HOUSE HOLD LEVEL BIOGAS TECHNOLOGY STATUS AND ITS CONTRIBUTION TO LIVELIHOODS OF LOCAL COMMUNITIES: THE CASE OF BISHOFTU TOWN, EAST SHOA ZONE, OROMIA REGIONAL STATE, ETHIOPIA

MSc. THESIS


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WONDO-GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES

HAWASSA UNIVERSITY WONDO GENET, ETHIOPIA

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A THESIS SUBMITED TO

THE SCHOOL OF NATURAL RESOURCE AND ENVIRONMENTAL STUDIES, HAWASSA UNIVERSITY, WONDO-GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN RENEWABLE ENERGY UTILIZATION AND MANAGEMENT

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APPROVAL SHEET-1

This is to certify that the thesis entitled "Household Level Biogas Technology Status and Its Contribution to Livelihoods of Local Communities": The case of Bishoftu Town, East Shoa Zone; Oromia Regional State, Ethiopia, in partial fulfillment of the requirements for the degree of masters of Science in Renewable Energy Utilization and Management. It is a record of original research carried out by **Teka Fida Meskele** Id. No. MSC/REUM/R0012/09. Under my supervision; and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended it to be accepted as fulfilling the thesis requirements.

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Name of major advisor Signature Date

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Name of post graduate coordinator Signature Date

APPROVAL SHEET-2

We, the undersigned, members of the Board of Examiners of the final open defense by Teka Fida have read and evaluated his thesis entitled "Household Level Biogas Technology Status and Its Contribution to Livelihoods of Local Communities: The case of Bishoftu Town, East Shoa Zone; Oromia Regional State, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Utilization and Management.

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DEDICATION

This part is especially dedicated to my lovely son, Yisak Teka! I wish him all my blessing as he grows up and undertaking into the world of academics! Always I wish that Almighty God can care and bless him.

This thesis manuscript is dedicated to my beloved father, Mr. Fida Meskele, my brothers, Mr. Sisay Fida and Mr. Birehanu Fida, for devoting their time to help me throughout their life.

STATEMENT OF THE CANDIDATE

I hereby declare and affirm that this thesis entitled "Household Level Biogas Technology Status and Its Contribution to Livelihoods of Local Communities: The case of Bishoftu town, East Shoa Zone; Oromia Regional State, Ethiopia" is my own work. Any scholarly matter that is included in the thesis has been given recognition through citation.

This thesis is submitted in partial fulfillment of the requirements for the degree of masters of Science in Renewable Energy Utilization and Management. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Teka Fida_______________________________ ________________________

Name of student Signature Date

LIST OFACRONYMS AND ABBREVIATIONS

ABPP	Africa Biogas Partnership Program
AFREA	Africa Renewable Energy Access
AWMEO	Adea Water, Mine and Energy Office
BSP	Biogas Support Program
CBOs	Community based Organizations
CSA	Central Statistical Agency
EREDPC	Ethiopian Rural Energy Development and Promotion Center
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GHG	Greenhouse gas
GWP	Global Warming Potential
IEA	International Energy Agency
KII	Key Informants Interview
IPCC	Intergovernmental Panel on Climate Change
MoWIE	Ministry of Water, Irrigation and Electricity
ORS	Oromia Regional State
HH	Household
HIVOS	Humanist Institute for Development Cooperation
SNV	Netherlands Development Organization
SSA	Sub-Saharan Africa
THCU	The Health Communication Unit
UN	United Nation
UNEP	United Nation Education Policy

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OPERATIONAL DEFINITIONS

Biogas energy: Biogas energy is one of the renewable energy sources that originated from animal dung through anaerobic digestion process and produces burnable gas_ methane which uses for cooking and lighting purpose.

Fuel wood: Part of a tree or shrub which is ready to be used as fuel.

Household: A group of people, whether with blood relations or not, who live together and share a single meal.

Organization: An entity which has its own specific line of commands with clear accountability, defined members and membership criteria, defined members' responsibilities, rules and regulations to be abided by all members, and clear objectives or goals to be achieved in specified time schedules.

Livelihood: A means of attaining a living through involving assets, capabilities, and activities (Chambers and Conway, 1991).

Old-style biomass fuels: Types of energy sources that are locally available and produced, and require no high level of conversion. They include fuel wood, charcoal, cow dung and crop residues. They may simply be called traditional fuels or biomass fuels.

Technology distribution: A process by which the final version of a technology is multiplied, communicated, evaluated, accepted, and spread through a certain channels over time in a given community. Thus, technology status is part of technology dissemination.

Wood-fuel: Any fuel derived from tree or shrub including firewood and charcoal

ABSTRACT

Household Level Biogas Technology Status and Its Contribution to Livelihoods of Local Communities: The case of Bishoftu Ethiopia.

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Renewable energy like biogas technology is a significant requirement for human life. It deeply contributes to all aspects of human welfare such as cooking food, heat and light; health care and sanitation, education and job creation. In the study area, the community was with severe scarcity of fuelwood and associated problems. In the study area, forestland has been changed to other land uses like urbanization, industrialization, expansion of grazing and cultivation land causing high fuel wood scarcity. The objective of the study was to investigate the contribution of biogas technology in saving fuel wood and reducing deforestation in Bishoftu town, Ethiopia. Multi-stage sampling procedure was employed to select sample households. A total of 133 sample households (37 users and 96 non-users) were involved in the household survey. The major domestic energy sources for consumption were fuel wood, dung cake and charcoal accounting 4533.90kg, 4060kg and 1143.5kg per week in the study area, respectively. The results of the study showed that each household can save 11.88 kg of fire wood per day and 4348.08 kg per year. Out of the 59 regular functioning biogas digesters 256,536.72kg of firewood can be saved per year. The households' average charcoal consumption before the biogas digester construction was 4.16 kg per day and the consumption of charcoal was reduced to 1.66 kg after they start using biogas. This means 2.5kg of charcoal was saved per day and 915kg of charcoal was saved per year in each household. Overall out of the 59 regular functioning biogas digesters in the study area 53,985 kg of charcoal can be saved per year. Findings have shown that lack of awareness creation activities has significantly affected people's attitude towards biogas technology status. This has been the most difficulties to the contribution of biogas technology to local communities in the study area. Energy policies should focus on raising awareness of the community to use modern renewable energy and at the same time to save fuel wood consumption.

***Keywords**: Biogas energy, Fuel wood, Household, digester, consumption*

1. INTRODUCTION

1.1. Background

Energy plays a crucial role in changing the standard of life of human beings. The worldwide energy demand is increasing rapidly as the result of population growth and economic development; and about 88% of this demand relies upon fossil fuels (Weiland, 2010). The effects are significant on socio-economic groups whose adaptive capacity is low, especially the poor in developing countries (IPCC, 2001).

One of the means to reduce dependence on traditional use of biomass energy is to promote and supply energy efficient technologies, called renewable energy, such as, biogas energy from biomass for heat and light which are currently in wide use and being introduced in some areas in developing countries (IEA, 2011). Strategies which assist to reduce fuel wood consumption have the potential of simultaneously using alternative renewable energy technology, conserving forests and improving human livelihoods.

Currently, consumption of solid biomass energy for cooking and lighting is an important issue for the decline of forests and aggravate fuel wood consumption. In Sub-Saharan Africa (SSA), deforestation and degradation of forests contribute to a huge amount of GHGs in many developing countries (Hosonuma *et al.*, 2012). At the same time, energy from fuel wood is essential to sustain livelihoods in SSA (Gurung and Oh, 2013). Fuel wood collection for cooking is a main driver of forest degradation in SSA (Skutsch *et al.*, 2011). As a result, in most areas of SSA, indoor air pollution caused by traditional cooking constitutes a major health risk (Johnson *et al.*, 2013). According to Arthur *et al.*, (2011), the rampant exhaustion of fuel wood supplies, predicted increase in fuel wood demand in the future and the resulting social and environmental effects urge the need to look for alternative and clean fuel sources in developing countries. Fuel wood and degradation of forests contribute a huge amount of greenhouse gas emissions in many developing countries, mainly in Sub-Saharan Africa (Hosonuma, *et al.*, 2012).

To overcome the fuel wood problems, alternative renewable energy sources have recently become more and more attractive due to the increasing demand for energy, the limited resource for buying fossil fuel, the environmental concerns, and the strategy to survive post-fossil fuel economy era (Siltan, 1985).

Ethiopia is one of the top ranking countries in Africa and among the first ten in the world in terms of livestock resource (FAO, 2009). Consequently the country has the greatest potential to the development of biogas technology (Zenebe *et al*., 2010). According to Mogues (2009), biogas technology in Ethiopia can be seen as being relatively mature as compared to other African countries as its history dates back to1950. But Ethiopia is still depending on biomass for cooking and lighting (Hilawe, 2010 and Aklilu, 2008).

Access to modern energy services remains an issue for poor people in developing countries. In Ethiopia about 83% of the population does not have access to electricity and 93% uses biomass-based energy for cooking, which surpasses 99% in rural areas (IEA, 2011). Firewood and charcoal produced from common resource pools also serve as a means of income to poor rural and urban households.

To answer the need for addressing the adverse impacts of the increasing trend in biomass energy consumption in Ethiopia, biogas as an alternative renewable that was introduced in Ethiopia since late 1970s albeit on a fragmented manner and with limited success in penetration of the technology (Kidane *et al.*, 2007 and Getachew *et.al.*, 2006). According to Lansing *et al.* (2008) biogas is a renewable energy technology that utilizes also organic wastes to produce a flammable methane gas suitable for cooking and lighting purposes. Biogas consists between 40% and 70% CH_4 with the remainder being CO_2, H_2S and other trace gases (Shin *et al.*, 2005).The resulting CH_4 gas is an efficient source of energy for cooking, lighting, combustion engine and burned to produce electricity.

Bishoftu was one of the town in which the first national biogas program was started. In the Bishoftu town, in two study area of kebeles (kebele 01 and Genda Gorba), there are 91 biogas plants, which were built by Oromia regional biogas program. Regarding functional status of these biogas plants in in the study area, 59 plants are functional and 32 plants are non-functional. Even though, this number of biogas plants were built in the study area, the amount of energy provided by these plants are not adequate and also the scarcity of wood-fuel and associated problems are more severe. Thus, community are using more fuel wood, charcoal and dung cake. On the other hand, the status, benefits and the contribution of these biogas plants was not scientifically studied in the study area. Moreover, community perception regarding benefits biogas technology in the study area was not studied well.

Hence, this study was examined the root causes for the low status of biogas technology in relation to contribution, benefits, promotion efforts used by biogas users and non-users in study area by identifying the people's awareness and attitude towards biogas technology. In addition to this, the fuel wood reduction due to using biogas plants in study area was analyzed. So this study has come up with findings which could inform appropriate allocation of resources by the local government and shape the future of renewable energy like biogas technology input sources.

1.2 Statement of the Problem

Internationally, 55% of the wood removed from forests are for fuel and fuel wood are responsible for 5% of worldwide fuel wood (Miles and Duckson, 2010). Over 80% of SSA countries including Ethiopia rely mainly on solid biomass such as firewood, charcoal, agricultural by-products and animal wastes to meet basic needs for cooking and lighting (Brown, 2006).Unless the economy and awareness of such countries improved, most of the rural communities will continue to rely on forest biomass for cooking and lighting. Although developed world has replaced highly polluting fuel sources with cleaner sources, it is estimated that 50% of all households worldwide and 90% of all rural households continue to use biomass fuel as their main domestic source of energy (Bruce *et al*., 2000).

Ethiopia is among the twenty three Sub-Saharan Africa countries where more than 90% of their population, particularly almost all the rural household, relies on traditional biomass fuels for cooking (IEA, 2014; Tucho et al., 2014). Study conducted by Shannon H., (2014) revealed that, in every year, every year; nearly 200,000 hectares of land are destroyed due to collection of fuel wood for energy consumption. For this reasons Ethiopian government has attempted to reduce dependence on biomass as a source of energy and enhance environmental conservation, human health and poverty reduction of rural households by promoting renewable energy technology like biogas technology.

Ethiopia is one of the highest level countries in Africa and from the first ten in the world in terms of livestock resource (Anderson *et al.,* 2011) which indicates the country has the greatest potential to the development of biogas technology (Guta, 2012). Based on this Biogas technology in Ethiopia has continuously been promoted by national and International Government and Non-Government over the last 50 years. However, its energy consumption relies extremely on biomass that accounts about 94% of the total energy consumption for cooking and lighting (Hilawe, 2010).

Furthermore, in Bishoftu town large area of forestland has been converted to other land cover like different buildings and industrial areas in the last few decades. On the other hand the biogas users have relatively shifted from the traditional energy sources like fuel wood, charcoal and cow dung and reduced deforestation and health and sanitation problem. However, there was no research studied that show the saved of fuel wood, charcoal and the contribution for improving health and sanitation due to using biogas technology in study area. According to Zebider (2011), in Bishoftu area the forest cover has been declining at an alarming rate. This study aimed at filling the above mentioned knowledge gaps.

1.3. Objectives of the study

1.3.1. General objective

- The main objective of this study was to investigate Household Level Biogas Technology Status and Its Contribution to Livelihoods of Local Communities in Bishoftu town.

1.3.2. Specific objectives

- To evaluate the current status of household level biogas technology
- To estimate proportion of fuel wood consumption reduced by using biogas plants
- To examine the contribution of Biogas technology to the livelihood of local communities
- To identify households' attitude towards benefits of biogas technology.

1.4. Research questions

- What is the current status of biogas plants in the study area?
- What amount of fuel wood can be saved by using biogas plants?

- Does biogas plants improve livelihood of local communities in the study area?
- What are the households' attitude towards benefits of biogas technology

1.5. Significance of the Study

The study generates research out up which could be important to understanding of the root causes of low status rate of biogas technology to take early action in the local area. Furthermore, the outcome of this research can be used as a significant source of information for interventions by interested stakeholders (e.g., policy makers, planners, government sectors, research and education institutions, researchers and development experts, donors and local and international NGOs) those like to implement and used.

1.6. Scope and Limitations of the Study

This study was limited to investigating the status of household level biogas technology and its contribution to the livelihoods of local communities in Bishoftu town. Therefore the study focused on to evaluation of the current status of household level biogas technology, to examine the contribution of biogas technology for the livelihood of local communities and also gave consideration to estimating proportion of fuel wood consumption reduced by using biogas plants in the study area. Due to the constraints of budget, practically the study was also limited to only one season and on a small number of households and to assess the contribution of biogas plant technology for livelihood of local communities.

1.7. Conceptual Framework

Conceptual Framework is information method that deliver theoretical base for investigating the issues manipulating technology status (Davis *et al.*, 1989). According to household level biogas technology promotion theories awareness is the first stage in the household level biogas technology implementation process. Before any household level the technology is made, people must be made aware about new innovation and its benefits (Simon, 2006). The awareness occurs when people get access to information on the technology. The sources of information include government institutions through extension services and awareness creation campaigns and through financial support. Other sources of information include biogas projects and non-governmental organizations dealing with energy issues and biogas beneficiaries which can influence the household level biogas technology. Environmental issues such as availability of fuel wood, availability of water and access of feedstock; and technological characteristics including availability of technical service and status of biogas plants which is simple, reliable, easily visible and compatible with the local are expected as issues that influence of biogas technology status in this study. A combined of socio-economic, environmental and technological issues would influenced the individual household's willingness to invest technology resulting into status of biogas technology. Study conducted by Rogers, (1995) underlined that no issues works in its own; these issues influence one another and in turn influence the technology status process. Therefore, conceptual frame work for this study were precisely illustrated as following (figure 1).

