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MASTER OF SCIENCE IN RENEWABLE ENERGY

Master's Thesis

Opportunities of small scale biogas plants to overcome lack of cooking energy

CASE STUDY: Eastern Province

A thesis submitted in partial fulfillment of the requirements for the award of Master of Science in Renewable Energy.

Thesis done and submitted by

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CERTIFICATION

The project work presented in this thesis entitled, "**Opportunities of small scale biogas plants to overcome lack of cooking energy**", is a record of the original work done by Mr. Adalbert MBONYUMUKUNZI (Ref. No**:** 217041558) in partial fulfillment of the requirement for the award of a **Master of Science in Renewable Energy** at the University of Rwanda, College of science and technology.

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Submitted to the project examination held at CST on ……/…..../**2019**

DECLARATION

I, **MBONYUMUKUNZI Adalbert (Ref. No: 217041558),** hereby declare that this project entitled "**Opportunities of small scale biogas plants to overcome lack of cooking energy**" is conducted for the partial fulfillment of **Master of Science in Renewable Energy**. This work is my contribution to the best of my knowledge under supervision of Dr. Venant KAYIBANDA and has not been presented for a degree in any other university.

Signature: .... Date...

MBONYUMUKUNZI Adalbert

This thesis has been submitted for examination with our approval as the University

Supervisor:

Signature: .... Date...

Dr. Venant KAYIBANDA

University of Rwanda.

DEDICATION

To almighty God, My beloved parents, brothers, sisters and friends, my supervisor and classmates, Thanks to all for your ending encouragement and support, without you, this dissertation would never have not been possible.

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This is my wish to take this opportunity to express thanks to individuals or groups who have contributed on achievement of this project.

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ABSTRACT

The majority of population in Africa lacks access of sustainable energy, and a lot of countries in African depend on traded energy. Rwanda has a massive vision comprises exploitation of little resources it has despite the fact of replying to the currently energy demand, development of private sector, poverty eradication, financial inclusiveness, and so on. Biogas technology showed area linking all components cited, Rwanda share the same problems with others African countries where people from rural areas do not have enough energy access in their daily life activities and they depend much on biomass like firewood, solid waste, agricultural products, wastes from animal, ... in order to fulfil energy demand for cooking, and other purpose on their daily life activities, and there are many disadvantages of these traditional fuels such as they release harmful gases, they carrier ineffective energy and it is difficult to manage their heat released, most of them they are environmental not safe and it is a poverty contributor also a burden on country development. Small scale biogas technology is one of the solution to those issues above because it is more efficiency and 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 like EDPRS's, *One Cow per Family, Girinka munyarwanda, etc.* which can make easy and feasible the project of biogas technology, this thesis drive on production of energy with small scale biogas digesters and introduces, discusses various potential tools and feasibility studies that this technology can fit well and will focus on sites statistical data through which will shows the real situation and be based on making discussions and teaching on awareness on resources already present on field for well recognize everything deal and in what way to exploit benefits as much as possible of small scale biogas mostly for low income households to assist as solution to Rwandan energy sector as well as Rwanda vision through the following innovations; renewable energy built on integrating innovative approaches and knowledge on biogas technology, and agro-slurry, ecosystem recovery, occupation establishment, generation of profits, reduction of poverty for rural and protection on social level, from there are various opportunities to attract more investors to invest in the sector and the possibilities of financial support will be higher and the country will benefits in selling carbon credits.

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LIST OF ABBREVIATION

AD: Anaerobic Digestion

BOD: Biochemical Oxygen Demand

C: N: Carbon to Nitrogen

COD: Chemical Oxygen Demand

CPI: Consumer Price Index

DM: Dry Matter

FBW: Free Basic Water

GHG: Greenhouse Gas

GWh: Giga Watt Hour

GWP: Global Warming Potential

HRT: Hydraulic Retention Time

IAP: Indoor Air Pollution

LPG: Liquefied Petroleum Gas

m.a.s.l: Meters above Sea Level

NERSA: National Energy Regulator of South Africa

OLR: Organic Loading Rate

Ppm: Parts Per Million

PV: Photovoltaic

PVC: Polyvinyl Chloride

TS: Total Solids

UNEP: United Nations Environment Programme

US$: United States Dollar

v/v: volume by volume

VS: Volatile Solids

WHO: World Health Organization

NOMENCLATURE LIST

C: Carbon

$C_6H_{12}O_6$: Glucose

$CH_3(CH_2)_2COOH$: Butyric acid

$CH_3(CH_2)COOH$: Propionic acid

CH_3CH_2OH: Ethanol

CH_3COOH: Acetic acid

CH_4: Methane

CO: Carbon Monoxide

CO_2: Carbon Dioxide

H: Hydrogen

H_2: Hydrogen gas

H_2O: Water

H_2S: Hydrogen Sulphide

K_2O: Potassium Oxide

N_2: Nitrogen gas

NH_3: Ammonia

NO_x: Oxides of Nitrogen

O: Oxygen

O_2: Oxygen gas

P_2O_5: Phosphorus Pentoxide

PM: Particulate Matter

PM_{10}: Particulate matter having an aerodynamic diameter less than 10 μm

$PM_{2.5}$: Particulate matter having an aerodynamic diameter less than 2.5 μm

Q: Heat

SO_2: Sulphur Dioxide

η: Thermal Efficiency

CHAPTER ONE

1. INTRODUCTION

The insufficiency of petroleum products it scares supply of fuel across worldwide, their ignition problem, the rising of problem associated on deforestation in developing countries, likewise Rwanda is affected too and maximum of population depends on firewood, coal for energy supply which read to cutting down and removal threes and the effect are higher for example it can damage the environmental thru soil erosion, destroying animals depend on, decrease biodiversity,.. Usage of solid waste like firewood, dungs as source of energy represent dangerous and bad effect for health and as arising of smoke are major influence of global pollution and ecosystem supernumerary and replacement energy is required to substitute.

All of these drive to explore in various angles to get sustainable sources of energy, as non-conventional or energy resources who are renewable; wind energy, solar energy, bioenergy, geothermal and hydro energy resources, all of these are non-conventional energy resources. But, biogas is different to other non-conventional energies since of its features of monitoring, usage manner and its production is naturally it is a clean and renewable. And about topographical condition biogas can be implemented whenever also it is easy to use.

Cow dang is high calorific value organic substance and worthy rate nourishment to microorganisms and the way the reactor size means greater efficacy and biogas production charge become cheap. Inadequate management of wastes can cause significant issues like polluting ground water, surface and numerous consequences of hygienic and sanitation diseases.

This problem can be take on effectively by the production of CH_4 (methane gas), yet there have not been profited as much as possible, because of ignorance of basic sciences then new technologies and research pursues to recognize the opportunities, limitation and challenges which may have impact on the people's lives and help to identify how can profit the present opportunity to overcome. In Eastern province Nyagatare district this thesis will find out and take consideration of small scale biogas production, a knowledge which is already upgrade the lives of low income in different parts of the developing world wide

The difficult will not be associate to establishing digester of small-scale biogas or on digestion process because all are already well realized with various designs on low-cost and are operational across the world. The important is adoption of that technology to easy accessible and possibilities to explore that technology to the people of Nyagatare district with low income and those with a lack to access of clean energy to meet household energy demand, improve sanitation and daily life.

1.2 Problems Statement

Energy has become a big issue for the economic development for many countries. Rwanda also is facing a serious energy crisis, which can be continuous growing and can be also multi-dimensional. Hence, research for rising energy substitute source has progressively become significant.

Cow dungs are worthy basis element for producing energy in biogas plant due to its high calorific value organic substance and worthy rate nourishment to microorganisms.

In Easter province precisely Nyagatare district there are many cow famers, which represent a large amount dung waste on daily basis and can help for improved purposes. The production of biogas needs the closed environment without oxygen presence called anaerobic digestion. This thesis will show the process to facilitate and create small scale biogas that is a good value, and ecosystem friendly, reduce the usage of firewood, and minimize CO_2 & CH_4 emissions.

Largely by establishing small scale biogas digester at local areas will be beneficial. Cow dung will be organized from cages as digester input to be processed through anaerobic digester to harvest biogas energy as output. The anaerobic digestion is a microbial process by which microorganism break down biodegradable material in environment free of oxygen for production of a gas called biogas along with digested solid. Biogas technology can serve as energy generation as well for many purposes and whatever needs a level of understanding and skills about production process detailed.

