CHALLENGES OF HOUSEHOLD BIOGAS TECHNOLOGY ADOPTION AS AN ALTERNATIVE ENERGY SOURCE IN GOZAMIN DISTRICT; EAST GOJJAM ZONE, ETHIOPIA.

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MSc .THESIS WORK

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ADVISOR: MENFESE TADESSE (PhD)

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APPROVAL SHEET- I

This is to certify that the thesis entitled *"Challenges of Household Biogas Technology Adoption as an Alternative Energy Source in Gozamin District; East Gojjam Zone, Ethiopia."* submitted in partial fulfillment of the requirements for the degree of Master of Science(s) with specialization in Renewable Energy Utilization and Management of the Graduate Program of the school of Natural Resource and Environment Studies, Wondo Genet College of Forestry and Natural Resources, and is a record of original research carried out by ***Adem Ahmed Mohammed***, under my supervision, and no part of the thesis has been submitted for educational institutions for achieving any academic awards. The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommended to be accepted as fulfilling the thesis requirement.

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APPROVAL SHEET-II

We, the undersigned, members of the Board of examiners of the final open defense by ***Adem Ahmed Mohammed*** have read and evaluated the thesis entitled *"Challenges of Household Biogas Technology Adoption as an Alternative Energy Source in Gozamin District; East Gojjam Zone, 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(s) in Renewable Energy Utilization and Management.

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DECLARATION

I, Adem Ahmed mohammed, hereby declare that this thesis is my original work and has not been presented for a degree in any other University. Again, all the materials used in the thesis have been indicated and acknowledged duly with references.

Name of student	Signature	Date
Adem Ahmed	…………………	……………….

DEDICATION

This paper is dedicated to the Almighty Allah, to him be all the glory and honour for by his mercy and grace, I have been able to accomplish this work. Also to my beloved mother Asya Osman, my children Hayat Adem, Mubarek Adem and Izedin Adem.

LIST OF ABBREVIATIONS AND ACRONYMS

ABPP--------African Biogas Partnership Programme

AFREA------Africa Renewable Energy Access programme

CO_2e----------Carbon dioxide equivalent

CSA ----------Central Statistical Agency

EEA----------Ethiopian Energy Authority

EEPCO -----Ethiopian Electric Power Corporation

EGZWIE…..East Gojjam Zone Water and Energy

EREDPC----Ethiopian Rural Energy Development and Promotion Center

FAO----------Food and Agricultural Organization

FDRE--------Federal Democratic Republic of Ethiopia

GHG---------Green House Gas

HIVOS ------Humanist Institute for Cooperation in Dutch

MoWE-------Ministry of Water and Energy

MoWIE------Ministry of Water, Irrigation and Electricity

MW………..Ministry of Water

NBPCO------National Biogas Programme Coordination Office

NBPE--------National Biogas Programme of Ethiopia

NBPSC------ National Biogas Programme Steering Committee

NGOs--------Non Governmental Organisations

PID-----------Programme Implementation Document

SNNP -------Southern Nations Nationalities and Peoples

SNV---------The Netherlands Development Organization

SPSS---------Statistical Package for Social Sciences

Std-----------Standard Deviation

TABLE OF CONTENT

Contents…………………………………………………………………...…pages

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

Figures **Pages**

LIST OF APPENDICES

Appendices **Pages**

ABSTRACT

Challenges of Household Biogas Technology Adoption as an Alternative Energy Source in Gozamin District; East Gojjam Zone, Ethiopia

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Energy is an essential part of our daily life, often taken for granted by populations which enjoy the comforts of modern society. Despite the continually rising energy demands reported globally, however, millions of communities and households, mainly in developing countries, still lack access to basic energy services such as electricity, liquid fuels, and natural gas. Biogas technology use in Ethiopia has been relatively infant stage compared to other African countries. There are insufficient empirical evidences about the impact of demographic, socio-economic and environmental factors on biogas technology installations in Gozamin District. This study was conducted with the objectives of assessing peoples' awareness towards biogas technology, examining involvement of government institutions in promoting household biogas technology adoption and identifying factors affecting household biogas technology in the study area. A total 212 households were taken as a sample size but only 207 were interviewed. Among these 45 were biogas technology adopters and 162 were non-adopters. Interview (survey) and focus group discussion methods were used as data collection tools. Collected data were entered into SPSS software version 20. Descriptive analysis like frequency distributions, bar charts and binary logistic regression analysis were used as data analysis methodologies. The result of the study showed that majority of adopters (94%) installed biogas either with full sponsor or subsidy from biogas project or government. Education level at least to grade seven and above, livestock keeping and both farming and livestock keeping, number of cattle and use of fire wood and charcoal as main source of energy were positively affecting adoption. However, age group (36-45 years) and use of alternative source of energy were negatively affecting biogas adoption. Furthermore involvement of government institutions to promote biogas technology, to give technical services and training were low. Therefore, it is recommended that government institutions should create awareness, actively participate in promoting biogas adoption, ensure technical support as well as training and create conducive environment to access loan from financial institutions.

Key words: *Gozamin District, biogas, bio energy, adoption*

1. INTRODUCTION

1.1. Background and Justification

Energy is an essential part of our daily life, often taken for granted by populations which enjoy the comforts of modern society. Despite the continually rising energy demands reported globally millions of communities and households, mainly in developing countries, still lack access to basic energy services such as electricity, liquid fuels, and natural gas. For example, about 1.5 billion people (over 20% of the world population) do not have electrical power, and approximately 3 billion people (some 45% of the world population) rely on solid fuels such as fire wood, crop residues, cattle dung, and coal to meet their cooking needs (Surendra *et al*., 2014). Further, the number of households depending on traditional solid fuels is increasing as the population grows in Sub-Saharan Africa outpaced the number of new electrical connections. Additionally, per capita energy consumption often viewed as part of the development index is very low in developing countries compared to in developed countries.

Ethiopia is one of African country which endowed with huge potentials of renewable energy sources such as hydropower, wind, geothermal, and bio fuels including biogas. However, the resources have not yet been utilized to economically optimal levels. Various assumptions and arguments are forwarded with regard to the underdevelopment of the energy sector in the country. Some of the major assumptions and arguments include: less attention given to improve the traditional energy production, supply and utilization; little or no attention provided to develop renewable energy; the non existence of strong energy organization; the low level of household income; and lack of capital, technical know-how, and trained man power (Woldegiorgis, 2002).The potential of biogas technology as a sustainable energy source, as a medium for improving sanitation, and as a source of rich organic fertilizer has been clearly shown in a number of studies in Ethiopia. Despite the abovementioned benefits, Ethiopia's biogas industry is still at an infant stage.