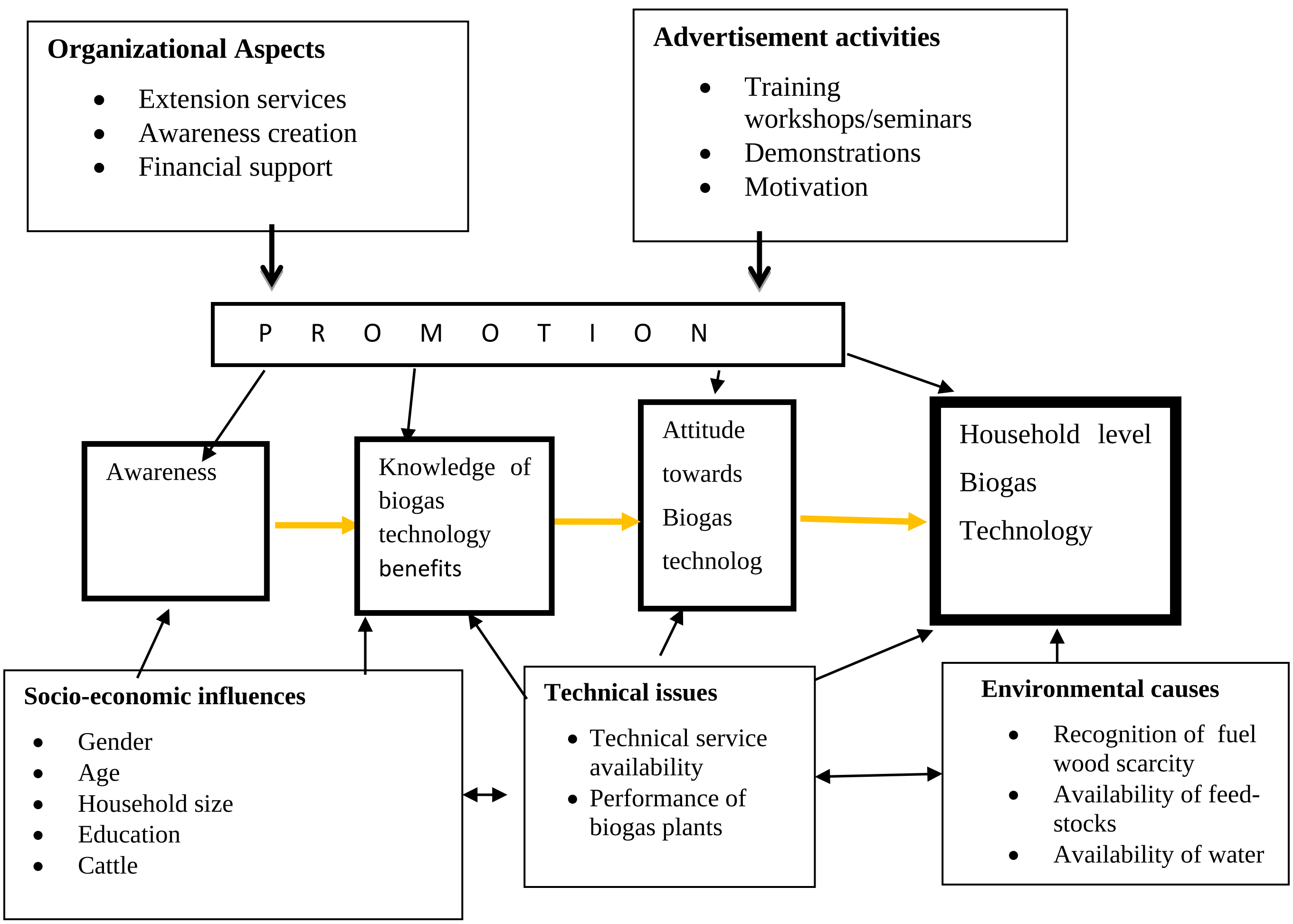

Figure 1: Conceptual Framework of Several Issues That Influence Of Biogas Technology

Source: Simon (2006)

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Overview of World Wide Energy Utilization

Energy is the basic factor contributing to development. Sustainable development is not possible without making energy systems more sustainable. No country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population (World Bank, 2000).Biomass energy in the form of firewood, charcoal and crop residues plays a vital role in the basic welfare and economic activities in many Sub Saharan Africa households, where they meet more than 90% of their energy needs (KIPPRA, 2010).

A 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 IEA (2008), about 2.4 billion people have no access to electricity and rely heavily on unsustainable biomass energy to meet their energy needs. 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).This scenario is not different in Africa, where figures for Eastern and Southern African countries indicate that a high proportion of total national energy supply is derived from the diminishing biomass energy (Karekezi, 2002).

Energy security is dependent on two factors: the source of supply and the distribution systems. On the global perspective, energy security is dependent on the availability of primary energy. In the developed nations of the world, energy for cooking, heating and lighting is readily available at a relatively low cost. This is because rich nations have invested in both centralized sources and extensive distribution systems to make that energy available to citizens and business.

In the developing world, on the other hand, processing and cooking of food is accomplished mainly by solid-biomass energy. Women spend a significant part of their time during the day gathering fuel wood and are exposed to harmful smoke and other by-products of burning organic materials. Continental wise, data show that India is the highest consumer of fuel wood followed by Africa (Table-1).

Table 1: Worldwide Fuel Wood Consumption (TJ) in 2005

Continent	Fuel wood	Charcoal	Black liquor	Total
Africa	5633	688	33	6354
North America	852	40	1284	2176
Latin America	2378	485	288	3150
Asia	7795	135	463	8393
Europe	1173	14	644	1831
Oceania	90	1	22	113
Total	17921	1361	2734	22017

Source: FAOSTAT (2005)

2.1.2. Overview of Energy Utilization in Ethiopia

The energy sector of Ethiopia is one of the least developed in the world despite the presence of an enormous energy resource endowment. This is reflected by the low per capita energy consumption of households. Furthermore, heavy reliance on traditional energy of rural households of Ethiopian has been revealed by a number of studies. For example, Jargstorf (2004) stated that Ethiopia is the third largest user in the world of traditional fuels for household energy use, with 96% of the population dependent on traditional biomass (e.g., fuel wood and dung) to meet their energy needs. This is in comparison to 90% for Sub-Saharan Africa and approximately 60% for the African continent. The excessive deforestation, which led to the depletion of tree stock, caused what is known as the household energy crisis in Ethiopia. In Ethiopia, presently 95 percent of national energy consumption is derived from fuel wood, dung, crop residues, and human and animal power. The remaining 5 percent is from electricity, 90 percent of which is generated by hydropower (World Bank, 2006). In Ethiopia the main sources are woody biomass (78%), dung (8%), crop residue (7%) and petroleum (5%) (Eshete *et al*., 2006).

2.1.3 Types of Biomass Energy Use

The categories in which biomass energy being harnessed is principally three based on efficiency quality and environmental benefits. They are traditional biomass energy, improved biomass energy and modern biomass energy. The traditional biomass energy use refers to the direct combustion (often in very inefficient devices) of wood, charcoal, leaves, agricultural residue and animal/human wastes for cooking and lighting. Improved traditional biomass energy technologies refers to improved and efficient technologies for direct combustion of biomass e.g. improved cook stoves, improved kilns, etc. Modern biomass energy use refers to the conversion of biomass energy to advanced fuels namely liquid fuels, gas and electricity (AFREPREN, 2002).

2.1.4. World Wide Biomass Energy

Since the beginning of civilization, biomass has been a major source of energy throughout the world. Biomass is the primary source of energy for nearly 50% of the world's population (Karekezi and Kithyoma, 2006) and wood biomass is a major renewable energy source in the developing world, representing a significant proportion of the rural energy supply (Hashiramoto, 2007). In the past decade, many countries exploiting biomass opportunities for the provision of energy has increased rapidly. Hence, they contribute to make biomass an attractive and promising option in comparison to other renewable energy sources. According to World Bank (2009), the global use of biomass for energy increases continuously and has doubled in the last 40 years.

As compared to other renewable energy sources, biomass is one of the most common and widespread resources in the world (WEC, 2004). Thus, biomass has the potential to be a source of renewable energy, both locally and in large parts of the world. Worldwide, biomass is the fourth largest energy resource after coal, oil, and natural gas estimated at about 10% of global primary energy and much higher in many developing countries. Compared to other renewable energy sources, biomass is currently the largest accounted for 79% while hydro power stands second having 17% (IEA, 2008).

About 2.4 billion people rely on traditional biomass, mainly for cooking and heating (IEA, 2002a).Fundamentally, all of those users of traditional fuels dwell in developing countries, and most of them live in rural areas; low incomes and the lack of access to alternative, modern fuels elucidate their choice of traditional energy supply (Nadejda *et al*., 2002).In developing countries, over 500 million households still use traditional biomass for cooking and heating (UNDP, 2009). Furthermore, two billion people (about 40 %) of the total world population depend on firewood and charcoal as their primary energy source. From these people, three quarters (1.5 billion) do not have an adequate, affordable supply (Mulugeta *et al*., 2005).The share of biomass energy in total primary energy supply for Asia, Africa and, Latin America and the Caribbean (LAC) in 2001 was 25%, 49% and 18% respectively (IEA, 2003a). Industrialized countries record significantly lower levels of biomass energy supply, most of which is modern biomass energy use and the average share of biomass in total primary energy supply was 3% (IEA, 2003b).

2.1.5. Traditional Biomass Energy in Ethiopia

There is a correlation between poverty levels and traditional biomass use in many developing countries (Karekezi, 2004). As a rule, the poorer the country is, the greater the reliance on traditional biomass resources. This is because the alternatives are unaffordable. Biomass energy is most utilized in form of fuelwood by the domestic sector. The use of fuelwood is most common in poor rural households. Fuel wood is considered the cheapest energy option available to households, although the labor, effort and externalities of fuelwood remain un-quantified (Batidzirai, 2006).

Ethiopia is the third largest user in the world of traditional biofuels for household energy use, next to Chad and Eritrea. About 96% of its population is dependent on traditional biomass (e.g. fuelwood and dung) to meet their energy needs (Jargstorf, 2004b). On the other hand, the finding of Konemund, 2002 revealed that traditional biomass energy consumption in the country accounts about 94% of the total national energy consumption. It is still a large amount of consumption even though the two researchers found different percentage of consumption. The household sector is the major consumer of energy in Ethiopia. It accounts about 89.2% of the total national energy consumption while the remaining 10.8% is shared among agriculture, transport, industry, and service sectors (EREDPC and MoARD, 2002).Specifically, fuelwood with charcoal and dung with crop residues account 83% and 16% respectively, whereas electricity and petroleum together contribute with 1% of the total household energy consumption. The contribution of biomass fuel is still greater in the rural households as compared to the urban counterpart. According to EREDPC and MoARD (2003), biomass fuels constitute 99.9% of the total energy consumption of the rural households.

According to Mekonnen and Alemu (2001), natural forests in the country have, in the past, represented a major source of energy. The depletion of these forest resources, however, has resulted in a serious wood fuel crisis. Regardless of the variations in the estimates from one study to the other and the limitation of the theoretical basis underling the estimates, different studies confirm the existence of a wider gap between supply and demand. There is a consensus that the volume of wood harvested in the past few decades far exceeds the incremental yield the forest resources, could generate leading to an ever diminishing stock.

2.2. Over View of Global Biogas Technology

The beginning of anaerobic fermentation mainly for the treatment of organic wastes traced back to the period before the Birth of Christ (Deublein & Steinhauser, 2011). However, it was in 1895 for the first time that biogas generation from a "carefully designed" manure treatment installation began providing street light in England (Mengistu et al., 2015). People's interest to use biogas as energy produced mainly during the Second World War. With the end of the war, a number of countries including England, United States of America, Canada, Russia, Japan, China, Kenya, Uganda, South Africa, New Zealand, and India became more interested in the use of biogas (Mital, 1997).

However, interest on the utilization of biogas diminished considerably since mid1950s mainly due to the low priced availability of fossil fuels. Consequently, nearly all biogas installations were abandoned. However, interest on biogas generation revived once again following the global oil shocks of the 1973 together with the rising concern for environmental protection in the decade (Deublein & Steinhauser, 2011).Thus, since this decade onwards, the use and dissemination of biogas technology has continued in both developed and developing countries. Indeed, the focus on scales of biogas generation differs between developed and developing countries. Developed countries focus dominantly on large scale biogas installations for combined heat and power generation whereas the primary focus of developing countries is on the construction of small scale biogas digesters that particularly generate heat for cooking (REN21, 2013).

Among the developed world, Germany is by far the leading country in biogas generation (Bramley *et al*, 2011). Germany has also a grand plan to raise the number of biogas projects to 43,000 up to 2020 (Deublein & Steinhauser, 2011). United Kingdom is the second country in the hierarchy (Van, 2012). Next to Germany and United Kingdom, other top biogas producing countries in Europe are Italy, France, Netherlands, Czech Republic, Spain (Kaparaju, 2013).

Of the developing countries, China outstandingly leads the world in the number of domestic biogas plants. India stands second in the number of domestic biogas installations in the developing world. There are also a number of other Asian countries where domestic biogas installations are being expanded. Some of these countries include Nepal, Vietnam, Bangladesh, Cambodia, Indonesia, Lao Peoples Democratic Republic and Pakistan (Dong, 2013; NSV, 2013; Mengistu et al., 2015).

Some African countries have also been working on the dissemination of biogas technology with renewed interest. African Biogas Partnership Program (ABPP), which was created by the Netherlands Development Organization (SNV) and Humanist Institute for Development Cooperation (HIVOS) planned to construct 70,000 biogas installations in six African countries (Kenya, Burkina Faso, Ethiopia, Tanzania, Uganda, and Senegal) with the aim to provide sustainable source of energy for about half million people by the end of 2013 (AFREA, 2011).

2.3. Biogas Plant Technology

Biogas plant technology has been progressive around the world as alternative renewable energy by various organizations such as government agencies, international organizations and non-governmental organizations (NGOs). For instance biogas plant technology support program (BSP-Nepal) has been promoting the use of biogas in Nepal since 2003 (Rai, 2009). In Africa different organizations such as African Biogas Partnership Program and SNV-Netherlands are actively

Involved in advancing the idea of biogas use in countries such as Uganda, Ethiopia Kenya and Rwanda (African biogas Partnership Program (ABPP, 2011).

Biogas plant technology can effectively be used to accomplish the organic fraction of wastes such as food and alcohol industrial waste, crop waste, farm waste, municipal waste, sewage sludge etc. When used in a fully engineered system, biogas plant technology not only a benefit of pollution prevention, but also permits for energy, compost and nutrient recovery (Balsam, 2006). Thus, biogas plants can convert a disposal problem into profit by leaving the environment intact.

Biogas is produced by methanogenic bacteria acting on bio-digestible materials in absence of oxygen in the process known as anaerobic digestion. Biogas is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition (Aargau, et al., 2013). The approximate composition of biogas is presented in Table 1.

Table 2: Composition of the biogas plant

N	Substance	Symbol	%
1	Methane	CH4	50-70
2	Carbon Dioxide	Co2	30-40
3	Hydrogen	H2	5-10
4	Nitrogen	N2	1-2
5	Water Vapor	H2O	0.3
6	Hydrogen Sulphide	H2S	Traces

Source: (Karki *et al.*, 2009)

2.3.1. Biogas Technology as a Renewable Energy

Biogas is a hygienic and alternative renewable energy which consists of methane (CH_4) 60%-70% and carbon dioxide (CO_2) 30%-40%, 1–5% hydrogen and traces of nitrogen, hydrogen sulphide, oxygen, water vapor, and slurry (Erdogdu, 2008). Biogas is produced by methanogen bacteria acting on bio-digestible materials in absence of oxygen in the process known as anaerobic digestion. Anaerobic digestion occurs in digestive systems, rubbish dumps and septic tanks (Harris, 2005). The energy from biogas reduces greenhouse gas emissions and dependency from very much expensive imported fossil fuel. Thus, the development and implementation of biogas plant technologies could provide several environmental, energy security and economic benefits thereby solving difficulties such as waste disposal and alternative renewable energy supply. The concept of the 'four R's', which stands for Reduce, Reuse, Recycle, and Renewable energy, has generally been accepted as a useful principle for appropriate waste handling. Thus, biogas digesters can address these principles (Sisouvong*et et al.*, 2006).Therefore, it is a clean and alternative renewable form of energy and could supplement conventional energy sources because of its environment friendliness allowing for efficient waste utilization and nutrient recycling (Bhat *et al*., 2001).

2.3. Overview and Status of Biogas Plant Technology in Africa

Biogas plant technology is viewed as one of the most valuable alternative renewable energy technologies in Africa that can support to alleviate its energy and environmental problems. So far, some digesters have been installed in several sub-Saharan countries, utilizing a variety of waste such as from slaughterhouses, municipal wastes, industrial wastes animal dung and human excreta. Small-scale biogas plants are situated all over the continent but very few of them are operational. In most African countries, for example, Burundi, Ivory Coast, and Tanzania, biogas is produced through anaerobic digestion of human and animal excreta using the Chinese fixed-dome digester and the Indian floating-cover biogas digester are not reliable and have poor status in most cases (Omer and Fadalla, 2003).

2.3.1. The Benefit of Biogas technology to Local Communities in Africa

Households in Africa, particularly in the countryside areas are increasingly facing energy supply and efficiency problems. According to United Nations (2010) there is approximately 60% of the total African population living in the rural areas. Biomass in form of wood, cow dung, and crop residues accounts 30% of the energy used in Africa and over 80% used in many sub-Saharan African countries such as Burundi (91%), Rwanda and Central Africa Republic (90%), Mozambique (89 %), Burkina Faso (87%), Benin (86%), Madagascar and Niger (85%) (Cited in United Nations Economic and Social Council, 2007). The availableness of these traditional fuels (wood, dried dung and agricultural wastes) is declining. Domestic biogas provides an opportunity to overcome these challenges in the rural areas. This is because biogas production makes use of easily available, cheap and local resources such as agricultural crop wastes and animal wastes such as pigs, cattle, and poultry as well as human excreta.