1.3 Objective of the Study

1.3.1 General objective

To develop production of renewable energy through bioenergy and digested bio-slurry by means of local wastes available resources like cow dung on energy generating purpose, profitable benefit and environmental conservation .

1.3.2 Specific Objectives

- Create domestic industry and employment opportunities
- Increase health associated condition conditions.
- Optimize gas production Compare with conventional plants
- Overcome cooking energy issue (firewood and charcoal usage)
- Reduces energy dependence on conventional energy.
- Reduction of pollution and create awareness on issue of deforestation produced by cutting threes for fire wood.

1.4 Significance of the project

Importance to implement the biogas technology in rural area of Easter province especially nyagatare district is growing through various government program of encouraging their usage for environmental benefit, social and economic benefit.

The biogas technology at small-scale has vast benefits to ecological progress as long as it present a huge diversity of economic and social profits, comprising shifting of energy supply, improve development in rural areas, domestic job creation and employment opportunities. The small scale biogas represent enormous advantages besides of producing energy that can be used in different daily activities, the requirement of implementation are minimum, most of construction materials can be available the rural areas, and doesn’t require higher rated study or technician for constriction and the period of implementation is considerable only the condition is the input must be available which are in this case the cow dung and water and the small scale biogas doesn’t require much quantity of water and rain water can be use in this case.

1.5. Survey Locations

Nyagatare is the second most populated and the biggest district of Rwanda. Placed in Eastern Province of Rwanda, it has the surface area of 1741 km2, what marks it the biggest district in Rwanda. With inhabitants around 466,944 people in 2012(2012 Population and Housing Census).

The sample sectors was designated by balanced randomly by method of sampling. Totally 5 sectors are nominated for study purpose to represent whole district.

Figure 1 Nyagatare district (source google map)

1.6 Limitations and assumptions

Even though the great profits, commitment in Rwanda of small scale biogas is minor by comparing to developing countries. Possible negative impacts are exceptional use of materials in constructing and installation which are not present at the site or which are too expensive for people with a low income, luckless access of water for mixing with dung for digesters, the possible microbes hidden in digested bio slurry at which can pass on a disease or affect humans who deals with it or ones consuming harvested crops fertilized by it, Concrete issues comprise expensive investment cost at initial stage and materials accessibility for digesters building, accessibility of biogas technicians, convenience of skills to use that technology, the amount of gas produced which is not enough to respond to the requests of the households because the system relay on input of feedstock.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

In chapter analyses the energy demand of households with little income by means of non-renewable domestic energy sources. Biogas is used as a potential replacement energy of non-renewable domestic energy. Biological and chemical concept involved in production of biogas are studied and all aspects that may affect biological and chemical processes are explored. The standing of local biogas technology across worldwide is also reviewed and the difficulties confronted are presented and it end with the evaluation of the profits of biogas technology at domestic level and the present Rwandan policies about biogas technology.

2.2. The demand of energy by households with low-income

A huge percentage of families in rural area depend on biomass energy as basis energy for cooking. Families lacking access to electricity are positioned in rural areas and are the ones that are subject more on fuelwood for cooking purposes and mainly are classified in the lowest income category.

2.3 Efficiency of domestic fuels energy

There have been a diversity efficiencies cooking stoves for of firewood which is mostly used to the varieties of cookers, stoves. The usage of old-style cooking stoves and three stand (stone) where open fires is still dominant in local areas of the developing countries represent 40% burning efficiency of firewood used in conventional stoves in India where 24% of firewood efficiency used in old-style stoves in China. These high efficiencies are used to the nature of the cooking stove used as well as its capacity to hold or spread hotness, the thermal efficiency in China of cooking stove vary from 5% to 20%, and the medium range was between 10% to 11%. The progress in efficiencies can be focalized into application of better-quality and improved cooking stoves. Cooking on three stand or exposed fires is still a routine in Africa. In Rwanda households from local areas, exposed or open fires are still the most prevalent cooking method.

Cooking on exposed or open fires represent a little efficiency vary from 3% to 8%, it states that about 92% to 97% of energy lost in surroundings environment, the fires efficiency which is too low in open fires is subjected to the low heat transfer efficiency from great losses to the ground. Numerous research studies have been made by researchers across the world to define and describe the efficiency of different stoves including three stand stove with boiling water test The water boiling test is a imitation of the cooking practice. Water boiling test includes working the stove under conditions of heating by means of water to pretend food. Water heated to boil as quickly as possible throughout the heating phase and is then conserved within 5°C of boiling for 30 minutes

The efficiency of a heat for the cookers using biogas varied between 50 and 60%

Additional usage of biogas further cooking is illumination. In inaccessible areas where there is a lack to electricity, Biogas utilized for illumination can be used in as LPG gas (Liquefied Petroleum Gas) lamps. Due to the ineffectiveness of those biogas lamps, it is not suggested to be used in lighting unless there is a surplus of biogas. The efficiency of biogas lamps can vary between 3% to 5%.

The usage of biogas for lighting purpose represent complication and difficulties due to its complication for safety and technical perception. The amount of energy needed by a household is also reliant on calorific value or heating value of the type of fuel used. The calorific value of any fuel is the amount of heat produced on complete burning of 1 gm when the fuel is burnt completely.

Table 2-2 shows described Domestic fuels Calorific values. Firewood has Lower Heating Value depending on its moisture content. The calorific value of hardwood that is grown expansively in Africa called SALIGNA was 19.76 MJ/kg and the calorific value of softwood called Pine was 20.42 MJ/kg.

According to the low quality of firewood available to rural local areas from deforestation, a little lower calorific value of fuelwood of 17 MJ per kg utilized in the current study is sensible according to the acceptable marginal variances in the calorific values of biogas represented in Table 2-1 (Domestic fuels Calorific values), 20 MJ/m3 is taken as an average of calorific rate and will be used in the calculations of the current study.

Table 2. 1 Domestic fuels Calorific values

Fuel	Calorific value	Units
Paraffin	35	MJ/L
Fuelwood	16	MJ/Kg
Biogas	20	MJ/m3
	21	MJ/m3
	22	MJ/m3

Source Pathak et al, 2009

2.3.1. Firewood economic value

The common value components of fuelwood are:

- Direct value : is when there is a place market where fuelwood is traded,
- Opportunity : is about the time used for pull together the resource

Around 1hour up to 5 hours are used on in a day to collect firewood by family member mainly children and women. During a month the time used can vary from a small number of hours to up or over 80 hours per month, depending on the rate of collection and the closeness of the firewood source, taking around of 45 hours in just one month all that time spent can be economically fruitful in alternative means.

2.3.2. Problem and disease associated to interior burn from firewood use

While air pollutant releases are conquered by outdoor sources and human daily activities playing a huge role on level of pollution of places. Using animal firewood, residues from agricultural, dung or coal in heating and cooking represent a huge source of indoor air pollution generally. By using a simple cooking stoves there is an emission of extensive amounts of pollutants, including respirable units, CO_2, Sulphur oxides and nitrogen... the ventilation is common in most case and most exposed are children who are still young and women are the ones who spend much time in inside of cooking are.

2.4. Biogas

Biogas is a combination of gases produced by the breakdown of organic matter in anaerobic condition. Biogas can be produced from different feeding raw material such as animal and human excreta, agriculture waste, kitchen waste, plants… apart of biogas the technology produces bio slurry. Biogas is renewable energy. Biogas is composed by 50% to 85% of methane gas, 20% to 35% of CO_2 (carbon dioxide), H_2, of additional gases such asH_2S, ammonia and hydrogen [9] Biogas is an odorless gas also colorless which burns with blue flame alike the one of Liquefied Petroleum Gas (LPG), Representative compositions of raw biogas and the properties of the components are summarized in Table 2-3 below [19]

Table 2. 2 Biogas Chemical composition and their properties

Constituents	Concentration (v/v)	Properties
CH_4	50 - 75%	Energy carrier.
CO_2	25 - 50%	Decreases heating value. Corrosive, especially in the presence of moisture.
H_2S	0 - 5 000 ppm	Corrosive and toxic. Sulphur dioxide emission during combustion.
NH_3	0 - 500 ppm	NO_x – Emissions during combustion.
N_2	0 - 5%	Decreases heating value
Water vapor	1 - 5%	Facilitates corrosion in the presence of CO_2 and Sulphur dioxide (SO_2).

