Assessing the Effectiveness, Adoption Rate and Technological Gaps of Household Biogas Technologies in Southern Ethiopia: The Case of Hadero Tunto and Boloso Sore Woredas

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This is to certify that the thesis prepared by Tarekegn Bekele, entitled assessing the Effectiveness and Adoption Rate of Household Biogas Technologies and Technological Gaps in Southerner Ethiopia. In the Case of Hadero Tunto and Boloso Sore Woreda. It submitted in partial fulfilment of the requirements for the degree of Master of Sciences (Energy Center). Complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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List of Abbreviation

SNNPR	South Nation Nationality people region
NBPE	National Biogas Program Ethiopia
NGO	Nongovernmental organization
GPS	Geographical position system
EREDPC	Ethiopian Rural Energy Development and Promotion Center
MDGs	Millennium Development Goals
SNV	Netherland Development Organization
GTZ	Germen Technical Cooperation
pH	Power of Hydrogen
HRT	Hydraulic Retention Time
HHs	Households
C/N	Carbon /Nitrogen ratio
SPSS	Statistical Package for Social Sciences
HTW	Hadero Tunto Woreda
BSW	Boloso Sore Woreda
TS	Total solid
VS	Volatile solid
FS	Fixed solid
Mcf	moisture correction factor

List of Symbols

MW	Mega Watt
M	Meter
GWh	Giga Watt hour
M^3	Meter cube

ABSTRACT

The implementation of household biogas technology programme at national level is a recent experience in Ethiopia. Consequently, there are limited empirical evidences concerning to among its effectiveness, adoption rate and technological gap. Thus, this study was done with the objective of assessing the effectiveness, adoption rate and Technological gaps of household biogas technologies in Southern Ethiopia. It employed a mixed triangulation approach involving a total of 80 sample biogas user and non-user households. Both qualitative and quantitative data analysis techniques were utilized. The study results showed that the effectiveness influenced by: About 45% insufficient feeding quantity, 55% poor installation quality, 35% health problem of adopters, feeding quality less than 50% of the biogas plants C/N ratio was recorded optimum level between 20 and 35wich is medium toxic to methanogenic bacteria. More over the digesters effluent pH value was recorded between slightly acidic and alkaline (6.26 – 8.47) media hence, the digesters were not affected by accumulation of acid. Similarly from ambient temperature 25 – 31^{0}C one can say that the area has operated in mesophilic range (10-45°C). The adoption rate was affected by: 45% lack financial source, 25% lack of feeding, 20% lack of interest level of the community, 40% non- functionality biogas plants negative promotion and 15% availability of alternative energy source. Technological gaps of stockholders such as 45% limitation of time and effort to control, 65% gaps of operation and maintenance of adopters and 85% gaps of sharing experience to fill technological gaps in study area. Accordingly, the following recommendation were forwarded to improve the effectiveness of biogas plant, in study area maximize volume of dung, installation quality should be by giving training for stockholders on operation and maintenance, hiring skilled person, in order to foster adoption rate of biogas technology and fill technological gaps, energy office should support Stockholders by supplying financial source to share experience and awareness creation training program, to shape attitude of some people in respective community training regularly adopters and non-adopters is better, disseminators skill also need to be developed through training, the interest level of the community should be shaped by improving the effectiveness of biogas plant.

Keywords: *Effectiveness, Adoption rate, Technological gap, Household, Biogas technology.*

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CHAPTER ONE

1 Introduction

1.1 Background

Energy plays a central role in national development process as domestic necessity and major factor of production, whose cost directly affects price of other goods and services (Amigun*et al*., 2012). It is well known that energy resources are classified in to conventional and non-conventional. Conventional fuels such as coal, lignite, petroleum products, natural gas, water**,** nuclear energy and others whereas non-conventional fuels include biomass energy such as fuel wood, cow dung, agricultural waste and others. About 40% of the global population (amounting to 3 billion people) rely on solid biomass fuels including fuel wood, crop residues, charcoal, coal, and animal dung for cooking and heating (Somnath*et al*.,2014). Similarly, in Ethiopia despite the access to modern electricity service coverage, which has increased to 13.2% between 2009 and 2013, approximately 85% of Ethiopian households still continue to depend on biomass energy (wood, dung, crop residue, sawdust, etc.), which compounds the adverse effects of climatic change for cooking and heating (Growth and Transformation Plan II, 2015). Such traditional biomass energy dependence has caused deforestation crisis, greenhouse gas emission and indoor air pollution, which claim thousands of Ethiopian lives each year (World Bank, 2016). Particularly, women and children are the most negatively affected as they are constantly exposed to black carbon smoke inhalation. Thus, sustainable energy production and use are important features for adequate energy services for satisfying basic human needs, improving social wellbeing, achieving economic development and keeping the quality of life of current and future generations without exceeding the carrying capacity of the ecosystems. Among the alternative energy sources, biogas derived from biomass are considered as the most promising alternative fuel sources because they are renewable, environmental friendly and economically viable.

Ethiopia has the largest number of cattle in the African continent and the moderate to hot temperature throughout the year makes suitable for biogas technology. Moreover, technologically, bio-digesters are relatively simple, reliable and robust with minimal operational and maintenance costs that can built from local materials and with local labour. This makes them highly suitable for poorer rural areas. Unlike some other off-grid solutions like micro hydro or solar PV, biogas does not become redundant even when the national or regional grid reaches the biogas households.

In Ethiopia, the demands of household energy are far greater than in the availability. Woody biomass represents the principal form of cooking and heating fuel Ethiopian's rural areas. Consequently, the uses of woody biomass for energy can lead to the vulnerability to deforestation, health impacts and increasing greenhouse gas emission, which causes global warming and finally led to climate change impacts **(**Amare, 2014**).** Therefore, modern biomass energy like biogas energy produced by anaerobic digestion from biomass wastes is widely used in many industrialized countries as well as in parts of the developing world. However, the contribution in Ethiopia is insignificant due to several reasons such as lack of appropriate and optimized technologies and skilled human power together with lack of capital. The use of biogas as a fuel source is environmentally sound because it contributes to a reduction of fossil fuel use and mitigates the greenhouse gases effect (Desideri*et al*., 2003).

However, in many developing countries including Ethiopia, the main challenges are that the biomass energy resources are used without proper planning in an unsustainable way and gaps on energy planning and technology improvement (Wargert , 2009), as well as to harness the biomass energy source which is not environmental friendly and ecologically balanced (Shrestha A, 2010) .

Biogas technology belongs to biomass energy, which refers to a wide range of biomass fuels such as wood, sawdust, agricultural residues, animal and human wastes. The trend in production and utilization of biomass fuels are often used in its traditional and unprocessed form. Consequently, the wood fuel scarcity issue has been intensified by overuse due to overpopulation, need for crop land expansion and urbanization, and high wood fuels demand usually in the form of charcoal and wood, accelerating the deforestation problem. Thus, biomass energy conversion would assist in mitigating the negative impact of wood fuels and high fossil fuel imports, by producing biogas as alternative energy.

Such biomass convention to biogas, create opportunity towards unemployment reduction, livestock industry development; and hence, rural people's welfare may be improved. In addition to that Biogas technology benefits are not only limited to energy for cooking, lighting, power generation or bio fuel, but also benefits like bio-effluent as fertilizer which farmers need and used to buy. Its positive effect on the soil quality, benefits associated with animal husbandry and reduction of greenhouse gas emission should not be side-line. In addition, the substitution of traditional stoves and the kerosene stove by the biogas stoves will increase the cooking efficiency of combustion and contribute by far the lowest GHG emission (Smith *et al*., 2000).

The Ethiopian government has showed interest in the use of biogas as an energy source, which has proven itself an important strategy in solving the problems of energy usage in rural areas of the country. In the last three and a half decades, several programmes have been implemented to disseminate biogas technology, and around 8,063 biogas plants were constructed in four regions of the country (EREDPC, 2013). Recently, the Ethiopian government in the GTP II document has described to implement 20,000 family based biogas plants in various parts of the country, including SNNP region. Inline to the GTP II, various NGOs are introduces and implemented biogas plants as alternative energy sources including Hadero Tunto (HT) and Boloso Sore (BS) woredas. The regional government of SNNPR has renewed interest in supporting the development of the biogas technology to boost energy supply at household level. Recently, 175 biogas digesters were installed in the HT and BS woredas. This show from the massive potential of the area dissemination of biogas technology is still very low. In addition, to that after the household biogas plants construction effectiveness of most plants were decreasing and stop functioning. For instant, a comprehensive Biogas Users' Survey carried out for plants installed during the NBPE (National Biogas program of Ethiopia) phase I (2009-2013) reported that the functionality rate at the national level is about 40%, despite the presence of lack of scientific information on the causes of non-functionality. Construction of biodigester without considering the optimization parameters, sustainability and effectiveness might lead to low guarantee on the biogas technology users. Moreover, the adoption rate on biogas technology is not well known due to limited study on the effectiveness and technological gap of the stokeholds in household biogas technology. Hence, a good understanding of the factors affecting biogas efficiency and quality and quantity of biogas production and its effectiveness to possible future changes could be very useful and informative for energy policy in Ethiopia. In this backdrop, the major objective of this study was to assess the factors that affect effectiveness, adoption rate and technological gaps of household biogas technologies in the Southern Ethiopia.

1.2 Statement of the problem

The main sources of energy in HaderoTunto (TH) and Boloso Sore (BS) Woredas are firewood, electricity, charcoal, solar PV and biogas. The electricity coverage in the districts are estimated at about 2.3%. More than 95% of rural energy needs are met by the use of fuel wood, cow dung and residue. In the district stove technology such as Mirt and gonzuye stove are still at early phase, so that almost 99% of rural people uses three stone stove. Furthermore, the populations of these districts are also dependent on the imported fossil fuels. Such utilization of fuel has created several socio-economic and health related adverse impacts on women, children and the poor. Hence, one way to minimize pressure on forests, improved indoor air conditions as well as mitigate against greenhouse gas emission is by adopting alternative sustainable energy technologies such as biogas energy technologies.

National biogas program was started in both HT and BS woredas in the year 2010 with an aim of achieving socio-economic benefit such as workload reduction specially for women and children, bright light to help quality education and household works, saving of expenditure on fuel sources, use of the high value organic fertilizer from the biogas slurry and improvement of health and development conditions for rural households. However, the adoption rate and the output of the constructed biogas digesters were not to the expected standard.

The regional government of SNNPR has renewed interest in supporting the development of the biogas technology to boost energy supply at household level to achieve the rate of functionality of the constructed biogas digesters to 95%. According HT and BS water, mine & energy office strategic plane (2017), out of total 175 installed biodigesters; 46% of them are non-functional and poorly functional after construction. Therefore, these non-functioning and poorly functioning biodigesters do not only cause capital waste but also damage adoption rate of biogas technology. Moreover, at national level, a comprehensive Biogas Users' Survey carried out for plants installed during the NBPE (National Biogas program of Ethiopia) phase I (2009-2013) reported that the functionality rate at the national level is about 40%. This indicated that there is a lot to be done to achieve the targeted functionality rate of 95% from 54% in the study areas and 60% at national level.

Moreover, there are limited data available to understand factors that affect the effectiveness and efficiency of the existed biogas plants, technological gaps and low adoption rate at districts level. It is believed to be convincing that a study of this kind has to serve as input information for improving and success implementation and methane production of this technology.

1.3 Research questions

As a whole based on the problems stated above the study was addressed, the following questions and seek answers for it.

- What are the factors influencing effectiveness of household biogas plants?
- What challenges face in the adoption of household biogas technology?
- What are technological gaps biogas technology disseminators in the study area?

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of the present research is to assess the factors that affect effectiveness, adoption rate and technological gaps of household biogas technologies in the Southern Ethiopia: the case of HT and BS Woredas.

1.4.1 Specific Objectives

- To evaluate and assess the factors that affect the household biogas plants effectiveness
- To find out the factors that caused low adoption rate of household biogas technology.
- To assess the technological gap on the constructed household biogas plants
- To recommend alternative solution for challenges of household biogas technology.

1.5 Significance of the study

- The major benefits of this study was to assessing effectiveness, adoption rate and technological gap of biogas technology and put alternative solution for effective application of housed biogas plant in study area.
- The finding of this study will serve as get way for the potential researchers who have to study the effectiveness, adoption rate and technological gap.
- It will also pave the way for the researcher of this study, to apply theoretical researched knowledge in to practice and to upgrade his existing ability of doing the research.
- Police makers, NGOs, Energy offices and respective universities to which it provided can use the results of this research.

1.6 Scope of the study

Due to the vast and huge area of the country and short duration of the study period, it is difficult to assess all biogas plants in the country in this research alone. The researcher limited the scope of the study to specific places

- This study was done in southern, Nation, Nationalities, people Region (SNNPR), Kembata Tembaro Zone in Hadrero Tunto (HT) woreda and Woliata Zone in Boloso Sore(BS) woreda.
- This research study was done by focusing only on the over all in sights effectiveness of existing biogas plants, adoption rate and their technological gaps stockholders.
- This study was planned to see past five years (2005-2009 E.C) attempts made by stakeholders to adopt biogas technology because it is this time interval (5years) which medium term plan of police implementation was done so that reports and other related research studies available.

1.7 Organization of the study

This study was encompassing of five chapters. Chapter one deals with introduction: background of the study, statement of the problem, basic research question, objective of the study, significance of the study, delimitation of the study and organization of the study. Chapter two deals with review of literatures. Chapter three deals with research methodology, research design, research method, population, sample size and sampling technique, source of data, instruments of data collections, validity and reliability of data collection tools, methods of data administration, methods of data analysis and ethical considerations. Chapter four deals with result and discussion. Finally, chapter five deals with conclusion and recommendation.

CHAPTER TWO

2 Review of Literatures

2.1 Overview of Global Energy Consumption and Sources of Energy

As cited in Wachera.W.R (2014), major challenge in 21st Century will be that of implementing sustainable development and meeting the energy needs of the ever-increasing world's population. According to the International Energy Agency (2008), about 2.4 billion people, (that is around a quarter of the world's population) have no access to electricity and rely heavily on unsustainable biomass energy to meet their energy needs (IEA, 2008). Moreover, under today's energy policies and investment trends in energy infrastructure, projections show that as many as 1.4 billion people will still rely on biomass in 2030 (IGAD, 2007).

2.2 Historical Background and Status of Biogas Technology in Ethiopia

Biogas technology was introduced in Ethiopia as early 1979 Gregorian calendar. As the NBPE (2014), report showed that through the money obtained from SNV 10,678 households with bio-digester plants were installed in various parts of the country. Until the present day dissemination of the plants have been increasing. Almost half of the installed biogas digesters are not operating due to lack of effective management and follow-up, various technical problems, and loss of interest, reduced animal holdings, water scarcity, and developed a farm scale digestion system. Other reasons for the limited success of the technology in Ethiopia include the adoption of a project-based stand-alone approach without a follow-up structure in place, variations in design, and the absence of a standardized biogas technology (Eshete&Workneh, 2007, Mogues, 2009). The country is now implementing its second phase (2014-2018) aims to install 20,000 plants. The design of the digesters is adapted from Nepal and it is fixed dome design called SINDU model digester (SINDU meaning "ready" in Ethiopian). This model has four different sizes such as $4m^3$, $6m^3$, $8m^3$, and $10m^3$

2.3 Biomass/ Biogas as an Alternate Energy Source

Biomass is the material from living, or recently living organisms and covers all kinds of organic matter from fuel wood to marine vegetation (Chowdhry et al, 2012). It also includes trash, animal waste/dung, cornstalk, corncobs that can be used to produce electricity and biofuels (Meaza.k.G, 2012). Biomass is considered as a resource that can yield valuable energy and fertilizer. Bio-residue is used in many countries; if this biodegradable waste is treated in an anaerobic digester it can produce environmentally sound energy and fertilizer, globally it is the fourth largest sources of energy in the world, providing about 14% of primary energy (Lusk, 1997). As shown in Figure 2.1.wastes from different sources put into biogas plant. The waste will then be covert into combustible gas and fertilizer which suitable for agriculture.

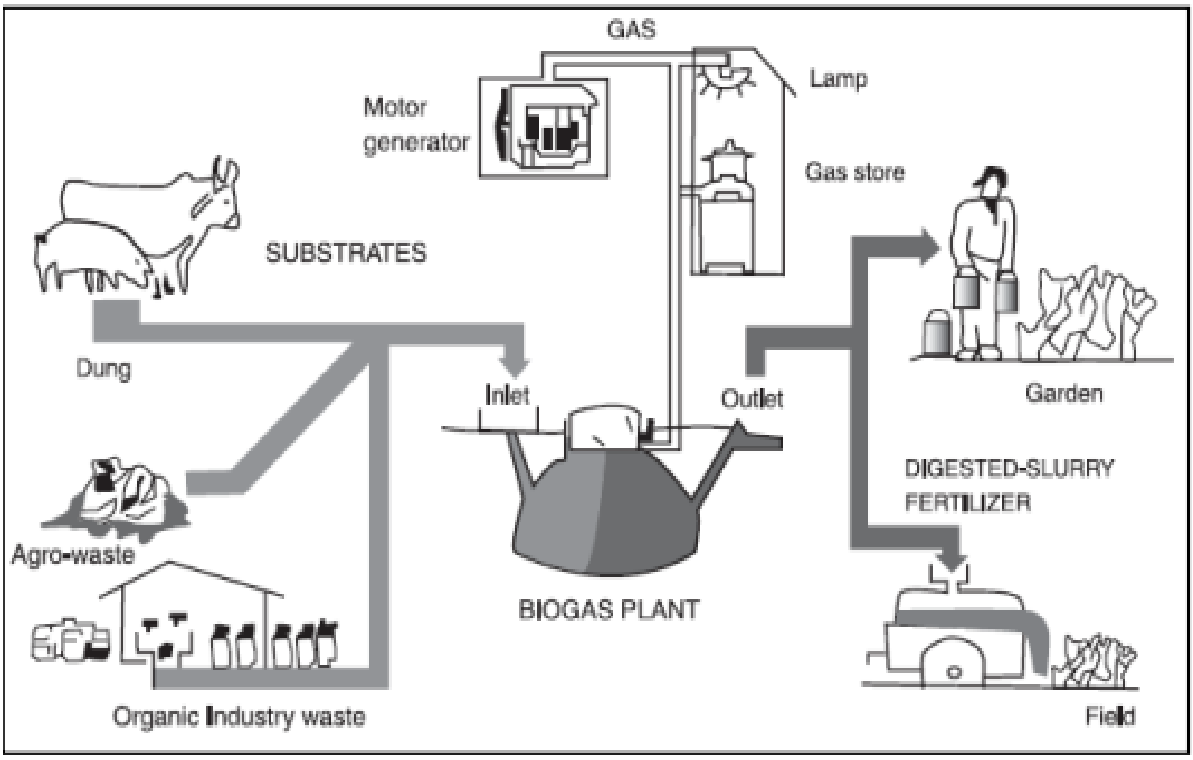


Figure 2.1: The figure show that the sketch a typical biogas system (ESCAP, 2007)

2.4.1 The main stages of biogas production process

In the anaerobic digestion process, organic matter is digested by microorganisms, and changed to produce methane and carbon dioxide as end products (Monnet, 2003). The anaerobic digestion is based on the fermentation of the organic waste in the absence of oxygen. Fermentation of the complex biodegradable organic waste takes place in three phases; described below and indicated in figure 2.2.

According Monnet, (2003) as showed above Figure 2.2 insoluble complex organic material (e.g. cellulose) is converted into soluble molecule (e.g. fatty acid, amino acids (the building blocks of protein) and sugars) by fermentative bacteria during the hydrolysis.