2.3.2. Contribution of Biogas to Improve Health and Sanitation

The substitution of highly polluting traditional fuels with biogas virtually eliminates indoor air pollution, which is a major cause of acute lower respiratory disease, particularly among women and children who spend a lot of time in smoke-filled kitchens (Getachew *et al.*, 2006). By connecting the biogas plant with latrine, the health benefits of biogas are enhanced. Toilet attached biogas plants decrease incidence of gastro-intestinal diseases and nuisance (Mary *et al.*, 2007).

2.3.3. Local Environmental Benefits of Biogas

Replacing biomass energy with biogas could help to solve many problems that are typically associated with using biomass fuels. The indoor air quality of homes was intensely improved as a result of employing biogas instead of burning firewood, crop residues and dung cakes. This would mean that a lot of the problems with hazardous smoke particles would be avoided (Li *et al.*, 2005). In addition, installation of biogas systems can help in improved management and disposal of animal dung and night soil. Biogas systems have also proven contribution to reduce the pressure on forests that have important advantages in management of watersheds and protection of soil erosion (Gaafar, 1994). In addition, use of bio-slurry reduces the depletion of soil nutrients by providing nutrients resulting in increased crop yield and hence reduction of the pressure to expand cropland areas, the principal cause of fuel wood (Anushiya, 2010 and Krishan, 2010).

2.3.4. Economic Benefits of Bio gas Plant Technology

The most important outputs of biogas plant technology are energy and bio-slurry. Biogas energy is consumed commonly for cooking, lighting, refrigeration, and running internal combustion engine (FAO, 1996). Biogas burns more efficiently as compared to fuel wood and dung. It burns at an efficiency of about 60 % whereas fuel wood burns at 5 % to 8 % efficiency in open fire place and dung burns at 60 % of that of fuel wood (FAO, 1997). Unlike the use of traditional biomass fuels, cooking with biogas is much easier because there is no need to keep the fire burning (Arthur *et al*., 2011).

Biogas installations can generate electricity and offer transportation fuel. Electricity generated from biogas could be useful for local pumping, lighting, communication, refrigeration, etc. When methane, the combustible component of biogas, is enriched, it can be used as transportation fuel (Larson and Kartha, 2000; Murphy *et al*., 2004). With regard to the advantages of biogas as transportation fuel, Kapdi *et al*., (2005) stated that after removing carbon dioxide, biogas enriched in methane becomes equivalent to natural gas. Thus, methane enriched biogas can be useful for all applications that natural gas can do. The bio-slurry from biogas digesters has been attested to be the best organic fertilizer which was lead to increased crop productivity. It can substitute chemical fertilizer and thus reduces the importation of chemical fertilizer and saves foreign currencies (Arthur *et al*., 2011). As stated by Breinholt (1992), the ammonia content of bio-slurry from biogas digester is about 10 % higher than the fresh manure. Moreover, bio-slurry is easier to dose and apply on crop fields than the fresh manure as it is less viscous and lumpy manure. Biogas effluents are also rich in phosphorus (the most expensive fertilizer) and potassium.

Biogas technology generates employment opportunities for both skilled and unskilled labor. Definitely, in a well-organized biogas development sector, biogas plant technology expansion makes employment opportunities for masons, plumbers, civil engineers, and agronomists. They are usually key promoters of the technology. Building of biogas installations, design and production of appliances, and construction equipment’s are crucial areas of employment opportunity .Researchers may engage themselves in the area of improving the biogas system (Lam et al., 2009; Arthur *et al*., 2011). For instance, in China, India and Germany, the total estimated number of people who directly or indirectly engage in biogas related jobs were 90,000, 85,000, and 50,000 respectively (REN21, 2013).

In a nutshell, Ghimire (2008) enumerated the economic benefits of biogas technology as follows. It saves expenditures on fuel sources; saves time to utilize in other income generation activities; increases soil fertility and reduces the required quantity of chemical fertilizer due to the use of bio-slurry; reduces health expenditures due to a decrease in smoke-borne diseases; and creates

2.3.5. Overall Benefit of biogas plant technology

As per the research conducted by Pathak *et al*., (2009) biogas technology is considered to provide the benefits of reducing the emission of GHGs and then mitigating global warming in ways of replacing firewood for cooking, replacing kerosene for lighting and cooking purposes, replacing chemical fertilizers and saving trees from fuel wood. For example, in India, a family size biogas plant substitutes 316 L of kerosene, 5,535 kg firewood and 4,400 kg cattle dung cake as fuels every year. The introduction of biogas technology saved 8732 tons of charcoal 27,162 tons of fuel wood and 5336 hectare of forest. Moreover, about 66,463 [t] of biomass and 485 [t] of fossil fuel was substituted with the total implemented plants. This leads to the reduction of 64,684 [t CO2eq] per year (NBPE, 2014).

Fuel wood consumption is a major cause to environmental degradation, and may lead to energy insecurity for rural African households, especially where the resource is commercialized (Hiemstra-van der Horst and Hovorka, 2009). The high dependence on fuel wood in the sub-Saharan Africa has resulted in an alarming rate of tree felling and fuel wood (cited in United

Nations Economic and Social Council, 2007). This would create a great challenge for Africa unless alternative renewable energy sources, which are clean and environmentally friendly energy sources, can't be given a great attention in the future. The use of alternative renewable energy such as biogas has a potential to reduce the demand for wood and charcoal use, hence reducing greenhouse gas emissions improving water quality, conserving of resources, particularly trees and forests, and producing wider macroeconomic benefits to the nation (Amigun and Blottnitz, 2010) due to reduced fuel wood.

2.3.6. The Contribution of Biogas Technology for Social benefits

Biogas technology has also various social roles. It improves social relations via minimizing bad odors and environmental pollutions of organic wastes which would serve as a source complaint among neighbors and negatively affect social relations (Aggarangsi *et al.,* 2013). Women and children would have more time for education when they don't have to spend as much time collecting firewood and other biomass fuels. The daily time spent in feeding a small biogas digester could be as little as 15 minutes compared to several hours in the collecting of biomass (Renwick, 2012). Time consumed cleaning pots and other kitchen equipment can also be lowered since biogas won't create as much soot as biomass generally does (Bajgain & Shakya, 2005).

This saved time is utilized for rest and leisure, schooling, social activities and/or productive purposes which definitely empower and promote women and girls' educations. The bright biogas light also assists in succeeding in children's educational statuss.

2.4. Energy Sources and Consumption in Ethiopia

According to Alemu et al., (2001) natural forests in the country have, in the past, represented a major source of energy. The depletion of these forest resources, however, has resulted in a serious wood fuel crisis. Regardless of the variations in the estimates from one study to the other and the limitation of the theoretical basis underling the estimates, different studies confirm the existence of a wider gap between supply and demand.

There is a consensus that the volume of wood harvested in the past few decades far exceeds the incremental yield the forest resources, could generate leading to an ever diminishing stock.

The current energy sources of Ethiopia can be categorized into two: modern and traditional. Modern sources of energy comprises electricity and pet advantage sum while traditional sources of energy include fuel wood, charcoal, dung, and crop residues. According to MoWE, 2011 in 2009, traditional biomass fuels accounted for 92 % of the total energy consumption whereas modern fuels constituted the remaining 8 % in Ethiopia. The household sector is the major consumer of energy in Ethiopia. It accounts about 89.2 % of the total national energy consumption while the remaining 10.8 % is shared among agriculture, transport, industry, and service sectors (EREDPC and MoARD, 2002). More than in any other sector, biomass fuel is important in the household sector. It makes up 98.6 % of the total energy consumption. The contribution of biomass fuels is still greater in the rural households as compared to the urban counterpart. According to EREDPC and MoARD (2003), biomass fuels constitute 99.9 % of the total energy consumption of the rural households.

2.4.1. History of biogas plant technology in Ethiopia

Biogas technology was introduced in Ethiopia as early as 1979, when the first batch type digester was constructed at the Ambo Agricultural College. In the last 25 years, about 1,000 biogas plants was constructed in households, communities, and governmental institutions in various parts of the country for confirming energy security all over the country. The domestic biogas technology attracted interest mainly due to consideration of the animal dung, the raw material that is plenty in many rural households in the country. After the establishment of the National Biogas Program Ethiopia in 2009, close to 859 biogas plants have been constructed and are in regular use. Among 859 functional biogas plants, 206 are found in TigrayRegion, 143 are in Amhara Region, 330 in Oromia Region and 180 are found in SNNP regional states (Getu, 2016).

2.4.2. Types Biogas Plant

Kauzeni *et al*., (1989) identified about 7 types of biogas plants or digesters. For the purpose of this study, three types which are commonly used in developing countries including Ethiopia were reviewed as following:- These include; the Fixed Dome (Chinese type), Floating Cover (Indian type) and Tubular Plastic or Bag Design (Taiwan, China) which are being promoted in developing countries (Gitonga, 2007).

2.4.2.1. Fixed-dome (Chinese design)

According to Kauzeni *et al*., (1989) fixed dome design is the most common digester type in developing countries. The size of this type of design is range from $2m^3$ for a single family of 5 people, to $140m^3$ for large communities. The digester consists of a gas tight tank constructed of bricks, stone or poured concrete. Both the top and the bottom of the reactor are hemispherical and joined together by straight sides. The inner surface is sealed by thin layers of mortar to make it gas tight. The plant is normally divided into three parts: digester, inlet and outlet slurry pits, and gasholder. Refer to (Figure 2).

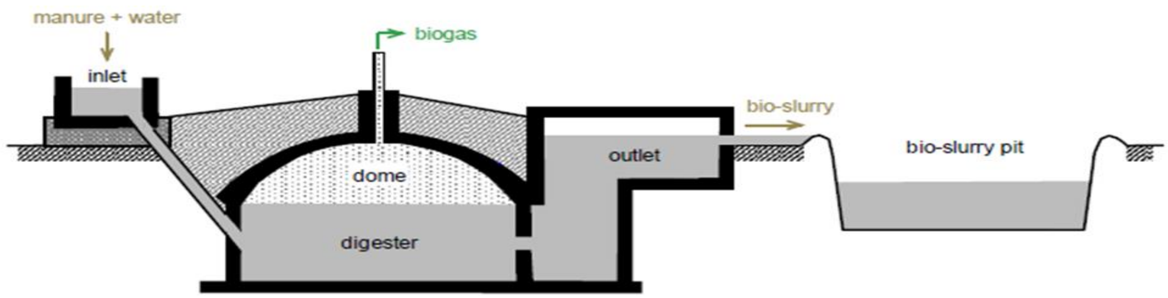

Figure 2: Fixed - dome biogas plant; Source: Kauzeni *et al*., (1989)

The advantages of a fixed dome plant design, according to Kauzeni *et al*., (1989) include long useful life-span and the basic design is compact, saves space and is well insulated. Since most of the materials are locally available (except for the outlet pipe) and with the free labor contributed by the family, digester costs are relatively low. The study of Kauzeni *et al*., (1989) also revealed that the main disadvantage of a fixed dome, on the other hand, is that the gas-holders require special sealants and high technical skills for gas-tight construction. Fixed dome plants can be recommended only where construction can be supervised by experienced biogas technicians.

2.4.2.2. Floating Cover (Indian design)

Floating cover is broadly used throughout the world. The sizes range between $5m^3$ to $15m^3$. Typical floating cover design consists of a reactor wall and bottom. Usually constructed of bricks of this type of design is protected with concrete. This acts as a container within which the gas can collect. The gas produced in the digester is trapped under a floating metal dome (Kauzeni *et al*., (1989). Refer to (Figure 3).

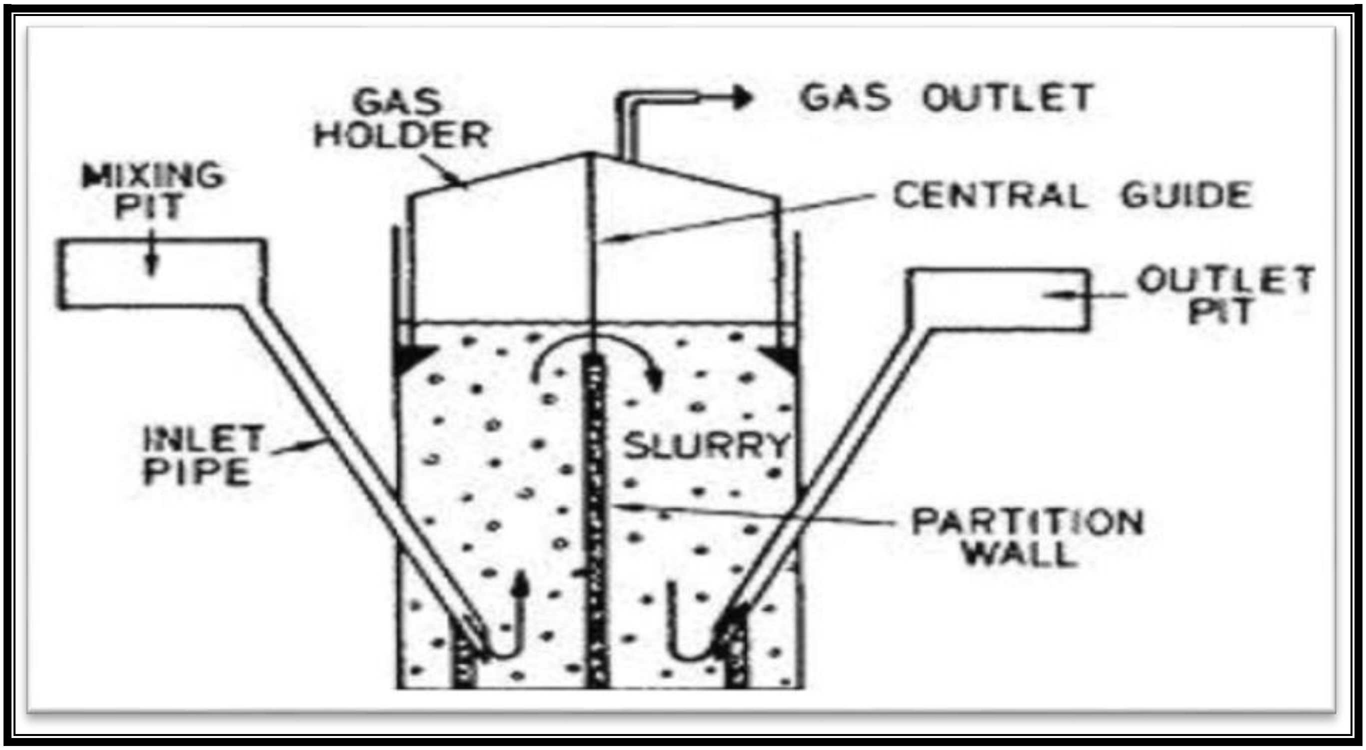

Figure 3: Floating Drum plants

Source: Kauzeni *et al*., (1989)

A major advantage of the Indian designed digester is that it does not demand a high level constructional skill, for the dome, which is the critical component, is manufactured elsewhere in a workshop. Corrosion is a major problem of this type of plants but other materials such as Ferro cement, high-density polyethylene and fiberglass have been used to tackle the problem. It is more expensive in contrast to the Chinese design (Kauzeni *et al*., (1989).

2.4.2.3. Tubular plastic design (Taiwan &China design)

Tubular plastic digester consists of a long cylinder and a Neoprene coated nylon fabric. The digester is placed in a trench and filled with water to expel air before dung is introduced. Depending on the temperature, it may take two weeks before gas is produced. Materials for a biogas plant are locally available and when all materials are delivered to the site it takes between 3 to 4 hours to set up the plant. Capacity of the former is about $8m^3$ to $9\ m^3$, with a gas holding chamber of 1-3 m^3. The smaller Plastic Tubular Bio-digesters can give gas for six hours using one burner. The tubular plastic bio-digesters are cheaper and affordable to poor farmers. The major drawback of the tubular plastic bio-digester is its limited durability due to its weakness (Kauzeni *et al*., (1989). Refer to (Figure 4).