The calorific value of biogas vary between 21 MJ/m3 to 24MJ/m3, and the bio sully which is rich in nutrients is produced as a bi-product in the biogas production process which can be used as organic fertilizer for crop production.

Biogas is a renewable form of energy at which could be replace mainly in rural area the nonrenewable source of energy like firewood, coal and oil which are affecting ecological system and harmful to environmental.

2.4.1. Biogas production through Biochemical processes

Digestion without presence of oxygen known as anaerobic digestion are following steps and biochemical reactions to produce gas which require the presence of bacteria.

The bio chemical process comprise in the creation of biogas is arranged in three stages:

- Hydrolysis,
- Acid-formation "Acidogenesis"
- Formation of methane "Methanogenesis"

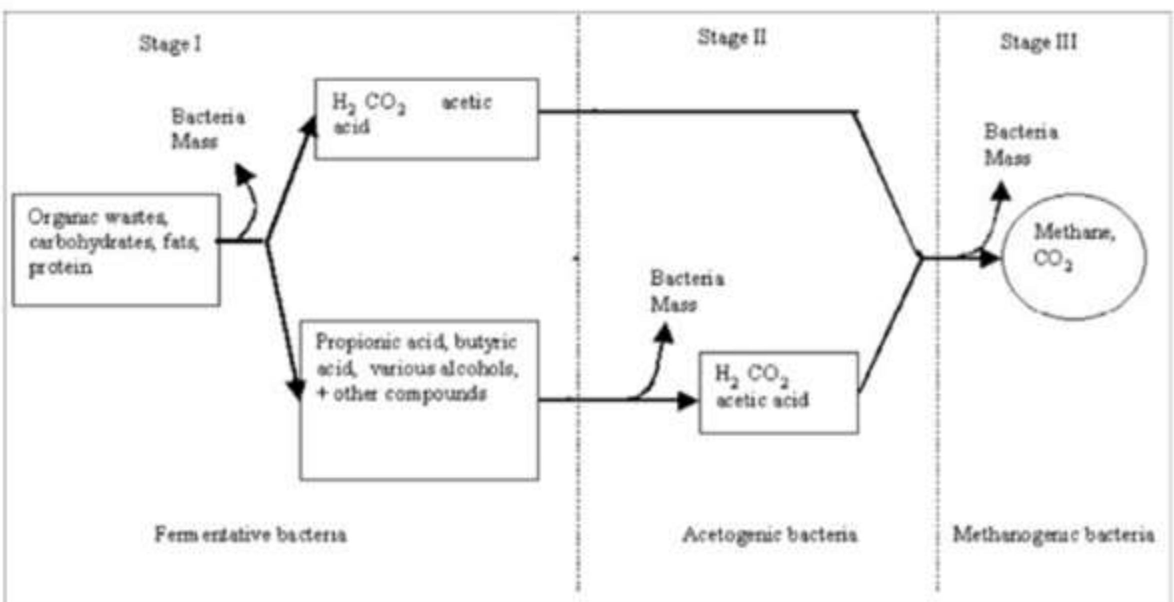

Figure 2. 1. Anaerobic fermentation of biomass stages [15]

2.4.1.1. Hydrolysis

Hydrolysis is a chemical process of breakdown of a long organic compound for example proteins, carbohydrates, fats, lipids and cellulose to the short molecules like amino acids, monosaccharides by help of added-cellular enzymes of facultative and anaerobic bacteria must be present [15]

Carbohydrates hydrolysis takes few hours to be done and for lipids and proteins hydrolysis takes few days. Lignin and Lignocellulose are deteriorated slowly and incompletely. The facultative anaerobic bacteria make use of the dissolved oxygen in the water and thus cause the reducing conditions necessary for obligatory anaerobic microorganisms [5]

2.4.1.2. Acid-formation "Acidogenesis"

Stage two deal with transformation of the fermented intermediate materials into organic acids short-chain, like acetic acid, acetate, butyric acid and propionic acid and acidogenic bacteria action deal with alcohols like ethanol, hydrogen and carbon dioxide [5]

Acetogenic bacteria are mandatory to produce hydrogen and the reduction of the hydrogen and carbon dioxide produce acetic acid.

They regularly eliminate the harvests of metabolism of the acetogenic bacteria from the substrate by keeping hydrogen partial pressure on the small level appropriate to the acetogenic bacteria.

When the partial pressure of hydrogen is low, H2, CO2 and acetate are predominately formed by the acetogenic bacteria [5]

When the partial pressure of hydrogen is higher, predominately butyric acid, propionic acid and ethanol are formed [5].

Around 30% of the whole CH4 gas production in the anaerobic can be accredited to the reduction of carbon dioxide with H2 , but simply around 6% of the entire CH4 creation can be accredited to the dissolved hydrogen.

2.4.1.3. Formation of methane “Methanogens”

Methanogens is the stage three and final stage of production of methane gas process. Where CH4 methane and CO2 carbon dioxide (biogas) are obtained by various conditions

The working without problems of acetogenic phase depend on the methane formation works, When there is disturbance in formation of methane, the acidification due to accumulation of organic acids from the acidogenesis step occurs.

Methanogens can be easily affected by different disturbances like toxic product present in a solution, changing, organic pollutants or dense metals

2.4.2. Technology of biogas digester

Biogas digester may exploited domestically and industrially level. On level of Industrial biogas are generally applied in developed countries on municipal solid waste treatments to discharge the burden from landfill sites and the produced gas mostly used for electricity production

The three types of reactors are classified as

- Fixed film reactors
- Anaerobic fluidized bed reactor.
- Up flow anaerobic sludge blanket reactor

Domestically biogas are greatest popular in the developing countries because of their generation capability of biogas on a small scale at rural area level. Produced gas is exploited as fuel to reduce the usage of biomass as fuel.

This thesis emphases on small scale biogas plant which are mainly common in the developing countries including Rwanda.

Table 2-3 describe the quantity of biogas, digester size and number of cattle’s may be required depending on the size of household.

Table 2. 3 Digester volumes requirements [9]

Persons number in the family	Necessities of biogas for cooking and lighting required (m3) per day	Volume of digester Required (m3)	Number of cattle needed
1-4	1	4	2 – 4
5 – 6	1.5	6	4 – 5
7 – 9	2	8	5 – 7
10 – 13	2.5	10	7 – 9
14 – 18	3.75	15	9 – 12
19 – 25	5	20	13 – 15

The common three type of domestic biogas digester are:

2.4.2.1. Chinese fixed dome

The Chinese fixed dome digester contains a big chamber designed in cylindrical shape with inlet feedstock and outlet a bio-slurry.

Gas produced is kept in the higher part named dome. Once Gas production begun bio slurry is moved to the overflow tank with a help of gas pressure in the upper part 'dome'. The overflow tank and the biogas storage volume are equal. As the storage volume with respect to the augmentation of gas pressure causing the slurry difference in levels among the inner of the digester and overflow tank.

It is built underground to simplify feeding and for insulation purpose of soil, therefore it retaining advantageous temperature inside the digester [13]. The local material are used in construction like as bricks, sand, concrete and stones.

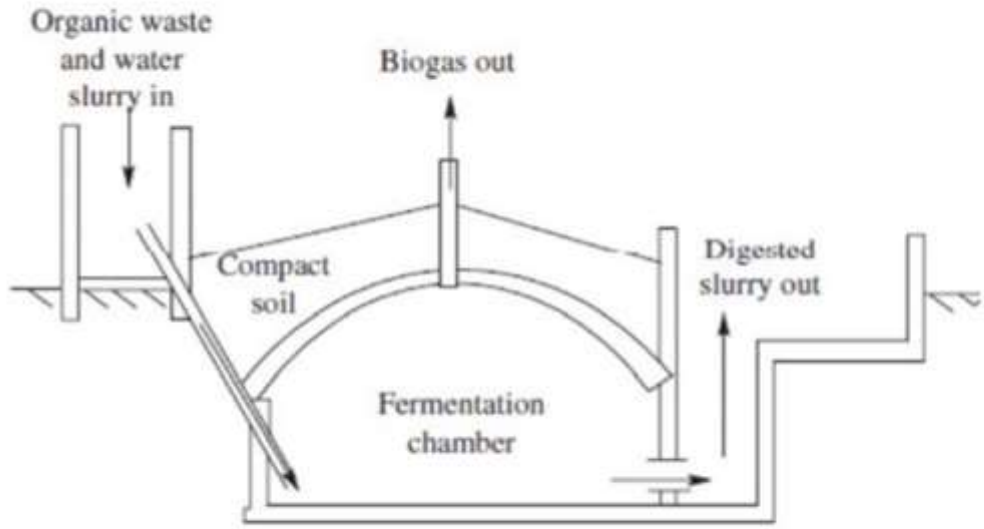

Figure 2. 2 Chinese fixed dome digester diagram [8]