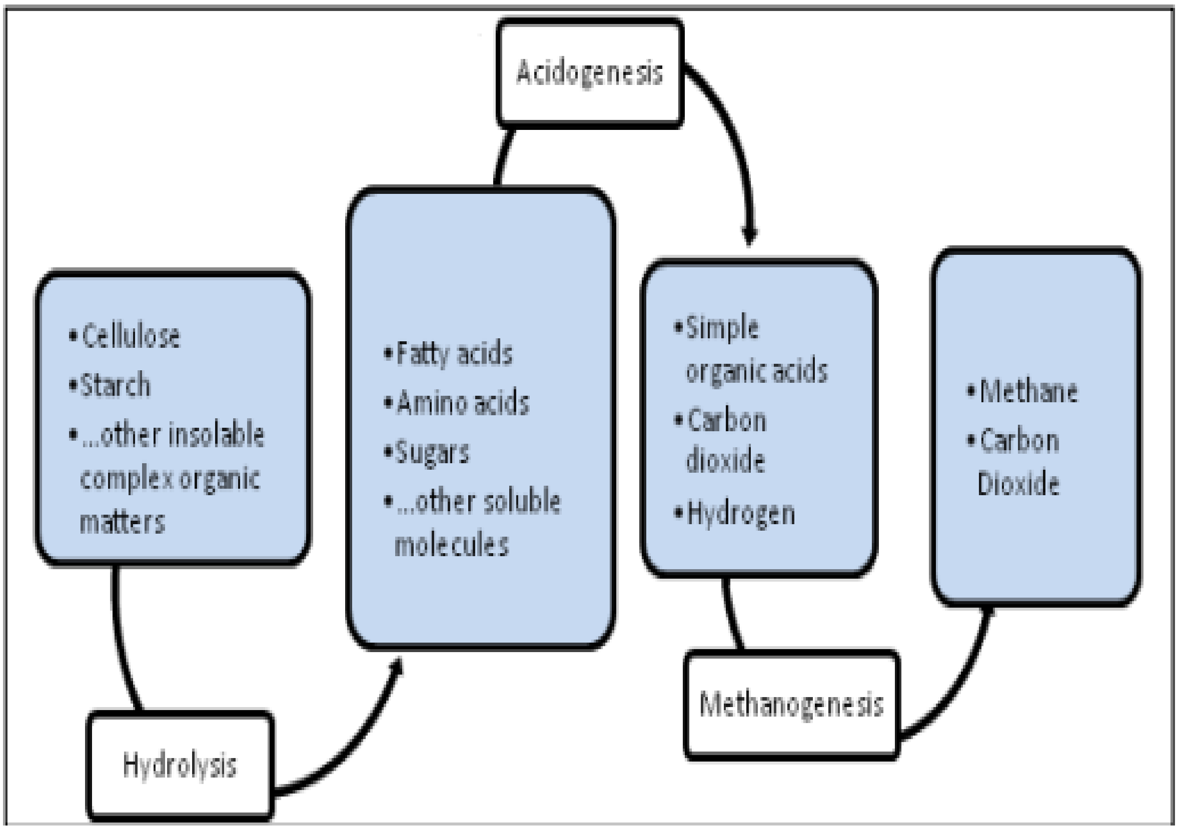


Figure 2.2:The three phases of hydrolysis, acidogenesis and methanogen **(**Monnet, 2003)

In the second phase, acidogenesi; the acedogenec bacteria (acid formers) from simple organic acids carbon dioxide and hydrogen out of the product from the first phase.

Finally methane forming bacteria generate methane .The process consists of cleaving two acetic acid molecules thus generating methane and carbon dioxide and by reduction of carbide dioxide with hydrogen.

2.4.2 Digestion Parameters

Numerous parameters affect how effective the process will be at digesting the organic matter. Some of the most important parameters Total Solids, Temperature, PH, loading rate, retention time, toxicity and mixing are some factors on which bacterial activity depends during decomposition of the organic matter which are important to be aware of in order to understand difficulties of the operation, are discussed in the following sections.

2.4.2.1Solids

All feeding materials consist of solid matter and water. The solids in turn consist of Volatile Solids (VS) and non-volatiles .Non-volatiles(fixed-solids) are not affected during digestion and come out of the digester unchanged. TS (Total Solids) are the percentage, or weight, of all solids in a liquid. The Volatile Solids (VS) parameter describes how much solids of the TS that are volatile. Fresh cattle dung for example, consists of about 80% water and 20% total solid (TS).This 20% total solids approximately contains 70%VS and 30% FS. (SNV, 2010).

2.4.2.2 Temperature

Optimal temperature in the digester will vary depending on influent (what goes into the digester) and type of digester, but it should be kept at a constant value (Monnet, 2003).

According to the Wendland (2009) different temperature ranges that can be used for biogas production

- The psychrophilic range (10 to 20^0C);
- Themesophilic range (20 to 40^0C); and
- Thethermophilic range (50 to 60^0C).

Each temperature range has its own specific micro flora, and it is recommended that temperatures be kept within one of the above ranges (Wendland, 2009).

Thermophile conditions require less retention time and will increase the gas yield. However, external heating is needed and the process is more sensitive to operation and environmental variables (Monnet, 2003). Most household digesters are therefore operated within the mesophilic range due to the robust large diversity of bacteria species (Wend land, 2009). Hydraulic Retention Time HRT (Hydraulic Retention Time), or just retention time, is the time needed to degrade the organic matter and is usually measured in days (Monnet, 2003). If the retention time is too short, the undigested slurry will be washed out without producing gas and with its pathogens still active. If the retention time is too long, the digester has to be very big and therefore expensive (Jenangi, 2000). The required retention time varies depending on type of digester, type of slurry, climate etc. Recommendations also vary between different authors, as will be shown. Monnet (2003) claims that digesters in the mesophilic range (which is the common small scale range in low-income countries) should have a retention time of 15 to 30 days. Barnett, Pyle and Subramanian (1978), on the other hand, suggests a retention time of 300 days.

2.4.2.3 PH

The pH of a solution is measure of the concentration of hydrogen ion and it indicates whether the solution is acidic, alkaline or neutral. In general, the majority of microorganisms grow fastest during neutral pH conditions (i.e. a value of 7). Other pH values may adversely affect the metabolism by changing the chemical equilibrium of enzymatic reactions and/or by destroying the enzymes (proteins that catalyse chemical reactions). Of the three phases, or types of microorganisms, the methanorganic group is the most sensitive to changing pH. If the pH is very low, the digestion may cease completely (Wendland, 2009). Different studies have shown different values for the pH that is most suitable for producing biogas, but most agree that it should be kept somewhere between 6 and 7.5 (Wendland, 2009)

2.4.2.4 Carbon to Nitrogen Ratio

Organic matter contains various chemical elements, in which the main elements are carbon(C), hydrogen (H), nitrogen (N), phosphor (P) and sulphur (s). The carbon to nitrogen-ratio (C: N) is an important index to evaluate the capacity of materials to decompose. Nitrogen in the slurry has two benefits. It is an essential element for synthesis of amino acids, proteins and nucleic acids (large molecules composed of chains of monomeric nucleotides, e.g. DNA and RNA). It is also converted to ammonia, which is a strong base (a chemical compound that, when dissolved in water, gives a solution with a pH greater than in pure water), thus neutralizing the volatile acids produced by the fermentative bacteria. Too much nitrogen, on the other hand, can lead to excessive ammonia formation with toxic effects (Marchaim, 1992). A C: N ratio of 20– 30(i.e. there are 20 – 30 times as much carbon than nitrogen) is recommended for general use (Monnet, 2003: 8) and 30 is often considered as optimal (Marchaim, 1992). However, since not all of the carbon and nitrogen in the organic material is available for digestion the overall C: N ratio can often vary from less than 10 to over 90 and still allow effective digestion (Marchaim, 1992). By mixing different feedstock materials (with different characteristics), an optimum C:N ratio can be reached (Monnet, 2003).

For example, by mixing kitchen waste (which has a low amount of nitrogen) with urine (which has a high amount of nitrogen) in correct proportions a desired C: N ratio of 30 can be reached. See Table 2.1 for examples of C: N ratios for different organic materials. When using different feedstock in a mix, it is known as co-digestion (Barnett, Pyle, Subramanian 1978).

Table 2.1. C: N ratio for different organic materials

	N(% of dry weight)	C:N ratio
Dark soil	6	6-10
Cow manure	1.7	18
Chicken manure	6.3	7.3
Hay, Grass	4	12
Wheat straw	0.5	150
Saw dust	0.1	200-500

Source: adopted from Subramanian (1978)

2.4.2.5 Mixing

Improved contact between the microorganisms in the slurry can be achieved by mixing within the digester. The improved contact will advance the bacterial population’s ability to obtain nutrients. Mixing will also prevent formation of scum and temperature differences within the digester. Too much mixing, however, may disturb the micro-organisms deliberate mixing is therefore preferred (Monnet, 2003).

If the slurry consists of different sub-parts, i.e. co-digestion, the slurry should thoroughly have mixed before entering the digester (Monnet, 2003). Organic Loading Rate (OLR) is the biologic conversion capacity of the system. It is expressed in kilograms of Volatile Solids (VS) per cubic metre of digester, or sometimes kilogram COD (Chemical Oxygen Demand) per cubic metre of digester (Monnet, 2003)

2.4.4 Benefits of Biogas Digesters

Benefits of anaerobic digestion developing for country Explanation Reference applications Improved indoor air quality Energy production in the form of biogas, which can be used as a cooking fuel provides an alternative to unsustainable deforestation Provides treatment of human and/or animal waste Combustion of solid biomass cooking fuels results in high levels of particulate matter in the indoor microenvironment. Particulate matter causes respiratory infections in children, adverse pregnancy outcomes, chronic lung diseases and heart diseases, and cancer anaerobic digestion is a net-energy producing process. Biogas, similar to natural gas, produces very little air pollution when combusted one cause of deforestation is the use of wood fuel for cooking and lighting. Introduction of household anaerobic digesters and the use of biogas for cooking reduce wood fuel use and therefore reduce deforestation. Prevents nutrient runoff into water basins, which drain to ocean environments, creating environmental problems. Prevents possible diarrheal disease downstream (Walekhwa, Mugisha and Drake, 2009).

2.5 Types of Digesters

There are different designs of household bio digesters being in used today. Hover, in developing countries there are mainly three types of digesters commonly such as floating drum digesters, fixed dome digesters and plastic/balloon/digesters. The basic feeding mechanism are continuous, batch, and semi-batch system. But majority small-scale biogas users uses continuous feeding mechanism that is fixed amount of manure and water is feed in the digester through the inlet every day the slurry is displaced through the outlet. Thus, the inlet, the digestion chamber and the outlet are three main components common to all the digesters (Rowse, 2011).

2.5.1Fixed Dome Plants

The fixed dome plant consists of digester with fixed, none movable gas holder and it have six main parts: inlet (mixing chamber), digester (digestion chamber), dome (gas storage chamber) outlet (displacement chamber)as shown below Figure 2.3.The gas conveyance and application system (pipes and appliances) and salary pits. The feedstock enters through the inlet chamber passes through the inlet pipe to the digester chamber and after digestion, process the produced gas accumulates in the upper part of the chamber (in the gas holder) and the digested slurry passes out from digester outlet tank and flow out to the compost pits through overflow opening in the outlet tank. The gas is then supplied to the kitchen through the pipe line and use the gas for cooking and lighting by using appliance such as gas stove and gas lamp.

The digesters are built underground thus are protected and easier to insulated the digester. This underground construction saves space, a long life span and makes it available for household usage. The size of the plant depends on the location, the number of households using the gas and the amount of substrate available. Commonly 6m^3 volume plants are sufficient to meet the cooking requirements of a household with seven to eight members, 15m^3 and 20m ^{3} plants cater for the requirements of a larger population and thus are referred as the community biogas plants (NBPE 208). Fixed dome digesters have a life span of minimum 20 years and are preferred as they have no moving parts and are low in cost. However, construction of the plant requires technical skills and the fluctuation in the gas pressure can cause difficulties to the users (Sasse,1988).

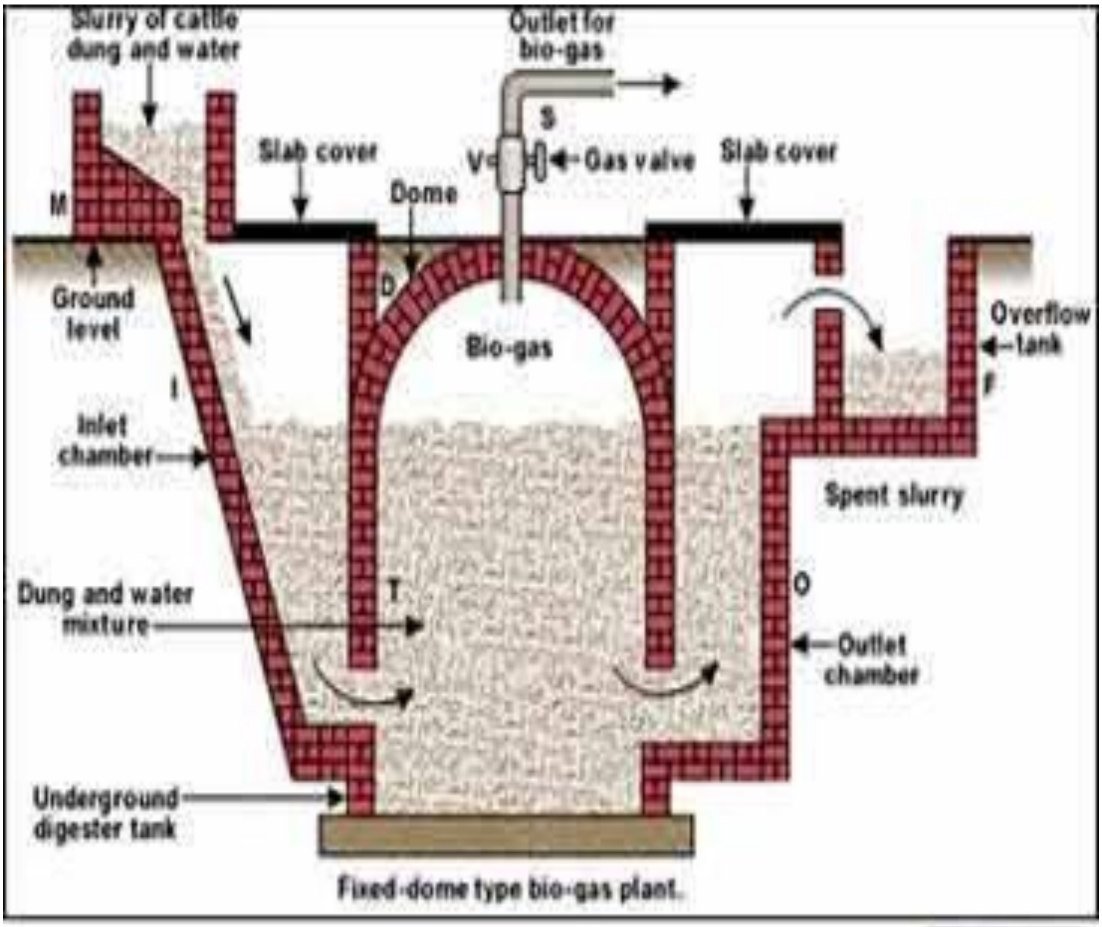


Figure 2.3 Sketch of affixed dome digester adapted from sasse (1966)

2.5.2 Floating Drum Digester

Indian design model, which began in the late 1930 and in 1962 the model, gained the popularity in India as well as the sub-continent. In the Khadi and Village Industries Commission (KVIC) design, the digester chamber is made of brick masonry in cement mortar, the profile Figure 2.4.

The floating drum digester also consists of underground digester and moving gasholder. In this design, the digester chamber is divide in to two parts. A mild steel drum is placed on top of the digester to collect the biogas produced from the digester. When the biogas is produce, the drum moves up and when it is consumed, the drum goes down.

Floating drum digester is expensive compared to fixed dome digester because it has a steel gasholder. On the other hand, it is less likely to leak than the Chinese design, which requires high quality internal plastering to avoid porosity and hence gas leaks. A typical design of floating drum digester is shown in Figure 2.4.

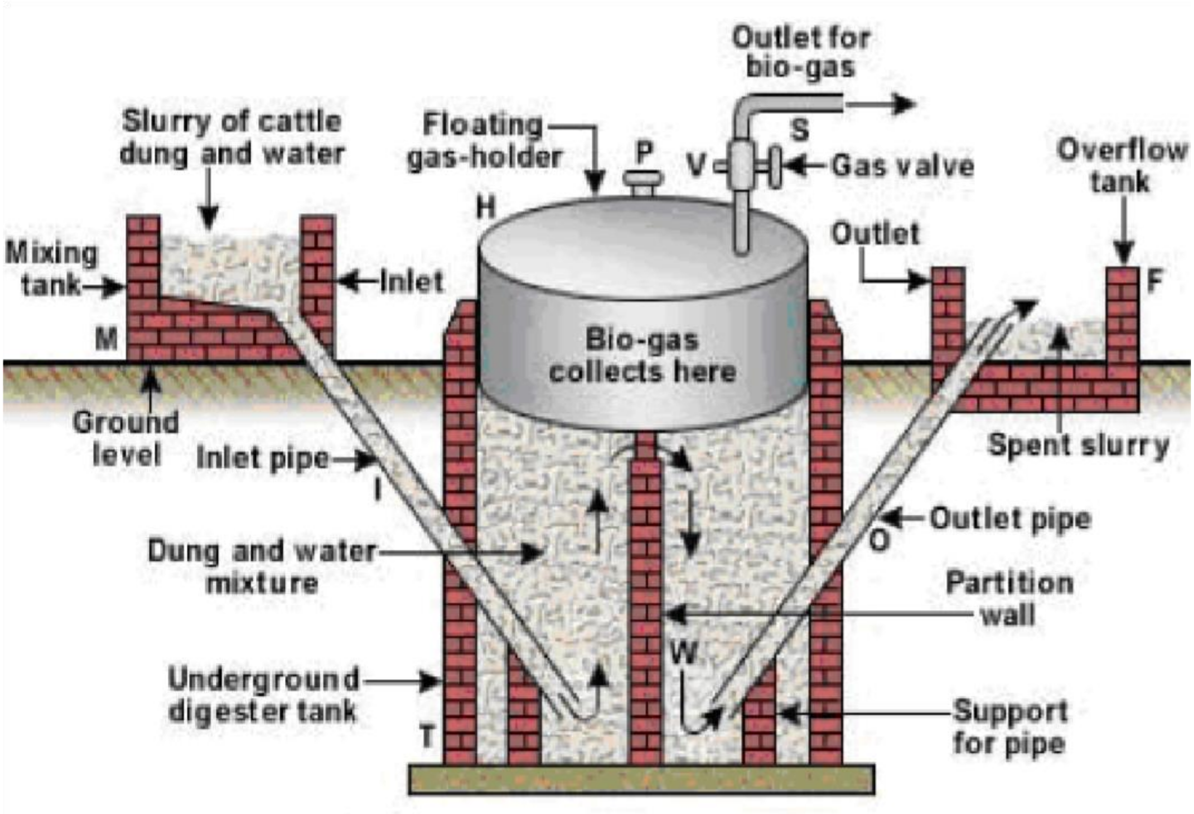


Figure 2.4: Schematic diagram of Floating Drum Digester (Arineitwe & Sengozi., 2009)

2.5.3. **plastic/balloon/ bio-digester**

A balloon digester consist of aplastic or rubber digester bog, in the upper part is where the gas is stored. The inlet and outlet pipes are attached directly to the skin of the balloon. The gas is moved from the balloon to where it will be used by the pressure boiled up inside the balloon and can be enhanced by placing weight on the balloon .the fermentation slurry is agitated slightly by the movement of the balloon skin This is a low cost digester compared to the first two types. The balloon material mast be UV-resistant. The technology is not complicated for rural farmers to adopt and materials are readily available and can easily be repaired and maintained. The balloon digester's can generated gas as shown in Figure 2.4.

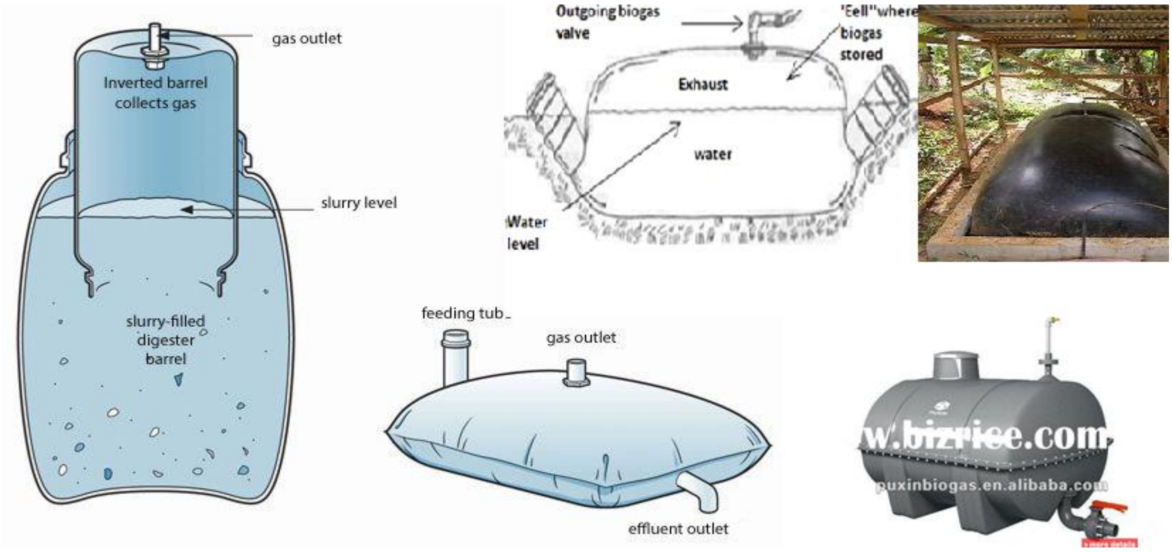


Figure 2.5: Schematic diagram of Tubular/ Balloon digesters (Arineitwe & Sengozi., 2009)

2.6. Selection of type of Bio digester

To successfully achieve anticipated objectives of biogas programme, it is imperative that the best-suited model/design of biogas plant is selected for the wide-scale dissemination. Varieties of model/designs of biogas plants are being used in different countries in the world with successful records of accomplishment. Based upon the performance of the existing plants and experiences from other biogas countries technology in the country.

According to the unpublished NBPTE Training Manual 2010) considered to evaluate the suitability of biogas plant assuming that the adoptability of any biogas plant in a given context depends mainly upon these factors.

Climatic and geo-physical parameters: ambient temperature**,** geo-physical condition of the soil and condition of ground water table.

Technological parameter: structural strength against different load condition (structural durability), methods of construction and supervision, and applicability/adoptability of design in different geographical context for mass dissemination, prospects for sharing of technical information and know-how.