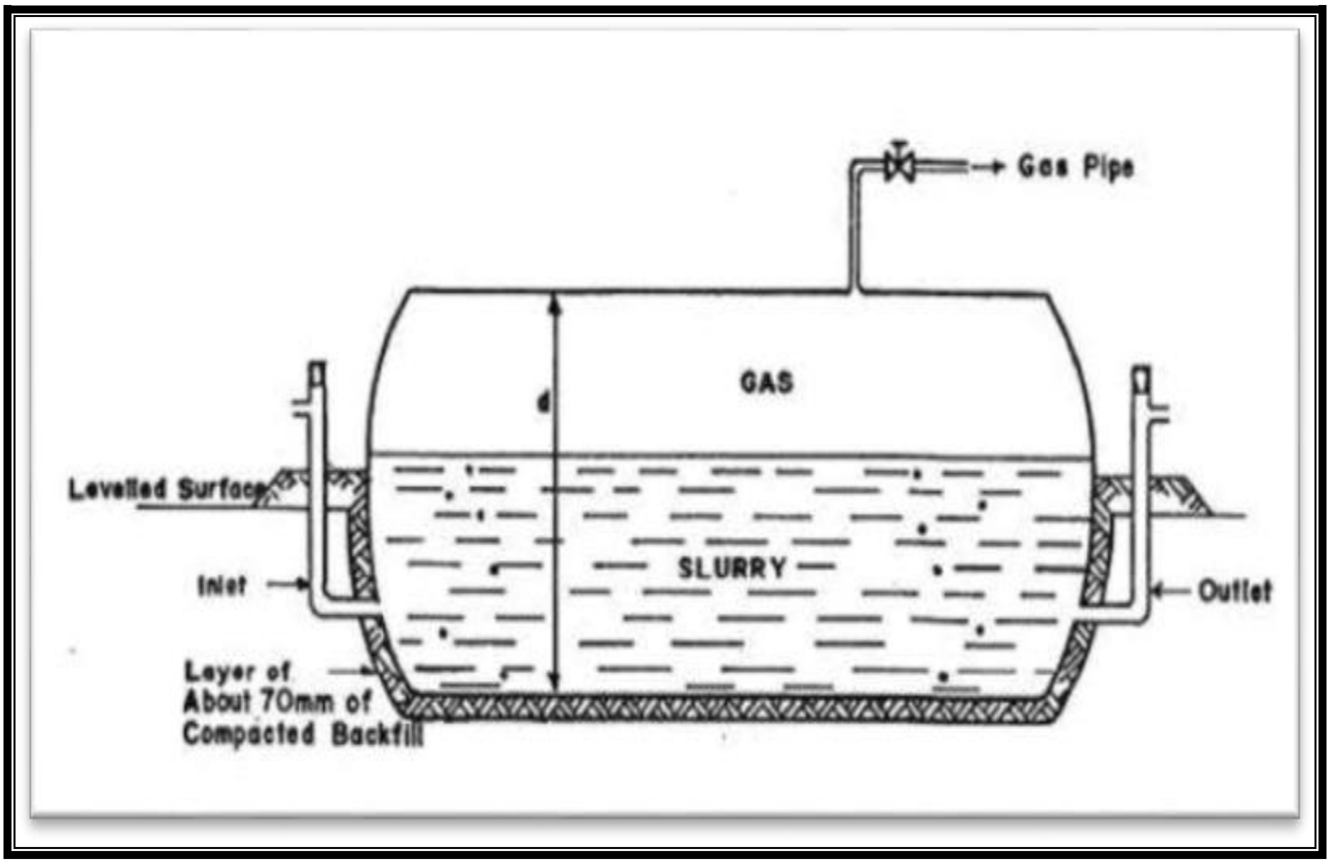

Figure 4: Tubular plastic biogas plant

Source: Kauzeni *et al*., (1989)

2.5. Biogas Plant Technology Utilization

Biogas is utilized mainly for cooking and lighting while the slurry can be used as a good source of manure for soil fertility improvement. For operating biogas plants, households use the slurry as fertilizer for their crops, especially vegetables and fruits (Walekhwa et al., 2009).Biogas is an ideal energy source and suitable for practically for numerous fuel requirements in the household, agriculture and industrial sectors. However, the different standards of gas quality are required by the individual gas utilization, which make purification and advancement of the gas necessary. In the developing countries the most common utilization of biogas from small-scale plants is on-farm application, including cooking, lighting, heating (space heating, water heating, and grain drying), cooling, etc. Ordinarily, the equipment designed for burning natural gas requires slightly adjustments to fit the different burn characteristics of biogas (Balsam, 2006).

2.5.1. Effect of Biogas Technology on Firewood Saving and Forest Preservation

As per the study investigated by Amare (2015), 60% biogas reduced the firewood, compare to 40% who believed that biogas has nothing to do with forest conservation. Upon interview with key informants revealed that 62% of the biogas impact on the environment reduces the firewood leading to the forest conservation. In addition to this before the installation of biogas plants, households used 3,596.4 kg of fuel wood /HH annually, after installation of biogas plant each household uses an average of 1062 of fuel wood/HH/year which is reduction of 2,534.4 kg 70.47% /HH/ annually. According to Muriuki (2015) most non-user households heavily relied on firewood and charcoal for their domestic energy needs. Average monthly firewood consumption for non-user households were 228.5 Kgs, associated to an average of 187.5 Kgs consumed by

Biogas user households before the installation of biogas plants. About 82 Kgs of charcoal was consumed on average by non-user households. Comparing fuel consumption for the non-user households and user households after biogas installation, the observable mean difference could not be over-emphasized. With the non-users using 228.5 Kgs of firewood monthly, biogas users consumed only 60.8 Kgs. The reduction in charcoal was also huge with the non-user households using 81.8kgs per month per household, whereas 18.3 Kgs consumed by households that have used biogas.

2.5.2. Fuel Wood Replacement Values of Biogas Energy

According to SNV (2010) $1m^3$ of biogas has fuel wood replacement value for different fuels as shown in (Table 1). Small sized eucalyptus tree, which is planted for construction and fuel wood purpose, has average height and diameter of 18 m and 12cm respectively (Woldeyohanes *et al.*, 2005). According to Scott *et al.* (2005), the total biomass of the tree can be calculated by using the equation below that could be considered as an average of all species.

$W = 0.25 * D^2 * H$ ---------------------- Equation 1 (For trees with $D<11$ feet)

$DW = W * 72.5\%$

Where: W = Above-ground weight of the tree in pounds

D = Diameter of the trunk in inches

H = Height of the tree in feet

DW= Dry weight of the tree in pounds

72.5%= average dry matter content of the tree According to Oballa, P.O *et al*. (2010), Eucalyptus tree seedlings are planted within 2m×2m spacing so that it has 2500 tree seedlings per hectare for fuel wood purpose and out of this 70% will become mature trees.

Table 3: Fuel Replacement Value Of Biogas Compared With Other Fuels

Fuel	Unit	Calorific value	Application	Efficiency	U/ m^3
	U	KWh/U		%	Biogas
Cow dung	kg	2.5	Cooking	12	11.11
Wood	Kg	5	Cooking	12	5.56
Charcoal	Kg	8	Cooking	25	1.64
Hard coal	Kg	9	Cooking	25	1.45
Butane	Kg	13.6	Cooking	60	0.4
Propane	Kg	12	Cooking	60	0.39
Diesel	Kg	12	Engine	30	0.55
Electricity	KWh	1	Motor	80	1.79
Biogas	m^3	6	Cooking	55	1

Source: SNV, (2010)

2.6. Acceptance of Biogas Technology

As a study directed by Iqbal *al* (2013) in Pakistan number of cattle, level of education, and size of household and family income was some of the issues that influenced a household's decision to accept biogas. According to Fei and Yu (2011) biogas use is affected by family size, age, gender, education level and knowledge and awareness in China. As per a study investigated in Bangladesh by Kabir *et al.*, (2013) revealed that education is cause in implementation of biogas as those who have more education want clean energy and they also recognize the importance of such energy to environmental conservation. Besides, He also found that that government or organizational subsidies or loans make it easier for households to implement biogas since the initial cost becomes or is made affordable and the people are given training and follow ups by the government. Employment opportunities.

2.7. Contribution and Status of biogas technology

Status of innovation depends on various issues; these issues may differ across regions and sometimes are location specific. Dissemination of renewable energy technologies in general and biogas technology in particular are constrained by a number of factors. Some of the factors that specifically influence dissemination of biogas technology are socio-economic issues, financial constraints and subsidies, availability of inputs, awareness about the technology, consumers' considerations, and success stories about the technology (Mengistu *et al*., 2015).

Some scholars have also generalized that contribution and distribution of new technologies depend to a larger extent on demographic characteristics, environmental characteristics, institutional support services, nature of the technology and its benefits as perceived by the society. Such characteristics make status responses unique as they are related to the situation in which the individual is and some to the nature of the practice (Somda et al., 2002; Nhembo, 2003; Bekele and Drake, 2003; Simon, 2006).

2.7.1. Socio- economic Characteristics

These are specific factors and/or attributes of an individual and his /her families that make him/her use or reject technology like biogas. These factors include age, educational level, family size, gender and wealth (Nhembo, 2003). Age of household head was expected to have a positive or negative influence on the decision to use biogas technology. According to Sufdar *et al*.,(2013) reported that the probability of using biogas increased with increasing age because older people have resources for construction of biogas plants in terms of finances and land ownership. However, other study by Walekhwa *et al.*, (2010) who reported that Younger people are more likely to accept risks associated with the new technologies than old people.

Household size may have positive or negative influence on status of technologies. For labor intensive technologies, family size positively influences status.A large family often has a large number of working members and thus more labor for biogas operation and maintenance activities, and the higher the probability of using biogas energy (Simon, 2006). On the other hand, walekway et al., (2010) stated that larger family could exert a heavier burden of dependence on the family resources to the extent that there are hardly any savings available for investment in biogas production. Under these circumstances, larger household size would negatively influence the decision to use biogas technology. An observation made by Kebede *et al.*, (1990) generalized that if larger household size is viewed as source of additional help, then the farmer may try new practices. Conversely, if they are viewed as dependents, then the household head may not be wasing to use a new technology.

Gender of household head was expected to have either a positive or negative effect. Since women dominate rural energy use at household level, it can be expected that households headed by women could have a higher probability of using fuel efficient new technology like biogas than male (Amigun et al., 2008; Abebe konch, 2011). However, study conducted by (Kabir *et al*., 2013) suggests that for a capital intensive technology like biogas, it is automatically a man who was decide on its status or non-status. Similarly in Ethiopia, Men dominate control, access, and ownership and decision making process concerning productive resources in the household and could directly influence investment decisions regarding biogas technology.

Formal education of household head is expected to have a positive relationship with status of new technology such as biogas energy. Findings by Ridell and Song, (2012) show that highly educated workers tend to use new technologies faster than those with less education. Low levels of literacy are associated with difficult in flow and comprehension of information which is likely to affect status of biogas (Uaiene *et al.*, 2009). Education level is also associated with reduce uncertainty and enhanced capacity for creativity and thereby encourages status. Consequently, educated individuals are expected to be more aware of and have more knowledge on a new technology than their less educated household (Akinola and Young, 1985).

The number of cattle owned by a household is a key factor in the biogas status process because they provide cow dung, the major substrate for family-sized digesters in Ethiopia. The number of cattle owned by the household is used as an indicator of the availability of feedstock for the digesters. For a biogas unit to run effectively and efficiently, all three components (bio-digester, animal unit and fodder component) need to be close to each other for easy running of biogas. It was reported that the greater the number of cattle owned, the higher the probability of the household using biogas technology (Walekhwa et al., 2010; Kabir et al., 2013).

Source of income is also another important factor in status of technologies. The source of income in rural area to be expected from agriculture, livestock, off-farm like business, wage employment, daily labor can influence status of biogas technology. Households with higher income levels are expected to use biogas technology more than their poorer counterparts. Household income is thus expected to carry a positive sign (Walekhwa et al., 2010).

2.7.2. Organizational Characteristics

Organizational support is another issues touching status of biogas technology. According to Kalineza *et al.,* (1999) rejection or acceptance of a new idea largely depends on how the information is relayed from the source, which is mainly from extension service. Extension is known to transform awareness, information, and technology promotion among individuals. The study by Baidu, (1999) observed that status is higher for farmers having contacts with extension agents working on new technologies than farmers who had never experienced any extension contacts.

Information distribution is a key process in bringing awareness about the presence of a new technology. After being aware of a new technology, people would accumulate knowledge and then test the technology and status is expected to happen after people become satisfied with the results of the test. Thus, People with more access to information are expected to benefit much from the technology introduced in their areas (Warschauer, 2004).

Other stakeholders like non-governmental organizations (NGOs), Community based Organizations (CBOs) and functional groups or clubs working at grassroots level can play advantages to promote the technology by motivating farmers through disseminating actual information on technology benefits through workshops and seminars and conduct users training capacity building, to facilitate operations and maintenance activities and be instrumental in penetrating rural needs communities. The existing and or potential users are also the key stakeholders of the technology. Satisfied users are very good motivators and disseminators of the technology through sharing of their views to potential users (Ghimire, 2008).

2.7.3. Technical Characteristics

Technical characteristics are also an issue influencing contribution of a technology. Rogers (1995) identified five major technical characteristics associated with high rate of availability of technology include the relative perceived advantage, compatibility with the local culture, low technical complexity, train-ability and afford-ability. Another technology specific characteristic is the status of a technology under individuals' conditions. Poor status of a technology can discourage people from accepting it.

Study conducted by Batz *et al.,* (1999) revealed that technologies with short-term assistances are more preferred than those perceived to have long term benefits since long periods required for realization of welfares of the technology make them more uncertain and less attractive. Governmental support to such technologies is more crucial, where the support can be in form of subsidies, loans and provision of technical services to encourage people to accept the technologies.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location, Population and Topography

The study was conducted in Bishoftu town, based on the Central Statistical Agency in 2007. Bishoftu has an estimated total population of 131,159, of whom 64,642 are men and 66,517 women. Bishoftu town is located at latitude and longitude of 8°45_N 38°59_E /8.75°N 38.983°E, respectively, and at an elevation of 1920 meters above sea level with an area coverage of about 5,444 hectares. It is found in East Shoa zone in the Oromia Region. The town has got a first rank urban grade level as per to the classification of urban grade levels of Oromia Region urban centers. Bishoftu town is found at about 47kms to the southeast of Addis Ababa and situated between Dukem and Mojo towns along Addis Ababa-Djibouti road **(**Gezahegn, 2009).

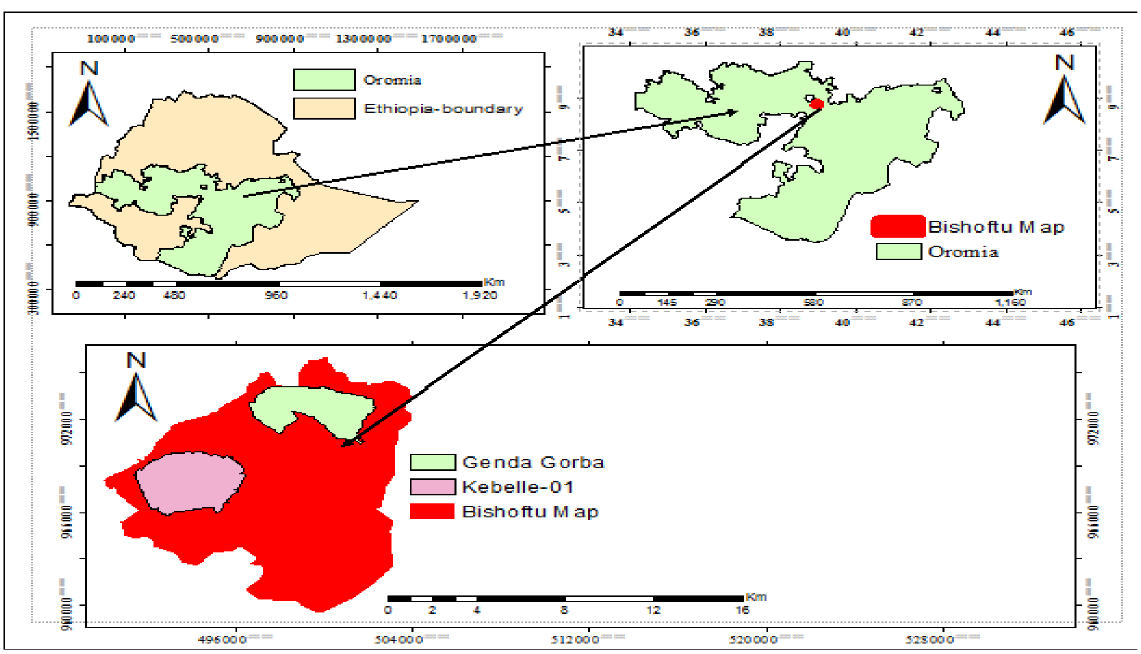

Figure 5: Location map of the study area

3.2. Energy Sector

In Bishoftu town biomass-based energy in the form of firewood and charcoal is the main source of energy for cooking (Zebider, 2011). Biomass wastes like crop residuals and dung cake are also used for energy source. Additionally, kerosene, electricity and biogas are others source of energy for lighting in the town. Renewable energy like improved stove and biogas technologies has also been promoted in the area.

Fixed dome model (local name- 'SINIDU') with different volumes including 4 m^2, 6m^2, 8m^2 and 10m^2 were constructed by the National Biogas Program Ethiopia /NBPE/ with Adea water and energy office and NGOs like PSDA. In the study area only one fifty nine domestic biogas digesters were constructed till the survey was conducted (AWMEO, 2017). The households use the biogas for cooking and lightening.

