3.1.1. Research design

The research design discusses the method framework and technical methods chosen, descriptive research design was worked on put together the among data bond on biogas failure in design and other adjustable information on biogas use. Other research design focused on biogas maintenance and repair. Descriptive research was applied by collecting data on identifying the causes of biogas failure which can occurs during biogas design, construction works and in biogas use and research design have been applied by proving the causes of biogas failure regarding the maintenance activities. All those methods were applied in order to bring a deeper comprehension and well understanding on the opportunity of biogas failure.

3.1.2. Study population

This study was carried out in 7 districts composed Eastern province of Rwanda, by considering one village per district. Total study population was 112 households and the surveying questionnaire form filled by indicating the biogas operation and other principles regarding biogas technology. This was to understand whether there are some challenges and/or benefits of biogas plants, it has also included, the households with non- operating biogas digester. This was aimed at understanding their reasons to do not have those biogases operated properly.

3.1.3. sampling techniques

This sampling techniques was used to the respondents, to know different causes of biogas failure in general and without consider only one part of people to involve in research but everyone to participate in this research and have equal contribution about the proper working and non-working properly biogas plants. This technique minimizes the number of people interviewed; Therefore, researcher needs to choose one by one purposively. The participated people were the biogas holders, technicians and biogas users and other people involving daily in biogas sector. The responses from the interviews with different selected participants, the qualitative and quantitative data, both were collected to know exactly different causes of biogas failure. Quantitative and qualitative data were collected to know exactly the different causes of biogas failure.

3.1.4. Source of data

➤ Primary data

The primary data of this research were coming from different sites, where the biogas plants were constructed in those data the researcher filled the questionnaire form by the data collected from the biogas households and on the online survey also, personal interviews were also used to collect the data from different sites of Eastern province regions, especially the research focused on biogas operation by referring on the general causes to the improperly working and non-working biogas plants. The researcher also used observations in order to gain the quality data on biogas operation by giving more general causes on the problem of biogas failure and by showing the feasibility of overcoming this problem in biogas plants of eastern province.

➤ Secondary data

The data were collected from the review of documentations from various textbooks and internet and other relevant sources, here it was found data about the general causes of biogas plants failure and general operation of biogas plants. Those different textbooks participated in this research giving the full information about various biogas plants functionality and deeper give which parts of biogas plant has the problem cause the mal functionality of biogas or totally failure of biogas plant in production of biogas.

3.1.5. Interviewing methodology

The technique of interview was used for getting information about the biogas performances, design, maintenance and feeding process. This was applied from various biogas users and holders, biogas construction companies, ministry of infrastructure, in different regions of Eastern Province, Rwanda. This technique was mainly used because it is more flexible and allows the researcher to get more answer that could not otherwise be covered in questionnaire in case the respondent, especially on local people are more comfortable, and easy to express their idea freely with this method. all evidence and data collected during the conversation in which the researcher gets information from the interviewer with main purpose is to obtain necessary information. The people interviewed were conducted in Gishari, Kigabiro, Nyakarambi, Kibungo, Muhazi, Jarama Sake... it was collected data about numbers of working properly, improperly and non-functioning biogas plants

3.1.6. Questionnaire methodology

This methodology has been used to collect data from various regions of eastern province by using the form of questions regarding the functionality of biogas plant and biogas technology in general. Here the questions were based on the improper or non-working of biogas plants by giving the deeper information on the causes of biogas failure and how this problem can be mitigated in this region. Here the questionnaire methodology provided a relatively quick and efficient way of obtaining large complete and accurate data from large sample of respondents of eastern province on biogas plants.

3.1.7. Surveying, observation methodology

This technique of surveying and observation was used for obtaining the first-hand information on biogas operating principle of eastern province from different regions, let look in Gishari sector where the biogas was surveyed and it find that on performance, at Rwamagana site in 20 biogas visited, 17 of them the households say that they didn't produce enough gas compare to the feeder stock and by using the pressure gauge it showed that the pressure inside the vessel was at low level in those biogas plant while the digester was completely with the feeder materials, there are the insufficient of biogas production which leads on biogas failure and on maintenance it found that the biogas holders they are missing the basics knowledge of biogas technology on maintenance area whereby the small problem failure of biogas plant they don't know to handle it and some of them

they don't even know whether the biogas plant need some maintenance as cleaning of digester before re-feeding and the feeding procedures of biogas plants which are negligible with biogas holders.

There are 2 different methods might be used for feeding biogas plants as follows: **Batch feeding and continuous feeding.**

➤ **Batch Feeding digesters**

The batch feeding digesters are biodigesters which use the feeding materials in periods, starts producing biogas slowly increase in the production then drop off two or one months. The tank is opened and the old slurry or used materials from digesters are used to fertilize the soil and other new feeding materials are added. Batch digesters are best operated in groups so that one is always producing useful quantities of gas production.