Affordability of potential farmers to install biogas plant: availability of construction materials, availability of human resources (skilled and unskilled) at the local level, cost of installation, operation and maintenance and transportation facilities.

Purpose of the use of the products from bi**ogas plant:** use of gas for cooking, lighting and /or operating dual-fuel engine and use of slurry as organic fertilizer.

Performance of existing models, if any, in the local and/ or regional conditions: exiting physical statues and functioning, and user's level of satisfaction.

Quality and quantity of available feeding materials: type of feeding material(cattle dug, pig manure, human excreta etc., availability of water for mixing and number of cattle per, household are the same of the criteria to select proper model of biogas plant for any applicable area.

2.6 Operation and Maintenance

Marchaim(1992) identified poor maintenance of biogas plants as one of the key reasons of plant failure. The following activities are vital to ensure stable operation (Rietzler, 2009):

- Frequent draining of condensed water from the gas;
- Cleaning of stoves and lamps;
- Oiling of gas valves and gas taps;
- Cleaning of overflow outlet;
- Checking for and fix gas leakage; and

If maintenance is carried out regularly, a biogas plant can have an operational life span exceeding 20 years (Rietzler, 2009). When problems do arise with the plant, it is usually the appurtenances rather than the digester that is faulty. Where biogas-lamps have been installed they are, compared to the other parts of the plant, the most likely part to fail. In most cases the owner can repair, the problems although a study from Bangladesh claims that the users do not usually have the capacity to manage even small technical problems (Quazi and Islam, 2008).

2.6.1Feeding the Digester

Livestock often graze outside during the day and are only kept inside or near houses (and the biogas system) during night. This makes it challenging to collect the dung for digestion (Rietzler, 2009).

When feeding the biogas plant, the influent is collected in the mixing tank, which is a vessel connected to the digester inlet. It is collected either by pipes, channels or containers. When the influent has been collected in the mixing chamber, water (usually at the same amount as the waste) is added and mixed together with a stick, or similar. When the mixture is liquid, a gate is opened so the feed-stock can flow into the digester (Koottatep, Ompont and Hwa, 2002) The effluent will exit automatically from the outlet when influent is added. The outlet should however be washed with water after each time the plant has been fed. If the outlet is clogged, a wooden stick is usually all that is required to clear it (Koottatep, Ompont and Hwa, 2002). The previously mentioned user survey in Lao DPR also found that 76 per cent of users provide the needed influent from their own animals. However, 15 per cent report that they do not own any livestock at all stating that they have neighbours who have enough manure from livestock for them to use (Rietzler, 92009).

2.6.2 Technical Problems

There is limited research available regarding technical problems of the plant types used by Households. Technical problems reported are often caused by bad masonry work. The reasons for the bad masonry work include (Chandararot and Dannet, 2007):

- Leakage from valve and rubber hose due to carelessness;
- Construction workers that lack skills;
- Construction workers that do not pay attention to their work;
- Waiting time until construction is long; and
- Construction of plant was too long

Chen et al. (2010) recently studied opportunities and constraints using biogas in rural China. The technical problems they identified were that the digesters were not properly de-signed for the influent and climate. The influent had high levels of cellulose, hemi-cellulose, lignin, pectin and wax in the straw (straw is used extensively as feeding material in China).

2.7 Literature review on empirical investigations of national and international findings on Biogas digesters

Many researches were carried-on in Household Biogas Technology all over the world and in Ethiopia. As many studies' result shows, they have been published for deferent form of applications; the researcher tried to investigate documented information on related studies. Some of the papers are reviewed in the following paragraphs.

Leta, 2009, was studied also the status of 92 previously installed institutional biogas digesters in Addis Ababa and four selected regional states called Amhara, Oromia SNNPR, Harari. It identified that 43% of the digesters were not operational. The reason, for failure of the digesters were due to drawbacks of the users (lack of interest & care, lack of skill to operate & maintain in case of failure, poor management and lack of ownership.) and technical causes such as bad design and poor workmanship in the whole construction, lack of training on how to operate for users while delivering the system, poor design to accommodate the energy demand with available feed material, no timely after-sale service for user. This study covers only the status of institutional biogas digesters. The study area of adoption rate of biogas technology and technological gap sides could not be studied.

Meaza.k.G(2012) studied the Field based assessment on the performance of household biogas plants at the Bishoftu(Debrezeit) site of Ethiopia. The work was begun by investigating performance and operational practice of biogas plants of desired site. compiling data from rural and urban sites by interview and survey and analysing them using SPSS software. According to the results obtained through the analysis, the site has study identified that 20 % of the digesters had very good performance, 40% of the digesters had good performance and more than 26% of the plants were producing less gas than the expected output of biogas but the remaining digesters were performing poorly. This study covers only the Performance of household biogas plant side. The study area of adoption rate of the biogas technology and technological gap sides were could not be studied.

According to *Eshete et al., 2006, SNV* gathered data on the status of previously installed household biogas digesters was done in four regional states (Amhara, Oromia, SNNP and Tigray) sites of Ethiopia. In addition, the study team were identified that above half of the installed digesters were non-operational. This was mainly due to lack of effective management and follow-up, technical problems (water trapped in the piping, unprotected piping damaged by cattle, broken stoves and biogas lamps, leaking gas hose, broken digester and inlet pipes, absence of technical back up services), water problem (longer distance to the water source), dung shortage (due to droughts, and changing cattle holding style), insufficient gas supply (especially for big stove users) loss of interest, reduced animal holdings, evacuation of ownership. Other reasons for the limited success of the technology include the adoption of a project-based stand-alone approach without follow-up structure in place, variations in design, and the absence of a standardized biogas technology.

CHAPTERTHREE

3 Research Methodology

3.1 Descriptions of the study area

The two sites identified for this study are HaderoTuntoand BoloseSoreworedaswich are locatedin kambataTembaro and wolayta Zones respectively, Southern Nations, Nationalities, and Peoples' region (SNNPR) state of Ethiopia (figure 3.1).

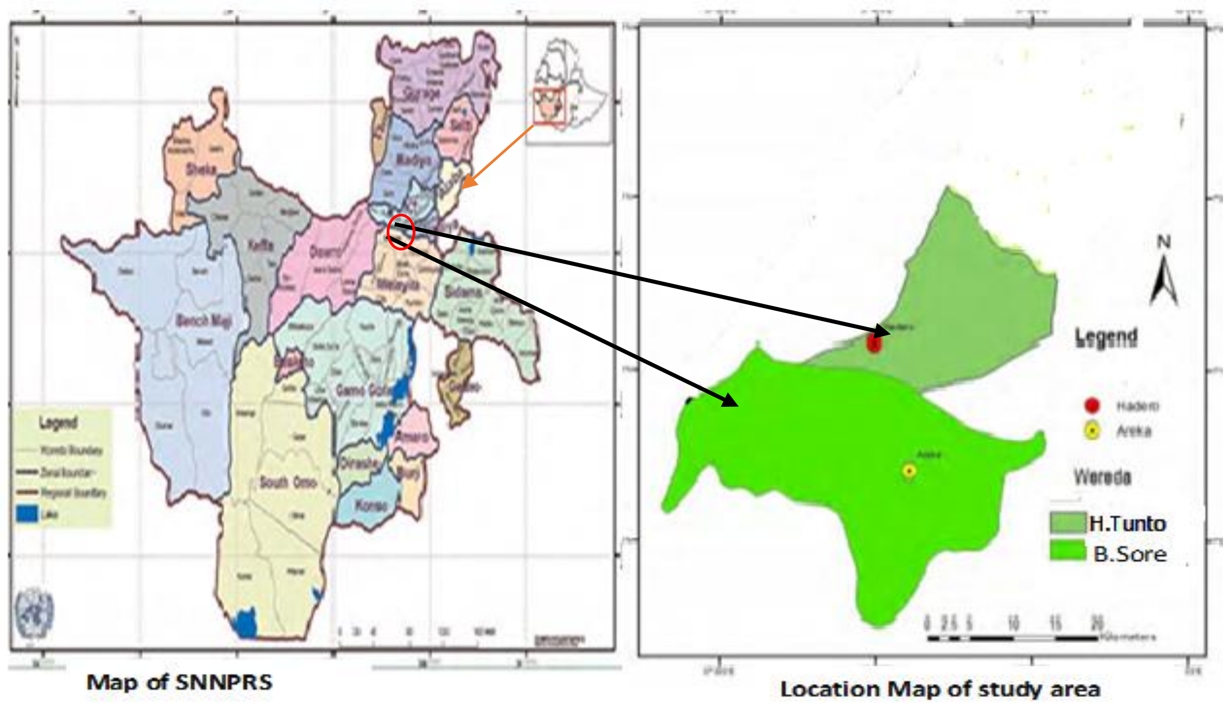


Figure 3.1: Map of SNNP Region sampling woredas highlighted in different colour of green and light green in south western Ethiopia. (Source: Map-of- SNNPRS-displaying.)

HaderoTunto is one of the seven districts of the KambataTamber ozone of SNNPR of Ethiopia. It has latitude of 7^{0}13′N, longitude 37^{0}38′E with an elevation of 1617 meters. The woreda with has a land area of 347.7 square kilometres.

Boloso Sore Woreda is located in Wolaita Zone, SNNPR state of Ethiopia. Astronomically the Woreda is located between 7^{0}00''00' and 7^{0}11''00'N Latitude and 37^{0} 00''00' and 37^{0}50 '' 00'E longitude. The Woreda with a total land area of 28,800 hectares.

HderoTunto woredais characterized by a hilly topography with several ridges and valleys. It can be divided into three main topographical zones: Dega (cool temperate), Woyna-Dega (temperate) and Kola (warm temperate). The maximum average annual temperature rises to 20-30 degree centigrade and also the area is lying between 1500 and 1800 above sea level, the highest rainfall reaches 1200-1800 millilitre and economic activities that are agriculture together with rearing of animals (Inft: Deneke Lambebo).

Boloso Sore Woredais classified as Woina-Degaand Dega. Since, it is found in the high land parts of Ethiopia .The average temperature varies between16 to 26.Annual rain fall of the Woreda is 1201ml to 1600 ml ,the basic livelihood of the *woreda* is mixed farming, i.e. crop faming and animal husbandry

In Hadero Tunto Woreda, The common diseases in the district in order of preference are smoke borne diseases like headache, eye burning, eye-infection, and respiratory organ infection and burning accidents. Almost the same condition in *Boloso Sore woreda*. Therefore, adoption of biogas technology has numerous health benefits.

3.2 The Research design

According to Anderson (1990), triangulation design was employed to showen situations as the currently existing and answers question related to the current statuesque of the problem. Based on thus ground, the type of research planned to applied the design in the case of descriptive survey studies because it was concerned with describing the effectiveness, adoption rate and technological gap of household biogas plant in study area with specific prediction, narration of facts, and drawing of conclusion in accordance with the topic of the study. Accordingly, mixed research design was employed because the weakness of one research method addressed by the strength of other so that through triangulation both quantitative and qualitative data the research was done in a comprehensive manner.

3.3 The Research plan

This research relied on both primary and secondary sources of data. The primary data were derived from field surveys using questionnaires, interview, field measurement personal observation and laboratory experiments. The secondary data different literature books on biogas technology and other information from electronic media.

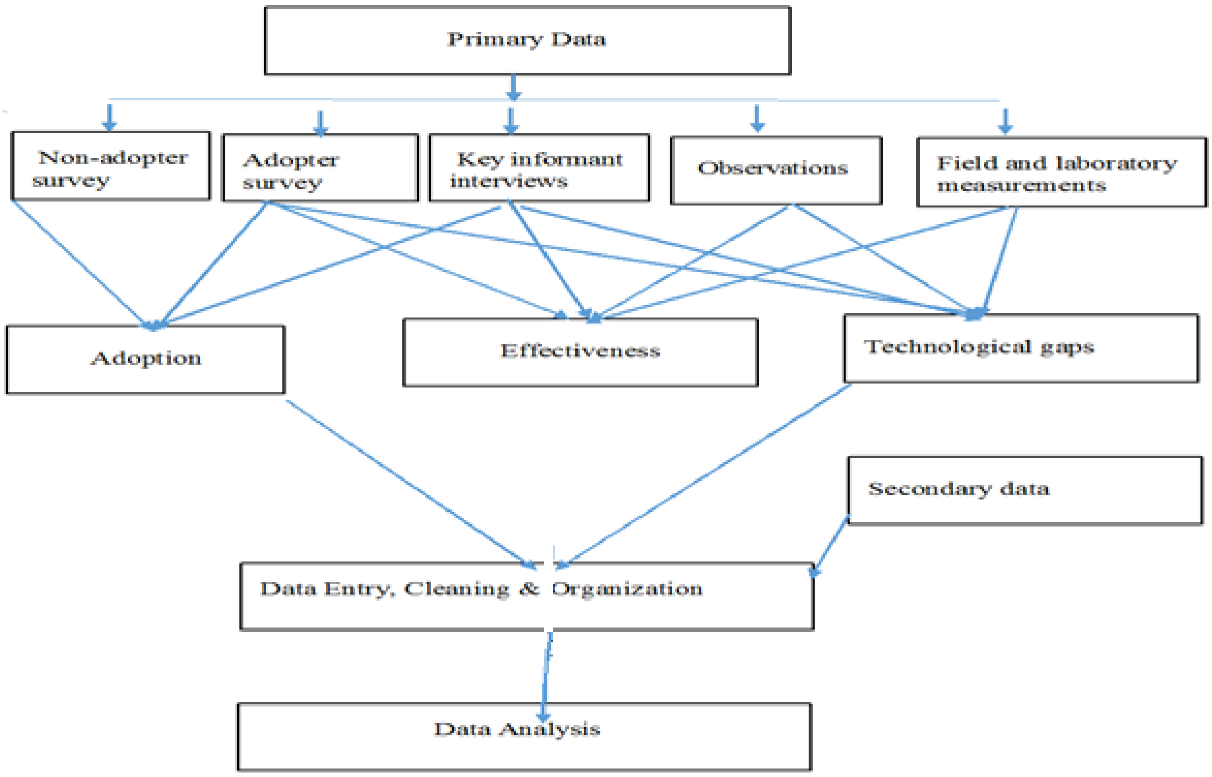


Figure 3.2 Research Plan

Primary data collection:

The primary data was collected by both qualitative and quantitative methods of data collection so that both methods would complement each other used. As Creswell (2003) stated, quantitative research method is preferred because it is economical and important in generalization for large population from small group. Qualitative data was used for an understanding of the human system and its subjective aspects of behaviour be it small or large (Scavenge and Rovison, 1996). In this research, the researcher was used to describe the study quantitative or numerically such as questionnaires (Appendix 1), field measurement (Appendix 4),observations (Appendix 2) and laboratory experiments (Appendix 5). While, qualitative method used to gather information, which was verbal or non-numerical. It was made used of qualitative data yielded through interviews (Appendix 3).

To evaluate the effectiveness and identify the technological gaps and causes for low adoption rate of the constructed biogas plant, primary and secondary data, field observation, and measurement (temperature, PH) coupled with sample collection for laboratory analysis (C/N and total Solid contents) were done.

The questioner schedules were administered to the plant users with related to factors affecting the effectiveness of biogas technology. Field observations were done, especially to examine the status of biogas plant and its application by households. Additional field measurement and laboratory experiment used to investigate related to feeding quality and climate condition on the study area.

Secondary data collection:

Supplementary data (mainly secondary) were obtained from other key informants and stakeholders in the biogas technology in the study area. Furthermore, different literature books on biogas technology and other information from electronic media related to objective of study was reviewed.

3.4 Population, sample size and sampling techniques

3.4.1 Population of the study

According to Nkpa, (1997) population refers as numbers of any well-defined class of people, events or objects. It means therefore that any entity, group or set of which constitutes a population must have at list one attribute or characteristics. Based on this theoretical concept the Population of the study was all house hold biogas plants of HT and BS Sore woredas which were 175 and residents of respective woredas both biogas adopters and non-adopters were taken as population of the study.

3.4.2Sample size and Sampling techniques

According to Ali, (1996), determining a sample size which would adequately and appropriately represent the population. And multistage sampling technique is the combination of sampling methods applied at each stage of sampling processes. It is the sampling technique in which the sample taken at each stage by using different sampling technique (Kothari, 2004). Accordingly, to select sample study area and sample subject's multi stage sampling technique was applied so that sample woredas, Kebeles and respondents selected for this study.

To select sample woreda lottery system of sampling technique was employed because equal chance to be given for all seven woredas of KembetaTembaro Zone and twelve woredes of Wliata Zone. Accordingly, two woredas such as HT,from KembetaTembaro Zone and BS worede from woliata zone were selected.

Purposive sampling techniques was used for the choices of biogas plan .It was included functionality and non-functionality of the plants and availability of the necessary data in that particular site. And purposive sampling method was used to gather information about the opinions of the end users and operators of the biogas plant using in-depth interviews. Data was collected in two parts. The first one was pilot study, during this specific visit, identification of, concerned organizations or bodies, funding sources, bio digester sites, types of digesters, status of digesters (whether it would be working or not), and quantification of bio digesters was done in both HT and BS woredas selected sites.

Then, 40 biodigesters were selected for intensive monitoring and assessing of twelve parameters in five sites of around both woredas .The parameters were categorize in three groups. Namely, field measurement (ambient temperature, effluent temperature, slurry temperature, water PH, effluent PH, Slurry PH ,Pressure); laboratory measurement (dry matter ,total solid) will be obtaining parameters.

To select sample biogas plant purposive sampling technique was used because it was aimed to select relatively effective and low effective biogas plants based on five years (2004- 2008E.C) reports of both BS and HT woredes water, mine and energy office so, that other sampling techniques assumed to be not appropriate because the sampling favouritism to unwanted sample subjects selection can occurs. Accordingly, 10 effefectiveand10 none effective house holed biogas plants were selected from each woreda. Therefore, total of 40 biogas plants were selected as the sample of the study.

In order to select sample respondents' purposive sampling was also appropriate to gather relevant information for the effective status of household biogas the owners of sampled household biogas plants were briefly described what makes some biogas effective and the other ineffective.

To select sample respondents from non-adopters of household biogas, geographic cluster sampling were employed since adoption rate of biogas plant mainly depends on geographic feasibility of the design and financial capacity of the society. Based on the above ground, the study areas are clustered in to four geographic units in each worede and then 20 sample households were taken as the sample none adopters by using simple random sampling from each cluster to users of biogas technology in study area.

3.5 Field Observation

Observation was conducted to households to assess and evaluate the status of biogas plants includes leakages, blockages, cracks and site selection of bio digester plants as well as identifying the types of biogas technology and materials used for construction.

3.6 Materials and chemicals used during field measurement and laboratory experiments

There are different types of measurements that are necessary for designing, monitoring, and controlling both the anaerobic processes, which produce biogas, and the systems, which improve the energy from the biogas. The equipment required varies depending on the source of the biogas as well as the complexity of the utilization system. For this specific study, the researcher used both portable and laboratory pieces of equipment to check physic chemical characteristics and climate condition of the areas. The followings are the materials used during measurement and experiment.

Table 3.1: Equipment and chemical used during measurement in laboratory

Equipment	Chemicals
➢ **Portable PH and Temperature measuring Instrument** ➢ **Electric oven** ➢ **Sampling bottle, beakers and Erlenmeyer flask** ➢ **Analytical Balance (weighing scale Spoon and magnetic stirrer)** ➢ **Digestion rack – with operational exhaust manifold** ➢ **Distillation rack – fitted with reflux traps, water– jacket condensers, and in flasks emitters** ➢ **Kjeldahl digestion flasks** ➢ **Erlenmeyer – 500 ml wide mouth**	➢ Concentrated Sulfuric acid (H_2SO_4), ➢ Catalyst mixture: K_2SO_4, $CuSO_4.5H_2O$ and selenium powder ➢ Sodium hydroxide (NaOH) ➢ Boric acid solution and distilled water ➢ Mixed indicator (Dissolve bromocresol green methyl red and ethanol) ➢ Oxalic acid(HOOCCOOH) ➢ Phenolphthalein indicator (phenolphthalein) ➢ Potassium Dichromate solution($K_2Cr_2O_7$) ➢ Concentrated orthophosphoric acid (H_3PO_4) ➢ Barium diphenylamine sulphonate indicator (barium diphenylamine sulphonate) ➢ Ferrous sulphate solution ($FeSO_4.7H_2O$)

3.7 Sample preparation for field analysis

Sample preparation mostly depends on the type of samples to be taken as shown Figure 3. For this specific study the researcher was used two types of sample preparation. The first one was, sample preparation for field measured data (pH, temperature). Samples for these data were taken from two points: inlet side and inside the digesters. Similarly, for laboratory analysis, samples were also collected from two sites, namely inlet side and inside the digesters.

Inlet side of the digester: Samples taken at inlet chamber was done after thoroughly mixed fresh cow dung with water or cattle urine then inserting in to sample bottle. Then immersing the PH metre device peak in to the sample bottle and measure pH values as shown below Figure 3.2. And at the same manner PH metre device peak in to the sample bottle measure and temperature of sample.