However, since the last decade due emphasis has been given to the development of the energy sector and intervention efforts have already started providing some fruits (Ethiopian climate Resilience Green Economy, ECRGE). One of the critical areas of intervention in the energy sector is the development and dissemination of biogas technology. In four regional states alone, namely Tigray, Amhara, Oromiya, and SNNP regions where feasibility study for national domestic biogas programme covered, the potential for mass dissemination of biogas technology ranges from 1.1 million to 3.5 million households (Eshete *et al.,* 2006). Accordingly, Ethiopia has launched implementation of successive domestic biogas programme. It already completed the first phase (2009-2013) and has begun implementing its second phase. In the first phase, it was able to build 8063 (57.6 %) out of the 14,000 domestic biogas plants intended to be constructed in the period (Kamp and Forn, 2015).

To this end, in the Amhara Regional State the biogas technology promotion, adoption and all of its development is not mature. The present study therefore; seeks to examine the challenges of household biogas technology adoption in comparison to promotional efforts so far accomplished by stakeholders in Gozamin District.

1.2. Statement of the problem

Ethiopia has been disseminating biogas technology as an alternative renewable energy source to reduce excessive dependence on fuel wood. Biogas technology use in Ethiopia has been relatively infant stage as compared to other African countries. An analysis undertaken by Amhara Regional State Water, Irrigation and Energy document, (2017) reveals that the exact numbers of household biogas technology installed were 5000. Though an estimated 20% of the installed biogas plants failed to stay in operation, other plants succeeded in providing the users with benefits over a number of years.

Therefore, thorough understanding of the problems why the progress of biogas technology adoption has been slow in rural Ethiopia, and to what extent the biogas installations, which have been built up to now, have contributed to the sustainable rural livelihood are relatively important for the next successful plans and dissemination action. In fact, there are some researches done on biogas technology in Ethiopia. There are also insufficient empirical evidences about the socio-economic impacts of the biogas installations in Gozamin District.

Besides, interest on the problem was initiated due to personal experiences and observations as well as reading from literature. In Gozamin district it is very common to observe children and women competing for dung fuel in communal grazing fields due to scarcity of wood-fuel. Seeing the problem of household energy some years back the government built model biogas installations in the area. Despite the efforts made in introducing the biogas technology success stories are limited. The way the biogas technology was disseminated and barriers to its adoption have not been scientifically investigated in the study area. Therefore, this study has attempted to examine the adoption of biogas technology in relation to promotion efforts used by biogas stakeholders, which assumed to influence the level of awareness and people's attitude towards biogas technology. The study focused on the rural Ethiopia, Gozamin District in East Gojjam zone where biogas projects have been in existence since the establishment of Biogas Project in 2012.

1.3. Objectives

1.3.1. General objective

To investigate the challenges of household biogas technology adoption as an alternative energy source in Gozamin District.

1.3.2. Specific objectives

1. Assess peoples' awareness towards household biogas technology.
2. Examine involvement of government institutions and non-governmental organizations in promoting biogas technology.
3. Examine factors affecting the adoption of household biogas technology in the study area.

1.4. Research questions

The following research questions are prepared to guide the study:

1. What is the level of awareness towards biogas technology?
2. What is the extent of involvement of government institutions and other stakeholders concerned in promotion of biogas technology?
3. What factors affect adoption of biogas technology in the study area?

1.5. Significance of the study

The continuing efforts to promote renewable energy technologies in Ethiopia need to be supported following the identification of energy scarcity. Biogas technology as an alternative renewable energy source has been introduced in Ethiopia before a reasonable period of time, but so far the technology is not adapted to the expected levels resulting into the continued exploitation of forests. If the responsible government institutions and other stakeholders would sufficiently promote biogas technology, many people will adopt and have an alternative sustainable source of energy. After that biogas dissemination and adoption will reduce deforestation, save time wasted in firewood collection and in turn increase women participation in other productive work. Organic fertilizer yielded as the end by-product of the technology will improve crop yields hence enriches the lives of users.

Recently, the dissemination of domestic biogas installations has been given a new emphasis and an independent office has been established for the purpose. The present report will be used as inputs for decision and policy makers, planners, non-governmental organizations, and implementers of bio-energy technologies and other projects of similar nature. In addition the findings will provide further knowledge on the present literature on bio-energy technologies about the potential of agro-forest residues to be used as raw materials for renewable energy source. It will be planned further that the study will also stimulate interest on more researches in the field of renewable energy sources.

1.6. Scope and Limitation of the study

The focus of this study was to determine and document peoples' awareness towards biogas technology, examine involvement of government institutions and non-governmental organizations in promoting household biogas technology and to observe factors affecting the adoption of biogas technology in Gozamin District. Therefore, this study was site specific in that it only focused in Gozamin District. Since only four kebeles: Aba Libanos, Wenka, Enerata and Chemored yezangera were included in this study, findings may be generalized the Gozamin District.

2. LITERATURE REVIEW

2.1. Global energy consumption

Energy security is dependent on two reasons: the source of supply and the distribution systems. On the global viewpoint, energy security is dependent on the availability of primary energy. According to Enger and Smith (2006) over 90% of the energy consumed in the United States obtains from three sources; oil, coal and natural gas (Figure 1). For many years there have been predictions that energy supplies particularly oil would run out and cause declines from which the world will not recover. Production of oil, gas and coal would not be able to sustain forever with growing global demand (Day, 2010).

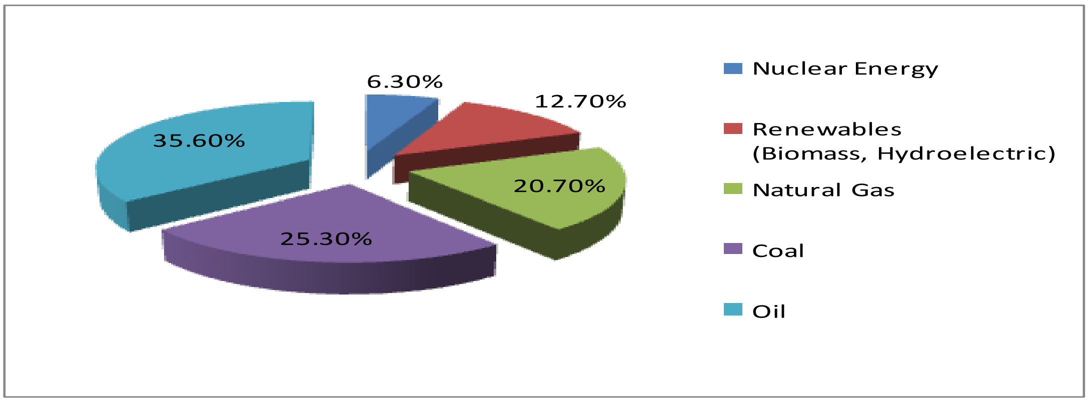

Figure 1 : Energy source and their % use in developed countries

Source: Enger and Smith (2006)

2.2. Energy situation in Ethiopia

Ethiopia is potentially gifted with various energy resources. These energy resources include: hydropower, wind, geothermal, solar, biomass, natural gas, coal, and oil-shale (table 1).But, much of the stated resources are either untouched or not developed to economically optimal levels. For instance, so far the country has developed less than 5 % (around 2000 MW) of its total hydroelectricity generation capacity (EEPCO, 2011; FDRE, 2015).