2.4.2.2. Indian floating drum

The Indian floating drum type digester contains lower tank and upper tank where the lower tank contains the slurry and the inverted tank (upper tank) used as a cap pick up by gas as it is produced. As the gas is being used, pressure drops then upper tank drops down. In commonly, plastic tanks are better comparing to steel tank. The inverted tank is directly above the ground for the fixed dome type digester

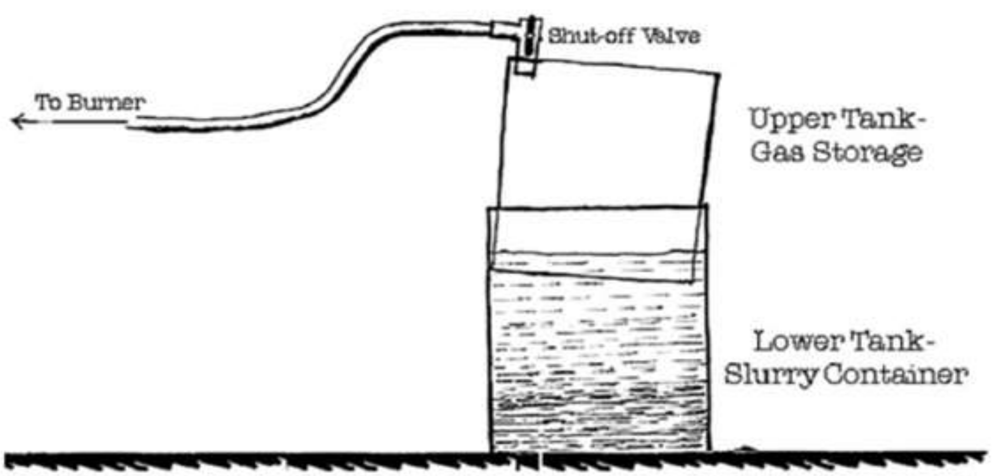

Figure 2-3: Indian floating drum digester [17]

2.4.2.3. Taiwanese plastic tubular

The Taiwanese plastic tubular digester works in plug-flow mode. The digesters sizes varies from 2.4m3 to 7.5 m3 [8]. Feeding runs from the inlet through a tubular plastic bag to the outlet, and the biogas is harvested to a burner by help of a gas pipe linked. To uphold greater process temperatures and decrease over night temperature variations the system of digester must be buried or enclosed by a greenhouse [9]. The implementation and handling of Taiwanese plastic tubular digesters are simplest and very reasonable cost design but are at risk to mechanical damage and the operational life is a short only 2-10 years [8] .

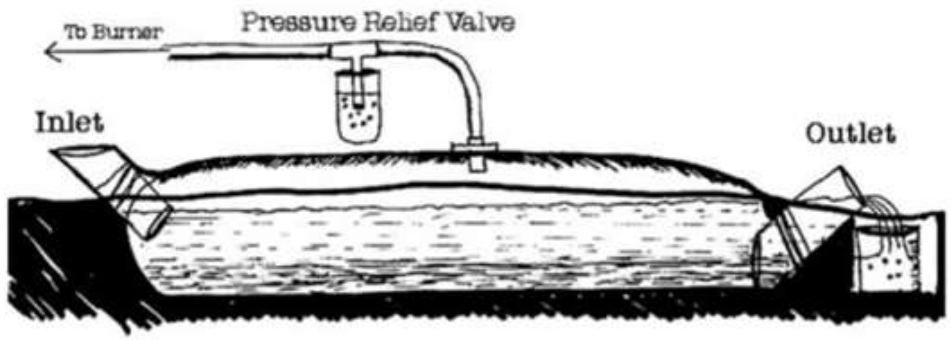

Figure 2. 3 Taiwanese plastic tubular digester diagram

Typical values for yield and rate constants for cattle dung in semi-continuous digesters are given in Table 2-5 below.

Table 2. 4 Cattle dung Kinetic constants in digesters [11]

Temperature (°C)	Yield Constant: C (L/kg)		Rate Constant: k (1/d)	
	Volatile Solids	COD	Volatile Solids	COD
33.5	402	347	0.083	00081
30.1	450	-	0.052	-
27.5	310	-	0.044	-
25	289	237	0.069	0.078
24.4	250	-	0.036	-
20.3	310	-	0..022	-
16	178	164	0.033	0.026

2.4.3. Feedstocks characteristics

In common, all of biomass types can be used as feedstock the necessity it must contain proteins, carbon based product like carbohydrates, fats, cellulose…Though, the biodecomposition of the input is influenced by it chemical and physical compositions

Usual feedstocks used for biogas production:

- Animal waste
- Human excreta
- Food waste
- Co-digestion

Typical standards material value properties with parameters are mentioned below.

Table 2. 5 Properties of typical feedstock

Type of Feedstock	% of Volatile Solid	C:N Ratio
Manure of Pig	80	14
Manure of Cow	77	20-30
Manure of Chicken	77	8
Human excreta	15-20	6-10

Volatile Solid is not the proper digestibility measure of feedstock some indigestible solids will burn at 500 °C like Lignin and other and other like sugars leave a carbon deposit when heated. The following table describe biogas typical yields per kg of dry matter of different feedstock material in digesters.

Table 2. 6 Feedstock Biogas production

Feedstock	Daily Feedstock production (kg/ani mal	%DM	Biogas yield (m^3/kg DM)	Biogas yield (m^3/animal/day)
Manure of Pig	2	17	0.25-0.5	0.128
Manure of Cow	8	16	0.2- 0.3	0.32
Manure Chicken	0.08	25	0.35-0.8	0.01
Excrement of Human	0.5	20	0.35-0.5	0.04
Vegetable Waste	-	5-20	0.4	-
Bio waste from households	-	40-75	0.3-1	-

As above detailed how rich animal waste is in microbial and nitrogen activity then co-digesting with feedstocks rich in carbohydrates but poor in nitrogen can considerably improve biogas production. Food waste feedstocks it contains rich organic fermentable matter can increase system stability and general biogas production [14].

Table 2. 7 Pure cow dung and other co-digested feed comparison of cumulative biogas production [cm3/kg solid feed]

Number of days	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Cow dung	400	988	2454	4657	11607	19237	26324	27858
Cow dung & corn waste	390	1061	2252	3402	6627	10855	13394	14203
Cow dung & kitchen waste	848	1590	2882	4330	6411	9727	13319	14819
Cow dung & spent tea waste	2429	3009	3659	3977	4318	7314	9688	10450

Biogas production evaluation of different feedstocks and pure cow dung, the table shows that after 25–30 days the production of gas is minus, while others feedstock can take up 25day to 30days. The effects achieved from cow dung mixed by tea waste displayed that firstly gas production is high because it contains sugar. Glucose are simply changed to acid and then methane [14]

2.4.4. Biogas digester operation affecting factors

Biogas digestion is a bacterial process it requires to take care to remain in conditions which is suitable growth to the biogas producing bacteria. The common influences that disturb production of biogas are:

2.4.4.1. Temperature

The inside temperature of digester plays a major role in production of biogas as it influences the development of the methane gas by producing bacteria [15] anaerobic fermentation require temperature ranges of operation: psychrophilic (<30 °C), mesophilic (30 – 40 °C) and thermophilic [15]   classified the three temperature ranges for the AD process as <20 °C for psychrophilic, 20 – 40 °C for mesophilic and >40 °C for thermophilic. However, anaerobes are more active in the mesophilic and thermophilic temperature ranges [15] .

The minor variants in term of temperature can be the reason a considerable reduction in activity and performance, consequential in a build-up of undigested impulsive acids initiating acidic conditions [5] hence, the range of ± 2 °C as variation must not exceeded. An unexpected change of above 5 °C in a day can be a reason a short-term inactivity of the methanogenic bacteria.