Figure 3.2: Portable PH and Temperature measuring instrument and analysis (Source field measurement of, 2018)

3.8 Sample preparation for laboratory analysis

The second duty was sample preparation for laboratory analysis. Here, the manure used to determine carbon, nitrogen, moisture and total solid contents was directly collected from pen. This was taken after thoroughly mixing the collected fresh manure and removing the straw inside it. Then the sample manure weighed up to one kilogram and put in plastics container as shown figure 3.2, and transported to the S/N/N/P/R State Agricultural institute Areka Agricultural research centre. Finally, the moisture content and total solid of the manure was analysed by heating (drying) at 105^0C for 24 hours. The carbon and nitrogen contents were also determined using titration and Kjeldahal methods respectively in soil laboratory. Results obtained from the laboratory were recorded in a sheet shown in (Appendix 4, Table A), then organized and are presented in (Appendix 4 Table Band C).

3.9 Procedure used during laboratory analysis

Adjacent to field measured data some samples were taken to laboratory as shown figure 3.3. Persuader for determination of amount of Carbon, Nitrogen, moisture content and total solid content in the biogas digesters and to determine volatile matter of each digester indirectly. Numerical values obtained during the laboratory measurements were presented in Appendix 5, while parameters range and mean values are presented.

Figure 3.3.Laboratory measurements (Source: Apr. 9 – May 8, 2018)

Procedures used during laboratory analysis were proximate analysis and ultimate analysis. Moisture content and total solid contents were determined using proximate analysis and organic carbon and total nitrogen using ultimate analysis. The following are the steps used in laboratory analysis.

3.9.1Determination of moisture content

There is no absolute moisture level, which is correct or ideal for manure, composts or waste products. The ideal moisture depends on handling technology and processing goals. Biologically, optimal moisture depends on a sample's water holding capacity. Optimal biological activity for composting occurs at up to 80 – 85% saturation of water holding capacity (www.woosend.org). The moisture content is determined by measuring the mass of manure before and after the water is removed by evaporation (McClements , 2003). The procedure is as follows:

- 40 empty containers are weighed using analytical balance.
- 5g of manure is weighed in all containers.
- Then the containers put in an oven at 105^0Cfor 24 hours.

- The containers are then removed from oven, closed with lid, and left in desiccators to cool for about 30 minute.
- Finally the cooled samples reweighed, (the following equation is used to determine the moisture content).

$$M_n = ((W_w - W_d)/W_w) \times 100\ldots \qquad 3.1$$

Where:

M_n = moisture content (%) of material n

W_W = wet weight of the sample, and

W_d = weight of the sample after drying.

3.9.2. Determination of Organic Carbon content

Organic carbon is the amount of carbon found in an organic compound. Chemical oxidation followed by titration with ferrous ammonium sulphate solution is used to determine the organic carbon in the manure samples. According sahiemedihin and Taye (2014) the following procedure was used during the test.

- 0.25g of manure was weighed using analytical balance and then transferred to a 500ml Erlenmeyer flask (total sample size 40). Similarly, two blacks are prepared.
- 10ml 1N $K_2Cr_2O_7$ solution was added for each samples and blanks using pipette.
- 20ml conc. H_2SO_4 is added carefully with measuring cylinder in the fume cupboard and then the flasks are swirled, and left for 30 minute on asbestos.
- 200ml distilled water then added and allow it to cool.
- 10ml concentric orthophosphoric acid and 0.5ml of barium diphenylamine sulphonate indicator separately added to both samples and blanks.
- Both samples and blanks titrated with 0.5N ferrous sulfate solution until the color changes to purple or blue, finally ferrous sulfate solution is added drop by drop until the color flashes to green then to a light green. The results were recorded to determine organic carbon in manure. The following formula was used for the calculation. (Sertsu and Bekele, 2008).

$$\% C = N \times 0.39 \times mcf \times (V_1 - V_2)/S\ldots \qquad 3.2$$

Where: N = normality of ferrous sulfate solution

V_1 = ml ferrous sulfate solution used for blank

V_2 = ml ferrous sulfate solution used for sample

S = weight of air dry sample in gram

Mcf = moisture correction factor.

3.9.3 Determination of Total Nitrogen using TKN

The Kjeldah procedure was used to determine the total nitrogen. It is based on the principle that the organic matter is oxidized by treating manure with concentrated sulfuric acid; nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. The acid traps NH_4^+ ions in the manure which are liberated by distilling with NaOH.TheNH_4^+ is absorbed in boric acid back titrated with standard H_2SO_4. Then potassium sulfateis added to raise the boiling point of the mixture during digestion and copper sulfate and selenium powder mixture is added as a catalyst. The procedure determines the manure nitrogen (including adsorbed NH_4^+) except that in nitrate form (Sertsu&Bekele, 2008).

- 1g of manure from each sample is weighed using analytical balance and transferred to digestion tubes. Two blank samples are prepared at the same time.
- Half spoon of catalyst mixture and few carborundum boiling stones are added and mixed together, and some water is added in each sample tube to moisten the mixture.
- 7ml of conc. $H_2SO_4$is added and mixed via swirling.
- Then the digestion tube stand is putted beside the block digester and then exhaust manifold is fitted on top of it. The tubes left for 3hours until the digest is white on the block digester preheated to 30^0C.
- Then cooled and 50ml of water is added cautiously, and then cooled again.
- The digested acid transferred to macro- kjeldahl flasks and rinsed using distilled water.
- 20ml of boric acid is added in to receivers Erlenmeyer flasks that correspond to the number of samples. Then 2 drop of indicator solution is added and placed under the condenser.
- 75ml of 40 percent NaOH is poured carefully down the neck of the distillation flasks containing the digests and mixed smoothly.
- Then the Prepared 250ml kjeldahl distillation flasks containing the digest are fitted to the corresponding holder and closed it, the distillation started by heating the flasks containing the digests.

- As soon as distillation is completed, after 80ml of distillate has been collected, then the receiver flasks removed.
- Stirrer bar is inserted in the receiver flasks and the solution is titrated until it changes from green to pink colour with 0.1N H_2SO_4. The equation below was used to determine the total nitrogen in the samples manure (Sertsu&Bekele, 2008).

  % N = ((a – b)/s) ×N×0.014 × 100 × mcf… 3.3

Where a= ml of H_2SO_4 required for titration of sample

b= ml of H_2SO_4 required for titration of blank

s= air dry sample weight in grams

N = normality of nitrogen in g

Mcf = moisture correction factor

3.10 Validity and Reliability of data collection Instrument

Validation of an instrument was done in order to insure that the instrument has validity. The next stage was to subject the instrument to trial or pilot testing. This involved administrating the instrument on a very small sample of those whom it was used in the final study under similar condition. The validity of questionnaire was insured by using SPSS 20.To this end, collection of questionnaires was made and feed into SPSS20 software. Accordingly, the result shows choriambs alpha 0.87. As it was stated if the result of SPSS20 was greater than 0.7 the reliability and validity of data collection instrument high. Thus, the reliability of data collection tools for the study was at the interval of very high.

3.11 Methods of data administration

First questionnaire, interview, observation and chick lists format were prepared based on the object of the study. The questionnaires were distributed to respondents and collected after relevant information written on them and interview was asked from respective woredas water mine, energy office energy departments' coordinators and observation was conducted by using observation chick lists. The responses were edited and organized for analysis by appropriate statically procedure.

3.12. Methods of Data Analysis

After the data collected, it was analysed by using Statistical Package for Social Sciences (SPSS200) computer package and Microsoft excel. In order to determine the current relative importance of energy sources, data was collected from the questionnaires and interview.

Questioner's interpretation was given as follows: for the responses mean within the range of 1-1.49 = very low (VL), 1.5-2.49= low (L), 2.5-3.49=medium (M), 3.5-4.49=high (H), 4.5-4.99=very high (VH) were assigned. The magnitude of the response vary based on the request asked .If the request was negative and the response positive the interpretation was made negative and vice-versa.

3.13 Ethical considerations

The main objectives of the research and or the questionnaire, guarantee of anonymity of the respondents and confidential treatment of the information supplied was explained to participants that the information provided by them was only be used for the study purpose. Moreover, it was ensured confidentiality by making the participants anonymous to eliminate the problems of ethical dilemma and facilitate smooth flow of information between data collected and respondents. Finally, appropriate credit was given for any use of another person's idea or word and the letter of permeation was written from Addis Ababa University to ensure that the study was for the academic purpose.

3.14 Limitation

The total number of biogas digesters visited was 80 in two woredas in southern Ethiopia. Same of biogas digesters found in both woredas were visited while some of the digesters found in very remote kebeles were not visited. This was mainly due to lack of means of transportation or road accessibility issues (remoteness of the sites) and rainy season.

Beside this, soil method was used for determination of total nitrogen in samples of manure. This was due to lack of materials for determination of total nitrogen content in manure. The only difference between the two methods is sample size. The size of the sample for manure is 5gram while for soil is 0.5 to 1gram. All other chemicals are the same for both.

CHAPTER FOUR

4 Result and Discussion

4.1 Demographic Analysis of Respondents

The total 80 households were covered in this study. The sex, age, marital status, family size, level of education and primary occupation of sampled biogas users (40HHs) and non-users household (40HHs) were assessed as demographic characteristics. This data needed because household biogas technology effectiveness depend on some of human demographic characters.

4.1.1 Sex and Age Ratio

From the total respondents the male-headed biogas users and non-users sample households constituted 29(72.5 %) and 32(80%), respectively while the females ones accounted 11(27.5%) and 8(20%), in the same order (Table 4.1). The study being gender neutral, the respondents were randomly selected and the low number of female-headed households, this may be attributed to the scenario in Ethiopia This difference between male and female headed indicating that there was a slight difference between biogas adopters and non-adopters in terms of gender. This indicates that switching from traditional biomass energy use into biogas energy was a gender-sensitive issue. For example, female members of the household in Ethiopia (Gwavuya*et al*., 2012) typically do 90% of dung collection. This idea were not opposed the result of this study, that was more of the respondents were male-headed than females-headed because, females existed indirectly behind their husband so, male-headed households were not expected to be disturbed adoption of small-scale biogas technology.

The mean ages of the biogas user household was 39 years with range from 18-60years old. The ages of the sample biogas non-user households ranged from 18 to 60years old with an average of 39 years. 67.5% of biogas user was at the middle age between 26 to 60 years old. This implies that most of the respondents were within productive age group (Lapar and Pandey, 1999). That is desirable for biogas technology adoption.

4.1.2 Analysis of household size and economic activity

From the total of 40 respondents from biogas user, their family size were ranged from 4 to 6 with an average size of 5 persons while the household sizes of the sampled non biogas users households ranged from 2 to 6 persons with an average of 4persons (Table 4).

Table 4.1: The demographic characteristics of respondents

NO	Items	Situation	Adopter		Non-adopter	
			F	**%**	**F**	**%**
1	Sex	Male	29	72.5	32	80
		Female	11	27.5	8	20
		Total	40	100	40	100
2	Household size	1-3	5	12.5	7	17.5
		4-6	29	72.5	26	65
		7-10	6	15	7	17.5
		Total	40	100	40	100
3	Age	18-25	2	5	3	7.5
		26-60	27	67.5	28	70
		Above 60	11	27.5	9	22.5
		Total	40	100	40	100
4	Educational Level	Not read and write	13	32.5	7	17.5
		1-5	17	42.5	20	50
		5-10/12	7	17.5	10	25
		Above 10/12	3	7.5	3	7.6
		Total	40	100	40	100
5	Occupation	Farming	24	60	21	52.5
		Daily labour	7	17.5	8	20
		Merchant	6	15	4	10
		Government employed	3	7.5	2	5
		Total	40	100	40	100

(Source: sample survey of 2018)

The respondent's data indicated that Biogas non-user with more than 4 families used an average of 6 women back/HH/month fuel wood while those with low family used an average of 2 women back/HH/month. This indicated that more firewood and charcoal was used when they cooked heavy meals for many people. Manifold uses of fuels have been mentioned to be the reason why most residents in the Sub-Saharan Africa are reluctant to switch to more efficient household energy alternatives (Osiolo, 2009).

4.1.3 Analysis of educational level

Education has been significantly linked to technology adoption, this is through the proven ability to understand and embrace new innovations and exposure to development dynamics. The study found about 24 (60%) of adopters biogas respondents and non-adopters who can 30(75%) can read and write so that they can follow any step of biogas operation(Table 4.1). A similar finding was reported by Mendola (2007. This implies that household biogas technology has been practiced irrespective of the farmer's level of education.

4.1.4 Occupation of Respondents

From the study, it was recognized that 24(60%) adopters and 21(52.5%) of the respondents were apportioned in farming activity, 3(7.5%) and 15(32.5 %) were on salaried and daily labours respectively, while 6(15%) practiced business and trading activities (Table 4.1).The finding was supported by. According to Walekhwa*et al.* (2009), empirical evidence suggest that probability of a household adopting biogas technology was directly proportional to the number of cattle owned and household sizes. This indicated that the occupation of the respondents was appropriate with the principles of household biogas adoption since most of the respondents were farmers that own cattle dung as inputs and relatively large household size to manage biogas plant.

4.2 Factors Influencing Effectiveness of Household Biogas Technology

The sample households had various response on reasons for factors influencing effectiveness of their biogas plants Such as: Construction quality of biogas digester for anaerobic condition, Installation quality of biogas plant, feeding quantity, economic status of adopters ,health status of adopters, environmental conditions and education level of adopters.

As shown Table 4.2, 6(80%) construction quality of biogas digester for anaerobic condition affects the efficiency of household biogas plants at medium level while the remain 4(20%) low. The mean was 3.1(SD=0.44721).This indicated that the effects of construction quality on the efficiency of biogas plant was at moderate level which was proved by field observation. Chandrarot and Dannet (2007), the effectiveness of biogas plant was affected by construction quality problem (bad masonry work) which cause cracks ad leakage also supported this. This implies that the effectiveness of household biogas plant affected by construction quality.

Table 4.2:The responses on the affecting the effectiveness of existing biogas plants in case of HTwereda

No	Variables	F & %	Very high affecting factor = VH Very low affecting factor =VL					Mean	SD	Rank
			VH	H	M	L	VL			
1	Construction quality of biogas	F			16	1		3.1	0.44721	1
		%			80	5				
2	Installation quality of biogas plant	F		3	8	4	5	2.45	1.05	4
		%		15	40	20	25			
3	Feeding quantity	F	5	4	9	2		3.6	0.44721	1
		%	25	20	45	10				
4	Economic status of adopters	F	1	4	8	5	2	2.85	0.6708	3
		%	5	20	40	25	10			
5	Health status of adopters	F	1	6	7	4	2	3.00	1.076	5
		%	5	30	35	20	10			
6	Environmental conditions	F	1	6	8	3	2	3.05	1.05	4
		%	5	30	40	15	10			

(Source: sample survey of, 2018)

As indicated Table 4.2, 3(15%), 8(40%)and 4(20%) the effects of installation quality of biogas plant on its efficiency were very high, high and medium, respectively. And the rest 5(25%) was low .The mean responses was at the range of 2.45(SD=1.05).This shows that the effectiveness of biogas plant was affected by installation quality of biogas plats moderately. Which was true as that of Chandrarot and Dannet (2007), gas leakage is a common problem regardless of the biogas plant installation design. This implies that installation quality of biogas plant the most influencing factors, which leads gas leakage.

The most important factors influencing effectiveness of household biogas technology was feeding quantity. In the same vine, 5(25%),4(20%)and 9(45%) was very high, high, and medium while the remain 2(10%)(Table 4.2) of them replied that low. The mean responses of the response was 3.6(SD=0.44721). This indicted that the effects of feeding quantity on the efficiency of biogas plant was as the range of moderate level. Which was supported by the idea of Rietzler (2009), that said the main source of household biogas digester input was animal dung while, livestock often graze out said during the day and are only kept inside or near houses during night. This implied that the effectiveness of biogas plant was affected by its feeding quantity in study area.

As shown in Table 4.2, 1(5%), 4(20%)and 8(40%) the effects of economic status on the efficiency of house hold biogas plant were very high, high and medium respectively and there main 5(25%) and 2(10%) were low and very low .the mean score was 2.85(SD=.6708).The responses gained from interview also strengthens that the status of the adopters economy positively affects particularly when bio digest or feeding quantity decreased they timelyad just the quantity by increasing the number of livestock and their feeding to increase the volume of dung and then the plants volume. This implied that the economic status of biogas adopters and the effectives of biogas plant were related strongly.

With regard to table 4.2, 1(5%),6(30%)and 7(35%) very high, high and medium respectively while the remain 4(20%) and 2(10%) the effects of health status on the efficiency of biogas digest or were low and very low. The mean score was 3.0(SD=1.076).This indicates that the effects of health status of biogas plant adopters on the effectiveness of biogas plant was at the interval of modest level. The interview also supplements any health problem of biogas adopters disturbs the effective management of biogas plant and then the effectiveness of biogas plant affected. This points out that the health status of biogas adopters affects the effectiveness of biogas plant in study area.

In Table 4.2, the effects of environmental condition on the efficiency of biogas plant. For that reason 1(5%), 6(30%) and 8(40%) was very high, high and medium respectively while the remain 3(15%) and 2(10%) was low and very low. The mean score of the response was 3.05(SD=1.05). This indicates that the effects of environmental condition on the efficiency of biogas plant was at moderate level. Beside to this the field measured by the researcher of this study support the idea that said the environmental condition particularly temperature of the study area was highly suitable for household biogas production. This indicated that environmental condition was not significant factor on the efficiency of biogas plant.

Table 4.3:The responses on effectiveness of existing biogas plants in case of BS woreda

No	**Variables**	**F & %**	Very high affecting factor = VH Very low affecting factor =VL					**Mean**	**SD**	**Rank**
			VH	H	M	L	VL			
1	Constriction quality of biogas digester for anaerobic condition	F	1	4	13	2		3.2	0.69585	3
		%	5	20	65	10				
2	Installation quality of biogas plant	F		4	9	7		2.85	0.745	4
		%		20	45	35				
3	Feeding quantity	F		1	13	5	1	2.7	0.656	2
		%		5	65	25	5			
4	Economic status of adopters	F	1	5	11	1	1	2.95	0.599	
		%	5	25	55	5	5			6
5	Health status of adopters	F	1	5	10	3	1	3.1	0.911	5
		%	5	25	50	15	5			
6	Environmental conditions	F		5	11	2	1	3.95	4.08431	8
		%		25	55	10	5			

(Source: sample survey of, 2018)

In Table 4.3,1(5%), 4(20%) and 13(65%) the effects of construction quality of biogas digester for anaerobic condition on the effectiveness of household biogas plant were very high, high and medium respectively while the remain 2(10%) was low. The mean score of the responses was 3.2(SD=0.69585). The mean score of HTW woreda responses was 3.1(SD=0.44721).This indicated that the both woredas have almost the same response with regarding to construction quality of biogas digester. In addition to this, the result of observation and interview of the two woredas showed similar to each other.

As can be seen from table 4.3 of item 2, the effects ofinstallation quality of biogas plant on effectiveness of biogas plant. In line with this request,4(20%), 9(45%) and 7(35%) was high, medium and lower reactively. The mean score of the responses was 2.85(SD=0.74516).The mean score of HT woreda was2.45 (SD=1.05). As indicated above the lower the mean showed the better installation quality of BS woreda than HT woredas the result of field observation also confirmed the same truth.

With regard to item 3 of table 4.3, the effects of feeding quantity on the efficiency of house hold biogas plant. Accordingly, 1(5%), 13(65%) and 5(25%) of the respondents replied that were high, medium and low respectively while the remain 1(5%) of them replied that the effects of feeding quantity on the efficiency of house hold biogas plant very low. The mean score was 2.7(SD=0.65695).The mean score of HT woreda responses was3.6 (SD=0.44721). The mean difference between BS and HT woredas showed HT has better feeding quantity to effectively practice biogas technology, which emanate from relatively better plot of land than BS woreda..

As can be see Table 4.3, 1(5%), 5(25%) and 11(55%) the effects of economic status of biogas adopter on the effectiveness of biogas plant was very high ,high and medium respectively while the remain very low 1(5%) . The mean score of the responses was 2.95(SD=0.5999). The mean score of HT woreda was 2.85(SD=0.6708).This indicated that the both woredas have almost the same response with regarding to economic status of biogas adopters. In addition to this, the result of observation and interview of the two woredas go hand in hand to each other**.**

In item 6 of Table 4.3, the effects of Health status of adopters on the effectiveness of biogas plant. In line with this, 1(5%), 5(25%) and 10(50%) were very high, high and medium respectively while the remain 3(15%) and 1(5%) were low and very low respectively. The mean score of the responses was 3.1(SD=0.91191).The mean score of HT woreda was 3.0(SD=1.076).This indicated that the effects of Health status of adopters on the effectiveness of biogas plant was at range of moderate level. This implied that both woredas have almost the same response with regarding to health status of biogas adopters. Furthermore, the result of interview of the two woredas supplement each other**.**

With regarding to Table 4.3, 5(25%), 11(55%) and 2(10%) the effects of environmental benefits of biogas on its effectiveness was high, medium and low while the remain 1(5%) was very low. The mean score of the responses was 3.95(SD=4.08431).The mean score of HT woreda was 3.05(SD=1.05). Whatever, the mean differences of the response seen, Environmental conditions particularly temperature was as the interval of Mesophilic range (20-40^{0}C) which is suitable for small-scale biogas production in both woredas.