Table 1: Energy resource potentials of Ethiopia

S.No	Resource type	Unit	Potentials	Remark
1	Hydropower	MW	45,000	Based on the recent national development plan documents including FDRE (2010, 2015)
2	Wind	MW	10,000	Recent studies indicate that the potential is about 100,000 MW
3	Geothermal	MW	5,000	Still to be explored
4	Solar	kWh/m2/day	5.2	Still to be explored
5	Woody biomass	Tonnes	1120 million	Estimated based on a 3 % forest coverage of Ethiopia with 1tree/4 m2, and average weight of 0.2 t/tree (EREDPC, 2000 cited in Wolde-Ghiorgis, 2002)
6	Agricultural wastes	Tonnes	15-20 million	Still to be explored
7	Natural gas	Cubic feet	4 trillion	Still to be explored
8	Coal	Tonnes	>300 million	Still to be explored
9	Oil-shale	Tonnes	253 million	Still to be explored

Source: MoWE, 2011

In Ethiopia, there are compelling reasons to promote household biogas technology. First, the country has large livestock population mainly cattle. Second, dung is increasingly used as household fuel. Third, the soil structure and fertility has negatively been affected as it is deprived of its natural fertilizer-dung (Mulu., 2016).

Adoption and dissemination of biogas technology in a given society depends on a number of reasons. Some of the major reasons include: socio-demographic characters of households; economic characters of households including access to alternative sources of energy like electricity and photovoltaic; biophysical factors such as access to woody biomass, land, and water resources; legal and institutional factors such as promotion work, supports, and subsidies; private sector participation in promotion, construction, and manufacturing and supplies of appliances and spare parts; and attributes of the technology itself (Mulu, 2016).

Here it should be recognized that adoption of biogas technology is household selective. It requires per households to have sufficient size of minimum four or more number of cattle to feed biogas digester, sufficient and reliable water sources within reasonable distances, and labor to operate the biogas installation. It also needs households either to have access to financial services or sufficient own financial capital to cover the full or partial subsidy cost of biogas technology investment.

Once biogas technology is adopted, sustained and efficient utilization of the technology can lead to different development results. Some of the major sustainable development results may include: accessing energy needs, saved time, decreased workload, reduced health risk, reduced expenditure, increased income and job opportunities, increased productivity, reduced deforestation, reduced GHG emissions, enhanced soil fertility, reduced indoor air pollution, and improved sanitation (Mulu, 2016).

2.3. Biogas technology

A technology is people using knowledge, tools, and systems to make their lives easier and better. Biogas technology is a complete system by itself; it includes cost effective production of energy and fertilizer for soil. The following sections will investigate some facts.

2.3.1. Biogas production

Biogas is produced by methanogenic bacteria creating on bio-digestible materials in absence of oxygen in the process of anaerobic digestion. It is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide and low amount of other gases like

Hydrogen (5-10), Nitrogen (1-2), water vapor (0.3) and traces of hydrogen sulphide (FAO/CMS, 1996).Production of energy from biogas is influenced by factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors (FAO/CMS, 1996).

2.3.2. Biogas plant

Gunnerson and Stuckey (1986) identify about 7 types of biogas plants or digesters. Some include; the Fixed Dome, Floating Cover (Indian type) and Tubular Plastic or Bag Design. For the purpose of this study, only one type which is commonly used in Ethiopia will be assessed. This is; the Fixed Dome (Nepalese type, in the name of SINIDU).

2.3.2.1. Fixed-dome

Fixed dome design, according to Gunnerson and Stuckey (1986) is the most common biogas digester type in developing countries.

2.3.3. History of biogas technology

2.3.3.1. Global overview of biogas technology disseminations and uses

2.3.3.1.1. Disseminations of biogas technology

Current household biogas dissemination status

Among the developed nation, Germany is by far the leading country in biogas generation. In 2010, it had about 5,800 large scale biogas installations from which it generated 2300 MW of electricity. Whereas United States of America possessed merely 160 anaerobic digesters from which it generated 57.1 MW of electricity (Bramley *et al.*, 2011).

Of the developing countries, China outstandingly leads the world in the number of household biogas plants. By the end of 2010, the total number of domestic biogas installations reached 40 million from which the country produced 15, 400 hm3 biogas annually (Dong, 2012).

Some African countries have also been working on the dissemination of biogas technology with renewed interest. The total numbers of biogas installations constructed up to 2011 in nine African countries, namely: Rwanda, Ethiopia, Tanzania, Kenya, Uganda, Burkina Faso, Cameron, Benin and Senegal summed up 24,990 (SNV, 2013). ABPP, which was created by SNV and HIVOS, planned to build 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 a million people by the end of 2013 (AFREA, 2011). HIVOS manages the programme; SNV provides technical assistance whereas national agencies take the responsibility of implementing the programme with a range of partners. The major source of funding for ABPP is the Dutch Ministry for Development Cooperation (DGIS). Currently, ABPP is active in five countries with the dropped out of Senegal at the beginning of 2012 (ABPP, 2012).

Controls of biogas technology distribution

Some of the factors that specifically influence dissemination of biogas technology include policies and institutions, financial constraints, subsidies, availability of inputs, awareness about the technology, consumers’ concerns, and success stories about the technology.

Appropriate government policies create conducive environments to stimulate dissemination of renewable energy technologies, mobilize resources and encourage involvement of private investors (Karekezi and Kithyoma, 2003).

Financial constraint is one of the most frequently cited challenges limiting the expansion of biogas technology. According to Arthur *et al.* (2011), though biogas technology can solve some of the energy and environmental problems of rural and urban communities and industrial institutions, it requires high initial investment cost. The principal obstacle for the use of the technology by rural cattle farmers is their inability to afford the full cost of biogas installations. Subsidies increase the speed and relative advantage of adoption. Subsidies lead to adoption of technologies by those individuals who would not adopt otherwise (Rogers, 1983). Furthermore, FAO (1996) stated that it is unjustifiable to make the individual users to shoulder the total cost of the technology provided that benefits are shared by the non-users too.

Availability of sufficient inputs for biogas digesters such as animal manure and water are among the main factors limiting the rate of biogas technology development. Even in some conditions, where households possess adequate number of livestock, the nature of grazing systems: nomadic, semi-nomadic, and free grazing systems have created inconvenience to gather manure and feed the biogas digesters (Winrock International, 2007).

Awareness about the technology is another important constraint limiting adoption and dissemination of biogas technology development. For instance, in Ghana, lack of awareness about the technology is mentioned to be one barrier for the adoption of biogas. Some cultural outlooks like stigmatization of utilization of human excreta as input to biogas digesters can also potentially discourage its dissemination (Arthur *et al.,* 2011).

2.3.3.1.2. Uses of biogas technology

Economic uses: Two of the most important outputs of biogas technology are energy and bio-slurry. Biogas energy is utilized commonly for cooking, lighting, refrigeration, and running internal combustion engine (FAO, 1996). Biogas technology generates employment opportunities for both skilled and unskilled labor (Lam *et al.,* 2010; Arthur *et al.,* 2011).