➤ **Continuous-feeding digester**

With continuous-load digesters, a small quantity of raw material is added to the digester every day. Continuous-feeding digesters are especially efficient when raw materials consist of a regular supply of easily digestible wastes from nearby sources such as livestock manures. Continuous-feeding digesters can be of two basic designs: **vertical-mixing or displacement** as shown in figures below. Vertical-mixing digesters consist of vertical chambers into which raw materials are added. The slurry rises through the digester and overflows at the top. Single-chamber designs the digested or "spent" slurry can be withdrawn directly from effluent pipes.

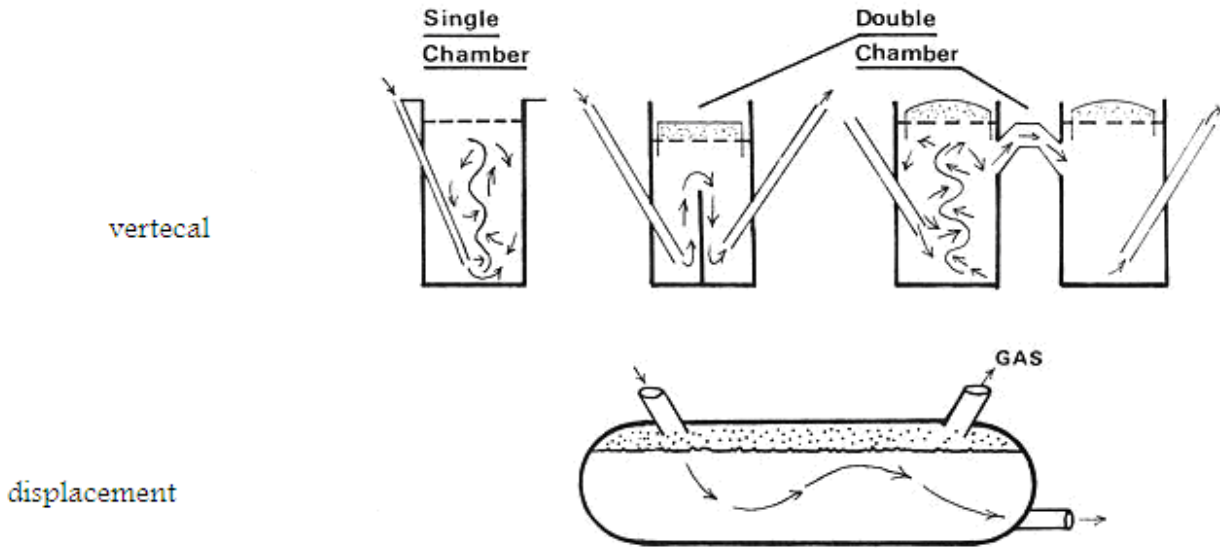


Figure 12: Continuous-feeding digesters

3.1.8. Data collection Methods

In this research work, it was used quantitative research and qualitative. Quantitative was used for collecting data about total number of biogas plants in eastern province and qualitative was used for collecting data on how those biogases operate if are working properly or if have been failure. Quantitative research is reflected to quantify the biogas failure problem in order to produce numerical data and data at which can be used in statistical way it focuses on quantification of data like behaviors, attitudes, opinions and so on. Qualitative research is reflected to explore, to understand reasons, motivations, and opinions. It offers comprehensions into the situation of a problem and help to develop hypothesis ideas on biogas plant functionality by referring the problem of improper working of biogas plants in various region of eastern province of Rwanda.

3.1.9. Limitation of study

There are some limitations that made the research process challenging and these were as follow: Differences in data and information provided by different respondents; Time constraints: most of the respondents had little or no time to respond to the interview guide. This is because they are very busy with daily life activity. To overcome all the above limitations, it was done the comparison of



data, reports and their time of delivery. To eliminate that doubts about the relevance of data such as survey, questionnaire, different government reports and textbooks were used to reduce the chances of data withhold, and stuck to the timetable by best use of the short time to meet the deadline. And in data collection there is other challenges meet with the pandemic of COVID-19, the challenge was to reach on site by means of transports and the trust between the questioner and the respondents regarding the healthcare to deal with this problem we use many reports regarding biogas plants status in Rwanda and other textbooks. The other challenges were in internet connectivity because no way to reach to the campus to discuss with the classmates and to have access on campus internet connections and no research funds provided to the research expenses which was them mainly challenge for this research thesis.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0. Introduction

The section describes the results for data collected, discussion and analysis of those data collected and emphasizes on data collected of domestics, Prisons biogas plants and other targets especially the people involved in biogas sector of Eastern province. The section has results on the number of biogas plants are in eastern province, the biogas working properly and other huge number of failures with the main causes of those biogas failure and the prevention measures of this problem.

4.1. Demographic characteristics of the respondents

The respondent's demographic characteristics who participated in this research includes: biogas status, biogas plants don't operate properly, main causes of non-operating bios plants, main occupation of the family head, connectivity with electricity and other information collected related to the awareness of biogas plants, by providing the preventive measures on this problem of biogas failure of biogas plants in eastern province.