4.3 Factors Influencing Adoption rate of household Biogas Technology

The sample households had various reasons for adopting biogas technology. Anderson (2002) stated that decisions that involve allocation of resources include consideration of multiple alternatives and reasons. Hence, the reasons given for adoption of biogas technology included economic benefit, bright light, governmental subsidy for plant, health related risk, fast and more convenient stove, existence of credit arrangement, saving time and reducing work load. The biogas adopter group elicit their reasons for adoption on 5-level, likert-scale on the other hand there reasons given for non-adoption biogas technology embrace: adequacy of fund feeding quantity, community's attitude towards biogas energy, low interest level of community, functionality of biogas existed plant, awareness level of biogas technology and availability of alternative Energy source.

4.3.1 Reasons to invest Biogas Technology

As indicated in the Table 4.3, the effects of economic benefit on the adoption rate of biogas plant. Accordingly,10(50%)and 6(30%) were high and medium while the remain 4(20%) of was low. The mean score of the response was 3.6(SD =.80131).This indicates that the effects of economic benefit were at the range of moderate level. Biogas plant installations can generate methane gas for bright light and cooking stove reduces fossil fuel and woody fuel and the bio-slurry from biogas digesters has been attested to be the best organic fertilizer which will lead to increased crop productivity by substituting chemical fertilizer and thus reduces the importation of chemical fertilizer and saves foreign currencies and Biogas technology generates employment opportunities for both skilled and unskilled labour (Arthur et al. 2011). From this one understand that economic benefit of household biogas motivated the adoption rate of biogas technology.

In Table 4.4, 5(25%) and 9(45%) the effects of governmental subsidy for plant on biogas plant adoption rate were high and medium while the remain 6(30%) was low. The mean score of the response was3.53(SD=0.67082).This indicated that the effects of governmental subsidy on the adoption rate of the biogas plant was at the range of moderate level .In addition to this though interview of biogas users there was government subsiding systems to facilitate household biogas technology dissemination. In support of this (Kabir et. al., 2013) postulated that Subsidy was indicated to be important for respondents in taking a decision to adopt biogas technology. This implied that household biogas technology was accelerated by government subsidy.

Table 4.4: Reasons to Invest on Biogas Technology HT woreda

No	Variables	F & %	**Very high motivating factor= VH Very low motivating factor =VL**					Mean	SD	Rank
			VH	H	M	L	VL			
1	Economic benefit	F	6	12	2			3.6	0.50262	1
		%	30	60	10					
2	Governmental subsidy for plant	F	1	6	12	1		3.3	0.67082	2
		%	5	30	60	5		5		
3	Reducing health risk	F		4	10	6		2.9	0.71818	6
		%		20	50	30				
4	Fast and more convenient cooking stove	F		11	6	2	1	3.3	0.87509	9
		%		55	30	10	5	5		
5	Bright biogas light	F	2	4	12	2		3.3	0.80131	7
		%	10	20	60	10				
6	Better quality bio-slurry for fertilizer	F	3	10	6	1		3.7	0.78640	6
		%	15	50	30	5		3		
7	Non-availability of other fuel sources	F		2	4	14		2.4	0.68056	3
		%		10	20	70				
8	Saving time and Reducing work load	F	2	9	5	1		3.7	0.71635	5
		%	10	60	25	5		5		
		%		20	55	25				

As shown in the Table 4.4, 4(20%),10(50%) and 6(30%) the effects of reducing health risk as stimulation of biogas technology adoption rate were very high, high and medium respectively. The mean score was 2.9(SD=0.71818). This indicated that the arousal of biogas technology adoption rate were at the range of moderate level. The use of biogas technology has numerous health benefits such as reduction in smoke borne diseases like headache, eye burning, eye-infection, and respiratory organ infection and reduction in burning accidents (Ghimire, 2008). This implied that the adoption rate of biogas plant was fostered by its reduction health risk.

As indicated in Table 4.4, fast and more convenient cooking stove as the proxy for the adoption rate of biogas technology. In line with this request,11(55%), 6(30%) and 2(10%) were high, medium and low respectively while the remain 1(5%) was very low. The mean score of the responses was 3.35(SD=0.87509).This indicated that fast and more convenient cooking stove as the alternative for the adoption rate of biogas technology was at the range of moderate level. It was also proven by interview of adopters the fastness and convenience of biogas cooking stove was one of deriving factor to adopt biogas technology. This pointed out that adoption rate of biogas technology was speeded up by the fastness and convenience of biogas cooking stove in study area.

In Table 4.4, 2(10%), 4(20%) and 12(60%) bright light of biogas as motivator of biogas adoption rate were high, medium and low respectively while the rest 2(10%) of them replied that bright light of biogas as motivator of biogas adoption rate very low. The mean score of the responses was 3.3(SD= 0.80131).This showed that bright light of biogas as motivator of biogas adoption rate at the interval of moderate level. In connection with this, (Surendra et al. 2014) stated that the primary uses of biogas technology in developing countriesare cooking and lighting. (Eshete et al. 2006) also pointed out that biogas is utilized both for cooking and lighting in Ethiopia. In rural areas where electricity is absent, biogas lighting is highly appreciated. Children are taking care of feeding the biogas digesters to get bright lighting in the evening. In this context, the need for biogas lighting had to be number one reason. This implied that bright light of biogas was motivator of biogas users to adopt the technology.

As can be seen from Table 4.4, better quality bio-slurry for fertilizer as initiator of biogas adopter’s adoption rate of biogas technology. Accordingly, 3(15%), 10(50%) and 6(30%) were very high, high and medium respectively while the remain 1(5%) of them was low. The mean score was 3.73(SD=0.78640). This indicated that better quality bio-slurry for fertilizer as initiator of biogas adopter’s adoption rate of biogas technology was at the range of moderate level. As stated by Breinholt (1992), the ammonia content of bio-slurry from biogas digester is about 10 % higher than the fresh manure. From this, one can understand better quality bio-slurry for fertilizer as initiator of biogas adopter’s adoption rate of biogas technology.

The respondents asked to rate saving time and reducing work load as encouraging factor for biogas adoption rate. Based on this request, 2(10%), 9(60%) and 5(25%) were very high, high and medium respectively. while the remain 1(5%) was very low. The mean score was 3.75(SD=0.71635).This indicated that saving time and reducing work load as encouraging factor for biogas adoption rate was at the range of medium level. In connection to this

Ghimire (2008), stated that biogas adoption saves time for social activities; it diminishes women and children's work burden; and it offers brighter light that assists education and household duties. This saved time is utilized for rest and leisure, schooling, social activities and/or productive purposes which definitely empower women and promote women and girls' education. This implied that saving time and reducing work load was inspired adopters' adoption rate.

Table 4.5 Reasons to Invest on Biogas Technology in Boloso Sore woreda

No	Variables	F & %	Very high motivating factor= VH Very low motivating factor =VL					Mean	SD	Rank
			VH	H	M	L	VL			
1	Economic benefit	F		10	6	4		3.3	0.8013	8
		%		50	30	20				
2	Governmental subsidy for plant	F		5	9	6		3.53	0.6708	2
		%		25	45	30				
3	Reducing health risk	F	1	6	12	1		2.95	0.7591	4
		%	5	30	60	5				
4	Fast and more convenient cooking stove	F		1	10	9		3.6	0.5982	1
		%		5	10	45				
5	Bright biogas light	F	1	5	11	3		3.2	0.7677	5
		%	5	25	55	15				
6	Better quality bio-slurry for fertilizer	F	4	5	11			3.65	0.8127	9
		%	20	25	55					
7	Non-availability of other fuel sources	F	1	1	8	10		2.65	0.8127	9
		%	5	5	40	50				
8	Saving time and Reducing work load	F		3	6	11		3.6	0.7539	3
		%		15	30	55				

(Source: sample survey of, 2018)

As indicated in the Table 4.5, 10(50%) and 6(30%) that effects of economic benefit on the adoption rate of biogas plant was high and medium while the remain 4(20%) was low. The mean score was 3.3(SD=.80131).The mean score of HT woreda response was 3.6(SD=.80131).This indicates that the both woredas have similar mean response on the causes to biogas adoption. From this one understand economic benefit derive users to adopt biogas technology in HT and BS woredes.

In item 2 of Table 4.5, the consequence of governmental subsidy on the adoption rate of biogas plant. In line with this,5(25%)and 9(45%) were high and medium while the remain 6(30%) was low. The mean score of the response was3.53(SD=0.67082).The mean score of the response HT woredawas3.53(SD=0.67082).This indicated that the consequence of governmental subsidy on the adoption rate of biogas plant was at the range of moderate level. This showed that the both woredas have the same mean response on the causes to biogas adoption. This implied the consequence of governmental subsidy on the adoption rate of biogas plant could derive users to adopt biogas technology in both woredas.

As it was shown in the table 4.4, 31(5%),6(30%) and 12(60%) the reducing health risk as arousal of biogas technology adoption rate were very high, high and medium respectively while the remain 1(5%) was low. The mean score of the responses was 2.95(SD=0.75915).The mean score HT woredawas 2.9(SD=0.71818)This indicated that the reducing health risk as stimulation of biogas technology adoption rate were at the range of moderate level both woredas.

As presented in Table 4.5 of item 4,fast and more convenient cooking stove as the proxy for the adoption rate of biogas technology. Accordingly,1(5%),2(10%) and 9(45%) was high, medium and low respectively. The mean score of the response was 3.6(SD=0.59824).The mean score of the HT woreda responses was 3.35(SD=0.87509)This indicated that fast and more convenient cooking stove as the proxy for the adoption rate of biogas technology was at range of moderate level in both HT and BS woredas.

As can be shown in Table 4.4,1(5%)and 5(25%) of the respondents said that, bright light of biogas as motivator of biogas adoption rate was very high and high respectively while the remain 11(55%) and 3(15%) the bright light of biogas as motivator of biogas adoption rate was medium and low respectively. The mean score was 3.2(SD=0.76777).The mean score of the HT woreda responses was 3.3(SD= 0.80131).This indicates that bright light of biogas as motivator of biogas adoption rate in both woredas.

In Table 4.5, 4(20%)and 5(25%) the better quality bio-slurry for fertilizer as initiator of biogas adopter's adoption rate of biogas technology was very high and high respectively while the remain 11(55%) as low on the same request. The mean score of the responses was 2.65(SD= 0.81273).The mean score of the HT woreda was 3.73(SD=0.78640). The mean difference implied that the better quality bio-slurry for fertilizer as initiator of biogas adopter's adoption rate of biogas technology was well in HT woreda than BS. The result of the interview confirmed that HT woreda users were made awe red the benefits of bio-slurry for fertilizer than BS users.

In Table 4.5, the respondents asked to rate saving time and reducing work load as encouraging factor for biogas adoption rate. In line with, 3(15%) and 6(30%) of the respondents said that saving time and reducing work load as encouraging factor for biogas adoption rate was high and medium while the rest 11(55%) of them replied that saving time and reducing work load as encouraging factor for biogas adoption rate was low.

4.3.2Reasons for Not Adopting the Biogas Technology

Table 4.6: Reasons for not adopting the biogas technology in case of both woredas

No	Variables	F & %	Very high factor for non-adopting=VH **Very low factor for non-adopting =VL**					**Mean**	**SD**
			VH	H	M	L	VL		
1	Adequacy of fund	F	10	8	12	10		3.45	1.1459
		%	25	20	30	25			
2	Feeding quantity	F		10	26	4		3.15	0.58714
		%		25	65	10			
3	Community's attitude towards	F		22	4	12	2	3.15	1.03999
		%		55	10	30	5		
4	Interest level of community	F		20	18	2		3.45	0.60481
		%		50	45	5			
5	Functionality of biogas existed plant	F	2	14	14	8	2	3.15	0.98809
		%	5	35	35	20	5		
6	Suitability of climatic condition	F	2	14	16	8		3.25	0.8507
		%	5	35	40	20			
7	Family size	F		2	12	18	8	2.22	0.83351
		%		5	30	45	20		
8	Availability of alternative Energy	F		6	8	16	10	2.25	1.901955
		%		15	20	40	25		

The mean score of the responses was 3.6 (SD=0.75394).The mean score of the HT woreda responses 3.75(SD=0.71635). This indicates that the both woredas have the same mean response on the indication to biogas adoption. This implied saving time and reducing work load was encouraging factor for biogas adoption rate in both woredas.

As can be seen in table 4.6the adequacy of fund on the adoption rate of biogas technology. Accordingly, 10(25%), 8(20%) and 12(30%) were very high, high and medium respectively while the remain 10(25%) was low. The mean score of the responses was 3.45(SD=1.1459).

This indicated that the effects of adequacy of fund on the adoption rate of biogas technology was at the range of moderate level. Financial status is one of the most critical and frequently mentioned factors that determine adoption of biogas technology (Walekhwa et al., 2009).This implied that the adoption of biogas technology in study area was challenged by the lack of adequate fund.

In Table 4.6,10(25%), and 26(65%) the effects of feeding quantity on the adoption rate of biogas was high and medium while the remain4(10%) of them was low. The mean score of the responses was 3.15(SD=0.58714). This indicated that the effects of feeding quantity were at the interval of moderate level. The promotion tool has targeted only at those households who own four or more heads of cattle. Possession of four or more heads of cattle was indicated to be sufficient to feed the minimum recommended digester size (EREDPC and SNV, 2008). However, the households have interest to construct biogas technology that owe less than four cattle cannot adopted biogas. From this, one can understand that feeding quantity in study area moderately affecting factors of biogas technology adoption rate.

In Table 4.6,4(10%),14(35%)and 14(35%) the effects of interest level of the community on the adoption rate of biogas technology were very high, high and medium while the rest 8(20%) was low and very low. The mean score of the response was3.15 (SD=0.98809).This indicated that the effects of interest level of the community on the adoption rate of biogas technology at the range of moderate level. Beside to this, the information collected by interview proved households' interested biogas technology but some of them were not interested due to existence of alternative energy sources.

As indicated in Table 4.6, the effects of biogas functionality on the adoption rate of biogas technology. In line with this, 2(5%),14(35%) and 16(40%) were at very high, high and medium while the remain 8(20%) low. The mean score of the responses was 3.25(SD=0.8507). This point out that the effects of biogas functionality on the adoption rate of biogas technology was at range of moderate level. As stated in EREDPC and SNV (2008), a satisfied user from the proper functioning of biogas installation can serve as the best advocator of the technology. Moreover, the information from interview supplemented problems faced by their biogas adopter friends, especially non-functioning and poorly function biogas plant neighbours and relatives of the non-adopter respondents disturbed the potential biogas adopters' interest. This implied that the level of biogas functionality determined its adoption rate in study area.

As showed in Table 4.6, the effects of climate condition on adoption rate of biogas technology. In the same vein, 2(5%), 14(35%) and 16(40%) were high, medium and low respectively while the remain 8(20%) was low. The mean score of the response was 3.25(SD= 0.8507). This indicated that the effects of climate condition on adoption rate of biogas technology were at the interval of moderate level. In relation to this the result of field measurement during data collection pointed the measure value of ambient temperature was at preferable mesophilic range (20-40^{0}C).This implies that climatic condition particularly temperature was suitable for small-scale biogas technology in study area so that adoption rate cannot be affected by climatic condition.

As can be seen from the Table 4.6, the respondents requested to rate the effects of family size on adoption rate of biogas technology. In view of that, 2(5%),12(30%) and 18(40%) high ,medium and low respectively while the rest 8(20%) was very low. The mean score of the responses was 2.22 (SD=0.83351).This indicated that the effects of family size on adoption rate of biogas technology was at the interval of moderate level. Moreover, the information from interview supplemented, The number of family size influenced the adoption rate of biogas technology since biogas plant constructed need humane source management but in study area, the other problem of family size related with biogas technology adoption in study area was human excreta used as input for the biogas production decreased that affects the feeding quantity of biogas plant which in turn leads to non-functionality of biogas and then the adoption rate of biogas technology disturbed. The implied that the number of family in study area affected the adoption rate of biogas technology.

Table 4.6, 6(15%),8(20%)and 16(40%) the effects of availability of alternative energy source on the adoption rate of biogas technology was , high medium and low respectively while the remain 10(25%) was very low .The mean score of the response was 2.25(SD=1.901955).This indicated that the effects of availability of alternative energy source on the adoption rate of biogas technology medium. This implied that the adoption rate of biogas technology was not that much affected by existence of alternative energy in study area because there was alternative energy source observed.

4.4 Technological gap in household biogas technology in study area

The goal of household biogas technology stockholder are disseminating effective biogas technology for household biogas users by full-filing biogas technological gaps. According to unpublished NBPTE. Training Manual (2010), technological parameters such as: structural durability, Method of construction and supervision, time and effort in quality control, methods of operation and maintenanis, adoptability of design and sharing of experience to fill technical gaps were considered in this study.

As indicated Table 4.7, the structural durability of existing biogas plant as technological gap. Accordingly,3(15%)was high and the remain most 17(85%) low. The mean score of the responses was 3.15 (SD=0.36635).

Table 4.7 The stokeholds technological gap in household biogas in the case of HTwereda

No	Variables	F &%	Very high T.gap=VH Very low T.gap = VL					Mean	SD	Rank
			VH	H	M	L	VL			
1	Structural durability	F		3	17			3.15	0.36635	1
		%		15	85					
2	Method of construction supervision	F			3	14	3	3	0.56195	2
		%			15	70	15			
3	Time and effort in quality control	F	1	8	7	4		3.3	0.8645	4
		%	5	40	35	20				
4	Methods of operation and maintenance	F	6	9	3	1	1	3.9	1.0712	5
		%	30	45	15	5	5			
5	Adoptability of design	F		5	13	2		3.15	0.58714	3
		%		25	65	10				
6	Sharing of experience to fill technical gap	F	5	10	1	3	1	4.25	1.86025	6
		%	25	50	5	15	5			

(Source: sample survey of 2018)

This indicates that the structural durability of existing biogas plant was at the range of moderate level. Moreover, the interview supports the idea that the structural durability of existing biogas plant was low, which was witness the maximum durability of biogas plant in study area was 10-15 years but maintenance is carried out regularly a biogas plant can have an operational life span exceeding 20 years (Rietzler, 2009). This implied that the structural durability of existing biogas plant was not live long that emanate from low quality of construction materials that showed the existence of technological gap expressed by low durability of the structure.

According Table 4.7,3(15%) and 14(70%) the method of construction supervision being considering as technological gap was medium and low respectively while the rest 3(15%) replied very low. The mean score of the reposes was3(SD=0.56195) (Table 4.7). This indicated that the method of supervision as technological gap was at the range of moderate level. Moreover, the information gathered though open ended questions points out that there was limited supervision of responsible body during construction and it was told that limited skilled human resource .In relation to this, supervision is a very important role to play in effectiveness of biogas technology starting from root level (NBPE, 2010). This showed that there was technological gap that revealed through limited skill in biogas technology that hinder the method of supervision of biogas plant.

The respondents demanded to replay the time and effort in quality control as technological gap. In line with this, 1(5%),8(40%) and 7(35%) was very high and medium respectively while the remain 4(20%) of them said low on the same request. The mean score of response was 3.3(SD=0.8645) (Table 4.7).This indicated that the time and effort to control quality of biogas construction and operation was at the range of moderate level. The information gathered by interview strengthens the idea that said there was limited time and effort to control the construction and operation of biogas plant with tangible evidences the construction of biogas plant delay because of bureaucracy of government finance system which requires long time to process that need time and effort of controlling. As stated by Rietzler (2009), both the construction of biogas plant and its financing to protect the building of biogas plant from delay, time and effort in quality control is important. However, in study area the biogas construction was not timely controlled so that their low durability after construction was common problem. This points out that there was technological gap in study area with regarding to controlling the status of biogas construction to avoid damage due to delay during construction.

As can be seen Table 4.7,6(30%),9(45%) and 3(15%) the methods of operation as technological gap were very high, high and medium respectively while 1(5%) and 1(5%) was low very low. The mean score of the response was 3.9(S.D=1.0712).This indicated that the methods of operation as technological gap at the range of moderate level. In addition to this, the information collected by interview and open ended question also supported the idea that said the methods of operation as technological gap was the major problem in study area that was witnessed by observation biogas plants stop functioning were not operated because lack of skilled man power. Accordingly, Marchaim (1992) poor operation of biogas plant is one of key reasons of plant failure .This points out that the methods of operation and maintenance was the significant technological gap of the study area.

The respondents requested to rate adoptability of the design as technological gap. So, 5(25%) and 13(65%) was high, and medium while 2(10%) the design as technological gap was low. The mean score of the responses was 3.15 (SD=0.58714) (Table 4.7).This indicated that adoptability of the design as technological gap was at the range of moderate level. Moreover, the information collected by observation points out same biogas plants' digester far away from the soil compacted during construction this due to miss selection of construction season (summer). Due to unwise site and season selection structures on low bearing soil capacity were sinking (NBPE, 2010). This implied that even if SNIDU model was preferred in study area adoptability of the design was one of the major technological gap in study area.

As can be seen Table 4.7, 5(25%),10(5) and 1(5%) Sharing of experience to fill technical gap was very high, high and medium respectively while the rest 3(15%) and 1(5%) of them replied was low and very low. The mean score of the responses was 4.25(1.86025). This indicated that Sharing of experience to fill technical gap as technological gap was at the interval of high level. In addition this, the information gained from interview supported that sharing of experience among biogas adopters was very low because budget limitation to facilitate the training programme. This pointed out that sharing of experience to fill technical gap as technological gap in study.