3.3. Sampling Technique and Sample Size Determination

3.3.1. Sampling technique

A multi-stage sampling technique was followed in this study. The biogas plant user's households that participated in the study were determined using the formula designed by Yemane (Yamane, 1967) and 10% of household was involved in the study from the selected kebeles. The first sampling stage used in this study was related to selected kebeles. Accordingly, based on the contribution and status of household level biogas technology and higher availability of biogas plants, Kebele 01 and Genda Gorba kebeles were purposely selected. In the second sampling stage, households were classified into two groups (namely users and non-users of biogas technology). Users and non-users, households of biogas technology were nominated for this study by using a simple random sampling technique so that each household has an equal probability of being chosen. This approach was preferred due to its simplicity and easiness to conduct and its ability to provide equal opportunity to be included in the sample, hence low degree of sampling error (Rwegoshora, 2006).

3.3.2. Sample size determination

The total sample size was determined by using the approach from (Yamane, 1967) and confidence interval level 10% (0.1) (*e*), the total sample size is determined as;

$$n = \frac{N}{1 + N(e)2}$$

Where "n" is the sample size, "N" is the population size (total household heads size), and "e" is the level of precision. In the two kebeles, there were a total of 1271 none users' household and 59 biogas users' household.

Therefore, $n = \frac{1271}{1+1271(0.01)}$ = 93+3=96 (non- users' household) and $n = \frac{59}{1+59(0.1)^2}$ = 37 (biogas users' household). Hence, totally the sample sizes for this study were 133. To determine sample size in each kebele, proportional to population size (based on the total number of biogas user and non-user households in each kebele) was employed (Table 4). List of biogas users of each kebele was provided by Water, Mineral and Energy office and the list of non-user households was provided by respective kebele executive officers.

Table 4 : Proportional Sample Size Of Biogas Users and Non-Users

Name of kebele	Number of HH		Sample size		Total sample size
	Non-users	Users	Non-users	Users	
Kebele 01	704	24	51+2=53	15	68
G/Gorba	567	35	41+2=43	22	65
Total	1271	59	96	37	133

Source: Own computation, 2018

3.4. Data Collection Methods

Both qualitative and quantitative methods was employed due to the nature of the study. The qualitative approaches enable the researcher to make an in-depth examination of the variables related to users and non-users biogas technology (Rwegoshora, 2006).

A combination of methods was used to collect both qualitative and quantitative data. These include structured and semi structured interviews, checklists for focus group discussion and field observations. The use of a combination of methods in data collection was due to diversity of information that was required to achieve the objective of the study. The interview guide for this study consists of both open and closed ended questions. Open ended questions were asked information relating to actual and expected returns on respondents and study area characteristics and their relations to household level biogas technology. Closed ended questions on the other hand were intended to capture information relating to respondents‟ attitude towards the household level biogas technology.

Ten key informants were used to obtain data at the town and it's surrounding by involving officials in the natural resource, energy departments and NGOs. Whereas at the kebeles level: executive officers, kebeles chairpersons and cell leaders were involved. The information generated from discussions with these respondents was helpful to confirm some findings from household respondents and making relevant recommendations.

From eight focus group discussions, qualitative information such as general opinion, awareness and attitude towards biogas technology was collected. The advantage of this method, according to May, (1993) is that it allows the interaction with a range of key informants and useful in verifying and clarifying information and in filling in gaps of information was caused by inadequate information gather from the interviews and observations. Field observation was occurring, simply watches people as they do and say things. This enables the generation of first hand data that are uncontaminated by factors standing between the investigator and the object of the research (Nachimias, 1976). Furthermore, observation helps to study some facial expressions, gestures and other behaviors during interviews which described the hidden or doubtful responses during interactions between interviewer and respondent.

3.4.1. Data sources

3.4.1.1. Primary Data Sources

The primary data was obtained from primary sources including household survey, focus group discussions, key informant interviews, and field observation.

3.4.1.1.1 Household Survey

A set of closed ended and open ended questionnaires was developed and administered to respondents. The questionnaires were developed in English and translated into Afaan Oromo language. The questionnaire was useful in collecting general information about households' characteristics, the status of biogas plants and its contribution to the livelihoods of local communities. The questionnaire survey was held with the head of households. The questionnaire was pre-tested on two biogas user and non-biogas user household heads before the formal survey was conducted, and modified slightly for clarity. Both qualitative and quantitative questions were included in the questionnaire (appendix, 1). These questions were focused on basic issues which include household characteristics, environmental characteristic and biogas technology characteristic. To develop the respondent's trust, each respondent was well informed about the purpose of the survey and why he/she was chosen for the interview. Before the actual data collection the enumerators were well practiced the questionnaire with the local language (Afan Oromo) during orientation.

3.4.1.1.2. Focus Group Discussion

A focus group discussion was organized to help issues which needed more clarification after administration of questionnaires. An eight focus group members involved in discussions. Focus group discussions were undertaken within users and non-users of biogas technology independently. The focus group discussion (FGD) is a qualitative data gathering technique that uses the interaction between purposefully selected set of small groups of participants to discuss issues and concerns based on a list of key themes drawn up by the researcher/facilitator (Branigan and Mitchel, 2002). Having this, FGDs' was held in each of the selected kebeles. Each group involved individuals from young, old, male and female and different education level to avoid specific group's idea dominancy. To guide the discussion, checklists were designed specifically to the research issues (appendix 7) .

3.4.1. 1.3. Key Informants Interview (KII)

The interview proceeded as a method for data collection partly due to its cost effectiveness and its strength of capturing empirical data in both informal and formal settings (Kothari, 1990). KII was employed in order to support the data, which was collected from household surveys. Informants were interviewed in their homes during the weekend, time to find them easily and get genuine information. The interviews were conducted in Afan Oromo language and for those who cannot speak and hear Afan Oromo language, the interviews were undertaken by translating the questions into their Amharic language. The key informants were those experienced and knowledgeable on biogas technology. Ten key informants were selected with the help of energy experts of the district (Appendix 11)

3.4.1.1.4. Field observation

An observation schedule was developed to gather information in the field. Observation provided an opportunity to have a better understanding of what was happening on the ground. The technique ensured information gathered was free from respondent bias. An observation guide helped in understanding the conditions of the biogas plants whether it is functional or not. Furthermore, observation helped to study some facial expressions, motions and other behaviors during interviews which described the hidden or doubtful responses during interactions between interviewer and respondent.

3.4.1.1.5. Data collection procedures

Since the study was performed in two kebeles for survey and practice, first all data related to findings were collected from one kebele then followed to others kebele. Notes, survey type and practice type were separately conducted in different time. Two enumerators and one facilitator have involved in data collection. In order to collect real data from the respondents the enumerator and facilitators took half day training about the questionnaires. The data were collected within almost one and a half month (December, 2017 and January, 2018).

3.4.1.2. Secondary Data Sources

It was collected from available sources of information such as published and unpublished documents. The major sources for this information were relevant government offices' and NGOs' including data from books, newspaper, reports and survey, records, articles and other publications or related research papers, Common at early stages.

3.5. Estimation of fuel wood saved by using biogas plants

To estimate the contribution of biogas technology in reducing firewood, sixteen sample sizes from both users and non-users household were purposefully selected to compare the impact of biogas on fuel consumption. This practice was done by comparing fuel consumption between households for a period of one week.

First the households were stratified into two groups, i.e. biogas users and non-bogus users. After stratification, the status of biogas digesters in the study areas were observed and identified the fully functional of biogas digesters.

3.6. Data processing and data analyzing

3.6.1. Data processing

Data collected through interviews and field observations were coded and entered into the Microsoft Excel. Data cleaning was done by running frequencies of individual variables and later were analyzed. Then clean data were exported to the Statistical Package for Social Sciences (SPSS, 16) for further analysis.

3.6. 2. Methods of Data analysis

3.6.2.1. Descriptive Analysis

First the data were summarized using Microsoft Excel. Then, SPSS version 16.0/23 software was used to analyze the collected data. Tables, pie charts, graphs and figures were used to present the analyzed data. Descriptive statistics were employed to determine and assess the following aspects: respondents' demographic and socioeconomic characteristics and their attitude towards biogas technology.

3.6.2.2 Independent sample t-test

Independent sample t-test and chi square were employed to test the existence of a significant difference between the means of each variable for users and non-users of biogas technology.

3.6.2.3. Fuel Replacement Values of Biogas Energy

According to SNV (2010) 1m^3 of biogas has fuel wood replacement value of 5.56 kg. The total biomass of the tree was calculated by using the equation below that could be considered as an average of all species:

$W = 0.25 \times D^2 \times H$ -----------------------------(1) (For trees with D<11 feet)

$DW = W \times 72.5\ \%$

Where: W = Above-ground weight of the tree in pounds

D = Diameter of the trunk in inches

H = Height of the tree in feet

DW= Dry weight of the tree in pounds

72.5%= average dry matter content of the tree (Scott *et al*; 2005)

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

This chapter presents the key findings of the study. The chapter is categorized under four subsections. The first sub-section provides the current status of biogas plants. The second sub-section deals with estimation of proportion of fuel wood consumption reduced by using biogas plants and the third sub-section presents the contribution of biogas technology to the livelihood of local communities and the fourth sub-section deals with identified households' attitude towards the benefits of biogas technology.

4.1. The Current Status of Biogas plants in study area

From the study findings in Table (5) about 27.8% of respondents owned a biogas plant. This indicates that biogas status in study area is low.

Table 5: Size and Current Status of Biogas Plants in the Study Area

		Respondents	
	Categories	N	%
Ownership biogas plant	yes	37	27.8
	No	96	72.2
Size of biogas plant	4m3	1	2.7
	$6m^3$	10	27
	$8m^3$	24	64.86
	$10m^3$	2	5.4
	Total	37	100
production of biogas	Function	37	27.8
	Non function	32	35.2

Source: field survey, 2018

The majority of bio gas users have a biogas digester of $8m^3$ (Table 5). This is basically expected that a family sized digester which can be run with large number of cattle as they can produce enough substrate for the digester. The results from Table (5) further indicate that about 27.8% of biogas plants are in working condition. This indicates that there was a less status in the distribution of biogas plants by government and stakeholders. The proportion of non-functional biogas plants 35.2% is smaller than the finding of Wawa, A.I., (2012) which showed that about 47% of installed biogas plants in the study area were not functioning. Low function of biogas digester is an indication of low status of biogas technology use.

As the account of respondents, the main reason for non-function of biogas plants were due to feeding related problem. The results in Table (6) indicated that, 35.2% of non-functioned biogas plants were due to lack of feedstock which is related to the amounts of cattle and their management system. Some respondents have been managing their cattle by the outdoor grazing system. This management system can limit cattle dung spatially for a small number of animals owned. This situation can influence the status of biogas plant directly. Moreover, focus group discussants and key informants witnessed that sometimes there is a problem of delay in providing maintenance service and spare parts. (Table 6).

Table 6: Reason for Non-Functionality of Biogas Plants in Study Area

Reason	Bio gas users	
	No of respondents	%
Feeding related problem	27	84.375
Insufficient labor	2	6.25
Inadequate water	3	9.4
Total	32	100

Source: field survey, 2018

Table 7: Availability of Technical Service in %

Variable	No of respondents	In %
Easily available	10	27
Available but not frequent	25	67.6
Not available	2	5.6
Total	37	100

Source: field survey, 2018

The second main and very essential reason for non-function of biogas technology in study area is due to lack of availability of technical service (table 7). Biogas plant types in study area are fixed dome model (local name- 'SINIDU') which could be recommended only where construction can be supervised by experienced biogas technicians (Kauzeni *et al*, 1989).

New technology such as biogas need technical assistance frequently to check their status and early maintain them; unless dissatisfaction of bio gas users due to poor status of biogas plants in the study area spread negative information about biogas technology. Study by Nasery (2011) found out that when people at the grassroots had access to trained technicians who provided construction and maintenance services for biogas plants, many households were able to use biogas and production of biogas were sustainable. Thus in this study, access of technical services is expected to influence biogas technology status. This results Similar with findings reported by Bensah and Brew, (2010) who indicated that lack of skilled personnel in repair of biogas plants had led to most being abandoned and hence, los acceptance.

Figure 6: biogas plant that has been abandoned due to lack of maintenance

Source: Photo taken during field observation, 2018

4.1.1. Socio-Economic Profiles of the Sample Households

4.1.1.1. Age status of respondents

Results in Table (8) indicate that the biogas users of mean and standard deviation are 49 and 10.23 respectively. Whereas the mean and standard deviation of non-biogas users are 38.54 and 14.69, respectively. The result indicates that the mean age of biogas users is greater than the mean age of biogas non-users. The statistical result also revealed that, there is significant difference between age of biogas user and age of biogas non-user (t-test, $P<0.001$). This shows that the age of household head is directly influenced status of biogas technology in study area.

Table 8: Age Of Household Head In Study Area

Variable	Categories	N	Mean	Std.	t-test	Sig(p)
	Biogas users	37	49	10.23		
Age of HHH	Non-biogas users	96	38.54	14.69	3.97	.000***
	Total	133				

Note: - *** indicates the significance at 99% confidence interval: Source: field survey, 2018

4.1.1.2. Sex status of the household head in the study area

Table 9: Sex Of Household Head And Biogas Technology Status In Study Area

Variable	Categories		biogas status				
			users	Non-users	Total	Ch^2-test	p-value
	Male	N	35	96	131		
sex of HH head		%	94.6	100	98.5	1.25	0.000***
	Female	N	2	0	2		
		%	5.4	0	1.5		

Note: ** indicated that significance at 95% confidence interval

Source: field survey, 2018

Results in Table (9) indicate that majority of household head in study area is found to be male. From interviewed biogas non-users, 100% of household heads were found to be males, while not household head were found to be females; and from interviewed biogas users, 94.6% of household heads were males, while 5.4% of household heads were found to females (Table 9). Furthermore, results in Table (9) indicate that the percent of male household head of biogas users is more than percent of male household head of non-biogas users. Chi-square test statistic also indicates that, there is more significant difference between sex household head of biogas users and sex household head of non-biogas users (chi^2-test, $p< 0.01$) (table 9). This implies that the male headed household was greater than female headed household to use biogas technology if other issues were remaining constant. This finding was consistence with other study by (Ng'wandu *et al*., 2009; *Kabir et al*., 2013) who revealed that, traditionally the male household head use biogas since they dominates decision making as well as resource ownership. Damte and Koch, (2011) who also reported that women household head are more likely use fuel efficient new technology as compare to men household head.

4.1.1.3. Household size for biogas status

Table 10 : Household size of biogas users and non-users in the study area

Variable	Categories	Mean	SD	t-test	p-value
HHsize	User	0.54	o.60	1.45	0.15*
	Non-user	0.35	0.68		

Note: *indicates significance level at 95% confidence interval

Source: field survey, 2018

The household sizes of the sample households ranged from one to sixteen and above: 1-5=90(67.7%), 6-10= 34(25.6%), 11-15= 7(5.3%) and 16 and above 2(1.5%) with an average size of 7.5 persons. This average is much higher than the national level which is 4.7 persons (IPCC, 2008). One possible reason for this difference can be the operational definition used to define the term 'household' in this study. A household was defined to include hired labour and/or relative(s) who shared a single meal regularly.

The average household sizes of the sample biogas users, non-users, were 0.54 and 0.35 persons, respectively. The mean difference between the households sizes of the biogas users and non-users sample households was statistically significant t-test, p>0.15. But the Statistical result shown that there is no significance different between family size of biogas users and biogas non-users (t-test, p>0.15) (Table 10). This indicates that family size of household does not influence status of biogas technology in the study area.