Health and social uses: The use of biogas technology has numerous health and social uses. The health benefits encompass: reduction in smoke borne diseases such as headache, eye-burning, eye-infection, and respiratory organ infection; improvement in household sanitation via toilet connection with bio-digesters and absence of sooth and ashes in the kitchen; and reduction in burning accidents (Ghimire, 2008). Biogas technology has also various social roles. It improves social relations via minimizing bad odors and environmental pollutions of organic wastes which would have been otherwise serve as a source of grievance among neighbors (Aggarangsi *et al.,* 2013). It saves time for social activities; it improves social status in the community; it lessens women and children's work burden; and it offers brighter light that assists quality education and household duties (Ghimire, 2008).

Environmental uses: i) it provides sustainable source of energy and soil enriching bio-slurry as a by-product, ii) it gives an opportunity to treat and reutilize variety of organic wastes, iii) it minimizes the environmental impacts of GHG emissions, and iv) it reduces land use problem associated with disposing organic waste (Aggarangsi *et al.,* 2013).

2.3.3.2. Biogas technology in Ethiopia

There are variations among authors as to the exact time when biogas was introduced into Ethiopia. But, it seems reasonable to take the fact that Bekele (1978) wrote as he himself constructed the first biogas installation in 1962 at Ambo School of Agriculture, the later Ambo College of Agriculture (Eshete *et al.,* 2006).

Once biogas installations are built, they may fail to function for a number of factors. Some of the major ones include: technical problems, availability of water supply, decline in the number of cows owned, change in the mode of livestock keeping, clumsy operation, and absence of demand and interest (Eshete *et al.,* 2006).Success or failure of a model biogas installation in a given area can positively or negatively affect its advance promotion in that area. Thus, social influence created by successfully operated biogas installations is a necessary condition for wider dissemination and acceptability of the technology.

The feasibility study on potential of household biogas plants in the country was initiated and conducted by SNV-Ethiopia in 2006. It was a very comprehensive study which addressed a wide range of issues including problems and functional status of previous installations, constraining reasons for adoption and potential for the promotion of the technology. The study covered four major regional states: Tigray, Amhara, Oromiya, and SNNP. These regions are the homes of around 70 % of the livestock and over 70 % of the human population in Ethiopia (Eshete *et al.,* 2006). Following the recommendation, SNV-Ethiopia in collaboration with the EREDPC, a government institution, prepared PID in 2008 (EREDPC and SNV, 2008). This finally led to the establishment of NBPE and NBPCO as well as the onset of programme implementation in the four regional states. SNV Ethiopia was the technical advisor of the programme right from the start.

The objectives of the NBPE included developing sustainable market-driven biogas sector in Ethiopia; constructing 14,000 domestic biogas plants of various digester sizes ($4m^3$, $6m^3$, $8m^3$, and $10m^3$s) (EREDPC and SNV, 2008), 3500 in each of the four regional states within the first phase (2009-2013) (Yilma, 2011); and ensuring the uninterrupted functions of the biogas installations to be built in the programme period. The financial sources for the NBPE included: an external donor (the African Biogas Partnership Programme), SNV-Ethiopia, farmers, federal government and regional governments which covered 39 %, 11.4 % (in service forms), 42 %, 4.4 % and 3.2 % of the total programme costs, respectively (EREDPC and SNV, 2008).

2.3.3.3. Biogas technology in East Gojjam Zone

The dissemination of household biogas technology in East Gojjam Zone started in 2012 by Amhara regional State household biogas programme office. But there is no any non-governmental organization participating in the dissemination of biogas technology. Deforestation in East Gojjam Zone is caused by demand on firewood, both in rural and urban areas.

Biogas plants adopted in East Gojjam are of the Napeles fixed dome design with sizes ranging from 4, 6, 8 and 10 cubic meters. Installation costs for a biogas plant ranged from roughly 12,000-15,000 birr including around 6,000 birr with regional state biogas programme subsidy E.G.Z.W.I.E., (2017).

2.4. Empirical evidences on biogas technology

There are so many empirical evidences on biogas technology. Some are:

As stated Mulu (2016), the majority (85.3 %) of the sample biogas users realized that the utilization of biogas technology highly reduced the problem of health through the declined use of traditional biomass fuels. The finding 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.

The time saved through the use of biogas technology was devoted partly to leisure time, schooling, agricultural activities, and other income generating activities. The feasibility study for national domestic biogas programme in Ethiopia indicated that the utilization of biogas technology can on average lessen the overall household workload by two to three hours per day (Eshete *et al.,* 2006).In a similar study in Nepal too, the use of biogas technology enabled the biogas user households to cut back the time required for household activities on average by three hours per day than the non-user households (Singh and Maharjan, 2003). The possible justification for the slightly less time saved from the use of biogas in this particular case study could be related to the functional status of the biogas plants.

According to Mulu (2016), the use of biogas energy enabled the biogas user households to be able to reduce the consumptions of various traditional biomass fuels and, in turn, emissions of GHGs. The average amounts of GHG emission reductions obtained through the reduced use of dung fuel, kerosene, and fuel wood were 2.7 t, 182 kg, and 45 kg of CO2e per digester per annum, respectively. The main justification for the highest GHG emission reduction from the use of dung fuel is, obviously, the shift in its role from direct combustion in air-dried form to an input for the biogas digester.

2.5. Technology adoption

Adopting a technology mentioned by Manros and Rice (1986) include absence of users' involvement, lack of understanding, technical difficulties, lack of training and ineffective support from top management and perceived technology complexity. The biogas adopters with a minimum of one year old biogas installations was to acquire clear-cut information about whether or not they utilize bio-slurry as organic fertilizer. Besides, respondents from such households were expected to have relatively better experience and familiarity with the technology's benefits and drawbacks. Among the non-adopter households, only those who owned four or more heads of cattle potential biogas adopters (EREDPC and SNV, 2008).This is because with the exception of toilet connections to some biogas digesters, cattle dung is the only source of biogas in rural Ethiopia.

2.5.1. Adoption process

In this process an adopter goes through unlike stages whereby awareness is the first stage and adoption the last stage. At the awareness stage people get general information about a new idea, product or practice for the first time but not its details. With the detailed information people decide whether the idea is good or not after which the potential adopter would try the new idea or practice a little and more late (Rogers, 1995).

2.5.2. Factors affecting adoption of innovation

Several studies (Baidu-Forson, 1999; Bartz *et al.,* 1999; Wawa *et al.,* 2017); Simon, 2006) have pointed out that adoption and dissemination 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 clientele.

2.5.2.1. Socio-economic characteristics

These factors include age, educational level, family size, gender, ethnicity, religion and wealth (Wawa *et al.,* 2017).

Education level is associated with greater access to information and improved capacity for creativity, so educated individuals are expected to be more aware of and have more knowledge on a new technology (Wawa *et al.,* 2017).