4.1.1. The biogas plant status in eastern province region

For this study, the research done in eastern province of Rwanda on biogas failure showed that is where the huge number of biogas projects implemented, but even if those different projects implemented also immense failure happened. The table below shows the status of biogas sector in eastern province as provided by provincial office in charge of biogas plants. the study shows that 3,434 biogas plants from 2012-2019, in those biogas plants;1129 working properly which has 32.9% and non-working properly are 2,305 this occupied big number of 67.1%. this research shows that there is biogas problem of biogas failure in this region. The overall status of biogas constructed status in eastern province within the region constructed in are as indicated in table below:

District	Biogas number	year	Biogas operates properly		Biogas do not operate properly	
			Number	Percentage (%)	Number	Percentage (%)
Rwamagana	463	2012-2019	232	50.1	231	49.9
Kayonza	514	2012-2019	102	19.8	412	80.2
Ngoma	418	2012-2019	104	24.9	314	75.1
Kirehe	573	2012-2019	207	36.1	366	63.9
Gatsibo	496	2012-2019	117	23.6	379	76.4
Bugesera	403	2012-2019	124	30.8	279	69.2
Nyagatare	567	2012-2019	243	42.9	324	57.1
Total	3,434		1,129	32.9	2,305	67.1

Table 4: Biogas plants constructed in eastern province of Rwanda (source: data collected from land management authority of eastern province, rwamagana head office)

4.1.2. Biogas status for the respondents

The distribution of biogas status for the respondents in this research shows that respondents with Operational domestic biogas plants participated on the proportion of 23.3%, Non-operational domestic biogas plants occupied 66% and the remaining 5.4% is for respondents without any biogas plants so far but involved in biogas sector. The reason of having big number of non-operational domestic biogas plants this indicate how the biogas technology failure relied to the country and many failures shows that the biogas failure is a big problem to the biogas implementation in eastern province of Rwanda. those results are presented in the table below;

Category	Number of households	Percentage (%)
Operational domestic biogas plants	32	28.6
Non-operational domestic biogas plants	74	66
Without any biogas plants so far but involved	6	5.4

in biogas sector		
Total	112	100

Table 5: Biogas status for respondents

4.1.3. The biogas plant construction Investment

This study of biogas plants failure collected data on the how those biogas plants has been constructed based on the economic condition and social aspects of the households contributed in construction financial constraint of building biogas plants. Many of respondents who were using biogas are totally financed by the government programs and the few numbers were on their own financial. The results of surveyed biogas plants show the details are presented by the table below.

Category	Frequency	Percentage (%)
Valid on government program	107	95.5
Valid on the owners themselves	5	4.5
Total	112	100

Table 6: The biogas plant Investment for respondents

4.1.4. Main barriers to adoption of household biodigesters

Below table 8 identify the specifics technical barrier for the adoption of household biodigesters in eastern province of Rwanda, as identified during households' interviews and survey. This help to know really the main barriers of biogas technology may leads the many biogas plants to fail, as indicated by the data collected on sites in table below and recommendations for how to address them.

Main technical barriers to adoption of household biogas are:	<i>Main Barriers</i>	<i>Household Frequency</i>	<i>Percentage (%)</i>
	Poor technical expertise and inadequate training and follow-up	47	42
	Lack of water or feedstock (dung, crop residues)	41	36.5
	Lack of suitability and availability of the material used	10	9
	The low rate of functional installed biogas systems or short lifespans	14	12.5
Total		112	100%

Table 7: Main technical barriers to adoption for household biogas

And the below table represents the summary of specific institutional barriers for adoption of biogas on household in eastern province of Rwanda, as identified by respondents and my observation during households' interviews and survey. This help to know really the main barriers of biogas technology may leads the many biogas plants to fail, as indicated by the data collected on sites.

Main institutional barriers to adoption of household biogas are:	<i>Main Barriers</i>	<i>Household Frequency</i>	<i>Percentage (%)</i>
	Absence of policies, regulatory frameworks, and standards	44	39.3
	Absence of information, knowledge	47	42
	Absence of explicit organization to promote biogas	21	18.7
Total		112	100%

Table 8: Main institutional barriers to adoption of household biogas

4.1.5. Status of visited biogas plants

In this research, the respondents mentioned technical, social and institutional causes of the biogas plants not operate in this region according to their knowledge and skills. But also, in the surveyed families, many people indicated other causes which are not indicated in tree diagram below. As indicated in **table 5** above, there are status of biogas plants in eastern province; the number of biogas plants working properly and non-working properly. This table below indicated different causes of those biogas failure in various regions.