4.1.1.4. Education level of household head and biogas technology status

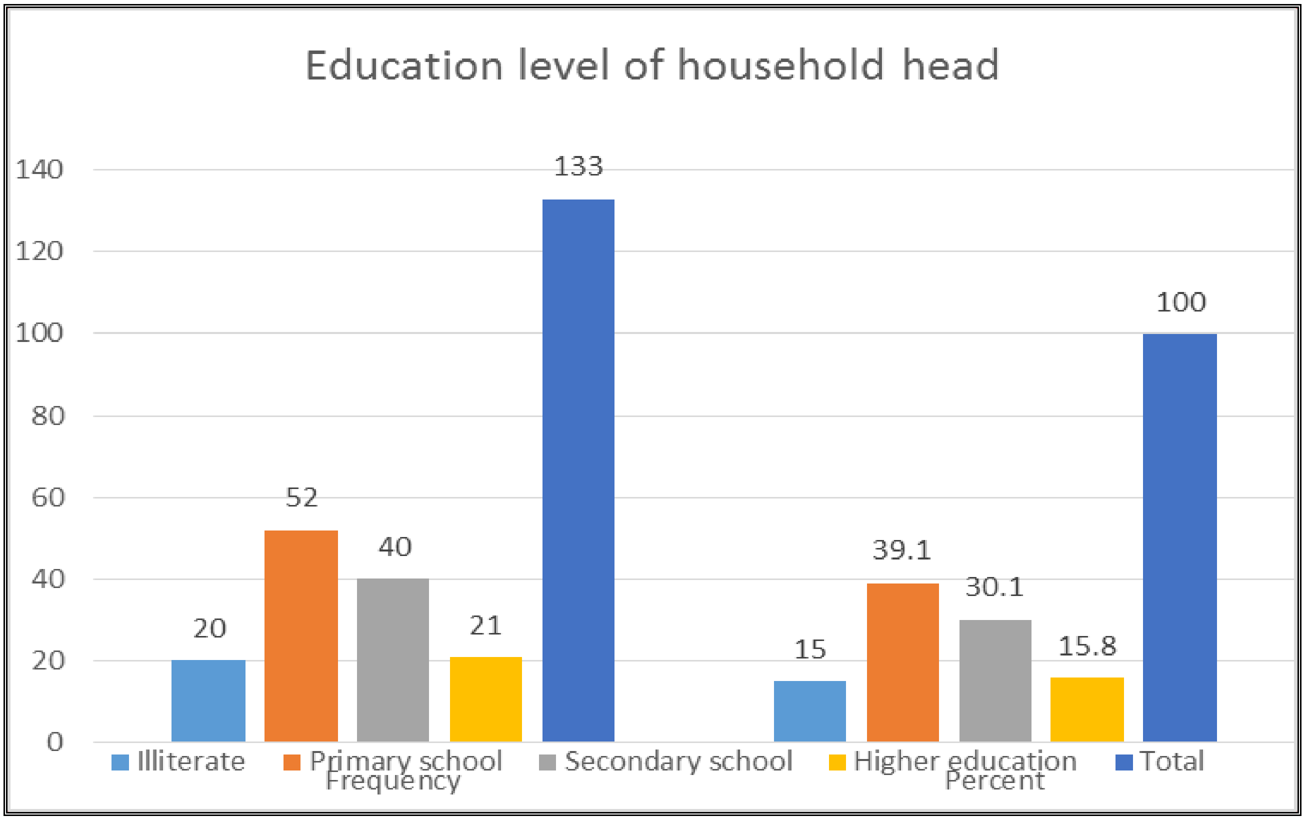

Figure 7 : Education level of household head in the study area

Source: field survey, 2018

The results in Figure (8) indicate that an average educational level of biogas users is 1.57 with standard deviation 0.93 which is greater than the average education level of biogas non-users 1.43 with standard deviation 0.94. The findings further revealed that, statistically there is a significant difference between the education level of bogus users and education level of non-biogas users (t- test, $p < 0.05$) (Figure 8). This implies that the higher education level of household head, the better will be the status of biogas technology as compare to the low education level of the household head. This indicates that higher educated person can easily aware, understand, accept and use new technology like biogas than lower educated person if other issues are remaining constant. The findings are similar to Wayne *et al.*, (2009) who reported that household heads with low education level often have a low capacity of interpreting and responding to information on new innovations. Therefore, education level of household head is one issue that determines biogas technology status in the study area.

Table 11 : Education Level Of Household Head And Biogas Technology Status In Study Area Influenced Biogas

variable	categories	Mean	Std.	t-test	p-value
	Users	1.57	0.93		
Ed.level of HH head	Non-users	1.43	0.92	0.71	0.48*

Note ** indicate there is significance at 95% confidence level

Source: field survey, 2018

4.1.1.5. Cattle, total land size and biogas technology status

Another requirement for status of biogas technology is availability of feed-stocks for biogas digester. Cattle dung is the common feed-stock for biogas plants in the study area. Adeoti *et al.*, (2000) reported that two head of cattle per household per day were adequate for the necessary substrate required daily for gas production from a family-sized digester. So that the number of cattle one of determine the biogas technology status. Based on the results of the present study, the average number of cattle owned by a household was 1.13 with standard deviation 0.35 for biogas users and 0.45 with standard deviation 0.52 for biogas non-users (Table 12). Statistically, t-test statistic clarified that there is significant difference between cattle of biogas users and that of biogas non-users (Table 12). This implies that the number of cattle in study area has influence on biogas status. The commonly practiced modern grazing system of rearing cattle which greatly affect the quantity and quality of cow dung becomes in modern system (zero grazing).

Table 12 : Number of Cattle, Total Land Size and Biogas Technology in Study Area

variable	categories	mean	SD	t-value	p-value
	Users	1.13	0.35		
No. cattle	Non-users	0.45	0.52	7.29	0.000
	Users	0.32	0.47		
farmland size	Non-users	0.45	0.50	-1.40	0.163*

Note: ** indicated that significance at 5% significant level

Source: field survey, 2018

Furthermore, results in Table (12) indicate that an average farmland size of non-biogas users is 0.45 with standard deviation 0.50 which is greater than an average farmland size of biogas users is 0.32 with standard deviation 0.47, in hectare. T-test also suggest that there is significant different between farm land size of biogas users and non-biogas users at 95% confidence interval (t-test, $p<0.05$ (Table 12). This implies that household that owned larger sizes of farmland in hectare has enough area for cash crop production to have more money in addition to produce crop for subsistence. The results are contradict with study by Gulbrandsen, (2011) who reported that more households with larger sizes of land had used the technology as opposed to households with smaller sizes of land in Tanzania.

4.1.1.6. Livestock management system in study area

Cattle management is another determinant of feed-stocks for biogas technology. Due to random sampled system, out of 133 respondents 80 household head do have cattle; while 53 respondents do not have cattle (Table, 13). Results show that, among of those cattle owner respondents ,75% of households manage their animals by zero grazing, while 10% and 15% of households manage their animals by semi grazing and outdoor grazing, respectively (Table, 12). This indicates that cattle of only small number of households walk long distances in search for pastures so that reduce the quantity and quality of cattle dung due to the fact that it is not easy to collect the scattered dung from walking animals. Large amount of dung can collect from cattle sheds dropped all the day and the night which more affects the availability of feed-stocks and that greatly affect the operation of biogas plants. This result is similar to Muriuki *et al*., (2015) who indicated that Cattle management regime was predominantly by zero-grazing (97%) greatly affected the status of biogas technology. And also this finding is contradict with Walekhwa *et al*., (2010) who suggested that free range or outdoor system of rearing cattle could greatly affect the quantity of cow dung available for biogas production. Hence, results show that livestock managements system in study area is one of the issues that influence status of biogas technology (Livestock are sources of manure for biogas production. By using conversion factors determined by Storck *et al.* (1991).

Table 13: Types of Livestock Management System in Study Area

		Respondents	
Variable	Category	N	%
	zero grazing	60	75
Types of livestock management	semi grazing	8	10
	outdoor grazing	12	15
	Total	80	100

Source: field survey, 2018

During focus group discussion in Genda Gorba kebele, members also indicated that livestock keepers migrate with their cattle to distance (about 45 km from their home) especially during dry seasons to search of pastures. During this time, the numbers of biogas plants are stopped operation due to lack of feedstock.

4.1.1.7. Awareness creation activities contribute to biogas technology status

Results in table 13 indicate that the majority of households in study area did not have an excess of any awareness creation activities of biogas technology. From all respondents, about 54.1% of household head never attended on any awareness creation activities (Table 13). The results in

Table (13) further shown that, from within groups, 70.8% of biogas non-users never got awareness; while 10.8% are biogas users never got awareness. On the other hand, almost 25% of biogas users have attended on awareness creation activities either training or demonstration; while non-biogas users did not participate in awareness creation activities of biogas technology. Chi^2-test also indicated that there is highly existence of significant difference between biogas users who attended on biogas technology awareness creation activities at 99% confidence interval (Table 14). The result of the present study is supported by Fei and Yu (2011) who investigated that biogas status is affected by awareness. In contrast, the result of this study is in line with the finding of Wawa, A.I., (2012) which indicates that a majority of biogas users were aware of biogas which implies that household who have attended on any awareness creation activity of technology can easily receive and use it than household who never accessed any awareness creation activities. Hence, shortage of awareness creation activities was one the issues which determine bio gas status in the study area.

Table 14: Respondents Who Attend Biogas Awareness Creation Activities Study Area

variable	categories		Respondents				
			non-users	Users	Total	chi2-test	p-value
Awareness of HH about BT		N	0	25	25		
	Training	%	0	67.6	18.8		
	Visited	N	28	32	60	5.702	0.000***
		%	29.2	86.5	45.1		
	Never attended	N	68	4	72		
		%	70.8	10.8	54.1		

Note: BT = biogas technology, *** indicate significant is at 99% confidence interval

4.1.1.7.1. Sources of Information about Biogas Technology

Information sources are basic to facilitate using and dissemination of biogas technology. In the study area, a significant proportion of respondents (64.86%) had information about biogas technology from energy experts of the district for the first time Neighbors, Television and Radio were additional sources of information, accounting about 16.22, 13.5% and 5.4%, respectively (Table 15).

Table 15**:** Sources Of Information About Biogas Technology

Source of information	Frequency	Percent
Energy experts	24	64.86
Television	5	13.5
Radio	2	5.4
Neighbors	6	16.22
Total	37	100

Source: field survey, 2018

4.2. Estimation of proportion of fuel wood consumption reduced by using biogas plants

Table 16: Weekly Fuel Wood(Eucalyptus tree) Consumption Of Biogas Users And Non-Users

Variable	Categories	Mean	SD	t-test	p-value
Fuel wood(kg)	User	10.77	12.51	-4.667	0.000***
	Non-user	43.08	41.29		

Note: ***indicates significance level at 1%

Source: field survey, 2018

Table 17: Weekly Dung Cake Consumption Of Biogas Users And Non-Users

Variable	Categories	Mean	SD	t-test	p-value
Dung cake (kg)	User	21.95	14.35	-1.571	0.119
	Non-user	33.83	45.06		

Source: field survey, 2018

Table 18: Weekly Charcoal Consumption Of Biogas Users And Non-Users

Variable	Categories	Mean	SD	t-test	p-value
Charcoal (kg)	User	2.28	2.23	-6.545	0.000***
	Non-user	11.03	7.99		

Note: ***indicates significance level at 1%
Source: field survey, 2018

The average daily biogas consumption per household is 2.15 m3, which is high consumption because the households use the biogas in addition to cooking and lighting for boiling of water to wash milk containers and breast of cows (Zebider, 2011). This result is in agreement with the report by Getachew *et al*; (2006) which that report the households generate over 1.3 m3 biogas daily. The annual biogas consumption will be 783.64 m3. According to SNV (2009), 1m3 of biogas is equivalent to 5.56 kg of firewood; therefore the result in a table (16) indicated that each biogas owner household can save 11.88 kg of firewood per day and 4348.08 kg per year. Out of the 59 regular functioning biogas digesters 256,536.72kg of firewood can be saved per year. According to (Zebider, 2011), the household average charcoal consumption before the bogus digester construction was 4.16 kg per day and it is reduced to 1.66 kg after they start using biogas. The finding in table (18) clearly shows that 2.5kg of charcoal was saved per day and 915kg of charcoal was saved per year in each household. Out of the 59 regular functioning biogas digesters 53,985 kg of charcoal can be saved per year. Dung cake consumption in table (16) approved that both begs users and non-users not differ significantly. The reason was biogas plant also not used to baking injera in the study area, then both users and non-users households were used dung cake for baking injera.

This study is similar to the finding of Jetter *et al*., 2012 which revealed that cooking in open fires and rudimentary stoves have approximately 10-20% conversion efficiency, leading to very high primary energy consumption. Advanced wood burning and biogas stoves can potentially reduce biomass fuel consumption by 60% or more. Furthermore, the result of the present study is smaller than the finding of Amare (2015) which indicated that households used 3,596.4 kg of fuel wood annually before the installation of biogas plants an average of 1062 kg of fuel wood per year after installation of biogas plant which results in a reduction of 2,534.4 kg 70.47% /households annually. Also, this finding is supported by the Study of Xiaohua *et al.* (2007) showed that biogas digesters, used in different regions of rural China, reduced the use of biomass fuel by 40% (Xiaohua *et al.*, 2007).

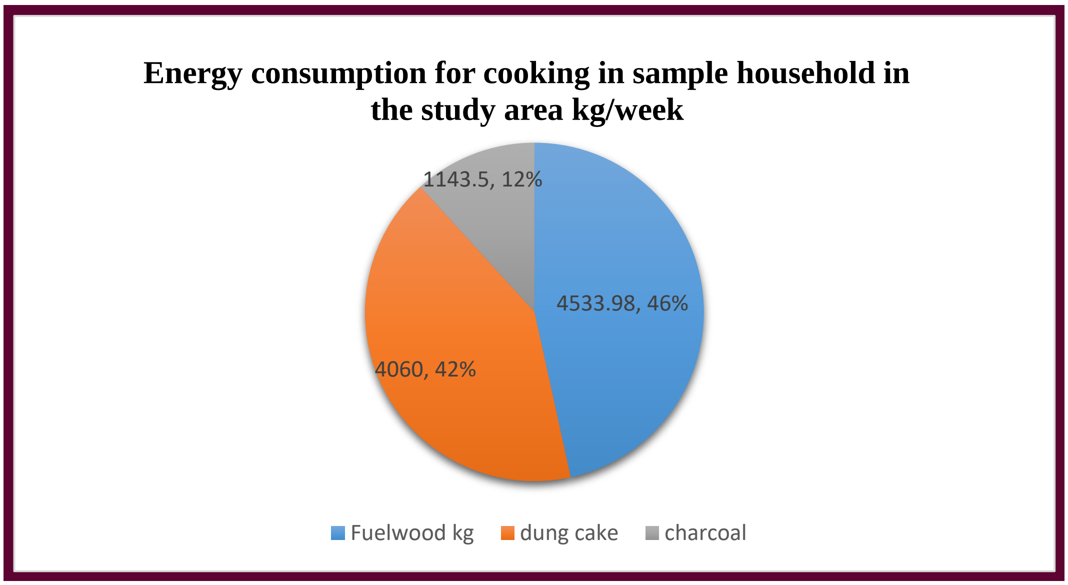

Figure 8: Type of energy consumption in the study area

4.2.1 Fuel wood collectors

The majority of fuel wood collectors (60.9%) were mothers followed by daughters (30.08%) and boys (5.26%). Among the family members, fathers accounted the minimum proportion (3.76%) in fuel wood collection activity (Table 19). This result is in line with the finding of Legesse (2011) which indicated that the proportion of mothers, daughters, child boys and fathers in households with no access to modern fuel were about 34.33%,29.85%, 17.91% and13.43%respectively. This shows that female members of a household are mostly responsible for fuel wood collection, which would eventually influence daughters' access to education.

Table 19: Fuel Wood Collection Patterns Of Household Members

Fuel wood collectors	Frequency	Percent
Mother	81	60.9
Father	5	3.76
Boys	7	5.26
Daughters	40	30.08
Total	133	100

Source: Field survey, 2018

4.2.2. Availability of fuel wood

The primary energy source for domestic use in study area is woody biomass in the form of fire wood and charcoal. The result in figure (10) indicates that, from all respondents, 51.13% of household heads mainly use fire wood, 27.8% of them mainly use biogas and followed by 15.04% of household head mainly use crop residual as source of energy for cooking. This finding also revealed that, charcoal was contributed as source of energy for cooking in study area was used only by small number of households (figure 10). This implies that the constant use of woody biomass as the main sources of energy which has been led to deforestation is high despite the existence of biogas development in the study area. This finding is supported by study (Alemu and Kohlin, 2008) who reported that, in Ethiopia, almost all rural households depend on fuel wood as major source of energy.