Age and experience have a range of influences on household decision making in adoption. Older ages, according to Wawa *et al.*, (2017) may influence an individual in the direction of not adopting new ideas due to conservatism. However, with regard to experience, older people may have more experience and more resources that allow them to adopt capital-intensive technologies than younger people (Shiferaw and Holden, 1997).

Household size may have positive or negative influence on adoption of technologies. For labor intensive technologies, family size positively influences adoption (Simon, 2006). Income is also an important reason in adoption of technologies.

Availability of cash enables an individual to gather costs associated with a technology to be adopted (Simon, 2006).

Gender can influence adoption of a technology positively or negatively depending on gender responsibilities and ownership of resources (Simon, 2006). The gender responsibilities can be in form of performing tasks among men and women in energy supply and management systems and differences in resource ownership such as livestock, houses and land.

2.5.2.2. Institutional characteristics

According to Kalineza *et al.,* (1999) rejection or acceptance of a new idea largely depends on how the information is transmitted from the source, which is mainly the extension service. Extension is known to catalyze awareness, organization, and information exchange and technology promotion among individuals.

2.5.2.3. Technological characteristics

Rogers (1995) identified five major technological characteristics associated with high rate of adoption of technologies. They include the relative perceived advantage, compatibility with the local culture, low technical complexity, train-ability and afford-ability.

2.5.2.4. Environmental characteristics

Simon (2006) in his study on adoption of rotational woodlot technology observed that a majority of adopters lived in either urban, division centers or sub urban areas.

2.6. Knowledge gap

Literature has shown that biogas technology has been adopted but not at expected level in Gozamin District despite its potential. Still no studies have explored factors for the low adoption of biogas technology in the District. And the factors identified which include high costs of installation, training, marketing, coordination of stakeholders, public awareness seem to have direct link with institutional support services for promotion of biogas technology. And the promotion factor has not fully been explored by studies in the District. The Ethiopia energy policy does specifically promote biogas as an appropriate renewable and alternative energy source for rural population. In addition there is no studies reported the influence of institutional factors on promotion of biogas technology in the District. Promotion embraces many other factors influencing adoption process, effective promotion contribute to peoples' awareness and knowledge which are the foremost stages of technology adoption. Furthermore this study aims at establishing the extent and rate of biogas adoption and factors influencing biogas adoption. This study therefore seeks to fill these all knowledge gaps and add onto the existing knowledge, particularly by developing conceptual framework for assessing factors influencing adoption of biogas technology based on adoption theories.

3. MATERIALS AND METHODS

3.1. Description of the study area

Location: The study was conducted in Gozamin district East Gojjam Zone. Gozamin is one of the 18 Districts in East Gojjam Zone of Amhara National Regional State. Debre Markos is the capital of the District and a District contains 25 rural-kebeles. Gozamin as bordered by Aneded and Debay Tilat gin in the East, Machakel and Debre Elias in West, Sinan District in North, Baso Liben District and Abay River in the South. Its distance is 265 kms far away from Bahir Dar, the Regional capital city and northwest 300km far from Addis Ababa. It is found in the North western highlands of Ethiopia at a geographical location of 10°1′ 46″ and 10° 35′ 12″ N latitudes and 37° 23′ 45″ and 37° 55′ 52″ E longitudes (Gashe *et.al*, 2017).

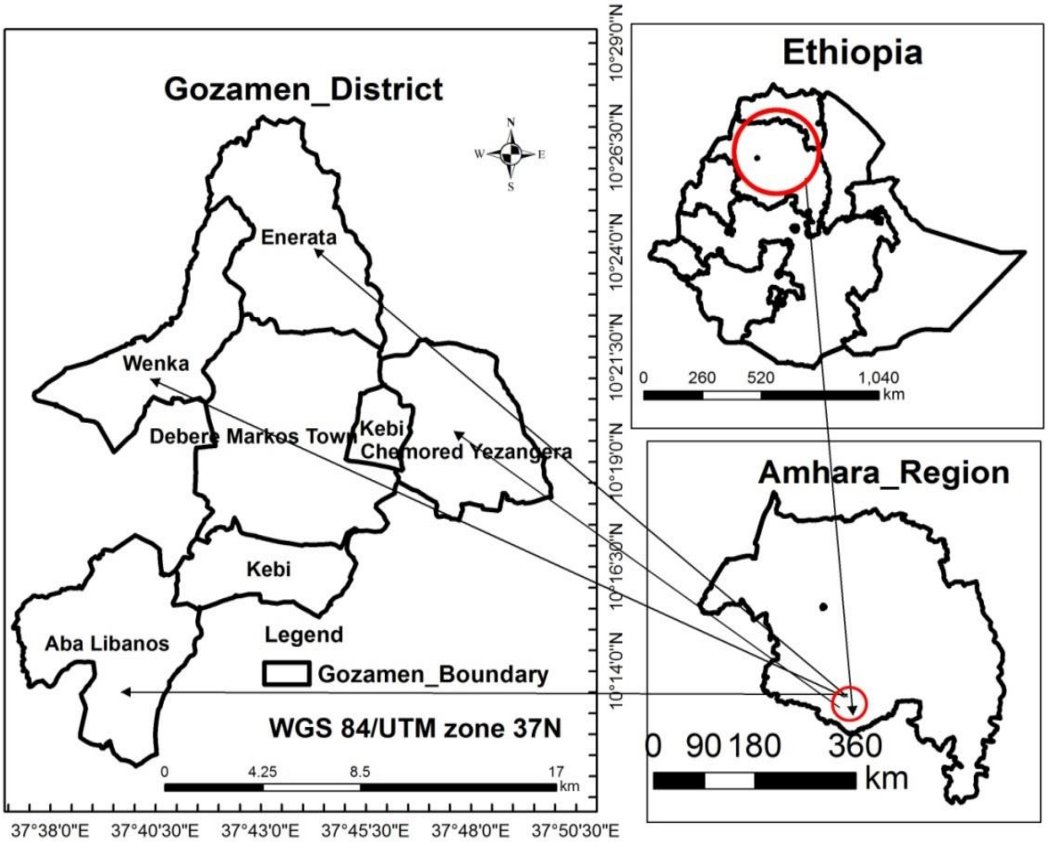

Figure 2: Map of the study sites

Topography and Climate: According to Gozamin District Administration sector office documents, (2016). It has a total area of 1,217.8 sq.km and three agro-ecological zones that is, 19 % high altitude, 65 % mid-altitude and 16 % low altitude.

The altitudinal ranges from 1200-3510 meter above sea level. The average annual rainfall of the district is1628 mm with the rainy season extended up to 6 months. However, the heavy rainfall is concentrated in the meher season of June to September. The maximum and minimum average temperatures are 25°C and 11°C, respectively.