Region	Biogas plant visited	Visited Biogas operates properly		Visited Biogas do not operate properly	
		Number	Percentage (%)	Number	Percentage (%)
Rwamagana	35	14	40	21	60
Kayonza	26	11	42.3	15	57.7
Ngoma	14	8	57	6	43
Kirehe	17	10	58.9	7	41.1
Gatsibo	9	4	44.4	5	55.6
Nyagatare	11	5	45.5	6	54.5
Total	112	52	46.4	60	53.6

Table 9: Status of visited biogas plants in eastern province

As mentioned on table 10 above; the big number of visited 112 biogas plants failed, the failed biogas plants are 60 which has the percentage of 53.6%. those various failure of biogas plants visited it find different causes of non-working properly of those biogas plants. In the table below the study will indicate different region, the failed biogas plants number, the components of biogas failed and the causes of those failure presented in table below:

Region visited	Visited Biogas failed	Main Components and causes of biogas plants failed
Rwamagana	21	<ul style="list-style-type: none"> ➤ Corrosion of gas holder ➤ Pin-hole leakages (digester tank, inlet, holder and outlet)

		<ul style="list-style-type: none"> ➤ Occurrence of CO₂ reducing the calorific value of biogas ➤ Occurrence of water condensate in gas supply system ➤ Digester tank cracks ➤ Lack of knowledge of feeding process ➤ Lack of knowledge of biogas utilization
Kayonza	15	<ul style="list-style-type: none"> ➤ poor quality of construction materials on biogas foundation ➤ Digester cracks and poor quality of construction materials ➤ Gas holder or gas storage masonry dome ➤ Mixing tank cracks ➤ Lack of funds for repair and maintenance ➤ Absence of smooth outflow from biodigesters
Ngoma	6	<ul style="list-style-type: none"> ➤ Inlet chamber/pipe leakage ➤ Outlet chamber/pipe busted ➤ Gas outlet broken ➤ Pipe leakages ➤ Improper site selection ➤ gas distribution pipeline leakages ➤ water trap broken and leaks ➤ Lack of funds for maintenance and repair
Kirehe	7	<ul style="list-style-type: none"> ➤ Lack of knowledge of biogas utilization ➤ Lack of funds for repair and maintenance ➤ fittings loosen ➤ Poor knowledge about feeding ➤ lack of feeding materials ➤ Digester cracks and poor quality of

		construction materials
Gatsibo	5	<ul style="list-style-type: none"> ➤ lack of technicians to repair and for maintenance ➤ Inlet chamber/pipe leakage ➤ Outlet chamber/pipe busted ➤ Gas outlet broken ➤ pipe leakages ➤ poor knowledge on biogas utilization ➤ gate valve loosens ➤ gas distribution pipeline leakages ➤ water trap broken and leaks
Nyagatare	6	<ul style="list-style-type: none"> ➤ The lack of funds for repair and maintenance ➤ poor quality of construction materials on biogas foundation ➤ Digester cracks and poor quality of construction materials ➤ Gas holder or gas storage masonry dome ➤ Mixing tank cracks ➤ Lack of interest ➤ Absence of smooth outflow from biodigesters ➤ Inexperienced and untrained biogas householders

Table 10: The main causes of visited biogas plants failure in eastern province

➤ **The lack of funds for repair and maintenance**

The repair and maintenance of biogas plants requires much money and is very expensive on rural households, before 2017 The part of those money was given by government of Rwanda and the rest are household's own money, but after 2017 the government supports have been ended so the households still have some economic pressures and if there a required maintain or repair of biogas plant it is not possible for some households, this leads many of biogas plants in eastern province to failure.

➤ **The lack of knowledge of biogas utilization**

Many households use small-scales biogas digesters, as shown by the survey some of them they don't know sufficiently the working of biogas plants and the main components of biogas, the knowledge about different steps involve in biogas feeding and production processes and they don't know how the biogas plants operate in general. If any components of biogas plants have a problem no skills how they can repair and maintain those various components for easy problems, because of this lack of knowledge cause the biogas plants to failure totally.

➤ **Poor quality of construction materials and inexperienced masons**

Based on the survey there is the problem of quality of materials used in construction of biogas plants which can be given by poor training of the masons, however when the masons were not experience many biogas digesters failure according to poor construction skills and the knowledge of quality in biogas construction materials .This leading to failure of biogas plant when you don't consider the technical skills and quality of materials which must take into consideration for biogas construction works.

- Here to solve this problem of poor quality of construction materials there are the criteria that must take in consideration and the training for masons in order to improve their skills and knowledges on biogas technology, the quality of the biogas construction materials ensured before use. The following table indicate some required quality of materials that must take into consideration when construct the biogas plants:

S/N	Materials	Quality needed of materials
1	bricks	Good quality bricks preferably machine-made First-class bricks with uniform size and shape
2	cement	Pure port and land with no impurities
3	sand	Fine and coarse with good quality
4	steel for big size plant	standard
5	concrete	Hard without impurities
6	Reinforce concrete for large tank	Having good quality of composition cement, sand and water
7	Asbestos cement pipes for inlet and outlet	Good quality with no leakage and should have uniform diameter and length needed
8	Ferro cement	Having the few layers of iron wire mesh plastered with diameter and length required
9	Bricks ferro-cement	Outer wall with bricks, inner surface plastered with ferro-cement
10	plastic	Fiber glass reinforced plastics, PVC polythene.