2.4.4.2. Ph

The potential of hydrogen (PH) level is very significant in term of performance of the methanogenic bacteria at the beginning of biogas production the acidogens come to be active first, as the acid level rise the PH decrease and methanogens then start consuming acids, take the PH back to neutral[14]

2.4.4.3. Carbon to Nitrogen ratio

For best development of bacteria in biogas production, it is preferred that the feeding must contains adequate nutrients. Whereas carbon stores energy and nitrogen is required for growing cells. It is mostly initiate that during aerobic digestion bacteria use carbon 25 to 30 times quicker than nitrogen.

A little ratio of C: N states that the content is rich in nitrogen and vice versa. Contents with a too little C: N ratio conduct to ammonia production augmentation and inhibition of methane production [8]

2.4.4.4. Availability of nutrients

Digester feeding must hold sufficient nutrients to increase the growing of microorganisms. The necessary for other nutrients apart nitrogen and carbon is too low.

2.4.4.5. Solids concentration

Solids concentration is the quantity of feeding material to be fermented in a unit volume of bio-slurry normally 7% to 9% solids concentration is a well-matched for ideal aerobic digester when is high concentration more than 12% it doesn't flow easily over the inlet pipes [8].

When toxins are existing, like high nitrogen concentration, bacteria have a big chance to be affected. Yet slurries may reach up to 30% of solids can be digested in a dry fermenter [12] If water content is little, acetic acids will accumulate, inhibiting the fermentation process and hence production; also a rather thick scum will form on the surface [18]

The are other important factors that can affect the biogas production like organic loading rate, hydraulic retention time etc.… which must be considered

2.5. Biogas in the developing world

2.5.1. Biogas technology status in Africa

Differently to Asia, technology of biogas in Africa is still developing and the potential is present. Africa is expected to have more than 168 million head of domestic cows and more than18.5 million households are expected to have that. By seeing only animal excreta as feed there are initiatives project that are presently operating in Africa such as SNV, SNV support biogas project on national level which are active in nine African countries[9] . From those programs, Africa rise by 44% of installed biogas digesters from 2011 to 2012.

Table 2. 8 Number of biogas plants installed in selected African countries

Country	Year of program initiation	Cumulative number of biogas plants installed up to 2009 [9]	Cumulative number of biogas plants installed up to 2012 [9]
Rwanda	2007	434	2619
Ethiopia	2008	128	5011
Tanzania	2008	3	4980
Cameroun	2009	23	159
Uganda	2009	40	3083
Burkina Faso	2009	1	2013
Kenya	2009	106	6749
Senegal	2010	-	334
Benin	2010	-	42
Total		**735**	**24990**

2.5.2. Domestic biogas technology status in Rwanda

Biomass energy represent 85% of all energy used up and is mainly spent in cooking, with firewood by rural households and in urban area many are using charcoal. The analysis on demand and supply of biomass bring out a policy of reduction of dependence and reliance on charcoal and firewood.

Through Rwandan energy transformation programs, the energy sector aim is to have a big number of households shifting from traditional cooking technologies to succeed sustainable energy efficient technologies.

2.5.3. Challenges for the dissemination of domestic biogas technology

2.5.3.1. Lack of a renewable energy policy

Renewable energy is essentials to be in main streaming agenda of a government as apparent from the successful programs of biogas in India and China.

Country must manage to pay for active rising and facilitate through different angles like taxes and custom exclusion, laws and other supports to promote biogas technology (Ghimire, 2013). The successful countries like India, Nepal and China inject financially and provides technical support to develop quickly that technology which a good example to be followed

2.5.3.2. Climate too cold or too dry

Places where the temperature at times goes under of 10 °C are not appropriate for biogas production except the digester is secured against temperature extremes.

2.5.3.3. Participation of private sector

The participation of private sector play important role in supporting renewable energy sector and by participating commercially in biogas sector sustainable and its market. The national strategy must be established in a way that it interests more companies to contribute in the biogas sector [8]

2.5.3.4. Low income of the target group

The main problem and obstacles for spreading of biogas technology is the high cost in initially phase on installation, operating and maintenance in term of financial way of many rural households. Accessibility to financial institutions also are still an issue to the low income households.

Carbon credits can be a sustainable resources of capitals in the longer term, carbon credit incomes might be for local biogas research and development.

2.5.3.5. Lack of technical knowledge

The skills about implementation, construction, maintenance operation of biogas systems is regularly a reason for non-acceptance of biogas technology in different countries in Africa [8] where people have installed biogas digester facing problem in under standard units poor operation performance at certain time they leave the usage of biogas digesters.

2.5.3.6. Water availability Limitation

Water is among the major content of the biogas system and some area are inadequate to the water sources, limitation on water source for functioning biogas represent a important interruption for adoption of biogas technology; mainly if water source is fall away from their home of there is a big temperature variation during annual seasons.

Only a minor percentage of the population who live in mountainous regions has regular enough water accessibility [18] Sub-Saharan countries like Botswana and Tanzania due to their climate are categorized as dry countries then unfitting to domestic biogas technology. Several parts of those countries are described by long periods of drought between rainy seasons.

2.6. Benefits of biogas technology

Apart to be a renewable energy resources, clean anaerobic digestion technology present additional benefits.

2.6.1. Health benefits

Using solid fuels like firewood, dung, residues from agricultural and coal discharges toxic smoke at which covers toxic gases like hydrocarbons, carbon monoxide with particulate matter. Cooking is typically done indoors where there is a minus ventilation consequently causing severe health disease associated with respiration and eyes problem.

Biogas improves health of the rural low-income households by providing a cleaner cooking fuel thus avoiding these health problems [2]. Women spend a lot of time in the kitchen with children cradled on their backs therefore they are at high risk of these health problems [2].

2.6.2. Organic fertilizer

Apart of fuel form of energy biogas produces bio-slurry as organic fertilizer is very rich in potassium, nitrogen, and phosphorus which is major content needed for crop production when applied to the land.

Table 2. 9 Nutriment content of important organic manure [17]

Organic Manure	Organic Matter (%) C	N	N_2 (%)	P2O5 (%)	K_2O (%)
Farm yard manure	25-55	15-20	0.40-0.80	0.60-0.82	0.50-0.65
Biogas slurry	60-73	17-23	1.50-2.25	0.90-1.20	0.80-1.20
Vermicomposting	9.80-13.40	-	0.51-1.61	0.19-1.02	0.15-0.73

Human waste covers great amounts of plant nutrients than cow dung, so the utilization of human excreta as a feedstock can improve the overall nutrient qualities of the slurry, and if treated properly, the slurry can be utilized in agriculture as a complete fertilizer [17].

2.6.3. Economic benefits

Economic profits from aerobic digestion are jobs creation sector and other funds that can made through carbon credits.

The bio sully fertilizer can be an alternative to chemical fertilizers. The chemical fertilizers are commonly imported so there is a big probability to use those means spend in importations to other economic way.

An article in the Nepal Times pointed out that the Nepal's successful biogas program brought farmers a clean fuel, conserved forests and provided high quality fertilizer for crops. Moreover, Nepal also benefits in terms of hard cash (in the form of carbon revenues) received from the industrialized nations for the burning of biomass to release greenhouse gas emissions into the atmosphere [11]

2.6.4. Social development

Here is strictly related in reduction of assignment from children, women and other concerned and also the accessibility to sustainable energy in their home will contribute huge in development of a country, normally in Africa children and women are in charge for firewood collection at which consuming their time and exhausting tasks.

2.6.5. Greenhouse gas emissions reduction

Domestic use nonrenewable energy fuels like firewood, charcoal through low efficient stoves to meet energy demands which lead to greenhouse gas emissions. Biogas technlogy helps to reduce greenhouse gas emissions by dislodging the consumption of firewood and other solid biomass.

Biogas technology does not only contribute to controlling environmental pollution and recycling of nutrients but alleviates dependence on imported fossil fuels. In Rwanda context, utilization of biogas to meet energy demands of low income households can assist in reducing dependency on firewood for cooking.

2.6.6. Reduced deforestation

The greatest significant consequence of high dependency on firewood for fuel is its association to deforestation. Firelwood accounts around 55% of forest extinct risks[2] Global deforestation is responsible for 17–25% of all anthropogenic GHG emissions, making it one of the leading causes of increased GHG emissions [17]. In Nepal, the installation of biogas plants has helped protect the forest [8]. For instance, there is an annual saving of 2 tons of fuelwood per household that has installed a biogas plant [8] reported 50% higher annual fuelwood savings in Nepal of 3 tons per household. This means that there is a nationwide saving of more than 200 000 tons of fuelwood per annum [8].