Soil and vegetation type: The most dominant soil types are Nitosols, Vertisols and Cambisols while, Pheazomes, Acrisols and Leptosols are associate soil types in different parts of the District (Gashe *et.al,* .2017).Vegetation type is more dispersed such as: Eucalyptus species, Acacia species, C*roton macrostachyus*, Jibra (*Lobelia gibberroa*), bushes to some extent Podocurpus falctus, Juniperus specie, C*ordia africana*, F*icus sycomorus, Erythrina brucei* and Hyginia abssynica (Alemayehu, 2017). Biomass fuel in the form of firewood and charcoal is the main source of energy used in households and commercial premises for cooking (Gashe *et.al,* .2017).

Population: Based on the federal democratic republic of Ethiopia (CSA, 2014-2017) population projection at wereda level the total population of the District has an estimated size of 149,498 of which 74,183 are males and 75,315 are females. From these 1,799 males, 2,019 females, total 3,818 and 72,384 males, 73,296 females, total 145,680 are urban and rural population respectively.

Land use and socioeconomic activities: From the total area of the District 79.02 % is used for agricultural land, 2.55% covered by forest and bushes, 15.9% for settlement and 2.53% for grazing land (Gashe *et.al,* .2017). Agriculture is the basis of farmers in the district which is characterized by mixed crop livestock production systems. The district has a livestock population of 155,287 cattle, 97,263 sheep, 8,577 goats, 25,473 equines, 56,920 poultry and 10,019 beehives. Free grazing livestock is the main practice (Gashe *et.al,* .2017).

3.2. Selection of the study area

A district has highland, midland or temperate and lowland Agro ecologies area and has all the signs of scarcity of fuel wood hence a need for alternative energy sources. In this study from midland agro ecology areas: Enerata and Chemored Yezangera Kebeles and from lowland: Aba Libanos and Wenka Kebeles were purposefully selected, but highland agro ecology is not suitable for biogas fermentation. As a result, out of the 25 kebeles in the District, 5 high altitude areas were not included in the study. Other factors for the selection of the study site include: numbers of livestock, water and feed stocks availability with favorable temperatures that are important for the operation of biogas plants.

3.3. Sample population

The sample households were categorized into adopters and non- adopters of biogas technology. However, adopters of biogas technology are small in number; therefore, all 45 adopters in four sample kebeles (Aba Libanos, Wenka, Chemored Yezangera and Enerata) were selected as a sample. The non-adopters were 167 selected using random sampling techniques since to obtain equal chance from the District four kebeles. Further the kebeles were selected based on agro ecology, biogas potential and best number of biogas adopters. Key informants and focus group discussants were selected purposively and pertinent to the target population and the research topic.

3.4. Sample size

The appropriate sample size for household survey was determined by using a simplified formula provided by Yamane (1967) at 93% confidence level, degree of variability level of precision=7%.

$$n = \frac{N}{1+N\,(e^2)} = \frac{4030}{1+4030\,(0.07^2)} \approx 194 \qquad .$$

Where: n = the required sample size

N = Total number of households in the targeted four kebeles (4030) and

e = Sampling error (0.07)

Assuming 10% of non-response rate, add it to total sample size so as to get information from all selected samples. Then adding 10% of 194, the total sample size were 212 households.

The table below shows total and sample households in selected kebeles. All biogas adopters' households in each kebeles were interviewed but non-biogas adopters were selected proportionally from each kebeles.

Table 2: Proportional allocation of samples within selected kebeles

Kebele	Total households			Sample households		
	Biogas adopters	Non-adopters	Total	Biogas adopters	Non-adopters	Total
Aba Libanos	12	1360	1372	12	60	72
Wenka	10	609	619	10	23	33
Chemored Yezangera	11	897	908	11	37	48
Enerata	12	1119	1131	12	47	59
Total	45	3985	4030	45	167	212

3.5. Data sources and types

Both primary and secondary data were collected. Primary data were related to study area characteristics, analysis of biogas technology such as: factors influencing adoption and non adoption and people's awareness towards biogas technology. Also data relating to promotion of biogas technology by the government and other stakeholders were during the household survey. Secondary data were collected from various sources such as government officials at District and Zonal levels and from NGOs reports, libraries, institutions and websites and others.

3.6. Data collection methods

Both qualitative and quantitative approaches were employed due to the nature of the study.

These included 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 will require in achieving the objective of the study.

3.6.1. Survey

This study was employed cross sectional research design (sometimes called survey design) (Casley and Kumar, 1988).

It was consisted four major parts:

Information on household characteristics and availability of important energy resources; collect information on biogas awareness in the study area and experiences from biogas adopters, gender involvement in biogas related activities; and information relating to policy environment particularly government involvement in promotion of biogas technology. Both structured and semi-structured interviews were used. The interview were included both open and closed ended questions.

3.6.2. Focus group discussion

Focus group discussion is useful in verifying and clarifying information and in filling in gaps of information caused by inadequate information gathered from the interviews and observations.

They were conducted in four kebeles from a District. The focus groups comprised 8- 10 participants who were selected with consideration of all social groups representations; in the kebele and kebele leaders. From these, qualitative information such as general opinion, awareness towards biogas technology was collected. The checklist was prepared to conduct focus group discussions.

3.6.3. Field observation

It was used to evaluate existence of biogas plants, designs and types of plant feeds also to confirm functioning of biogas plants. And also help to study some facial expressions, gestures and other behaviours during interviews.

3.7. Field survey

3.7.1. Pilot survey

The survey was directed for the purpose of: inspecting background information about the study areas; familiarizing with the areas where the main survey was conducted; establishing sampling frames and units; pre-testing the questionnaires to validate the importance of the questions to the intended respondents; determining the approximate time or duration taken to fill a questionnaire with one respondent and finding out the most efficient way of carrying out main survey. This was carried out with household heads, village leaders, assistances, kebele development agents and District concerned bodies. The pilot survey was carried out in selected villages and conducted informal discussions with household heads, village leaders and district authorities. Following the pilot survey some modifications was made to the questionnaires and interview guidelines as required.

3.7.2. The formal field survey

The formal survey was conducted by involving household interviews, focus group discussions and discussions with government officials, representatives of NGOs and other key informants. The interviews were conducted by the researcher with the assistance of four well-trained kebele development agents or enumerators in each kebele. Prior to the beginning of interviews, the researcher visited the districts and kebeles to inform relevant authorities about the purpose of the study. Individual respondents were interviewed in their homes or offices after an initial appointment. The interviews were conducted in Amharic to overcome language barrier because most household respondents did not speak English language.

3.8. Data processing, analysis and presentation

3.8.1. Data processing

The data were coded and entered into the Statistical Package for Social Sciences (SPSS). Data cleaning was done by running frequencies of individual variables and later analysed.

3.8.2. Data analysis

Both descriptive and quantitative techniques were used to analyse the data. A substantial part of the analysis is based on descriptive statistics such as frequencies, cross-tabulations, and correlation coefficients. These statistics were used to determine and to assess the following aspects: respondents' characteristics, their awareness towards household biogas technology, factors influencing adoption and non adoption of biogas technology; and assessment of the adequacy of strategies for promoting adoption of biogas technology in the study area.