As can be seen from item 1 of Table 4.8, 2(10%) and 14(70%) the effects of technological gap on structural durability of biogas plant was high, and medium while the remain that replied low and very low were 1(5%) each. The mean score of the responses was 3.2(SD=0.52315). The mean score of the responses HT woreda was 3.15 (SD=0.36635). This indicated that the effects of technological gap on structural durability of biogas plant were at range of moderate level. This indicates that the both woredas have the same mean response on the effects of technological gap on structural durability of biogas plant. This implied the effects of technological gap on structural durability of biogas plant was affect at medium level in both study areas.

Table 4.8: The stokeholds technological gap in household biogas in case of BS woreda

No	Variables	F &%	Very high T.gap=VH Very low T.gap = VL					Mean	SD	Rank
			VH	H	M	L	VL			
1	Structural durability durability	F		2	14	1	1	3.2	0.52315	
		%		10	70	5	5			
2	Method of constriction supervision	F			12	7	1	3.3	0.76089	
		%			60	35	5			
3	Time and effort in quality control	F	1	5	10	2		4.25	1.0245	
		%	5	25	50	10				
4	Methods of operation and maintenance	F	10	3	6	1		4.1	1.02084	
		%	50	15	30	5				
5	Adoptability of design	F	1	7	6	6		3.15	0.93330	
		%	5	35	30	30				
6	Sharing of experience to fill technical gap	F	4	13	2	1		4	0.7258	
		%	20	65	10	5				

(Source: sample survey of 2018.)

In Table 4.8, 12(60%),7(35%) and 1(5%) the limited methods of construction supervision was medium, low and very low respectively. The mean score of the responses was 3.3(SD= 0.76089).The mean score of the reposes HT woredawas 3(SD=0.56195). This indicated that the effects technological gap that revealed through limited methods of construction supervision at range of moderate level at study area.

With regard to item 3 of Table 4.8, the level time and effort to control biogas plant quality. In line with,1(5%), 5(25%) and 10(50%) the time and effort to control biogas plant quality very high ,high and medium while the remain 2(10%) was low. The mean score of the responses was 4.25(SD=1.02084).This indicated that the level time and effort to control biogas plant quality was at range of moderate interval. The mean score of response HT woredawas 3.3(SD=0.8645).This implied that the level time and effort to control biogas plant in HT woreda was better than BS woreda quality.

In Table 4.8, 10(50%),3(15%) and 6(30%) methods of operation and maintenance of biogas plant as technological gap were very high, high and medium while the rest 1(5%) of them was low. The mean score of the response was 4.1(SD=1.02084).The mean score of the response HT woreda was 3.9(S.D=1.0712).This indicated that methods of operation and maintenance of biogas plant as technological gap in both woreda were at the range of moderate level.

As can be seen in the table 4.8 of item5, 1(5%) and 7(35%) were very high, high while the respondents that said the adoptability of biogas plant as technological gap was medium and low were 6(30%) each. The mean score of the responses was 3.15(SD=O.93330).The mean score of the HT woreda responses was 3.15 (SD=0.58714).This indicated that the adoptability of biogas plant as technological gap in both woredas were at range of moderate level.

In item 6 of table 4.8, 4(20%) and 13(65%) of the respondents said that sharing of experience among household biogas adopters as technology gap filling was very high and high while the remain 2(10%) and 1(5%) of them were medium and low. The mean score of the responses was 4(SD=0.7558).The mean score of the HT woreda responses was 4.25(1.86025).This indicated that sharing of experience among household biogas adopters of HT and BS woreda were as technology gap was at the range of moderate level.

4.5 Field and Laboratory Analysis

4.5.1Field data analysis

As shown in Table 4.9belowfield measured parameters range and mean values, the data provides a foundation for understanding basic anaerobic digestion process and operational practices in the selected sites. Hence, the researcher can easily make conclusions on the level of feeding quality on efficiency of existing household biogas in study area for its effectiveness.

Table 4.9: Field measurement parameters

No	parameters	HTZ Woreda		Boloso Sore woreda		Optimum value
		Range	**mean**	**Range**	**mean**	
1	**Ambient temperature**	**25-31**^{0} C	**27.7**^{0}C	26.8 -30.6	28.3575^{0}C	35^{0}C
2	Slurry Temperature	21^{0}C -26^{0}C	24.5^{0}C	24.5- 27.7	26^{0}C	10-45^{0}C
3	Water pH	5.98 -8.35	7.05875	5.75 - 7.8	6.609667	
4	Effluent pH	6.26 -8.47	7.439524	7.26-8.42	7.881167	6.5-8.5
5	Slurry pH	6.90 - 7.76	7.331	7.3 - 8.46	8.018667	

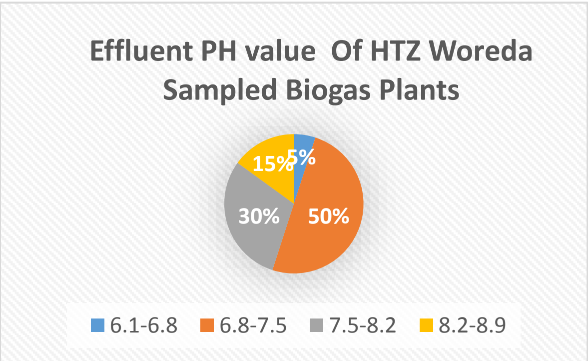
N.B. Optimum Values vary from source to source but for this study, it is used (NBPE,2010). SNV (Heegde, 2010) & Biogas utilization Hand Book (Waishet al.1988). Mean annual temperature for unheated bio digester, assuming that the bacteria found in the digesters are methanogenic, optimum pH ranges for all processes.

4.5.1.1 Ambient Temperature

Ambient temperature is one of the main factors of biogas production. Hence, any stockholders involved in the construction of biogas plant has to first attention on the surrounding temperature (NBPE, 2010). Therefore, the researchers gave also attention to measurements of this parameter, which was at feeding and exiting chamber of biogas digester by using portable thermometer the complete data gathered was present in appendix 4, the range and the mean values of ambient temperature measured during the field visit was 25^{0}C - 31^{0}C and 26.8^{0}C -31^{0}C, and mean 27.7^{0}Cand 28.4^{0}C in HT and BS woradas respectively. According to (NBPE, 2010) The biogas plants in Ethiopia are expected to be operated in mesophilic range (10-45^{0}C), so that the ambient temperature of existing household biogas in study areas was at suitable level.

4.5.1.2 pH

The range and mean pH values recorded for water was above seven. This indicates that the water available in the sites was alkaline. Similarly, slurry pH recorded was above seven, while effluent was slightly acidic and alkaline as shown in Figure 4.1. And Table 4.9. According to Heegde (2010), the optimum value for mesophilic bacteria is in the range between 6.8 and 7.5 pH effluent PH obtained during the survey presented in graph as shown below at both study area (Figure 4.1) showed that 50%, 45% Effluent PH value were ta optimum range of HT woreda and BS woreda respectively. This indicated that the effects of PH value of the digester of existing household biogas in study areas was at Medium level.



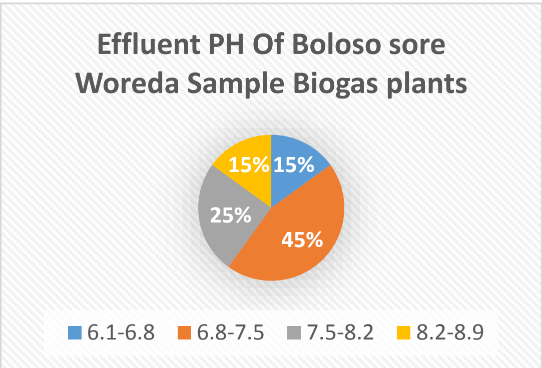


Figure 4.1 Percentage of PH value at sampled biogas plant in study area (Source: sample survey of, 2018)

4.5.2 Laboratory data analysis

4.5.2.1 Total solid content

Composition of substrate and water was highly variable; it depended on individual operator charging practices. Some of the parameters listed in Table 4.10, such as total solid content, fixed solid content and volatile solid content were directly affected by variation in operational charging practices.

Table4.10. laboratory result of Total solid

Fresh cattle dung	Result of HT Woreda			Result of Boloso sore Woreda			% of Optimal value
	Range	mean	S.D	Range	mean	S.D	
% of Total solid content(TS)	14 -28	21.9	5.23	14-34	23.6	5.87	20
% of Moister content	72-86	78.1	5.23	66-86	76.4	5.87	80
% of Fixed solid(FS) from% of (TS) after mixing water	18 -52.3	32	9.76	32-43	35	3.5	30
% of Volatile solid (VS) from % of (TS) after mixing water	41-81	69.2	10.8	56-69.5	66.53	7.5	70

N.B. Optimum Values vary from source to source but for this study, based on cow dung manure NBPE (2010) and it is used SNV Heegde, (2010) in the above (Table 4.10)

This was mainly because most biodigester operators mixing practice were through experience rather than one to one ratio. There was also lack of fixed number of operators in charging and controlling the digesters in most households. It can be seen from Table 4.10 that the% of Fixed solid (FS) from% of (TS) after mixing water were rang (18 -52.3) and (32-43),and mean 32 and 35 in both HTZ and BS woredas. Therefore, the users of existing household biogas in study areas were not able to mix or diluted cattle dung with water or urine in the ratio of 1:1, which affects the effectiveness of existing household biogas in study areas.

4.5.2.2 Carbon to Nitrogen ratio (C/N ratio)

The Carbon/Nitrogen ratio is an important index to evaluate the capacity of materials to decompose and its ratio obtained from the laboratory is presented in for the purposes of interpretation (see table 4.11), while detail results obtained from laboratory is presented in (Appendix 4). The data showed that the values obtained were the highest C/N ratio was recorded between 25-30 in both woreda were 50% and 45% HT and BS woredas respectively. This Show the effect of C/N on effectiveness of existing household biogas in study area were at medium level, which is medium toxic to methanogenic bacteria

Table 4.11.Mid-point, Frequency and percentile distribution of Carbon to Nitrogen ratio

Result of HTZ Woreda				**Result of Boloso sore Woreda**				**Optimal value**
Range	Mid-point	frequency	%	Range	Mid-point	Freq.	%	
16-18	17	1	5	16-18	17	3	15	
18-20	19	4	20	18-20	19	1	5	25-30
20-22	21	5	25	20-22	21	7	35	
22-24	23	4	20	22-24	23	2	10	
24-26	25	3	15	24-26	25	2	10	
26-28	27	3	15	26-28	27	4	20	
28-30	29			28-30	29	1	5	

(Source: sample survey of, 2018)

4.6 Discussion on Observation Results

In this part of the study, the data collected though observation ofbiogas plant system components existing condition was discussed. The results help to visualize the effectiveness of existed biogas plants and there technological gap indictors.

Table 4.12 : Data from field Observation

No	**System component**	**Existing condition**			
		Very good	good	bad	Not exist
1	Inlet + mixer		40		
2	Outlet+ compensation chamber		32	2	
3	dome		38	2	
4	Water drain		20	18	2
5	Pressure gauge		37	3	
6	Gas pipe(diameter)		35	5	
7	Main gas valve		25	10	5
8	Hose pipe		21	3	16
9	Stoves/bulbs/appliances		22	16	2

4.6.1 Inlet tank, Dome and Outlet tank

All of the biogas plant inlet tank were at good condition. 38 of the dome parts of the biogas plates were at good condition while the remain two of them were at bad conditions. Most of biogas plant out lets were well condition but 2 of its slabs damaged and 2 of them were not covered but feeding system had been started in BS woreda as showed figure 4.2, and In HT woreda 1 biogas plat outlet tank hole in to salary pit was blocked and pose bad smell in the surrounding of biogas plant which critical level of health problem as showed as Figure 4.3.

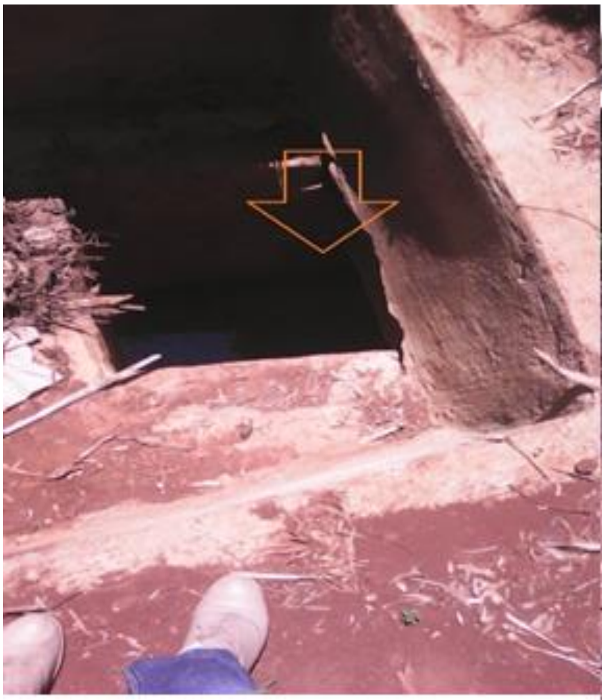


Figure 4.2: without covered slab but feeding system had been started in Boloso sore woreda (Source: field survey of 2018)

Figure 4.3: Outlet tank hole in to salary pit was blocked biogas plant in HT woreda (Source: field survey of 2018)

4.6.2 Installation parts of biogas plants

The house gas pipe of 35 biogas plant were at good condition while the remain 5 of them were at bad condition. And 39 of the biogas plant have stove and only 1 biogas plants have no stove. Accessibility and high cost of value were the major problems and Couse of none functionality of plant in study area with regard to appliance specially stove gas valve and bulb get value were simply damaged so that 8 of them at bad condition but 2 of them at worst level and the rest were good. Selection of bio digester construction sit out of 40 biogas digester 31 of them were 2 - 3 metre far from users home that is good sit selection while the rest were 3 - 7 meter far from their home which was affect economy and exposes for leakage problem. The result of observation shows that 8 of the biogas digesters have no anaerobic condition due to feeding and crack of biogas dome while 32 good aerobic condition but out of 32 biogas plant 12 of them were poorly functional and none functional due to installation or gas leakage problem. This was due to one of technological parameter mainly operation and maintenance gap such as the gas loosing parts (main gas get valve or tap, due to rust of water drain, hose fitting , pipe fitting).Figure 4.4, typical Examples of among none functional biogas gas losing part in both HTZ and BS woredas.

Main get valve leaking problem ***Water drain problem*** ***Spar part problem*** ***Heat Couse fittingproblem***

Figure 4.4: Gas losing part during field visit in HTZ and BS woredas (Source: field survey of 2018)

4.6.3 Types and volume of Digester

All Types of biogas digester in study area were fixed dome SNIDU model. The digesters were varying only in volume and the volumes were 6 and 8m^3 . General layout and different sizes of commonly adapted SINDU model digesters in Ethiopia are presented as follows in Figure 4.2 and Table 4.13

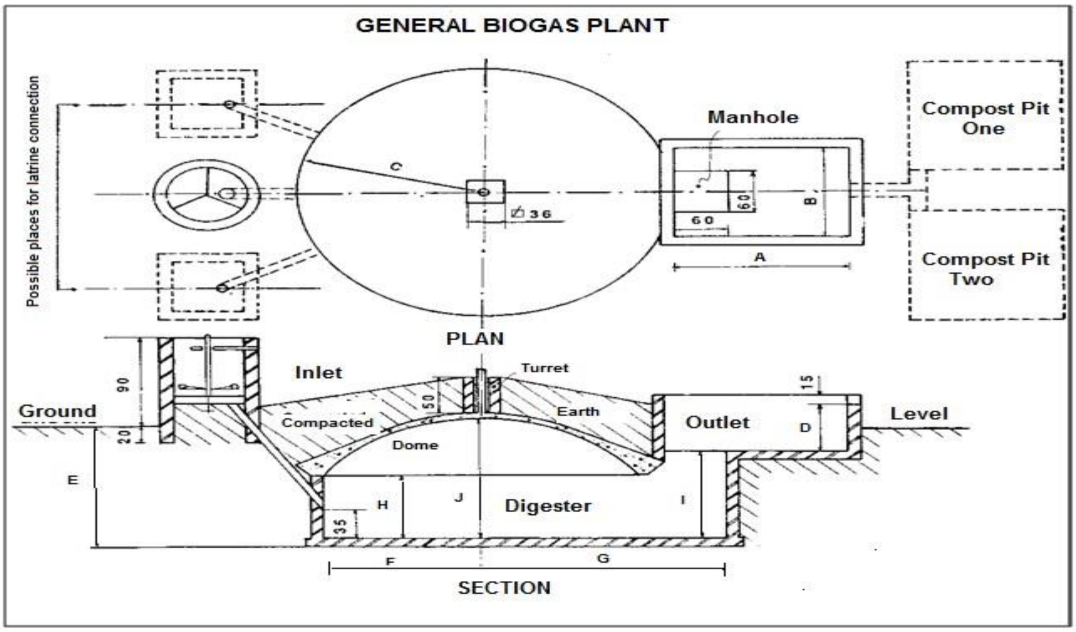


Figure 4.5General layout of SINDU model biogas digester

Table 4.13Sizes of Biogas digesters plant in cm

Size	6m^3	8m^3	10m^3
A	150	170	180
B	120	130	125
C	151	170	183
D	60	65	68
E	155	172	168
F	122	135	154
G	208	221	240
H	92	105	94
I	116	127	124
J	160	175	171

(Source: Eshete, (2006),SNV & EREDPC (2008)

All household Biogas plants in study area were constructed by SNV in collaboration with National Biogas Programme (NBP) .Figure 4.2 typical examples of effective biogas digesters benefits identified during the survey. Which constructed in 2013, in HTZ and BS woreda.The size of the digester is 8 and 6m3 respectively and its biogas was used for lighting and cooking a daily meal of family size 10 and 8.

Figure 4.5 : Biogas digester benefits identified during the survey constructed in 2013 in HTZ and Boloso Sore woredas (Source: field survey of 2018)

1.1.1. Mixing Practice and Loading Rate

It was seen that on the sampled biogas operation was taking place through manual systems in all of the digester plants. It was done using hand or a branch of wood as shown blow in Figures 4.5. In addition, half of the operators were mixing manure and water through experience rather than using balanced amounts. This show technological gap due to the awareness and operational training after construction which, also affects the effectiveness of the plant . The researcher also observed that 9 biogas users were filling the digester with manure 3 - 4 days in week and the rest were filling day to day The following figures were captured during the visit of Hadero andXadisakebele in study areas.

Figure 4.6: Mixing Practice in both HT and BS woreda sites. (Source sample observation 2018)

4.7 Discussion about interview

4.7.1 Interview discussion with regarding to effectiveness of existing household biogas

The effectiveness of biogas plant directly depends on the quality of construction work**,** materials used for construction and quality control as well assupervision during and after construction work. Therefore, there should be a plan for continuous assessment or structure for controlling biodigester plants. The following are some of the observations and information found during an interview.

- ❖ It was said that an aerobic conditions of same fixed dome biogas plant was affected by less quality of inputs of construction materials, because during construction of bio gas plants cement gruel ratio was not maintained which recessed by cracks. Furthermore, it was pointed out that some mason's workers have no educate skill technical parts of biogas plant particularly dome part and installation of gas pipes part of the plant. This imply that it is one of the problem that affect effectiveness and adoption rate of household biogas.
- ❖ The number of livestock in study area was low the reason provided for this was limited plot of land for cattle rearing that decreased the quantity of biogas plant and then the efficiency of biogas plant.
- ❖ The respective woredas' biogas construction quality management was constrained by lack of budget forwoeda experts that challenged the supervision of existing biogas plant and quality of control of potential biogas plant
- ❖ Most of the biogas technology adopters mixed water to manure ratio as they told to do so instead they mixed as they need.

4.7.2 Interview discussion with regard to adoption rate of biogas plant

- ❖ Financial source for the construction of biogas plant was government and farmers with better economic positions but farmer with relatively low and medium income challenged by financial source to construct biogas plant. Thus, the adoption rate of biogas technology by the limitation of financial source.
- ❖ It was pointed out that that training on biogas energy technology was not given in study area because budget was not allocated appropriately so as to arrange training programme on respective technology which was constrained adoption rate of biogas technology.

- It was said that the distance from home to water source was moderately affecting factors of biogas adoption rate.
- The responses of interview also showed that community's attitude towards biogas technology was diverted by their limited commitment for the implementation and non –functionality of existing biogas plant .Therefore , the attitudes of community was one of limiting factors that obstacles the adoption rate of biogas technology.
- Feeding quality of biogas plant was the major determinant factor that demands technological skill as the result farmers were not able to control feeding quality of biogas plant. This item was analysed in the parts of laboratory analysis of this study.