Deforestation is a major contributor to soil erosion causing susceptibility effects of scarcities and inundations. The more deforestation increases the more amount of time spent searching for fuelwood due to its insufficiency become. Hence biogas technology decreases enslavement of rural communities on firewood as well as decreasing soil erosion, deforestation and burden to women and children.

CHAPTER THREE: RESEARCH METHODOLOGY

In this chapter the research methodology, design sampling, collection and generated data, the design of research, instruments used for data analysis and collecting data, and difficulties confronted in the research and the answers.

3.1. Research design

Research design discusses a method framework and technical methods chosen, in this study the mixture of case study and descriptive research design methods are going to be used.

Descriptive research design will work on put together the bond among small scale biogas and others adjustable information on opportunity of usage. Other research design was case study design deal with a study of a household member (vulnerable of lack of energy) of nyagatare district. The combination was applied for the reason that it predicted to bring a deeper comprehension and well understanding on the opportunity of small scale biogas.

3.2 Study population

Population is all items a part of research studies. The target population of this study is 30 households of Nyagatare district from 5 different sectors which are Nyagatare, Rukomo, Katabagemu, Rwimiyaga and Karangazi.

The intentions for using a model sample, instead of using data from all-inclusive population In study inquiries involving numerous hundreds or thousands of data elements, it is almost impossible to assemble all data from or study each and every element, therefore, a universal sampling with 30 households of Nyagatare district presents total population of nyagatare district.

Table 3. 1 Study population

	Frequency	Percent (%)	Valid Percent (%)	Cumulative Percent (%)
Karangazi	4	13.3	13.3	13.3
Katabagemu	6	20.0	20.0	33.3
Nyagatare	9	30.0	30.0	63.3
Rukomo	7	23.3	23.3	86.7
Rwimiyaga	4	13.3	13.3	100.0
Total	30	100.0	100.0	

3.3. Sampling techniques

The study will use a technique of randomly sampling technique which refers on the samples selection of where all the people where each element of population have the equivalent chance of being involved in the sample taken.

3.4 Source of data

3.4.1. Primary data

Primary data is the information originated by the researcher for the purpose of take investigation at hand, the continued saying that primary data are necessary more especially when the information collected through secondary data is unable to provide required information to fit the precise purpose to the problems understudy. Therefore this data came from self-administered questionnaire; personal interviews and observation in order to solve a problem of lack of energy and show the feasibility to overcome same problem.

3.4.2. Secondary data

Secondary data is defined as the information not gathered for the immediate study at hand but for other purpose therefore, this data come from the review of documentations from various text books, periodic supports internet and other relevant source.

3.5 Instruments of data collection

This method of collecting data involved questionnaire, interview, observation and documentary study.

3.5.1. Interview

Defined as 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 person questioned must be in field and sometimes its needed some kind of response from individuals, the interview data collection was used in situation where respondents has no time of completing to the questionnaire.

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.

3.5.2 Questionnaire

The researcher to collect the information from respondents used self-administered questionnaire. Here a set of related questions are prepared and respondents are requested to answer special arrangements are made before the research period and the questions are put in form of open and closed questions to simplify the work.

3.5.3 Documentary study

According to Robert Ross (1974:128); the advantage of documents studies are to explore the resources in order to obtain clear information. Document study as a data collection method is used during the research for it permitted the researcher to examine subjects to whom he did not have physical access.

3.5.4. Observation

This technique was used because it is easy to get first-hand information from targeted sample and also enable to see what is answered is reflected in their performance.

3.6 Data collection Methods

In this research work, we used Quantitative and qualitative research method because it helped to gather quantitative information and qualitative information.

3.6.1 Quantitative Research

Quantitative Research is reflected to quantify the problem in order to produce numerical data or data at which can be used in statistical way it focus on quantification of data like behaviors, attitudes, opinions and so on.

3.6.2 Qualitative research

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.

3.7 Research procedure

The piloting of the research instrument will be conducted Nyagatare district and thereafter relevant amendments will be made on the final data collection instrument.

We give the full explanation and the purpose of the study to the sample population and the questionnaire are distributed to the sample and give time to fill it before its collection. A follow up is needed to assist them a cross check on questionnaire filling.

3.8 Data processing and analysis

Primary data are converted into significant statement by means of various software and techniques. There is commonly required of checking in order to end up with accurate data at which openly reflect the illustrated situation. Adjusting, editing, coding, and formulation are also included and must be done to minimize detailed data to the size which is manageable

3.9 Limitation of your study

The researcher was able to accomplish the study successfully through 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, there will make the comparison of data, reports and their time of delivery. To eliminate that doubts about the relevance of data, different data information collection techniques is used to reduce the chances of data withhold, and stuck to the timetable by best use of the short time to meet the deadline.

3.10 Moral Considerations and confidentiality

Approval from people of households from the place study is being piloted must be protected before data compiling. The privacy of the respondents must be conserved as promised. Nothing must be on survey form that may recognize the participants.The questionnaires must have ID numbers which doesn't identify of the respondent. The respondents are enunciated that the data information they offer is simply to be used for this study purpose only.

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter emphases on data collected analysis of 30 households of Nyagatare district. all data are displayed in the tables and chats with analysis. The survey has divided into three different parts. The number one is related to profile of respondents, second deal with energy status and problem associated the third is concerning is about awareness of biogas technology and opportunity related to the perception of respondents.

4.1 Respondents demographic characteristics

The respondent demographic characteristics who participated in this research include gender, age category, marital status, and education background of the respondent. Information related to awareness of the biogas technology also were collected; those include opportunity and obstacles of adopting the small scale biogas.

Table 4. 1 Distribution of respondents by Gender of Family Head

		Frequency	Percent	Valid Percent	Cumulative Percent
	male	21	70.0	70.0	70.0
	female	9	30.0	30.0	100.0
	Total	30	100.0	100.0	

Source: primary data 2019

The distribution of sex of respondents in this research. Respondents with female sex participated on the proportion of 30% and the remaining 70% is for male sex respondent. The reason of having big number of male this indicate how the biogas technology implementation relied to the country in gender.

4.1.1 Family size

The bigger family sizes it come the more energy resources requirement become in their daily life. The size of family reveals the overall consumption energy status of family.

Table 4. 2 Number of family member

	Frequency	Percent	Valid Percent	Cumulative Percent
3	2	6.7	6.7	6.7
4	4	13.3	13.3	20.0
5	7	23.3	23.3	43.3
6	7	23.3	23.3	66.7
7	6	20.0	20.0	86.7
8	1	3.3	3.3	90.0
9	2	6.7	6.7	96.7
11	1	3.3	3.3	100.0
Total	30	100.0	100.0	

Source: primary data 2019

The household size average surveyed is 6.7. The total population of the 30 households surveyed 201 people were found.

4.1.2 Literacy status

The implementation and adaptation of biogas technology is influenced by educated level od members of family. Moreover, the knowledge status specifies the general economic level and social status conditions of wellbeing.

Table 4. 3 Educational Status of family members

	Frequency	Percent	Valid Percent	Cumulative Percent
Illiterate	3	10.0	10.0	10.0
Literate	4	13.3	13.3	23.3
Primary	6	20.0	20.0	43.3
Lower Secondary	4	13.3	13.3	56.7
Secondary	6	20.0	20.0	76.7
TVET	4	13.3	13.3	90.0
Intermediate	2	6.7	6.7	96.7
Bachelors or above	1	3.3	3.3	100.0
Total	30	100.0	100.0	