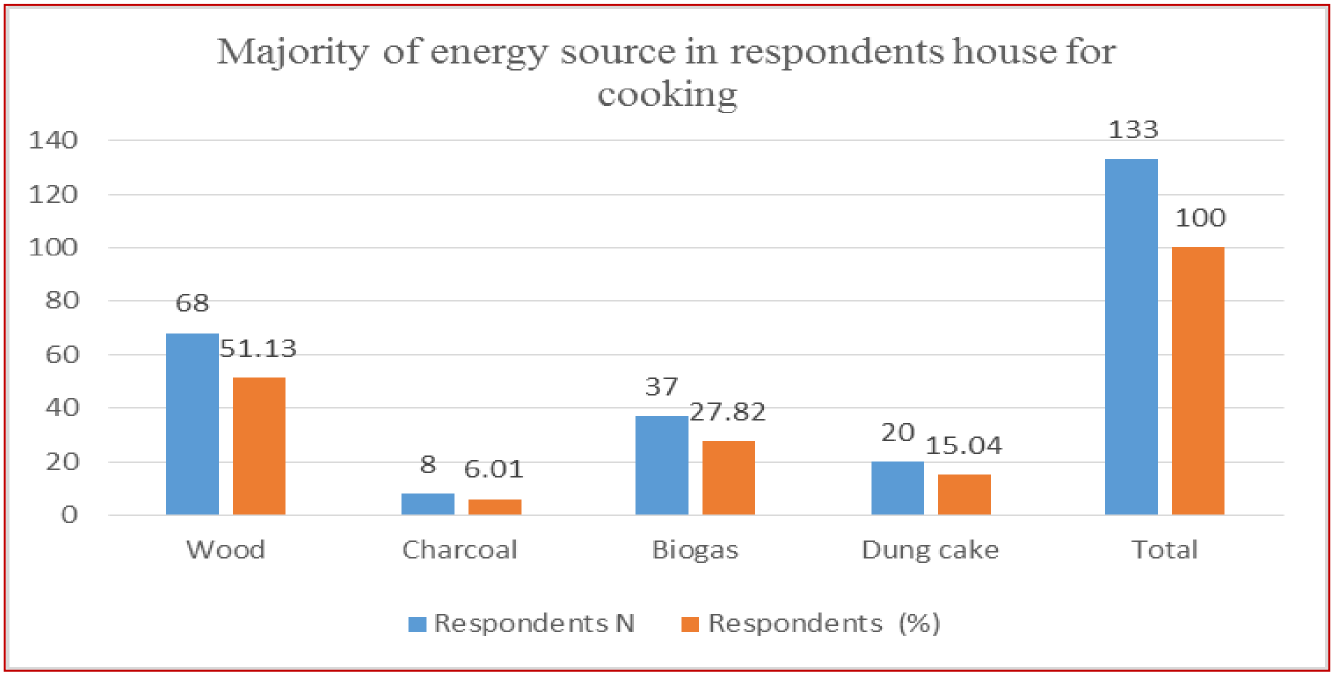

Figure 9 : Majority of energy source in the study area

According to the result of household survey, sources of fuel wood for cooking were obtained from different places (figure 11). Among the interviewed respondents, 34.58% of respondents collect fuel wood from nearby natural forest and 36.84% of respondents bought from market. Furthermore, the result in figure (11) showed that, 14.27% of respondents collect fuel wood from open field and again 8.27% of households collect from own wood plot and 6.01 collect from home garden. The least of fuel wood source, in this study area, is from home garden. The results indicate that majority of households use fire wood and charcoal which guide to sustain deforestation.

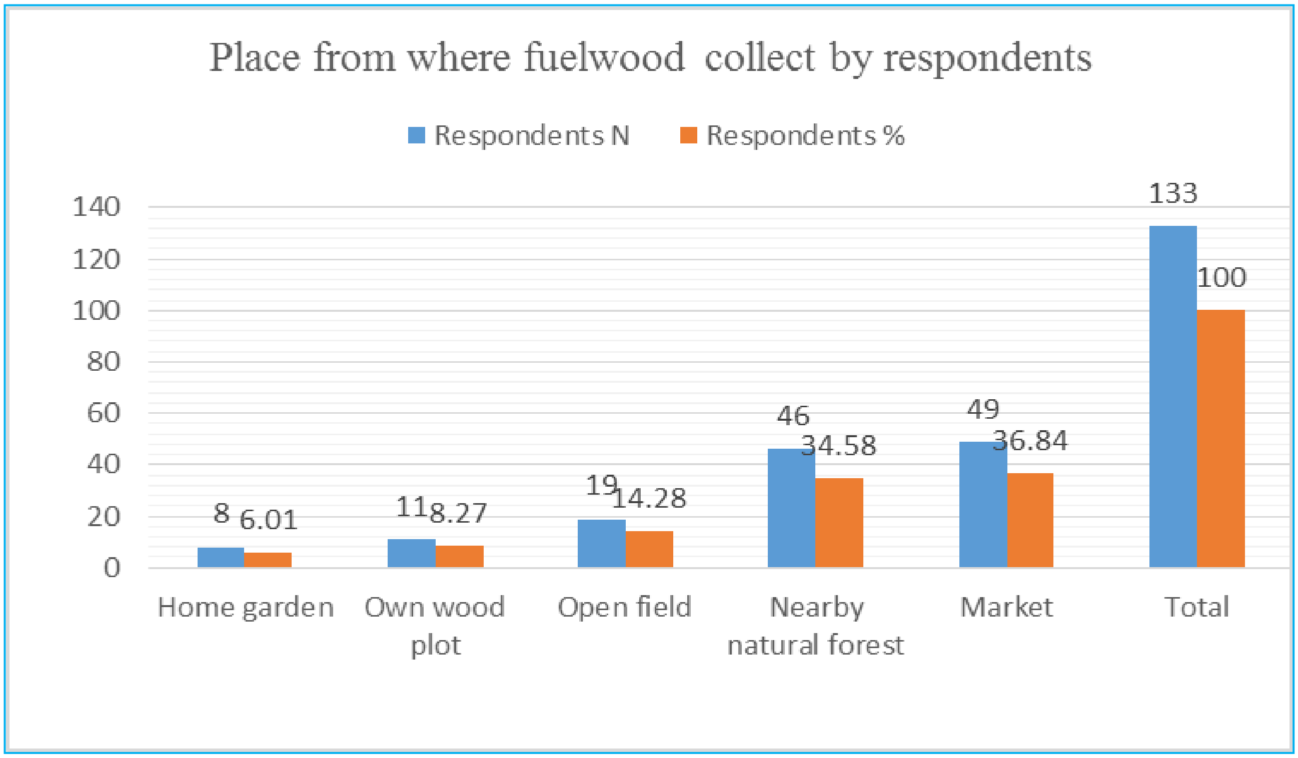

Figure 10: Place from where fuel wood collect by respondents

4.2.3, Source of energy for lighting in study area

The results in figure (12) indicate that the major source energy for lighting is electricity. Among respondents, 42.1% of households use biogas, 27.81% of households use biogas and 15.78% households use kerosene and 8.95% of households use battery. On the other hand, battery are the lowest source of energy for lighting purpose figure (8). This implies that still large number of people in study area use kerosene which are the main sources of air pollution and health problem though the dissemination of some renewable energy like electricity, solar energy, battery and biogas are increased from time to time.

Furthermore, result in figure (12) also revealed that the use of biogas technology for light is low as compare to other renewable energy such as electricity. During field survey biogas users mentioned that the satisfactions of biogas users are complained. Because biogas users do not have TV and charge. The intention of this study was not concern about question of household satisfy from biogas as compare to other alternative energy like electricity which are more common in study area. Therefore, another research will be needed to clarify this question. The interests and satisfaction of households may influence to use technology like biogas.

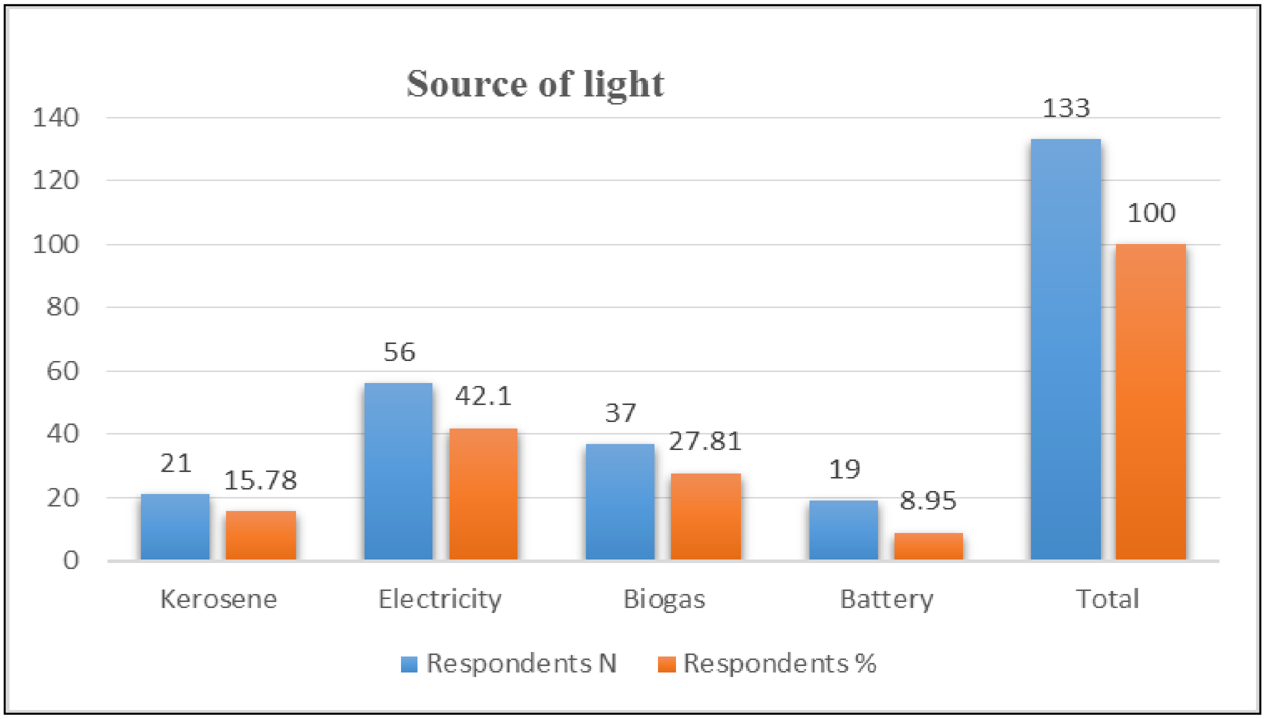

Figure 11 : Source of energy for lighting in study area

Generally, the results of the study showed that each house hold can save 11.88 kg of fuel wood from eucalyptus tree per day and 4348.08 kg per year. Out of the 59 regularly functioning biogas digesters 256,536.72kg of fire wood can be saved per year. The households' average charcoal consumption before the biogas digester construction was 4.16 kg per day and the consumption of charcoal was reduced to 1.66 kg after they start using biogas. This means 2.5kg of charcoal was saved per day and 915kg of charcoal was saved per year in each house hold. Overall out of the 59 regularly functioning biogas digesters in the study area 53,985 kg of charcoal can be saved per year.

4.3 The contribution of Biogas technology for the livelihood of local communities

4.3.1. Time was saved and work load reduced due to biogas plants

The effect of biogas technology on workload reduction was determined based on the estimated weekly average hours spent on various household activities. The household activities which were thought to be influenced by the use of biogas technology were included. These were: 1) collecting wood-fuel and preparing to use (collecting fuel wood, splitting fuel wood, making charcoal, and purchasing fuels) ; 2) collecting dung, feeding the biogas digester and/or making dung cakes; 3) collecting crop residue for fuel; 4) fetching water; 5) cooking food; and 6) cleaning utensils and kitchen. Besides, livestock care and fodder collecting which were thought to have some influence on the use of biogas technology were also considered. According to Keizer (1994), the main reproductive activities of women which were believed to have closer link with the use of biogas technology included collection of cooking fuels, cooking food, cleaning pots, and feeding the biogas digester. Though not included in the time measurement, herding, collecting fodder, and lighting were also mentioned to have some influence on the use of biogas technology. Thus, based on the survey result, the weekly mean hours spent on various household activities and their differences between biogas user and non-user households are shown in table 19.

Table 20 : Estimated Weekly Average Hours Spent On Various HH Activities By Biogas Users And Non-Users Households

S/N	HHactivites	Biogas users	Non-users	(b-a)
1	Collecting wood-fuel and preparing it for use	3	3.8	0.8*
2	Collecting dung, feeding the biogas digester	4.4	3.7	-0.7**
3	Fetching Water	8.9	5.8	-3.1**
4	Cooking food	22	33.7	11.1**
5	Cleaning utensils and kitchen	5.5	8.7	3.2**
	Total	43.8	55.7	11.9**

** And * represent statistically significant differences in mean values between biogas user and non-user households at $p < 0.01$ and $0.01 < p < 0.05$, respectively. (T-test was used to check differences in means.)

Even if the use of biogas technology involved carrying out a few extra duties such as fetching water, mixing dung and water, and feeding the biogas digester, the technology generally assisted in reducing the overall household workload by 11.9 hours per week (1.7hours per day) at $p<0.01$ significant level. Specifically, the average times taken for cooking food, cleaning utensils and kitchen, and collecting wood-fuel and its preparation for use were reduced by 11.1 hours, 3.2 hours, and 0.8 hours per week, respectively (Table 20). The time saved through the use of the technology was devoted partly to leisure time, schooling, agricultural activities and other income generating activities. This study is similar to (Eshete et al., 2006) the feasibility study of the national domestic biogas program in Ethiopia indicated that the utilization of biogas technology can on average lessen the overall household workload by two to three hours per day.

The possible justification for the slightly less time saved from the use of biogas in this particular case study could be related to the non-functional status of the biogas plants. No all biogas plants work to full capacity. Among other things, 37 (27’8%) of the biogas plants had either a non-functioning stoves or lamps. However, saving an average of about 11.9 hours.

4.3.2. The Benefits of Biogas Technology in Improving Health and Sanitation

All 37 (100%) of the sample biogas users realized that the consumption of biogas technology, highly reduced the problem of health through the declined use of traditional biomass fuels. The biogas user respondents were requested to choose from the list of energy-related health problems which they supposed decline following the status and use of biogas technology. Accordingly, eye diseases, respiratory problems like coughing and asthma, headaches, back pain resulting from the heavy load of traditional biomass fuels, injury mishaps during fuel collection, and burning accidents were the health problems that were reported decreasing by 70.1 %, 43.5 %, 32%, 20.5 %), 7.5 %) and 1 % of the respondents, respectively. The result is in line with the findings of Laramee and Davis (2013) in which it was reported that 75 % of the respondents in Tanzania realized the health improvements due to shifting from the use of fuel wood or kerosene to biogas cooking.

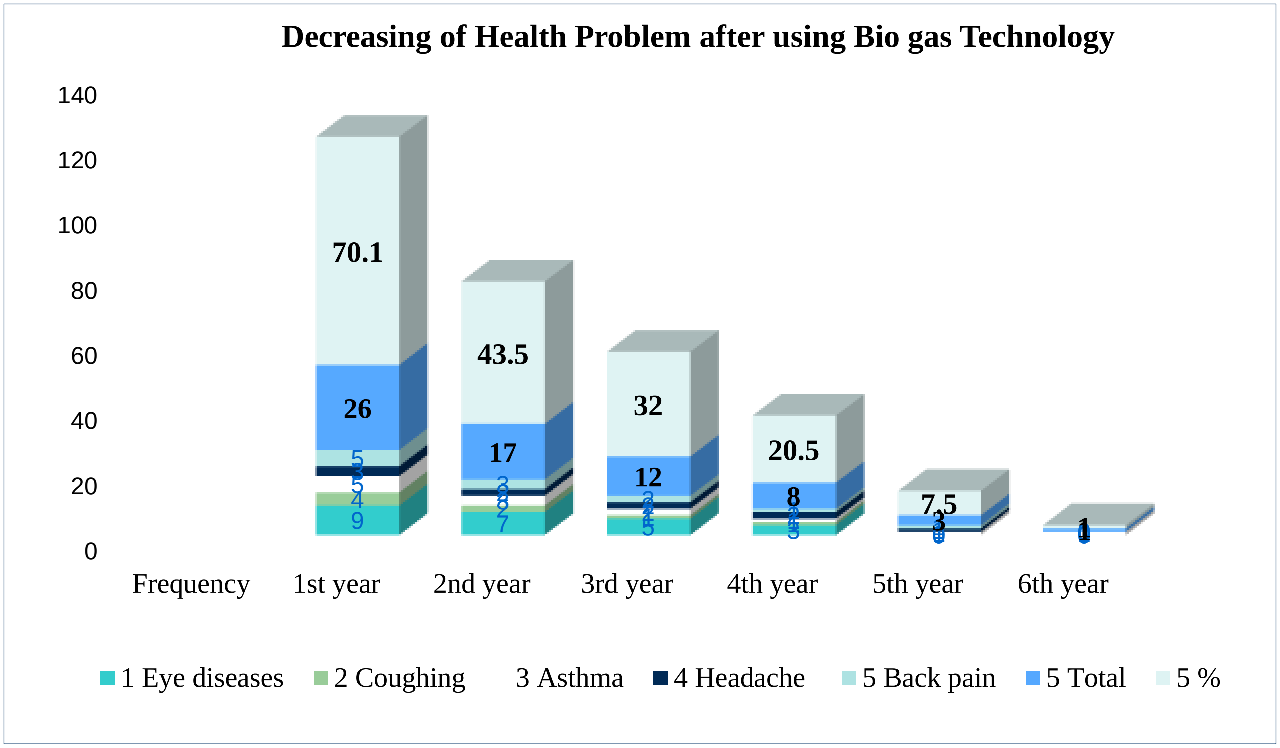

Figure 12: Decreasing of health problem from biogas users in the study area

Besides, as per the group discussants, the use of biogas lamps reduces the need for some students to rent dormitories in the town for the purpose of studying with electric light. Students who rent dormitories usually take cooked food in bulk for a week or so from their parents. In the absence of any food conservation facilities, the food gets moldy within two or three days. As a result, some students face serious health problems that can sometimes lead to school dropping. Moreover, the use of biogas lamp is a great relief for those students who used to study at home with kerosene lamps. While studying with a kerosene lamp, the lamp needs to be brought closer. Otherwise, it will be too dim to read. When it is brought closer, eye irritation and inhaling kerosene soot are inevitable. Moreover, the need to feed the biogas digester daily assists in maintaining the sanitation of the livestock barn through a daily collection of dung. This promotes the health of the livestock and reduces possibility of transmittable diseases from the livestock to humans. This in turn minimizes the exercise of random defecations and possible transmission of contagious diseases.