4.7.3 Interview analysis with regard to technological gap of community on biogas technology.

- With regard to durability of biogas plant its stockholders told that biogas plant was stayed from 10 to 15years but national standard set in Ethiopia was about 25 years .This implied that the structural durability of existing biogas plant was not live long that emanate from low quality of construction materials, skill of masonry, lack of good supervision due to assigned experts for biogas technology construction supervisors were not specialized on biogas energy technology so that they were not appropriately control construction and operation of biogas plant. This showed that there was technological gap that exposed the biogas plant for cracks and damage.
- It was pointed out that that any methods of experience sharing among biogas adopter and training were not given in study area because respective woredas government budget was not allocated appropriately so as to arrange training programme on respective technology which was constrained adoption rate of biogas technology. This implied that there were not attempts made to fill technological gap through experience sharing and to increase dissemination rate.
- The major technological gap told was for operation and maintenance the accessibility of spare parts of biogas plant because if the biogas plant damaged spare parts were not accessed easily and that affect effectiveness of biogas plant and that was, witnessed by observation biogas plants, which stop functioning or were, not operated because of lack of repairing materials and lack of skilled management to ensure continual functioning . This points out that the methods of operation and maintenance was the significant technological gap of the study area.
- All of biogas digester in study area were fixed dome SNIDU model. The construction materials used for all of them were cement, sand, gravel and stone. The interviewees agree that the fixed dome SNIDU model digester is a good design and functionality as long as the gas leaks are comparatively low. Unfortunately, it is often difficult to repair and maintain. This imply that adoptability of the design in the study area geographical context relatively good. Therefore, this is not major technological gap in study area.

CHAPTER FIVE

5 Conclusion and Recommendation

5.1 Conclusion

The main objective of this study was to assessing the effectiveness, the technological gap and adoption rate of biogas plant in HT and BS woredas. Hence, conclusions were made based on main findings obtained through measurements, interview and questionnaires, laboratory measurements and observation.

Attempts made by stockholders to practice biogas technology was better in terms of providing construction materials, feeding quality (C/N,PH) and facilitating conditions for construction materials but the effectiveness of biogas plant was constrained by construction quality, lack of skilled person who can manage the operation and maintenance activity, limited number of live stocks and low plot of land to rear cattle was affected feeding quantity of biogas plant which in turn affect its effectiveness, adopters status of economy positively affects particularly when bio digest or feeding quantity decreased they immediately adjust the quantity by increasing the number of livestock and their feeding to increase the volume of dung and then the plants volume otherwise it affect negatively the efficiency of biogas plant by decreasing quantity of biogas feeding and health problem of biogas adopters disturbs the efficient management of biogas plant and then the efficiency of biogas plant.

- In study area biogas technology was easily adoptable with minimum knowledge of the adopters and the environmental condition particularly, temperature of the study area was highly suitable for biogas production but the adoption rate of biogas technology was affected by the adequacy of financial source ,the quantity of feeding affect the adoption rate of biogas plant by providing tangible evidence that drought decreased the amount of dung produced and the biogas plant stop the functioning so that the new adopters fear to construct the biogas plant, the attitude of some people in respective community, disseminators skill, the interest level of the community, the functionality level of biogas plant, the effects of awareness creation program, the number of family size and availability of alternative energy source.
- Communities of the study area and other stock holders tried their best in order to practice biogas technology but its effectiveness and adoption rate was constrained by

technological gap such as, the structural durability of existing biogas, limited supervision of responsible body during construction and it was told that limited skilled human resource, the biogas construction was not timely controlled so that their low durability after construction was common problem, the methods of operation and maintenance was the significant and construction site was not appropriate because the digester was constructed far away from the home which leads to extra expenses and exposed to gas leakage and due to unwise site selection structures on low bearing soil capacity were sinking.

5.2 Recommendation

In this particular section suggestions were forwarded on the deviations addressed through the research study.

- ❖ To improve the effectiveness of biogas plant, its construction quality should be controlled by following up construction materials quality , hiring skilled person who can manage the operation and maintenance activity, maximize volume of dung from little number of through increased food for live stocks and planting modern grass on low plot of land to feed cattle , providing financial support for adopters to improve status of economy which positively affects particularly when bio digest or feeding quantity decreased they immediately adjust the quantity.

- ❖ In order to foster adoption rate of biogas technology, woredes energy office should support by supplying financial source because the cost of construction and maintenance of bio gas plant demands high financial source, the quantity of feeding increased by coping up with the change situation because the adoption rate of biogas plant affected seasonally by providing tangible evidence that drought decreased the amount of dung produced and the biogas plant stop the functioning so that the new adopters fear to construct the biogas plant, to shape attitude of some people in respective community training regularly adopters and non-adopters is better, disseminators skill also need to developed through training, the interest level of the community should be shaped by improving the functionality of biogas plant , it is better if the awareness creation program on biogas technology organized and applying biogas technology as the supplement with other availability alternative energy source.

- Communities of the study area and other stock holders should try their best in order to improve efficiency and adoption rate was by filling technological gaps such as the structural durability of existing biogas, consistent supervision of responsible body during construction and employing skilled human resource, the biogas construction timely controlled so that their low durability after construction and construction site should be appropriate to avoid extra expenses and gas leakage and due to unwise site selection structures on low bearing soil capacity were sinking.

- During field visit the researcher observed that majority of household biogas yields have not enough for cook and light consumption of the adopters. Therefore, the revision of Ethiopian biogas police is necessary. The researcher advice that biogas technology mixing with solar PV is one of alternative solution that means biogas for only cooking purpose and solar PV for lighting and charging purposes and further research necessary in this idea .

- All bio digester operators were mixing manure and water manually either by hand or a piece of wood, hence any interested researcher can develop a mechanism for mixing manure and water.

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Appendix -1Questionnaire

Addis Ababa University

Addis Ababa Institute of technology

Centre of Energy Technology

Questionnaire for adopters

Dear respondents

The purpose of these questionnaires is to prepare thesis for the partial fulfilment of the requirement for the degree of Master of Science in Energy technology. This study is purely an academic purpose and the responses given by you will be kept secretly so that in no way it can affect the respondents personally or their organization security. Therefore , you are kindly requested to extend your cooperation honestly by providing your genuine view ,frank opinion and timely response which are very valuable in determining the success of the study .

Thank you in advance for your cooperation.

1. **Personal information of the respondents**

Sex	Male --------	Female -----		
Marital status	Married ----	Single -----	Separated/Divorced	Widow/widower
Age	18-25 -----	26-40 -----	40-60-----	Above 60
Educational Level	Not read and write	1-5	5-10/12	Above 10/12
Occupation	Farming -----	Daily labour--	Merchant ----	Government employed -----
Farming Activity	Cash Crops -----	Food Crops ----	Livestock ------	Mixed -----

2. Questions with respect to research study.

Instruction

Please use tick mark () for the close ended question and write short and precise answer on the space provided for open ended question.

1. Items related with effectiveness of existing household biogas in study area.

No	Variables	F & %	The most influencing factor = VH The least influencing factor =VL					
			VH	H	M	L	VL	Total
1	Constriction quality of biogas digester for anaerobic condition							
2	Installation quality of biogas plant							
3	Feeding quantity							
4	Economic status of adopters							
6	Health status of adopters							
7	Environmental conditions							
8	Education level of adopters							

Please forward any efficiency factors of household biogas in your biogas____

____

2. Items related with stokeholds technological gap in household biogas in study area

No	Variables	F & %	Very high gap =VH Very low gap = VL					
			VH	H	M	L	VL	Total
1	Structural durability							
2	Method of construction supervision							
3	Time and effort in quality control							
4	Methods of operation and maintenance							
5	Adoptability of design							
6	Sharing of experience to fill technical gap							

Please forward any stokeholds 'biogas technological gaps ------------------------------------
----

----

3. Items related to Reasons to Invest on Biogas Technology in BS and HT woredas

No	**Variables**	**F & %**	Very high motivating factor= VH Very low motivating factor =VL					Mean	SD	Rank
			VH	H	M	L	VL			
1	Economic benefit									
2	Governmental subsidy for plant									
3	Reducing health risk									
4	Fast and more convenient cooking stove									
5	Bright biogas light									
6	Better quality bio-slurry for fertilizer									
7	Non-availability of other fuel sources									
8	Saving time and Reducing work load									

4.Items related to Reasons for not adopting the biogas technology in case of both woredas

No	Variables	F & %	Very high factor for non-adopting= VH Very low factor for non-adopting=VL					Mean	SD
			VH	H	M	L	VL		
1	Adequacy of fund								
2	Feeding quantity								
3	Community's attitude towards biogas energy								
4	Interest level of community								
5	Functionality of biogas existed plant								
6	Suitability of climatic condition								
7	Family size								
8	Availability of alternative Energy source								

Briefly explain your level of ratings above---

Appendix -2 Observation check list

II. What are the existing conditions of biogas system

No	System component	Existing condition			
		Very good	good	bad	Not exist
1	Inlet + mixer				
2	Outlet+ compensation chamber				
3	dome				
4	Water drain				
5	Pressure gauge				
6	Gas pipe(diameter)				
7	Main gas valve				
8	Hose pipe				
9	Stoves/bulbs/appliances				

2. What are types and volume of biogas digester?

3. Anaerobic condition biogas digester

4. Observe operation and maintenance practice and problem

5. Cause of none functionality of biogas plant

Appendix -3 Interview for Stock Holders

Addis Ababa University

Addis Ababa Institute of technology

Center of Energy Technology

Interview for woredas Water, Mine & Energy department

Dear Respondents,

The main purpose of this interview is to acquire information relevant for a research entitled "evaluate the efficiencies and adoption rate of household biogas technologies and assessing the technological gaps". The research outcome is expected to be helpful for the improvement of biogas dissemination programme and other energy and environment related interventions. Therefore, your genuine answer to the interview questionnaire is a necessary condition for the reliability of this research outputs. The information is meant only for academic purpose. The responses you give will not have a negative impact on anybody. I honestly assure you that your personal information will be kept confidentially. Hence, just feel free to provide the correct answer.

Thank you for your responsible cooperation in advance.

*Woreda*___________________

Kebele/ ________________

got ________________________

Interviewer's Name ______________________

Interviewee name ______________________

Date of interview______________________

Interview starting time ___________

1. **Interview question with regard to efficiency of existing household biogas plant**

a. What is types of material used for the construction of bio digester?

b. Do masonry workers have skill?

c. What is number of livestock condition?

d. How do you control quality of biogas construction?

e. Do you think adopters mixing practise was appropriate?

2. Interview question with regard to adoption rate of biogas plant

a. what is financial source for the construction?

b. Do you have training program on biogas energy technology?

c. Dose distance from home to water source mater for efficiency of biogas?

d. what about communities' attitude to words biogas technology?

e. How do you measure feeding quality?

3. Interview question with regard to technological gap of community on biogas technology

a. Do you have biogas plants long life?

b. Is there experience to follow up and control construction and operation of biogas plant?

c. Do you have any mechanisms of experience sharing among biogas adopters? How often?

d. To what extent your adopters accessed spar parts of biogas plant.

e. what is the major causes of non-functionality of biogas plant?

Appendix 4. Daily data sheet and field measured raw data tables

Table A. Daily Data Sheet

Date ……………….

code	Name	pH			Temperature(^{0}C)			
		Water pH	Effluent pH	Slurry pH	Ambient Temp	Effluent Temp	Slurry Temp	

Table B. Field measured data of Water, Effluent and Slurry temperature of HT aad BS Woredas

N.B. Code representation

For example: H3170 and B3949

3170 **- Represents sample biogas cod**

H - Represents HaderoTunto Zuriaa woreda

B- Represents Boloso sore woreda

Sample coder	Ambient temperature				Effluent temperature				Slurry temperature			
	1st day	2nd day	3rd day	Ave	1st day	2nd day	3rd day	Ave	1st day	2nd day	3rd day	Ave
H3170	28.1	27.5	26.8	27.46667	26.5	25.4	25.8	25.9	26.1	24.8	25.3	25.4
H3173	26.1	27.8	24.9	26.26667	24.5	25.7	22.9	24.36667	24	25.2	22.1	23.76667
HYH02	28	31.5	29.3	29.6	26.2	29.5	27.2	27.63333	25.5	26.7	26.6	26.26667
H2304	25	28.5	26.4	26.63333	23.2	26.1	24.5	24.6	22.8	25.7	25.1	24.53333
H3086	26	24.7	28.1	26.26667	24.1	23.1	26.3	24.5	23.7	21.7	25.8	23.73333
H3079	28.7	26.8	23.5	26.33333	26.2	24.1	21.6	23.96667	35.8	23.8	21.1	26.9
H3082	29.6	29.1	28.9	29.2	27.3	27.1	25.9	26.76667	25.9	25.6	23.8	25.1
H1138	32.2	28.3	26.5	29	29.6	27.3	24.8	27.23333	27.3	24.5	23.7	25.16667
H2305	28.2	28.5	25.5	27.4	25.9	26.7	23.3	25.3	23.9	26.1	22.6	24.2
H3168	32.8	29.7	30.1	30.86667	28.3	27.3	28.3	27.96667	27.4	26.5	27.5	27.13333
H3083	29.5	28.7	28.5	28.9	27.8	26.3	25.9	26.66667	25.6	24.9	24.1	24.86667
HAA01	24.7	25.3	26.3	25.43333	22.8	21.3	23.8	22.63333	21.6	20.5	23.6	21.9
H2276	25.7	26.6	26.9	26.4	23.5	24.5	22.7	23.56667	21.4	23.2	21.8	22.13333
H1140	27.4	28.5	27.4	27.76667	23.6	25.3	24.9	24.6	22.6	23.8	23.5	23.3
H2278	24.4	26.3	23.9	24.86667	24	25.7	22.5	24.06667	23.5	25.24	21.4	23.38
H2308	27.5	25.2	27.1	26.6	26.8	24.5	26.3	25.86667	25.6	23.9	25.1	24.86667
H3090	26.5	23.8	29.5	26.6	25.8	23.1	28.6	25.83333	24	22.4	27.5	24.63333
H2288	27.6	24.3	28.4	26.76667	26.1	23.7	27.8	25.86667	24.9	23.2	25.8	24.63333
H2305	23.9	24.5	26.3	24.9	22.5	23.9	25.3	23.9	21.4	23.5	24.1	23
H1141	21.5	24.3	23.8	23.2	20.7	23.1	22.9	22.23333	20.2	22.1	21.9	21.4
B3949	33.1	26.7	27.8	29.2	28.9	25.1	25.3	26.43333	28.1	24.5	24.7	25.76667
B2029	26.1	26.1	28.2	26.8	24.7	24.8	26.3	25.26667	24.2	24.1	25.2	24.5
B2103	27.2	29.4	28	28.2	26.5	27.6	26.8	26.96667	25.9	27.1	26.3	26.43333
BAH02	33.3	25.7	27.6	28.86667	29.8	23.6	25.9	26.43333	29.2	23	25.1	25.76667
B3941	26.8	28.3	28.8	27.96667	25.3	27.5	26.3	26.36667	24.7	27.1	25.4	25.73333
B2068	29.7	29.1	27.5	28.76667	29.2	27.2	24.9	27.1	28.4	26.5	24.2	26.36667
B0440	26.7	28.4	29	28.03333	24.3	27.5	27.3	26.36667	23.7	26.9	26.7	25.76667
B0434	26.1	33.1	30.05	29.75	26	29.2	28.8	28	25.4	28.5	28.3	27.4
B0442	29.4	26.1	27.7	27.73333	27.6	24.7	25.3	25.86667	27	24.1	24.5	25.2
B2083	25.7	27.2	28.4	27.1	24.7	25.4	26.2	25.43333	24.1	25	25.8	24.96667
BGO10	28.3	33.3	29.5	30.36667	27.6	30.6	27.5	28.56667	26.2	29.8	27.1	27.7
BAM11	29.1	26.8	27.6	27.83333	29.1	26.8	26.4	27.43333	28.5	26.2	26.1	26.93333
BAL12	28.4	29.7	27.7	28.6	26.9	26.5	24.5	25.96667	26.6	26.2	24.1	25.63333
BT/WD13	30.2	26.7	27.3	28.06667	28.7	25.6	26.2	26.83333	27.9	26.2	25.7	26.6
BEB14	31.4	26.1	27.6	28.36667	29.3	25.7	26.8	27.26667	28.6	25.2	25.3	26.36667
BAG15	28.6	29.4	28.9	28.96667	27.5	28.5	28.2	28.06667	26.5	27.5	27.5	27.16667
BTZ16	27.5	25.7	27.8	27	26.8	25.1	26.9	26.26667	25.1	24	25.6	24.9
BTD17	28.9	28.3	26.3	27.83333	27.8	27.2	25.1	26.7	27.3	26.7	24.5	26.16667
B3949	29.1	29.1	29.8	29.33333	28.4	28.3	28.3	28.33333	27.9	27.3	27.5	27.56667
B2029	29.3	28.5	27.3	28.36667	28.2	28	26.5	27.56667	27.6	27.6	25.8	27

Table C. Field measured data of Water, Effluent and Slurry pH (power of hydrogen) of HT and Boloso Sore woredas.

Sample coder	Water pH				EffluentpH				SlurrypH			
	1st day	2nd day	3rd day	Ave	1st day	2nd day	3rd day	Ave	1st day	2nd day	3rd day	Ave
H3170	8.2	8.01	7.81	8.006667	7.9	8.2	8.6	8.233333	7.1	7.2	7.3	7.2
H3173	7.39	7.02	7.28	7.23	7.9	7.82	8.5	8.073333	7.15	7.16	7.2	7.17
HYH02	5.82	6.02	6.11	5.983333	6.2	6.1	6.5	6.266667	7.07	7.02	7.3	7.13
H2304	7.25	7.82	7.05	7.373333	7.25	7.23	7.2	7.226667	7.1	7.12	7.16	7.126667
H3086	7.6	7.68	7.71	7.663333	7.6	7.2	7.9	7.566667	7.12	7.16	7.9	7.393333
H3079	7.04	6.82	7.08	6.98	7.15	7.23	7.29	7.223333	7.6	7.2	7.6	7.466667
H3082	7.34	7.68	7.7	7.573333	7	7.2	7.1	7.1	7.14	7.15	7.2	7.163333
H1138	8.42	8.25	8.39	8.353333	8.1	8.6	8.7	8.466667	7.25	7.29	7.9	7.48
H2305	6.77	7.02	7.35	7.046667	7.12	7.6	7.8	7.506667	7.6	7.62	7.2	7.473333
H3168	8.08	7.75	7.8	7.876667	7.65	7.2	7.28	7.376667	7.02	7.07	7.04	7.043333
H3083	7.3	7.6	7.6	7.5	7.25	7.02	7.6	7.29	7.25	7.23	7.62	7.366667
HAA01	7.85	7.67	7.7	7.74	6.99	7.25	7.6	7.28	7.25	7.62	7.5	7.456667
H2276	7.2	7.01	6.9	7.036667	7.9	8.05	8.22	8.056667	7.25	7.2	7.26	7.236667
H1140	7.72	7.94	7	7.553333	7.8	7.1	7	7.3	7.66	7.23	7.6	7.496667
H2278	8.12	8.01	7.98	8.036667	7.13	7.15	7.16	7.146667	7.81	7.5	7.1	7.47
H2308	7.2	7.5	7.52	7.406667	7	6.92	6.7	6.873333	7.25	7.26	7.19	7.233333
H3090	8.25	8.05	8.2	8.166667	8.1	7.1	7.2	7.466667	7.9	7.7	7.1	7.566667
H2288	6.5	6.2	6.8	6.5	6.7	6.2	6.9	6.6	6.25	7.25	7.22	6.906667
H2305	6.77	7.02	7.35	7.046667	7.12	7.6	7.8	7.506667	7.6	7.62	7.2	7.473333
H1141	6.58	6.68	6.42	6.56	7.2	7.15	7.26	7.203333	7.8	7.9	7.6	7.766667
B3949	5.9	6.2	5.89	5.996667	8.12	8.25	8.02	8.13	7.43	8.2	7.9	7.843333
B2029	7.07	7.09	7.72	7.293333	7.8	7.3	7.98	7.693333	8.53	8.4	8.47	8.466667
B2103	6.6	6.8	7.1	6.833333	7.08	7.45	7.25	7.26	7.7	8.03	8.35	8.026667
BAH02	5.75	6.9	6.02	6.223333	7.32	7.25	7.8	7.456667	7.68	7.96	7.57	7.736667
B3941	6.5	6.7	6.2	6.466667	7.58	7.89	7.67	7.713333	7.37	7.25	7.82	7.48
B2068	6.85	7.2	6.5	6.85	8.33	8.6	8.04	8.323333	8.7	7.98	8.2	8.293333
B0440	6.61	6.25	6.5	6.453333	8.71	8.3	8.25	8.42	8.7	8.3	7.8	8.266667
B0434	6.39	6.8	7.1	6.763333	7.41	7.54	7.38	7.443333	8.08	8.23	8.13	8.146667
B0442	7.2	7.8	8.1	7.7	7.89	7.59	7.78	7.753333	7.99	8.04	8.08	8.036667
B2083	6.37	6.5	6.52	6.463333	7.67	7.76	7.98	7.803333	8.02	8.26	8.23	8.17
BGO10	6.6	6.2	6.57	6.456667	7.2	7.34	7.81	7.45	7.9	8.45	8.28	8.21
BAM11	5.75	5.34	5.2	5.43	7.8	7.5	7.84	7.713333	8.2	8.29	8.19	8.226667
BAL12	6.5	6.2	6.1	6.266667	8.5	8.6	8.82	8.64	8.12	8.25	8.07	8.146667
BT/WD13	6.85	6.25	6.4	6.5	7.6	7.9	7.89	7.796667	8.5	8.57	8.23	8.433333
BEB14	6.61	6.03	6.7	6.446667	7.2	7.65	7.82	7.556667	8.3	7.34	7.98	7.873333
BAG15	6.23	6.2	6.1	6.176667	7.9	8.02	8.5	8.14	7.7	7.95	7.89	7.846667
BTZ16	7.89	7.67	7.87	7.81	8.04	8.09	8.34	8.156667	7.9	7.89	8.08	7.956667
BTD17	7.5	7.8	7.8	7.7	7.8	8.6	8.07	8.156667	7.54	7.29	7.17	7.333333
BTA18	6.5	6.78	6.56	6.613333	7.5	8.07	7.98	7.85	7.58	7.24	7.62	7.48
BDD19	5.8	5.9	5.55	5.75	8.25	8.08	8.17	8.166667	8.75	8.4	8.05	8.4