The logistic regression model was used to determine the factors affecting adopters and non-adopters of biogas technology.

To use logistic regression biogas adoption status of households was considered as dependent variable where if the household adopted biogas technology, then it is considered as "adopters " and coded as "1" otherwise non-adopters and coded as "0". Taking the natural log of odd of adopting, the model is given as:

$$\boldsymbol{ln}\left(\frac{\boldsymbol{P_i}}{\boldsymbol{1-P_i}}\right) = \boldsymbol{Z_i} = \boldsymbol{\beta}_o + \boldsymbol{\beta_1 X_1} + \boldsymbol{\beta_2 X_2} + \cdots \qquad + \boldsymbol{\beta_n X_n}$$

Where $\boldsymbol{P_i}$is the probability of adopting biogas technology

1-$\boldsymbol{P_i}$is probability of not adopting

$\frac{\boldsymbol{P_i}}{\boldsymbol{1-P_i}}$ is odd of adopting

$\boldsymbol{Z_i}$is logit of adoption.

$\boldsymbol{\beta}_o$ is an intercept

β is vector of coefficients

X is vector of predictors/ factors

The independent variables used in this study are described in the table below.

Table 3: Description of study variables

Variable name	Description	Measurement	Expected sign/effect
Sex	Sex of household head	Binary (1= male 2= female	+/-
Age	Age of household head	Categorical(1=26-35 years, 2=36-45 years, 3=46-55 years and 4= above 56 years	+/-
Educ.	Education level of household head	Categorical (1= never attended formal education, 2= below grade seven, 3= grade 7 and above	+
Occupation	Occupation status of household head	Categorical(1= farming, 2= livestock keeping, 3=farming and live stock keeping,	+
Income	Annual average income of household	Continuous	+
Cattle	Number of cattle a household owned	Continuous	+
Source fuel	Source of fuel for cooking	Categorical(1= firewood 2= Firewood and charcoal	+/-
Alternative	Use of alternative source of energy	Binary(1=yes and 0= no)	-

3.8.3. Data presentation

Finally Cross-tables and figures such as bar charts and pie-chart were used to present data for different study variables. Concluding remarks, recommendations and discussions are basically based on computed frequencies, percentages, and logistic regression analysis

4. RESULTS AND DISCUSSION

4.1. Chapter overview

This chapter presented the findings of the study and discussions of the results. This section presented an analysis of people's awareness towards biogas technology, factors influencing biogas technology, explores the involvement of government institutions and other stakeholders in promoting biogas technology and the strategies used to promote biogas technology, and the rate and extent of biogas technology adoption forms in the study area.

4.2. Overview of respondents characteristics

As indicated in table 2 and 3 above summarized the socio economic and demographic characteristics of sampled households in the study area. A total of 207 out of 212 (with response rate of 97.6%) household heads were interviewed in Gozamin district East Gojjam zone.

Sex: The results in table 4 indicated that the majority (88.4%) of interviewed households in the study area were male headed as compared to (11.6%) female headed households. This has an implication on household decision making systems, the decision on whether the household adopts biogas technology or not, greatly rests on the head of household.

Age: The young household heads are likely to be more flexible and liable to accept new technologies. But at the same time, they are likely to have less capital accumulations and have lower economic status than the old farmers. Hence, the age of the household head was expected to have either positive or negative influence on adoption of biogas technology. The result in table 4 further indicated that a majority of respondents were in the age group 36-45 years (42%) followed by age group 46-55 years (33.3%) who are economically active which relates to labor provision for biogas activities, and resource ownership hence affordability of biogas installation costs.

Educational level: The result in table 4 indicated that majority of household heads (47.8%) did not attend formal education which shows that it could be difficult to introduce (adapt) biogas technology in the study area. It implies that largest proportion of individuals is not trainable as far as biogas technology knowledge is concern.

The household size: Large household size may mean having sufficient labor required to manage and operate biogas technology. Or it may mean greater pressure on the household resources. Thus, household size was hypothesized to have either positive or negative influence on adoption of biogas technology. Table 4 further indicated that a majority of households (52.2%) in the study area had an average of 4– 6 family members followed by (33.3%) households with above 6 family members which is a sufficient number to provide adequate labor for running biogas plant operations.

Table 4: Socio - demographic characteristics of the sample population

Characteristics of respondents	(N=207)
Sex	
Male	88.4 (183)
Female	11.6 (24)
Total	100.0(207)
Age of respondent	
Between 26 -35 years	10.1 (21)
Between 36– 45 years	42 (87)
Between 46– 55 years	33.3(69)
Above 56 years	14.5 (30)
Total	100.0(207)
Education level	
Never attended formal education	47.8 (99)
Below grade seven	39.1 (81)
From grade 7 to grade 8	5.8 (12)
From grade 9 and above	7.2(15)
Total	100.0(207)
Household size	
1-3 members	14.5 (30)
4-6 members	52.2 (108)
Above 6 members	33.3 (69)
Total	100.0(207)

Source: Field survey (2017/2018)

The major economic activity (60.9%) in the study area has been farming as indicated by the results in table 5 where 34.8% of respondents earn their living through crop farming and livestock keeping. This is significant to the availability of biogas technology requirements such as feed-stocks from livestock for biogas plants feeding.

Table 5: Economic characteristics of the sample population

Characteristics of respondents	(N=207)
Main economic activity	
Crop farming	60.9 (126)
Livestock keeping	4.3 (9)
Crop farming and livestock keeping	34.8(72)
Total	100.0(207)
Main source of income	
Crop production	60.9(126)
Livestock keeping	14.5(30)
Livestock keeping and crop production	24.6(51)
Total	100.0(207)
Household annual income (birr)	
Less than 10,000 birr	23.2 (48)
Between 10,001-20,000 birr	21.7(45)
Above 20,000 birr	55.4 (114)
Total	100.0(207)

Source: Field survey 2017/2018

The result in table 5 shows the main source of income in the study area was crop production where 60.9% of interviewed households earned their income and 24.6% of households earn their income from mixed farming (crop production and livestock keeping).

Majority of households (55.4%) were earning on average more than 20,000 birr annually. This has an implication for affordability of biogas installation cost.

4.3. Demographic characteristics and biogas adoption

Table 6 summarizes the relationship between household characteristics and adoption of biogas technology. These characteristics include age of respondent, education level of household head, household size and sex.