Table 11: The quality of the biogas construction materials

➤ *Poor knowledge about feeding*

Many households start initial feeding of water and dung in four days but after the first time of feeding they don't know at which time they to feed also the biogas plants, some of them they don't have the knowledge on the feeding processes. They don't even know when we need to feed the biodigesters and remove slurry feeder materials, and some households and biogas users. however, if those different parameters regarding the biogas feeding taken into consideration there is low biogas production and cause the biogas failure in general.



Figure 13: Manure mixer

The above figure13, the manure is mixed with water in a mixer to form slurry. But some problem of lack of knowledge about feeding some biogas holders they don't know to how they must mix the manure with water to form homogeneous mixture of slurry, this leading to the failure of biogas production in biodigesters.



Figure 14: Biogas digester

**Lack of open-closing valve
handle**

For this figure 14 above of biogas digester, the opening and closing valve handle for biogas flow has lost some biogas holders and users they don't even know how this problem can be solved for biogas plant to continue operates without the problem, this require only the replacement of open and closing valve. The reason why some basics training about biogas maintenance and repair is needed to improve their knowledge as this research proven that is more likely for them to get those trainings. This problem may lead the biogas plant to the failure stage with lack of open and closing valve handle to open and close the gas from the biogas digesters.

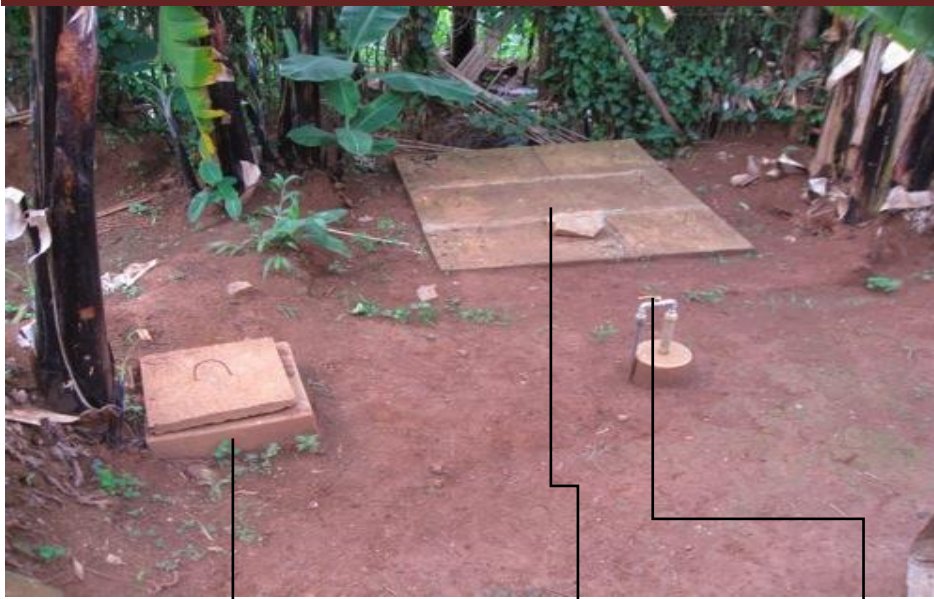


Figure 15: Biogas plant components



➤ **Lack of interest**

When consider the cost of construction of biogas plant for example the biogas plant of 6-8m³ the cost average in Rwanda is about 500,000-700,000 Rwandan francs (800USD). This means that if you spent 700,000 Rwandan Francs and after you realize that you don't get the enough production the interest on it will decrease[14]. those money might be used for maintenance and construction which are much money by considering the profits gained from using biogas this will cause discouragement of biogas holders and users then will affect the biogas failure in many regions of eastern province, Rwanda.

To mitigate this problem, the population suggest that government support for the people of poor family is needed especially in maintenance, repair and also in findings the feeding materials because some biogas holders and user lack of feeder stock materials. This will reduce the cost spent in those works of maintenance and repair of biogas plants.

➤ *Improper site selection*

The improper site selection can be caused by different problems such as: poor knowledge of biogas technology for technicians, careless in construction by not considering different criteria must be taken in consideration for site selection, poor quality of construction materials and unexperienced masons this also can cause improper site selection because of unexperienced masons, poor monitoring of field staff, this problem can also cause the improper site selection because when the management of field staff, each staff can work as he want without any control which may affect the site selection criteria. And to overcome this problem of site selection, Careful selection of the best site for installation of a biogas unit should be done for every beneficiary. The following points should be taken into consideration:

- ❖ The distance between the plant and site of gas consumption or kitchen should be less to Minimize cost on gas pipe line and gas leakage. For a plant of capacity 2m³, the optimum distance is 10m.
- ❖ It should be near the cattle-shed to minimize the distance for carrying cattle dung and transportation cost.
- ❖ There should be enough space for storage of digested slurry or construction of compost pit.
- ❖ It should be 10 to 15 meters away from any drinking water well to prevent contamination of water.
- ❖ The area should be free from roots of trees which are likely to creep into the digester and cause damage.
- ❖ It should be open to receive the Sun's rays for most part of the day and to keep the plant in warm. The sunlight should fall on the plant as temperature between 15°C to 30°C is essential for gas generation at good rate.
- ❖ It should be on an elevated area so that the plant does not get submerged during normal rains.
- ❖ Sufficient space must be available for day to day operation and maintenance. As a guide line
- ❖ 10 to 12 m² area is needed per m³ of the gas.