Source: primary data 2019

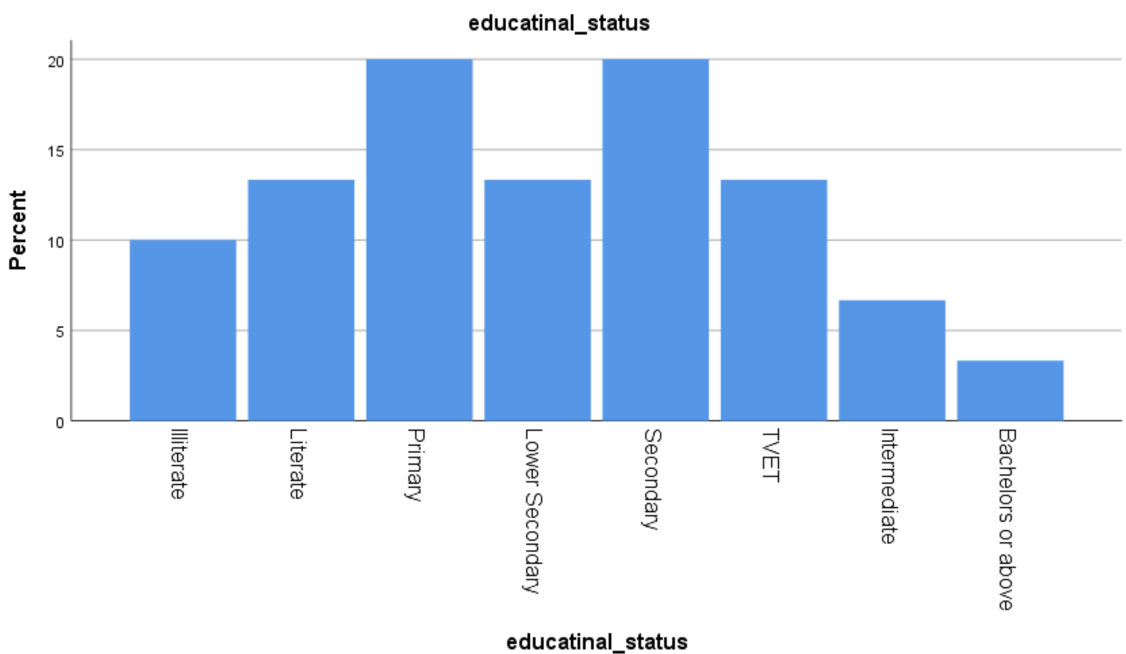

Figure 4. 1 Educational Status of family members

4.2 Socio-economic characteristics

4.2.1 Road distance

Position of the household to the road specifies and give a figure accessibility biogas plants. Numerous of the respondent were reachable within 20 to 30 min of walking distance from the road.

Table 4. 4 Distance from the road in minutes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	1	3.3	3.3	3.3
	10	5	16.7	16.7	20.0
	15	2	6.7	6.7	26.7
	20	7	23.3	23.3	50.0
	25	2	6.7	6.7	56.7
	30	8	26.7	26.7	83.3
	40	2	6.7	6.7	90.0
	45	3	10.0	10.0	100.0
	Total	30	100.0	100.0	

Source: primary data 2019

4.2.2 Water Resources Availability

Manly of the respondent households their accessibility of water resources to where they stay shows 86.4% doesn't have accessibility of water into home and stated that they can manage to get water less than 40 minutes.

Table 4. 5 Availability of Water Resources

	Frequency	Percent	Valid Percent	Cumulative Percent
0	1	3.3	3.3	3.3
5	4	13.3	13.3	16.7
15	1	3.3	3.3	20.0
20	11	36.7	36.7	56.7
25	1	3.3	3.3	60.0
30	6	20.0	20.0	80.0
40	6	20.0	20.0	100.0
Total	30	100.0	100.0	

Source: primary data 2019

4.2.3 Electricity Connectivity

Concerning the domestic electricity connection the survey shows 46.7% have access to electricity where they stay.

Table 6 shows the details of access to electricity facility.

Table 4. 6 Electricity Connectivity

	Frequency	Percent	Valid Percent	Cumulative Percent
yes	14	46.7	46.7	46.7
no	16	53.3	53.3	100.0
Total	30	100.0	100.0	

Source: primary data 2019

4.2.4 Occupation

Greatest of surveyed hang on agriculture for their life which represent 36.7and 30% of surveyed rely on Business and 10% on business service as daily activity. The details are shown in table below.

Table 4. 7 Occupational Status

	Frequency	Percent	Valid Percent	Cumulative Percent
Agriculture	11	36.7	36.7	36.7
Business	9	30.0	30.0	66.7
Service	3	10.0	10.0	76.7
Labor	3	10.0	10.0	86.7
Other	4	13.3	13.3	100.0
Total	30	100.0	100.0	

Source: primary data 2019

4.2.5 The plant Investment

The economic condition and social aspects of the households contribute in construction financial constraint of building biogas plant. All respondents which are using biogas are totally financed by the government program

Table 4. 8 Financing Way during biogas plant building

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	government program	11	36.7	100.0	100.0
Missing	System	19	63.3		
Total		30	100.0		

Source: primary data 2019

4.3 Impacts of biogas and bio slurry

Manure is an important contribution to maximize plant crops and Bio-slurry is rich because it has elements necessity for plantation like phosphorus, nitrogen, potassium, But after survey has recognized as a good fertilizer in rural areas the slurry found out a production of biogas can be utilized in cultivation and crops growing in growth of productivity and replacement of industrial fertilizers.

Table 4. 9 Bio-slurry use on productivity alongside Impact of on farming

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Increased	11	36.7	100.0	100.0
Missing	System	19	63.3		
Total		30	100.0		

Source: primary data 2019

4.4. Energy, Environment, Health and Sanitation

4.4.1 Firewood source

The firewood collection sources is from government, public or private forests. Process of collecting firewood represent the problem of resource degradation. Straight cutting trees can completely affect the restoration ability.

The respondent's surveyed state 46.7 told they collect firewood from government forest and 13.3% for community only 10% report that they buy it.

Table 4. 10 Firewood Collection place

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Government Forest	14	46.7	66.7	66.7
	Community Forest	4	13.3	19.0	85.7
	buy	3	10.0	14.3	100.0
	Total	21	70.0	100.0	
Missing	System	9	30.0		
Total		30	100.0		

Source: primary data 2019

During the firewood collection, the major responsibility goes children. 66.7% of the total respondents reported children are allocated with the duty of firewood collection while 3.3%

Table 4. 11Table 11: Responsibility of Fire Wood Collection

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	5	16.7	25.0	25.0
	female	2	6.7	10.0	35.0
	both	1	3.3	5.0	40.0
	children	12	40.0	60.0	100.0
	Total	20	66.7	100.0	
Missing	System	10	33.3		
Total		30	100.0		

Source: primary data 2019

Table 4. 12 The observed Impacts on the forest deterioration

		Frequency	Percent	Valid Percent	Cumulative Percent
	Excessively degeneration	12	40.0	40.0	40.0
	considerably degeneration (forest and trees are decreasing)	11	36.7	36.7	76.7
	forest and trees are not degenerated at all	2	6.7	6.7	83.3
	I don't know	5	16.7	16.7	100.0
	Total	30	100.0	100.0	

Source: primary data 2019

4.5 Health and Environment

4.5.1 Indoor air pollution Reduction

Straight ignition of solid biomass and fossil fuels discharge toxic gases like Carbone dioxide, Carbon-monoxide, sulfide, and particulate substances. When the combustion is incomplete they interfere with people's health. the usage of biogas in place of solid and traditional fuel sufficiently decreases pollution and all disease.

Table 4. 13 Reduced incidence of diseases

	Drastically reduced	Reduced	Don't Know
Eye Infection	8.79	78.02	13.19
Respiratory diseases	24.18	29.67	46.15
Cough	2.20	52.75	45.05
Fire related injured	2.20	37.36	45.05

Source: primary data 2019

4.6 Firewood use and biogas yield of organic substrates

The 30 households of Nyagatare district have on average six household members with a minimum of tree cows (20% of households in Nyagatare have none, 44% have up to 5, 27% have 6–10, and 9% more) (assessing GIRINKA PROGRAMME 2006-2016). These variations are reflected in the selection of area of implementation of biogas project.

Cooking were mentioned to require firewood in almost all households. Cooking is done three times average in day mean firewood consumption is too high.