4.3.3. Social Benefit of Biogas Technology

The result shows biogas users responds biogas technology generates employment opportunities for both skilled and unskilled labor. Definitely, in a study area biogas plant technology expansion makes employment opportunities for masons, plumbers, mechanical engineers, and agronomists. They are usually key promoters of the technology. Building of biogas installations, design and production of appliances and construction equipment's are crucial areas of employment opportunity. The current finding is supported by Lam et al., 2009; Arthur et al., 2011, REN21, 2013. According to Lam et al., 2009; Arthur et al., 2011, REN21, 2013, the users of biogas technology gave us social benefits generally, like: Extra time for social activities, saving time used for firewood collection, enhance prestige in community, improve health of community, reduce workload of women and children, contribute for educational quality by supporting students to study in a well manner way, easy and fast in use, clean, no soot as compared to fuel wood and low running cost after installation costs

4.4. Households' attitude towards benefits of biogas technology

This study is similar to (Abukhzam and Lee, 2010) which indicated that attitude is instrumental in the contribution of a technology and it can be a powerful activator or a barrier towards using of the technology. In this study, the response to targeted questions to assess attitude towards biogas technology (Table 21) showed that most user and non-user respondents had positive attitude towards the technology. This implies that users of the technology have a better access to information about the advantages of biogas technology and they have positively influenced. It also indicates non-users' appreciable access to information and level of awareness although a bit lower than users. About 100% of user and 90.7% of non-user had agreed with the idea that biogas technology reduces household fuel wood consumption rate. On the other hand, the 'disagreement scores' for both biogas user 0% and non-user households was 9.3%.

The findings of this study further show that the proportion of user and non-user respondents who perceived that biogas technology as an alternative energy for domestic use were 100% and 90.7%, respectively (Table 21). In addition, non-users might not be confident to judge whether biogas technology has advantages forwarded to them.

Table 21: Respondents' Attitude towards the Benefits of Biogas Technology

Variable	Agree		Disagree	
	Users	Non- users	Users	Non-users
	Percent	Percent	Percent	Percent
1. It offers cheaper energy	100	92.25	--	7.75
2. It solves fuel wood problem	100	94.75	--	5.25
3.It reduces HH fuel wood consumption rate	100	89.87	--	10.13
4. It improves health	100	87.92	--	13.8
5.It serves as waste treatment system	100	95.65	--	4.35
6.It decreases workload & it is alternative energy for domestic use	100	83.67	--	16.33
Total	100	90.7	--	9.3

Source: Field survey, 2018

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Results of this study revealed that only 27.8 % of respondents owned a biogas plant and about 35.2% of biogas plants are not functioned. Hence the status of biogas technology implementation among households were low. This is due to feeding related problems as a result of small number of cattle and poor management system of cattle and inadequate availability of technical services in the study area.

The results showed that from 59 regularly functioning biogas digesters 256,536.72kg of fuelwood and 53,985 kg of charcoal can be saved per year. This implies biogas technology reduced fuel wood consumption and deforestation in the study area.

The finding show that the biogas plants contributes to improve reduce workload of women and children, contribute for education and social benefits like extra time for social activities, saving time used for firewood collection, enhance prestige in community, improve health of community, contribute for educational quality by supporting students to study in a well manner way, easy and fast in use, clean, no soot as compared to fuel wood and low running cost after installation costs in the study area.

Findings have shown that lack of awareness creation activities have significantly affected people’s attitude towards benefits of biogas technology. This has been the most obstacles to the contribution of biogas technology to local community in the study area

5.2. Recommendation

The following recommendations are made for actions to be taken in order to promote and raise levels of status rates of biogas technology as an alternative energy source for rural communities.

- Energy policies should focus on raising awareness of the community to use modern renewable energy and at the same time to save fuel wood consumption.
- The local government should train to get adequate skilled man power who maintain biogas plants in the study area.
- Promotion work through energy experts, television and radio should be strengthened to maximize rural households' level of awareness about benefits of biogas technology.
- Water, Mineral and Energy office of the district should assign some experts who visit the households' biogas plant at least once a month to provide a timely maintenance service.
- Similar studies should be carried in the study area to solve the technical problems of the biogas plants thereby to come up with an inclusive way forward for the biogas development in Bishoftu Town.

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LIST OF APPENDIX

1. Ethical consideration

Before starting this research participant are voluntarily involved in the research and are informed of all potential risks. Therefore, researcher needs to clearly explain to the research participants the rights and responsibilities of both the researcher and the participants. The objective of this interview is to collect information which was used for the study on "House hold level biogas technology status and its contribution to livelihoods of local communities: The case of Bishoftu, east Shoa zone, Oromia regional state, Ethiopia. This study is going to be conducted for the partial fulfillment of MSc degree in 'Renewable Energy Utilization and Management program at Hawassa University, Wondo Genet College of Forestry and Natural Resources. Your full support and was ingress to respond the question is very essential for the success of the study. Therefore, you are kindly requested to answer all questions and give clear, appropriate and reliable information on the issues. Be sure that the information you provide is only for the purpose of this study. I would like to extend my special appreciation for your cooperation and commitment for the success of this research.

2. Instruction to Researcher or Enumerators

- Greet the respondents in locally accepted style and introduce your self
- Provide sufficient information on the objective of the survey and the importance of the data that they are going to provide.
- Fill the information that stated by the respondent (don't put your own opinion)
- Make the respondents feel free and ease of the communication by avoiding technical terms.

- Create friendly atmosphere of trust and confidence, so that respondents may feel at ease while talking to and discussing with the interviewer

Appendix1: Household survey Questionnaire

A: General Identification

Date of interview: …………………,

Name of respondents: …………………………..

Name of Kebele: ………………………………

B: Household/Institution information

1. Sex of household head (1.Male .... 2. Female…………)
2. Age of household head (year)………………………..
3. Highest level of education of household head …………………
4. Size of household
   a) Those who do provide labor………b) those who do not provide labor…………
5. Major source of income to household …..a) Farming b) Business c) Wage employment d) Other- Specify ……
6. Do you have your own livestock? 1) No 2) Yes
7. If answer of 6 is yes, Indicate number of livestock do you keep A) Cattle …………
   B) Goats ……….. C) Sheep……. D) Donkeys…….E) Chicken/ducks……F) others…….
8. Do you have your own farm land? 1) No 2) Yes
9. If your answer is yes, indicate your farm size in hectare………

Appendix 2: the Availability of important sources

10. Are the following resources available in your area?

Resources	**Availability (use key)**	**Distance to the resource (Kms)**	**Average of Time spent to collect (hr)**
Water for domestic use			
Grazing land for livestock			
Fuel wood for cooking			

Key on availability of resources

1) Readily available (2) is in short supply (3) Not available

11. Main Sources of energy for cooking? a) Kerosene b) Charcoal c) Firewood d) Electricity e) Biogas f) agricultural residuals g) dung cake
12. What is the source of power you use for light? A). Kerosene b). Electricity c).Firewood d) biogas
13. If the source is fire wood and or charcoal, from where do you get these fuels? 1. From forest 2. From trees around home 3. Bought from market 4. Other (specify)
14. Has the time you spend on gathering fuel wood a) increased, b) decreased or c) stayed the same over the last 5 years?
15. Has the distance you travel to gather fuel wood a) increased, b) decreased or c) stayed the same over the last 5 years?
16. If the source of power you use is fuel wood and or charcoal, indicate an average number of fuel wood bundles and or bags of charcoal used per week.

    A. Fire wood (Donkey load……….C. Man load…….) B. charcoal (bag …….

Appendix 3: Awareness of biogas technology at household level

Awareness

17. Have you ever heard about the biogas technology? A) Yes b) No

18. Who gave you information about biogas technology for the 1st time? (i) Biogas researcher

    (ii) Extension officers (iii) Neighbor, Relative, friend who used BT

    (v) NGOs (VI) Others (Specify)

19. What are reasons for not having bio gas technology? use a tick

    a. Do not see the benefit of biogas technology……..

    b. Number of cattle owned..........

    c. Lack of space (land size).........

    d. High Technology costs……………..

    e. Education of household head.........

    f. Not aware of the technology ………

    g. Gender of household head...........

    h. Shortage of household labor……

    i. Lack of loans and subsidies.....

    j. Age of household head……….

    k. Any other.............

Appendix 4: Attitude towards Biogas Technology

20. What is your comment concerning biogas technology as alternative energy source;

    a) Is Suitable technology b) Is Not suitable technology

21. What is your view of biogas as an alternative source of energy?

    A. Very expensive to install

    B. Requires technical skills

    C. Requires education

    D. Requires large land size

    E. Very complicated

    F. Labor intensive

22. If you are given 10,000 birr, what was your priority of investing? A. Invest in biogas technology b. Farm production c. Livestock production d. Petty businesses enterprise

    . Others (specify)……………………………

Appendix 5: Promotion of biogas technology & experience for users only

23. Are there regular promotions, seminars for promotion of biogas technology in your area

a) Yes b) No

24. If No, how can biogas production and utilization are promoted in the study area?

25. Do you have access to loans for biogas construction? 1) Yes 2) No

Experience on biogas technology. For biogas users only

23 When did you start using biogas technology as source of energy (year) ……….

24 What is the size of your digester? a) $6m^3$ b) $8m^3$ c) $10m^3$ d) other…….

25 What do you use it for? a) Cooking b) Light c) Other (specify).............................

26 Who initiated the idea of biogas to you?

a) Government extension officer b) NGOs c) Friend, relative or neighbor

d) Politician e) other (specify)……………………………………………..

27 What was the major reason for starting a biogas plant? a) Own interest b) Acute problem of fuel wood for domestic use c) Encouraged by extension officer & NGOs

d) Influenced by friend with biogas plant

28 What was the source of initial capital for construction of the biogas plant?

a) Own save b) Credit /Loan c) Fully Sponsored by NGOs

d)Own contribution and subsidy from NGOs e) Own contribution and subsidy from the Government f) Other sources (Specify)

29 Is your biogas plant functioning? a) Yes b) No

30 If yes what are the benefits of using the technology: a) Easy and fast in use b) Clean, no soot as compared to fuel wood c) Low running cost after installation costs d) Saving time used for firewood collection e) Others (specify)…………….

31 If No give reasons. a) Lack of technical services b) Feeding related problems

c) Insufficient labor d) Cost of maintenance e) Lack of water

32 How frequent are the Biogas project staff visit you to see the progress of the plant? a) Often

b) Not often c) Never came back since installation of the plant

33 Are technical services available when needed? a) Easily available

b) Available but not frequent c) Not available

Appendix 6: Observation Schedule

1. Biogas plant a) Present b) Absent

2. Status of biogas plant a) Complete b) Incomplete

3. Structural problems. a) Cracked digester b) Chocking of outlet/inlet

   C) Broken or leaking pipes d) Shortage of cow dung.

4. Presence of cattle a) yes b) No

5. Cattle rearing method a) Free range b) zero grazing

Appendix 7: Focus Group Guide

1. What are the major energy sources in your area? …………………………………………
2. Do you see a need for alternative energy sources? If yes which alternatives do you think are appropriate to your area? ………………………………………………………………..
3. What is the acceptance status of biogas technology in your area, do you think the technology has been used to the expected level? ....
4. If you think household level biogas plant implementation is low what are the reasons? ………………………………………
5. Some people accepted the technology and stopped using it in the way. What could be the reasons? ………………………………………………………………………………

Are people really aware of environmental and health problems that come as a result of using firewood as a source of energy...

6. For acceptors; do you have enough knowledge about biogas to the extent of being able to share the information with others? A) Yes B) no. If not what areas do you think need more education / training? ....
7. In your opinion what kind of strategies can be put in place to enhance household level biogas in Bishoftu?

   A)…………………………………..b)……………………………………

   C)…………………………………..
8. Is there sufficient water in this region for biogas production?
9. List the impact of household level biogas technology a) Age of household head, b) Size of household c) Economic status of house hold d) Education level of household head e) Number of cattle owner f) Size of land g) Lack of technical service h) Gender of household head i) Water problems

Appendix 8: Interview Guide for Organizations Dealing with Biogas Technology

1 Name of Organization ……………………………………….………………

2 When your organization did started disseminating biogas Technology in Bishoftu? ………………. (Year)

3 What motivated your organization to engage into biogas technology?

4 What was the targeted group of people to be reached by biogas technology as per your initial plans? …………………………..……………………………

5 At what extent does the targeted group me……..... If not met as Expected, what do you think are the reasons?

6 How many kebeles in this district have you reached for biogas technology …

7 Do you think many people are aware of biogas technology in Bishoftu? What percentage of population? ……………………………..……..

8 How many households in a District have used the technology through your organization?

9 If the implementers‟ percentage is small compared to the expected, what do you think are the factors for people not accepting biogas technology?

10 How many biogas plants you installed are functioning?

11 What are the major complains received from biogas users on the technology?

12 What technical problems affecting functioning of biogas plants?

13 Did your organization give any support/ contribution to people who accepted or who intend to use biogas technology? a) yes b) no

14 If yes what kind of support and at what level?

Kind of support	**Level of contribution (%)**
(i) ………………………………………	……..………………………
(ii)………………………………………	……………….……………
(iii)………………………………………	……………………………

15 Are the technical assistance/services available when needed by biogas users? How frequent do your technicians visit people who accepted the technology?

a) Often b) Not often

16 What are the problems facing your organization in disseminating the technology?

17 What support does your organization receive from the Government in technology dissemination efforts?

18 What is your opinion on Governments‟ involvement in biogas technology Dissemination? ....

Appendix 9: Check list to the Government Offices Dealing with Biogas Technology

1 When did the disseminating of biogas Technology started in Bishoftu? ……………. (year)

2 What are the promotion strategies and support services offered by office to Biogas projects and the community to facilitate promotion of biogas technology?

3 Do you think many people are aware of biogas technology in District? A) yes b) no

4 What percentages of population was afforded awareness? …………………..……..

5 What are the challenges facing your office on promotion of renewable energy technologies particularly Biogas technology.

6 How many kebeles in this District have you reached for biogas technology? ………..

7 What is the percentage of acceptors as per population of the area? ……………

8 What percentage of biogas plants installed in District is functioning? ....

9 Are the technical assistance/services available when needed by biogas users? How frequent do your technicians visit people who used the technology?

10 What are the major complains received from biogas users on the technology?

11 From your experience in which setting does Biogas technology is more appropriate?

(i) Rural, b) Sub-urban, c) Urban d) Both

Reasons for your response ………………………………………….

Appendix 10: Question for moderation part

1 If you don't have/ if you have biogas digester, what was/is the fuel you use most?

1. Wood 2. Charcoal 3.Dung cake 4. Agricultural residuals

2 How much fuel did you consumption in a week?

No.	Type of fuel	Amounts of fuel Consumption per week					Remark
		Donkey load	Man load	Number/cake	Kuntal	Letter	
1	Wood						
2	Dung						
3	Crop residues						
4	Charcoal						
5	Kerosene						

Appendix 11: Questions for KII

1. What is your view on the current status of fuel wood sources? Why?

2. Is charcoal production common in your locality?

3. When was dissemination of biogas technology started in your locality?

4. What are the problems that have been faced to produce biogas?

5. Which institutions are working and supporting dissemination of biogas technology?

7. How many of biogas plants are non-functional?

8. Have you offered any training about biogas technology? If no, try to justify the reason why?

BIOGRAPHICAL SKETCH

The MSc candidate was born on January 08/1976 G.C in Selka kebele, Sinana District, Bale zone, and Oromia Regional State, Ethiopia. He attended his elementary and secondary school education at Selka Primary School and Batu Terara Comprehensive Secondary School respectively. Then, He joined Arba Minch University to pursue his BSc. degree in 2006 G.C and certified in Chemistry after four years. Finally, he joined Hawassa University, Wondo Genet College of Forestry and Natural Resources to pursue his graduate study in Renewable Energy Utilization and Management in 2016 G.C.