➤ *Absence of smooth outflow from biodigesters*

This is when the mixture of cow dung and water after producing needed gas does not flow smoothly through the outlet channel, this happens by poor knowledge in biogas design, construction and also can be caused by poor knowledge on feeding even for maintenance skills. It can cause the damage of digester and reduce the production of biogas which will continue to the biogas failure stage totally. According to the respondents those mainly found in Kayonza, Rwamagana and Gatsibo districts, where many biogas plant failures because of absence of smooth outflow of slurry from digesters. Once primed and fed daily with new manure, the manure slurry out from digesters to overflow tank and into a manure pond. The manure slurry is removed from the pond and used for soil fertility.

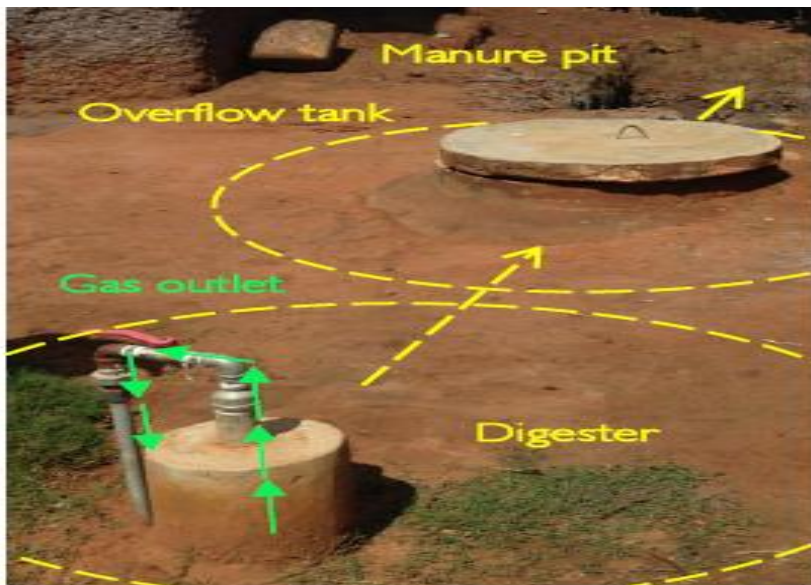


Figure 16: The manure slurry overflow from biodigester

➤ *Irregular and improper feeding to biodigesters*

According to the diameter of your digester or its capacity of production, you must know the proper time of feeding and the quantity which is proper in order to get good and high output gas production. This happens at Gishari sector, Rwamagana district, Eastern Province where many of the householders told me that, they feed their digesters if they got the cow dung because they don't have enough feeder stock, this means that they never got enough feedings at proper time. This also causes

the failure of biogas production by producing low quantity of biogas and then when this continue cause totally no gas production and the biogas plant failure completely.



Figure 17: Biodigester inlet

➤ ***Poor monitoring of field staff***

This problem of poor monitoring of field staff has also impacts on many biogas failures, this happen in construct ion works of biogas and also in maintenance of those biogas constructed. Sometimes chief staffs do not fulfill their responsibilities of surveying or controlling construction of biogas or biogas operation, this also led to the failure of biodigester. For example, this found mainly in Kayonza district where in construction activities there are some careless and after some days of working the digesters start to breaks up, this issue shows the poor monitoring of field staff which make to construct the biogas as they want without sufficient control in construction works.



Figure 18: Construction of biogas plant (CAMARTEC model)

➤ *Poor knowledge of the biodigester owner or technicians*

When the project of biogas comes, they didn't provide enough training to the people, this causes some problems like; poor maintenance of digester and poor mixing of dung and water even cleaning at proper time this also can lead some accident. This problem of poor knowledge causes many failures of biogas in eastern province as mentioned by respondents if got basics knowledge on biogas operation were helped them to do some maintenance and repair of their biogas as some problems were small to solve and because of lack on basics knowledge on biogas technology regarding the maintenance and repair, those small problems became big and cause the total failure of biogas.