From results above, there are biogas potential according to the number of cows a household have can use digester with respect to the below table of plant size and average daily feedstock

Pant Size (m^3)	Daily Feedstock (kg)	Daily Water (l)
4	24	24
6	36	36
8	48	48
10	60	60
15	90	90
20	120	120

Material that can be used for construction of small scale biogas of 4m3 which required minimum compare to others

	ITEM DESCRIPTION		4m3	
	General bulk Materials	UNIT	QUANTITY	Cost
	Cement-50 kg	bags	13	
	Water proof cement-1kg	bags	3	
	Quarry stones dressed/Blocks-390x190x150mm	pcs	145	
	Bricks-230x110x70mm	pcs	200	
	Sand	Tons	3	
	Ballast-25mm-1"	Tons	2	
	Lime 25kg bags	bags	4	
	Round bar-R8	Lengths(6m)	2	
	Weld mesh- heavy gauge	pcs	1	
	Binding wire	kg	1	
	Sub Total 1			
	Piping fittings + Assorted items			
	Dome pipe-3/4"-410mm		1	

	GI Ballcork-3/4"		1	
	Burner-Single		1	
	Pressure manometer		1	
	PVC pipes-3/4"		1	
	PVC T-joint		1	
	PVC Reducer-3/4"x1/2"		1	
	PVC Pipes-1/2"		1	
	GI Elbows-3/4"		1	
	PVC Elbows-1/2"		1	
	Reducer 1"x3/4"		1	
	Hexagonal nipples-3/4"		1	
	PVC Socket-3/4"		1	
	GI T-joint 1/2"		1	
	GI Socket-3/4"		1	
	Hexagonal nipples-1/2"		1	
	GI Reducer-1"x3/4"		1	
	Tangit glue-50ml		1	
	GI Ballcork-1/2"		1	
	Sub Total 2			
	Labor cost			
	Excavation &site preparation			
	GRAND TOTAL			

The cots vary according seasons the average calculation shows for the small scale biogas plant of $4m^3$ cost 1410000 frw to be ready to operate and for household with low income it seems to be high.

CONCLUSION

This thesis has been reevaluated all potential data information and established an exploration of potential profits of small scale biogas plant digester with primary data of sample on low income households and other factor that can prompting successfully application of small scale biogas in nyagatare district are reviews in literature and the potential to facilitate it was represented and the risks and benefits in implementation of this technology need additional exploration and commitment of multidisciplinary methodology to recognize most favorable approaches for executing small scale biogas in various countryside societies, concentrating on available materials in local areas to overcome energy problem for cooking, associated issues and provide other opportunities including expansion of energy sources, environmental protection, improved employment opportunities,… for small scale biogas to achieve success and its objectives, the government must figure out and perform different procedures including technical characteristics as well financing and debates on awareness on resources already present on field to well recognize how to maximize profits of small scale biogas mostly to the low income households and energy sector concerned.

In Rwanda, energy sector especially the renewable is yet to be developed in rural areas are still struggling in traditional methods in their daily activities mainly cooking, small scale biogas technology will enable them to have access to clean energy and gain more time which can be invested in other development activities. Grant has paying attention to many people to capitalize in any new project so it is another area to be focused. Regarding carbon credits, is another aspect due to the environment global pressure, from there are various opportunities to attract more investors to invest in the sector and the possibilities of financial support will be higher and the country will benefits in selling carbon credits.

RECOMMENDATION

The investment budgets currently are much higher than during past time when the existing biogas plants in Rwanda were installed. The increase in the price is due to a change in material as well as to a decrease in subsidies by the government and other NGO's.

The questionnaires administered to users also seek suggestions on biogas technology, from the survey, it recommended:

-The investment costs have to come down considerably, otherwise the targeted people (low income household) will not afford it, only wealthy families can afford it. Mass production and higher subsidies would be required to reduce investment expenses so mobilization must be great.

-Problem of loans must not be a barrier of system failure the finical institution must assessed, but low income household require a support of government of financial facilities and place a technic of accessible to them

- The government must provide sufficient training about awareness and exploiting energy potential resources available.
- Subsidy program could be flexible and be expressed in item price or physical materials as well as sponsors.
- Follow up on implementation activities should be done
- Furthermore, the government must attract investors in different sectors to invest in biogas technology and boost the number of rural area to obtaining biogas.
- Finally, I can recommend the introduction of loan, assurance and guarantee to the renewable energy project.

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ANNEX

Questionnaire for Biogas User and non-user Households

1. GENERAL INFORMATION			
	NAME		
	ID		
	CODE NUMBER		
HOUSEHOLD INFORMATION			
	Gender of household head	1. Male	2. Female
	Main Occupation of the Family Head	1. Agriculture 2. Business 3. Service 4. Labor 5. Other	
	Number of Family Members		
	Educational Status	level	
		Illiterate	
		Literate	
		Primary	
		Lower Secondary	
		Secondary	
		TVET	
		Intermediate	
		Bachelors or above	
LOCATION OF THE HOUSEHOLD			
	Sector		
	Walking distance from the road		

	Distance to water source		
	Connectivity with electricity	1. yes	2. no
HOUSEHOLD ENERGY SOURCES			
	Cooking energy	Firewood	
		biogas	
		Dung	
		Coal	
		LPG	
		Saw Dust	
		Petroleum product	
		Crop Residues	
		Other	
HOUSEHOLD USING FIREWOOD			
	Who is responsible for collection of firewood	1. Male	
		2. Female	
		3. Children	
	Place of collection	1 own forest	
		2 Government Forest	
		3 Community Forest	
		4 Private Forest/Land	
		5 Buy	
		6 Other	
	What impacts you have observed on the forest during firewood collection	1.Excessively degenerated	
		2. Considerably degenerated (no. of forest/trees had decreased?	
		3. Forest/trees were not degenerated at all	
		4. Don’t know	
	If the answer to the question above is 1 or 2,	1.Time taken in collecting firewood was increasing as the distance traveled was increasing	

<table>
<tr><td rowspan="3"></td><td rowspan="3">which of the following impact was more prominent.</td><td colspan="3">2. Price of firewood purchase was increasing due to increase in time or distance traveled in collection of firewood.</td></tr>
<tr><td colspan="3">3.Type of firewood collected was changing to lower grade due to scarcity of firewood, like twits, agro-waste, etc.</td></tr>
<tr><td colspan="3">4. None of the above.</td></tr>
<tr><td colspan="5">FAMILY HEALTH AND FIREWOOD RELATED ACCIDENT</td></tr>
<tr><td></td><td>1. Eye infection</td><td colspan="3"></td></tr>
<tr><td></td><td>2. Respiratory diseases</td><td colspan="3"></td></tr>
<tr><td></td><td>3. Cough</td><td colspan="3"></td></tr>
<tr><td></td><td>4. Fire related injury</td><td colspan="3"></td></tr>
<tr><td></td><td>5. Others (specify)</td><td colspan="3"></td></tr>
<tr><td colspan="5">AWARENESS</td></tr>
<tr><td></td><td>Do you know about Biogas?</td><td colspan="3"></td></tr>
<tr><td></td><td>Do you prefer to install a biogas plant?</td><td colspan="3"></td></tr>
<tr><td></td><td>Do you have any skills on biogas operation?</td><td colspan="3"></td></tr>
<tr><td colspan="5">HOUSEHOLD USING BIOGAS</td></tr>
<tr><td></td><td>Size of Biogas Plant</td><td colspan="3"></td></tr>
<tr><td rowspan="6"></td><td colspan="4">Investment on Plant</td></tr>
<tr><td rowspan="5">How did you manage financing for Construction of biogas plant</td><td colspan="3">1. Self</td></tr>
<tr><td colspan="3">2. Loan from village lender</td></tr>
<tr><td colspan="3">3. Bank loan (Large Banks)</td></tr>
<tr><td colspan="3">4. Loan from micro finance institutions (Cooperative, Rural Development Bank, Others)</td></tr>
<tr><td colspan="3">5. Others (specify)…………………….</td></tr>
<tr><td></td><td>Have you received subsidy for installing biogas plant?</td><td>Received</td><td>Not Received</td><td>Don’t Know</td></tr>
</table>

	IMPACTS ON BIOGAS				
	Time Saving for Family Member by using biogas				
	How much time of family members is saved when they have biogas in Hrs.	1. Firewood collection			
		2. Cooking			
		3. Other specify			
	How the saved time is utilized by the members of your family if they have biogas	1. Literacy classes			
		2. Listening Radio/Watching TV			
		3. Reading newspapers			
		4. Social works			
		5. Resting			
		6. Study			
		7. Income Generating Activity			
		6. Others …………….			
	Has the amount of smoke in the kitchen reduced after	Reduced to some extent			
		Reduced to greater extent			
		No			
	Bio-slurry Utilization				
	Do you use the bio-slurry manure?		Yes	No	
	If you are using slurry manure, in what way are you using it?	1. Slurry as it is			
		2. Making compost			
		3. After Drying			
	the impacts of slurry manure application on the productivity of crop?	1. Decreased			
		2. Increased			
		3. No Effect			
		4. Don't know			
WHAT ARE YOUR SUGGESTION TO IMPROVE THE OVERAL PERFORMANCE OF BIOGAS?					
	1.				
	2.				
	3.				

Date: ……………………………………..