Appendix 5. Laboratory results

Table A. Laboratory results of Moisture and Total solid content

Moisture and Total Solid Content						
Code	Tin wt(g)	Tin +sample wt Before drying	Tin +sample wtafterdrying	% moisture	Total solid value (% by wt)	% Total solid value after mixing with water (%kg)
H3173	34	39	35.1	78	22	14.2
HYH02	36	41	37.5	70	30	9.8
H2304	37	42	38.3	74	26	12.8
H3086	47	52	48.1	78	22	19.8
H3079	42	47	43.3	74	26	13.6
H3082	48	53	48.5	90	10	9.3
H1138	37	42	38	80	20	18.56
H2305	35	40	35.4	92	8	13.98
H3168	42	47	42.7	86	14	15.07
H3083	42	47	43.7	66	34	14.05
HAA01	35	40	35.7	86	14	9.6
H2276	34	39	35.2	76	24	8.9
H1140	36	41	37.4	72	28	21.3
H2278	37	42	38.4	72	28	22.3
H2308	47	52	48.2	76	24	9.4
H3090	42	47	43.2	76	24	17.5
H2288	42	47	43.1	78	22	11.5
H2305	48	53	48.4	92	8	6.3
H1141	37	42	38.1	78	22	10.9
H3173	35	40	35.5	90	10	6.7
B3949	47	52	48	80	20	7.4
B2029	34	39	35.6	68	32	17.6
B2103	40	45	41.5	70	30	19.2
BAH02	37	42	38.4	72	28	21.3
B3941	50	55	50.4	92	8	22.5
B2068	34	39	35.7	66	34	23.1
B0440	45	50	46.2	76	24	21.2
B0434	37	42	37.9	82	18	9.8

B0442	36	41	36.8	84	16	9.2
B2083	35	40	35.9	82	18	19.8
BGO10	40	45	41.1	78	22	11.7
BAM11	37	42	38.7	66	34	23.1
BAL12	50	55	50.9	82	18	9.5
BT/WD13	34	39	35.2	76	24	10.4
BEB14	45	50	46.1	78	22	12.1
BAG15	47	52	48.2	76	24	12.3
BTZ16	34	39	35.2	76	24	12.5
BTD17	36	41	36.9	82	18	9.5
BTA18	35	40	36.3	74	26	13.4
BDD19	40	45	41.3	74	26	13.8

Table B. Laboratory result of Organic carbon

Organic Carbon								
S.Code	V.blank	V.sample	Wt.ofsamle	NFeso4	Corection factor	%miosture	mcf	%O C
H3170	20	8	0.25	0.5	0.39	78	1.78	16.64416
H3173	20	10.5	0.25	0.5	0.39	75	1.75	12.95455
HYH02	20	11	0.25	0.5	0.39	74	1.74	12.2026
H2304	20	12.5	0.25	0.5	0.39	78	1.78	10.4026
H3086	20	12	0.25	0.5	0.39	76	1.76	10.97143
H3079	20	11.4	0.25	0.5	0.39	73	1.73	11.59325
H3082	20	9.8	0.25	0.5	0.39	79	1.79	14.22701
H1138	20	8.8	0.25	0.5	0.39	75	1.75	15.27273
H2305	20	9	0.25	0.5	0.39	72	1.72	14.74286
H3168	20	11.5	0.25	0.5	0.39	78	1.78	11.78961
H3083	20	9.5	0.25	0.5	0.39	72	1.72	14.07273
HAA01	20	11.5	0.25	0.5	0.39	76	1.76	11.65714
H2276	20	9.1	0.25	0.5	0.39	78	1.78	15.11844
H1140	20	12.6	0.25	0.5	0.39	75	1.75	10.09091
H2278	20	10.2	0.25	0.5	0.39	73	1.73	13.21091
H2308	20	8.5	0.25	0.5	0.39	74	1.74	15.59221
H3090	20	9	0.25	0.5	0.39	76	1.76	15.08571
H2288	20	9.2	0.25	0.5	0.39	79	1.79	15.0639
H2305	20	8.2	0.25	0.5	0.39	78	1.78	16.36675
B3949	20	12.5	0.25	0.5	0.39	75	1.75	10.2375
B2029	20	9.5	0.25	0.5	0.39	73	1.73	14.1687
B2103	20	8.3	0.25	0.5	0.39	78	1.78	16.24428
BAH02	20	8.7	0.25	0.5	0.39	81	1.81	15.95334
B3941	20	8.9	0.25	0.5	0.39	83	1.83	15.84414
B2068	20	8.4	0.25	0.5	0.39	82.1	1.821	16.47641
B0440	20	11.1	0.25	0.5	0.39	78.3	1.783	12.37759
B0434	20	11.3	0.25	0.5	0.39	78.4	1.784	12.10622
B0442	20	12.2	0.25	0.5	0.39	76.5	1.765	10.73826
B2083	20	10	0.25	0.5	0.39	76.4	1.764	13.7592
BGO10	20	11.5	0.25	0.5	0.39	75.5	1.755	11.63565
BAM11	20	12.3	0.25	0.5	0.39	72.1	1.721	10.33633
BAL12	20	10.5	0.25	0.5	0.39	81.5	1.815	13.44915
BT/WD13	20	10.8	0.25	0.5	0.39	81.4	1.814	13.01726
BEB14	20	11.5	0.25	0.5	0.39	78.5	1.785	11.83455
BAG15	20	11.5	0.25	0.5	0.39	78.5	1.785	11.83455
BTZ16	20	12.4	0.25	0.5	0.39	76.4	1.764	10.45699
BTD17	20	13.2	0.25	0.5	0.39	75.9	1.759	9.329736
BTA18	20	12.5	0.25	0.5	0.39	78.5	1.785	10.44225
BDD19	20	12.5	0.25	0.5	0.39	75.3	1.753	10.25505

Table C. Laboratory results of Total Nitrogen

Total Nitrogen							
S.Code	V.blank	V.sample	Wt.ofsamle	N H2SO4	%miosture	mcf	TN
H3170	0.28	2.79	1	0.1	80	1.8	0.63252
H3173	0.28	2.89	1	0.1	80.6	1.806	0.659912
HYH02	0.28	2.78	1	0.1	83.7	1.837	0.64295
H2304	0.28	2.57	1	0.1	81.5	1.815	0.581889
H3086	0.28	2.47	1	0.1	85.7	1.857	0.569356
H3079	0.28	2.64	1	0.1	80.6	1.806	0.596702
H3082	0.28	2.71	1	0.1	78.2	1.782	0.606236
H1138	0.28	2.58	1	0.1	80.6	1.806	0.581532
H2305	0.28	2.47	1	0.1	77.9	1.779	0.545441
H3168	0.28	2.42	1	0.1	78.3	1.783	0.534187
H3083	0.28	2.54	1	0.1	80.3	1.803	0.570469
HAA01	0.28	2.73	1	0.1	81.3	1.813	0.621859
H2276	0.28	2.56	1	0.1	81.5	1.815	0.579348
H1140	0.28	2.43	1	0.1	80.2	1.802	0.542402
H2278	0.28	2.38	1	0.1	78.8	1.788	0.525672
H2308	0.28	2.25	1	0.1	76.2	1.762	0.48596
H3090	0.28	2.78	1	0.1	82.6	1.826	0.6391
H2288	0.28	1.98	1	0.1	79	1.79	0.42602
H2305	0.28	2.29	1	0.1	78.2	1.782	0.501455
H1141	0.28	2.25	1	0.1	79.1	1.791	0.493958
B3949	0.28	2.69	1	0.1	78.2	1.782	0.601247
B2029	0.28	2.53	1	0.1	76.8	1.768	0.55692
B2103	0.28	2.76	1	0.1	80.5	1.805	0.626696
BAH02	0.28	2.97	1	0.1	77.9	1.779	0.669971
B3941	0.28	2.77	1	0.1	78.3	1.783	0.621554
B2068	0.28	2.82	1	0.1	80.3	1.803	0.641147
B0440	0.28	2.41	1	0.1	81.3	1.813	0.540637
B0434	0.28	2.63	1	0.1	81.5	1.815	0.597135
B0442	0.28	2.32	1	0.1	80.2	1.802	0.514651
B2083	0.28	2.32	1	0.1	78.8	1.788	0.510653
BGO10	0.28	2.47	1	0.1	76.2	1.762	0.540229
BAM11	0.28	2.73	1	0.1	82.6	1.826	0.626318
BAL12	0.28	2.34	1	0.1	79	1.79	0.516236
BT/WD13	0.28	2.93	1	0.1	78.2	1.782	0.661122
BEB14	0.28	2.48	1	0.1	79.1	1.791	0.551628
BAG15	0.28	2.49	1	0.1	28.2	1.282	0.396651
BTZ16	0.28	2.37	1	0.1	76.3	1.763	0.515854
BTD17	0.28	2.95	1	0.1	73	1.73	0.646674
BTA18	0.28	2.73	1	0.1	72	1.72	0.58996
BDD19	0.28	2.71	1	0.1	70.4	1.704	0.579701

Appendix -6 Total Number of Biogas digesters in study area.

Table A**.** Total Number of Biogas digesters in urban and rural sites ofHaderoTunto and Boloso sore

No	Name	code	Adders	Contact phone No	Size (M3)	Year of installation (G.C)
1	TadesseBonjore	SN-1137	Mandoye	0937322519	8	2012
2	TadessaBonjore	SN-2308	>>	0916282513	6	2013
3	AyanoGdebo	SN-2309	>>	0926198658	6	2014
4	TasfayeOkore	2238	>>		6	2014
5	AbrihamLangena	2284	>>	0937738065	8	2014
6	Samuel Sawore	2285	>>	0916409897	6	2014
7	ErmiyasBabore	2286	>>	0948155663	6	2014
8	DesalechKebeda	3080	>>	0965503127	6	2014
9	AlemuKelbore	3087	>>	0928606581	6	2014
10	CharinetAlaro	3092	>>	0927038382	6	2014
11	TefareTadessa		>>	0910149424	6	2014
12	AbirhamAShnigo	2306	>>	-	6	2014
13	SebilawongelCharinet	2287	>>	-	8	2014
14	Zelekewolore	3088	2ndTunto	0916406475	6	2015
15	Demise Shugute	2278	>>	0926083583	6	2014
16	AyelechHanikore	2307	>>	0932493572	6	2014
17	DenekeLimore	2274	>>	0946803173	8	2014
18	DesalegnDebancho	2276	>>	0925525693	8	2016
19	DastaDebancho	2275	>>	0916576085	6	2016
20	WorikeWatero	2288	>>	0929523677	6	2015
21	WondimuSugamo	1138	1stTunto	0912134344	8	2013
22	AdanechLare	2305	Tunto(01)	0917191509	6	2016
23	TseganeshChakebo	2307	>>	0946393036	6	2016
24	DastaHelisabo	3090	>>	0911375330	6	2014
25	BekeleBatiso	3093	>>	0911756694	6	2014
26	Daniel Takiso	2303	Ameleke	0916766649	6	2016
27	TarekegnPawulos	3081	Ajora	0983146659	8	2016
28	TarekeGnUsamo	3089	>>	0925310153	6	2016
29	DastaMisebo	3086	>>	0945403517	6	2016
30	ZelekeDAnamo	3079	>>	0916574284	6	2016
31	EnderiysMandoye	3085	Ajora	0967272221	6	2014
32	AsfewAbriham	3091	>>	0916573731	6	2014
33	LegesaMendoye	3083	>>	-	6	2014
34	Daniel Meliketo	3082	>>	0916288483	6	2014
35	SimionMoshikare	3084	>>	-	6	2014
36	DAruteJikamo	-	>>	-	6	2014
37	AbebeAboch	1141	Lalo	0913492729	6	2013
38	DeselegnAbebe	1877	>>	0916151141	6	2014
39	AbebeForsido		>>	-	6	2014

40	Haile Hibiso		Homa	0910923161	8	2014
41	AsfewuAnaye	1140	Mugunja	-	6	2013
42	MelesaAnshebo	1139	>>	09262812	6	
43	YohanisChafamo	-	>>	-	6	2016
44	MathewosDusume	-	>>	-	6	2016
45	TesfayeChalo	2312	He’chacho’	0986199426	6	2016
46	DaselegnMasebo	2313	>>	-	6	2016
47	EliyasBeyene	-	>>	-	6	2016
48	YohanisGobiyo	1143	>>	0912006889	6	2016
49	PawulosChafamo	-	>>	0926236000	8	2016
50	DobamoDoboch		>>	0916473250	6	2016
51	TadilaTadessa		>>	0911118553	6	2016
52	AbrihamAyele		>>	0923370595	8	2016
53	MishamoLomibiso		>>	0916275816	8	2016
54	Yosef Beyamo		>>	0910106634	8	2014
55	TumisoDebune	2317		-	6	2016
56	AberaGatebo	2320		0916396045	6	2016
57	MathewosMadebo	2302	Ameleke		6	2016
58	DastaTadessa	2297	>>	0916397415	6	2016
59	Samuel Sikato	2301	>>	0928716636	6	2016
60	TadessaAlore	2298	>>	0916737903	6	2016
61	AbrihamLangena	2299	>>	0916288445	6	2016
62	ZelekeEromo	2300	>>	0967956512	6	2016
63	WonjamoMegiso	2318	>>	-	6	2016
64	YohanisUkanso	2314	>>	0916716367	6	2014
65	SimionGechimo	2311	>>		6	2017
66	MarkosOriso	2316	>>		8	2016
67	Tashomaganamo	2319	>>	0984681036	8	2017
68	Mikael Detebo	2310	>>	0969760519	6	2017
69	TeferaEltamo	2315	>>	0916276279	6	2017
70	MathewosJabeniga	2280	>>		6	2017
71	TamratLimore	2281	>>	0916348021	8	2017
72	DesalegnDigamo	2282	>>	-	6	2017
73	Solomon Wchanigo	-	Hadero 01	0916275967	6	2013
74	Zelekeabebe	-	Hadero 01	0911004114	8	2013

Table B. Total Number of Biogas digesters in urban and rural sites ofand Boloso sore

No	Name	cod	Adders	Size (M3)	Year of installation (G.C)
1	DeresDeselegn		legama	6	2016
2	Gtawungona		>>	6	2016
3	Yohanisdana		>>	6	2016
4	LohaGodena		>>	6	2016
5	Abera Mega		>>	6	2016
6	Tomas Tolika		WoyboJoge	6	2016
7	BekeleBantero		GAragurdo	6	2016
8	TesemaAnjulo		DingaraSelete	6	2016
9	ShondeShalamo		Legama	6	2016
10	PawulosAjebo		>>	6	2016
11	AlitayeAnjulo		>>	6	2016
12	Kufalokusa		>>	6	2016
13	LabenLema		>>	6	2016
14	NigistAbebe		Legama	6	2016
15	Tashomelema		Yukara	6	2016
16	AyelechShalemo		BasaGofara	6	2016
17	DemekechGodebo		Legama	6	2016
18	HiraElibore		Yukara	6	2016
19	MadhinMana		Legama	6	2016
20	ZekaryasGanta		Xaddisa	6	2016
21	TibebuZekariays		>>	6	2016
22	MathewosTora		Yukara	6	2016
23	WorkineMana	2307	>>	8	2014
24	Malamomada	3090	>>	6	2014
25	Bujeboto	3093	>>	6	2014
26	Mogosekusa	2303	>>	6	2014
27	Bernesh G/wold	3081	>>	6	2014
28	Addisulako	3089	>>	6	2015
29	WondimuBorko	3086	>>	6	2015
30	FirewuFilitora	3079	>>	6	2015
31	AsiroAjabo	3085	Woyebajago	6	2015
32	Terso Bade	3091	>>	6	2015
33	AlemayewAsale	3083	>>	6	2015
34	BirhanuShalemo	3082	>>	6	2015
35	Mrhun Dana	3084	>>	6	2015
36	AyeleKoyera	-	>>	6	2015
37	MagazMamo	1141	Yukura	6	2015
38	TegegnJote	1877	>>	6	2015
39	BrgenaBasa		>>	6	2013
40	Demise Takele		>>	6	2013

41	W/Mikael hamso	1140	>>	6	2013
42	LakmoLa'a	1139	>>	6	2013
43	AbrihamQorga	-	>>	6	2013
44	Asalalabso	-	>>	6	2013
45	Gobzesiba	2312	Legama'	6	2013
46	Genet Chorefo	2313	>>	6	2013
47	Masan Mandado	-	>>	6	2013
48	KosuTonja	1143	>>	6	2013
49	Gnetubergena	-	>>	6	2013
50	TemesgenAbirham		>>	6	2013
51	TerekegnTkela		>>	6	2013
52	Wrequwoyiza		>>	6	2013
53	AsratAsale		>>	6	2013
54	KolibayeKoyira		>>	6	2013
55	TamiratGizawu	2317		6	2016
56	Wolideklay	2320		6	2014
57	WazaWadebo	2302	Xaddisa	6	2014
58	Alemayehuulisa	2297	>>	6	2014
59	MilikiyasGebayewu	2301	>>	6	2014
60	TesemaHydebo	2298	>>	6	2014
61	AddisuPeteros	2299	>>	6	2014
62	Fano Mano	2300	>>	6	2014
63	DokiteraBoje	2318	>>	6	2014
64	Mesfien Mena	2314	>>	6	2014
65	Abirham Abate	2311	>>	6	2014
66	W/silas Shale	2316	>>	6	2016
67	AyeleChilo	2319	Xoqissa	6	2016
68	TesfayeGenamo	2310	>>	6	2016
69	Bolitichoano	2315	>>	6	2016
70	T/woldDbana	2280	>>	6	2016
71	ElifineshBergena	2281	>>	6	2016
72	Tizita Dana	2282	>>	6	2016
73	AbrihamAlitaye	-	>>	6	2016
74	Teshalemena	-	>>	6	2016
75	AkeberaAtumo		>>	6	2016
76	AshukuShumago		>>	6	2016
77	AdimasuBogele		>>	6	2016
78	MamoBaza		>>	6	2016
79	EndashewuAlemu		>>	6	2016
80	TrikuBeza		>>	6	2016
81	Tafesa Fanta		>>	6	2016
82	Mengistukoshebo		>>	6	2017
83	Eshetu Asha		>>	6	2014
84	Daniel Bato		>>	6	2014
85	MarkenMasebo		GAragurdo	6	2014

86	Shiferawutura		>>	6	2014
87	TamiretTekela		>>	6	2014
88	DastaSoloro		>>	6	2014
89	AlemayewuAjoro		>>	6	2014
90	TesfayeMatora		>>	6	2014
91	TfariAlembo		>>	6	2015
92	Agbahirigo		>>	6	2015
93	Mdhinmana		>>	6	2015
94	AyeleAwano		>>	6	2015
95	Adisuendiryas		>>	6	2015
96	DamiseDerilo		DingaraSelete		2017
97	Dretosidena		>>		2017
98	Simyetakusa		>>		2017
99	Megegnmegze		>>		2017
100	Daniel Ataro		>>		2017
101	Abayneanitago		>>		2017

Appendix 7. Definition of formulas

1. Formula used to determine Mean value of C/N ratio
2. Mean = M = A.M + $((\Sigma fX^1)/N)i$

Where: M = mean

A.M = assumed mean

Σ = sum of

f = frequency

X^1= deviation of the score from the assumed mean divided by length of the class interval

i = width of class interval

N = total number of score or observation

3. Variance (σ^2) for grouped data

Variance = $\sigma^2 = ((i^2/N^2)*(N\Sigma f (X^1)^2 – (\Sigma fX^1)^2)$

Where: i = width of the class interval

N = total number of scores

f = frequency of the class interval

X^1 = deviation of the raw score from the assumed mean divided by the length of class interval.

4. Standard deviation (σ) for grouped data

Standard deviation = $\sigma = \{((i^2/N^2)*(N\Sigma f(X^1)^2 – (\Sigma fX^1)^2\}^1$

N.B. The symbols are similar to the variance.

0.39 = $3*10^{-3}$*100%*1.3 (3 = equivalent weight of carbon)

mcf = moisture correction factor.

mcf = (100 + % moisture)/100

Let V be the volume of 0.1N H_2SO_4 used after correcting for the blank

N x V = N/g of manure

N x V x 14 = mg of N per g of manure

N x V x 0.014 = g of N per g of manure

% N = ((a – b)/s) x N x 0.014 x 100 x mcf

Where a= ml of H_2SO_4 required for titration of sample

b= ml of H_2SO_4 required for titration of blank

s= air dry sample weight in grams

N = normality of nitrogen in g (0.098)

0.014 = weight of nitrogen in g