To deal with this problem of poor knowledge and skills on biogas plants, as indicated in the table below, some knowledge that are useful for biogas technician in construction of biogas as follows the size and dimensions of biogas plant and components:

No	Components (cm)	Symbol code	Biogas plant size			
			4m ³	6m ³	8m ³	10m ³
1	Length of Outlet	Lo	140	160	170	190
2	Breadth of Outlet	Bo	120	130	140	160
3	Height of Outlet	Ho	50	55	60	62
4	Radius of Digester	Rd	110	130	145	155
5	Radius of Pit	Rp	140	160	175	200
6	Height of Digester wall	He	80	85	90	95
7	Depth of Excavation	Dp	160	170	180	190
8	Height of Dome	Hdom	65	70	75	80
9	Curvature of Radius of dome	Rdom	126	156	178	190
10	Inner Height of Digester and Dome	Hall	145	155	165	175
11	Height of Maximum Slurry Displacement	Hd	25	25	25	28
12	Height of Outlet Passage	Hop	105	110	115	123
13	Thickness of concrete in Dome (side -Centre)	20-7	20-7	20-7	20-7	20-7

Table 12: Size and dimensions of biogas plant

➤ Site background

The site background problem also affects the failure of biogas plants, here prefer for eastern province, some districts during the summer season there is the problems of shortage water; and we know that in order the biogas to be operate well we need the mixture of water and feeding (ex: cow dung) when there is absence of water the biogas fail and after stop working. And also we need the presence of sunlight to help in the decomposition of feeder materials[16].the better it must take in consideration to deal with the problem of water and the huge sum in order to make biogas plant to be

operate in different seasons and regions here at Ngoma. Rwamagana, Kayonza, Nyagatare and Kirehe.

Here are other problems from textbooks and internet which can causes the biogas plant not to work properly and solutions to solve them.

Problems	Mostly likely causes	Recommended action
Gas yield dropped	<ul style="list-style-type: none"> • Drop in quality of substrates • Drop of temperature • Non homogeneous substrates • Drop of methanogenic bacteria 	<ul style="list-style-type: none"> ✓ Assure substrates mixing and quality ✓ Check heating system ✓ Check level of potential inhibitor compound ✓ Add digestate from another digester if the methanogenic bacteria drop
Methane concentration dropped	<ul style="list-style-type: none"> • Drop in quality of substrates • Drop of temperature • Compound inhibition 	<ul style="list-style-type: none"> ✓ Assure substrates mixing and quality ✓ Check heating system ✓ Check level of potential inhibitor compounds
Foaming problem	<ul style="list-style-type: none"> • A new substrate with high protein content has been added • Air is introduced in the digestion • Temperature is changing 	<ul style="list-style-type: none"> ✓ Analyze substrates ✓ Reduce air introduction ✓ Reduce or stop feeding
PH dropped (measure of acidity/alkalinity of a solution)	<ul style="list-style-type: none"> • Feeding rate is too high or variable • Operating temperature have changed • Agitation is not working 	<ul style="list-style-type: none"> ✓ Reduce substrates until system returns to normal ✓ Reduce or stop feeding ✓ Use only manure until system returns to normal

Table 13: relevant causes and solutions to biogas failure source: <https://www.biogasworld.com/biogas-plant-troubleshooting/> visited on 08 October 2020

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Energy is a backbone for economic development globally of Rwanda. It plays a variety of roles ranging from industries to the households use and lack of access to the reliable energy is a constraint for sustainable development and poverty reduction. The main objective of this study was to improve the sustainability of biogas plant projects and uphold the maintenance of biogas plants for making them comfortable and provides high performances and improving the knowledges, technical skills of biogas holders, biogas users and technicians with indicating the measures to mitigate the biogas projects failure in eastern province and in Rwanda generally.

Specifically, this thesis study was intended for analyses the main causes implicated in the biogas plants failure for the purpose of providing a reliable and sustainable energy from biogas. From this point of view, the energy required for usage at households were quantified in terms of cooking and feeding materials shows that many households lack of feeder stock which are mainly causes of biogas plant failure and there was other problem regarding biogas technology in terms of maintenance and repair, this problem happened mainly when the government support for biogas plants treatment terminated in 2017 now the biogas holders are in charge in biogas treatments for maintenance and repair which leads many biogas plants in eastern province in failure status. Even if the problem is not big of biogas failure is not corrected because of lack of maintenance funds, the problems become bigger and then the total failure of biogas happened.

The funds for treatment in deployment of biogas technology in rural areas also has great role in enhancing the biogas use in many rural houses and the people are essential need the arrangement on households' trainings and workshops on the use of biogas plants. This will improve the knowledge of biogas households and biogas users and mitigate some causes might happen because of poor knowledge on biogas technology.

The overall findings of this study, revealed that biogas technology can serve as an economic and environmentally friendly way to provide alternative fuel; that is useful in the households mainly for cooking and heating water. This can significantly reduce the reliance on the firewood and charcoal

as main energy sources for rural household in eastern province, Rwanda. Hence contribute to the environmental protection through forest preservations.

5.2. Recommendations

This master thesis presents many of the approaches to improve biogas dissemination technology particularly at domestic, schools and prisons areas. Biogas technology is proved to be able to reduce the greenhouse gases emitted by fossil fuel use. Several barriers for biogas deployment and development were presented from different participants in the survey such as high up-front cost; lack of information regarding the biogas technology itself; lack of awareness regarding substrates other than cow dung mainly for domestic level; and lack of knowledge regarding technology in case of maintenance. Hence, this section discusses some recommendations to policy makers, as well as to further researchers, as contributions to overcome those barriers with the tangible results.

Firstly, for policy makers, there is need for human capacity building in terms of money as the government support has terminated in 2017. This is a very essential point to increase the awareness on the biogas for households as an emerging technology far different from their tradition. Some arrangements of trainings and workshops on operational of biogas plant and biogas technology essentially.

Encourage people and government to understand the importance of using biogas in their daily activities either socially; as it will reduces the indoor air pollution and save time spent for women and children for collecting firewood and residues, or economically; as it generates incomes in terms of fertilizers, and long-term money saving for those who use to buy charcoal or firewood.

Policy makers can help people to be facilitated with loans from many banks as possible so that the biogas system can be built at large number throughout the country and Eastern province particular. Secondly, more alternative co-digestion technologies are recommended as the findings of this study have shown that co-digestion can be an economic way to access on a biogas at household levels and this helps to overcome lack of feeder stock materials as one problem causes of the biogas failure in eastern province, Rwanda.

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Research grant budget allocation

<i>S/N</i>	<i>Designation</i>	<i>Quantity</i>	<i>Price</i>
<i>1</i>	<i>Transport fees</i>	<i>In different regions at sites</i>	<i>30,000*30=900,000+400,000=1,300,000Rwf</i>
<i>2</i>	<i>Machine laptop</i>	<i>1laptop</i>	<i>500,000 Rwf</i>
<i>3</i>	<i>Camera for collecting data</i>	<i>1camera</i>	<i>150,000 Rwf</i>
<i>4</i>	<i>Print out</i>	<i>books and questionnaires papers</i>	<i>70,000*3=210,000 +100,000=310,000Rwf</i>
<i>5</i>	<i>Research fees for internet</i>	<i>30Gb per month</i>	<i>40,000*5=200,000 Rwf</i>
<i>6</i>	<i>Fees for advisory and questionnaires</i>	<i>20 days per month</i>	<i>20*5=100*1,000=150,000 Rwf</i>
TOTAL			2,610,000 RWF=\$2,800

ANNEX

Questionnaire for Data collection

Dear Respondent,

The researcher is a student in Masters of Science in Renewable Energy Engineering at University of Rwanda/ college of science and technology under African center of excellence in energy studies for sustainable development (ACE-ESD). You have been selected to be part of this study as one of the best respondents due to your unique experience about operations of biogas plants or as you are intended as pilot study for provision of centralized biodigester systems. Kindly give some minutes spare some minutes on busy schedule to respond to the questionnaires by giving vital views where needed and ticking one of the alternatives given. The information obtained will be used for academic purposes and we ensure you to treat the information with utmost confidentiality.

SECTION A: BACKGROUND DATA

A. Household head	
1	Father
2	Mother
3	Other (Specify)
B. Main Occupation of the Family Head	
1	Agriculture
2	Business
3	Service
4	Labor
5	Other (Specify)
C. Location of the Household	
1	District
2	Sector
3	Connectivity with electricity
4	Number of family members

SECTION B: HOUSEHOLDS ENERGY SYSTEMS

This section measures the performance of your energy systems in term of provision of energy and serving the intended purpose. Kindly respond to the following statements as honest as possible.

A. Fuel types for cooking and heating water	
1	Firewood
2	Charcoal
3	LPG
4	Electricity
5	Biogas
6	Other (Specify)
B. Monthly fuel consumption (Quantities), where applicable	
1	Firewood
2	Charcoal
3	Biogas
4	LPG
5	Electricity
6	Other (Specify)
C. How long have you been using Biogas (as selected reference fuel)	
1	Less than 6 months
2	Range of 6-12 months
3	Range of 12-18 months
4	More than 18 months
D. The biogas plant construction Investment	
1	Valid on government program
	Yes..... no



2	Valid on the owners themselves	Yes.....	no
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E. What are the main barriers to adoption of household biodigesters in eastern province?

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F. States the frequently causes of biogas plants failure in eastern province

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G. How much money do you spend on maintenance of your biogas systems (Rwf)? if applicable

.....

.....

.....

H. Does your biogas system meet all your energy demands? If applicable

- Yes
- No

I. Explain your answer in E above

.....

.....

.....

J. Do you think it is necessary to encourage biogas technology deployment in households?

.....

.....

.....



K. Do you think is necessary to arrange households’ trainings and workshops on the use of biogas plants?

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.....
.....

L. What do you think are mostly relevant causes of biogas failure? and how can you mitigate those causes?

.....
.....
.....
.....

Thank you.

Thank you for spending your precious time to all the information given in this questionnaire.

Warm regards.

Theoneste NSEKAMBABAYE

Masters’ Student at university of Rwanda-African center of excellence in energy studies for sustainable development (ACE-ESD), College of Science and Technology.