Table 6: Relationship of demographic characteristics and biogas adoption

Household characteristics	Biogas adopters (N=45)	Non adopters (N=162)	Total (N=207)
Gender of respondent			
Male	86.7 (39)	88.9 (144)	88.4 (183)
Female	13.3 (6)	11.1 (18)	11.6 (24)
Total	100.0 (45)	100.0 (162)	100.0 (207)
Age of respondent:			
Between 26 –35 years	20.0 (9)	7.4 (12)	10.1 (21)
Between 36 –45 years	33.3 (15)	44.4 (72)	42 (87)
Between 46-55 years	33.3 (15)	33.3 (54)	33.3 (69)
Above 56 years	13.4(6)	14.8(24)	14.5(30)
Total	100.0 (45)	100.0 (162)	100.0 (207)
Education level:			
Never attended formal education	53.3 (24)	46.3 (75)	47.8 (99)
Below grade seven	33.3(15)	40.7 (66)	39.1 (81)
Grade 7 to grade 8	13.4 (6)	3.7 (6)	5.8 (12)
Grade 9 and above	0.0 (0)	9.3 (15)	7.2 (15)
Total	100.0 (45)	100.0 (162)	100.0 (207)
Household size:			
Between 1–3 members	13.9 (11)	29.1 (70)	25.3 (81)
Between 4–6 members	51.9 (41)	56.0 (135)	55.0 (176)
Above 6 members	34.1 (27)	14.9 (36)	19.7 (63)
Total	100.0 (79)	100.0 (241)	100.0 (320)

Source: Field Survey (2017/2018)

4.3.1. Gender and biogas adoption

The use and management of household energy is primarily the duty of women in Ethiopia (EREDPC and SNV, 2008). But men dominantly control the household resources (Lim *et* *al.,* 2007) and often make final decisions both at household and community levels in the country (EREDPC and SNV, 2008). Thus, sex of the household head was expected to have either positive or negative influence on adoption of biogas technology.

The findings in table 4 indicated that male headed households are the majority in the study area. This relates with the results in table 6 which indicate that male headed households (86.7%) adopted biogas technology more than female headed households (13.3%). This is due to the patriarchal system where males are the heads of households. This implies that in normal condition it is the male who head the household at the household level which is assumed to influence adoption or non adoption of biogas technology.

The presence of female headed households might have been caused by either death of the husband or unmarried women who decided to establish their own homes or divorced women. However, for the purpose of this study the relationship between gender and biogas adoption is looked at the angle of responsibilities and involvement of male and female in biogas activities at the household level which is assumed to influence adoption or non adoption of biogas technology.

4.3.2. Age of respondent and biogas adoption

Findings in table 6 indicated that middle aged adults aged between 36-45 (33.3%) and 46-55(33.3%) years were more likely to adopt biogas technology compared to younger age groups 26-35(20%) and old age groups above 56(13.4%). The plausible explanation of this can be the resource ownership especially cattle ownership. Respondents at this age group (36-55) are likely to have more resources like cattle and established permanent premise. Cattle ownership is a prerequisite for biogas technology since it ensures availability of feed stocks for biogas plants. For young people who do not have their own premises and in many cases have not settled, it becomes difficult for them to decide on adopting this permanent installation. Older people will not have enough labor force at home and may not have sufficient resource to feed biogas plants. For instance, Walekhwa *et al.,* (2009) reported that as age increases, a person becomes less flexible and more resistant to accept new ideas and technologies, **s**o that they are unlikely to install biogas plants.

4.3.3. Education level and biogas adoption

Household heads with higher educational levels were indicated to be less conservative, more informed, more knowledgeable, and more vigilant to the environment (Walekhwa *et al.,* 2009). Thus, household heads who passed through greater number of schooling years were anticipated to have a greater probability of adopting biogas technology. The relationship between education and biogas adoption as indicated in table 6 is that the majority of adopters (53.3%) were those with no education compared to those with below grade seven and above education. This seems contradiction with assumption educated individuals is more likely to adopt new technology like biogas plant. But this could be due to the nature of technology itself and its raw materials requirements; cow-dung which requires cattle ownership that may not require education except having more cattle and labor. Comparatively, people who attained education in a village level were more likely to be in wage employment like teaching, village administration and police officers. People belonging to this category, firstly, most of them live in public or hired houses hence have no permanent premises, secondly being public or civil servants they are liable to be transferred to other work places, hence they are unlikely to invest in biogas technology which is a permanent and non transferable structure as compared to farmers who are likely to be settled in their places permanently.

4.3.4. Household size and biogas adoption

The relationship between household size and biogas adoption is that households with many members had adopted biogas technology than households with few members table 6. As part of cost sharing, the NBPE demand potential biogas adopters to: (a) present sufficient building materials including stones, gravels, and sands; and (b) excavate pit for the biogas digester that is required to be situated below the earth's surface (Eshete *et al.,* 2006). After the completion of the construction, household-labor is also required for feeding the biogas digester daily as well as taking care of the cattle (livestock) to ensure sustained digester feeding. Thus, the interaction effect of household size was expected to have positive influence on adoption of biogas technology. This can be also explained by labor availability due to the fact that biogas technology requires labor force for biogas plant operations. Biogas plant operation involves activities like collecting cow dung, cleaning the cow shed and ferrying the slurry to the farm. All these activities require sufficient labor without which it becomes an impediment to the sustenance of the technology. As shown in table 6 majority of households with family size 4-6 (51.9%) adopted biogas technology as compared to households with family 1-3 members. But percentage of households adopted biogas technology having family size above 6 (34.1%) was less than households with family size 4-6. This could be: one these families were less in number (19.7%), second children in these families might be sent to school that could not contribute much for biogas feeding process.

4.4. Economic characteristics and biogas adoption

4.4.1. Main economic activity and biogas adoption

Table 7 presented the relationship between socio economic characteristics such as the main economic activity of the study area and household income and the implication of these to biogas adoption. The results further indicated that a majority of adopters of biogas technology were those engaged in crop farming and livestock keeping (46.7%) as compared to households only keeping livestock (13.3%) and crop farming (40%). This can be explained by the nature of the biogas technology which requires livestock wastes as raw materials for biogas operations and permanency of the settlement.

Furthermore households whose secondary economic activity was livestock keeping (40%) were more likely to adopt biogas technology as compared to other secondary economic activities (Table 7). This is because animal waste is the main source of input for biogas sustainable function.

Table 7: Relationship between socio -economic characteristics and biogas adoption

Household characteristics	Biogas adopters (N=45)	Non adopters (N=162)	Total (N=207)
Main economic activity of household			
Crop farming	40 (18)	66.7 (108)	60.9 (126)
Livestock keeping	13.3 (6)	1.9 (3)	4.3 (9)
Crop farming and livestock keeping	46.7(21)	31.5(51)	34.8(72)
Total	100.0 (45)	100.0 (162)	100.0 (207)
Secondary economic activity of household			
Crop farming	33.3 (15)	20.4 (33)	23.2 (48)
Petty business	26.7 (12)	37 (60)	34.8 (72)
Livestock keeping	40 (18)	42.6 (69)	42 (87)
Total	100.0 (45)	100.0 (162)	100.0(207)
Households' annual income:			
less than 10,000 birr	33.3 (15)	20.4 (33)	23.2 (48)
10,001-20,000 birr	13.3(6)	24.1 (39)	21.7 (45)
Above 20,001 birr	53.3 (24)	55.6 (90)	55.14 (114)
Total	100.0 (45)	100.0 (162)	100.0 (207)

Source: Field survey (2017/2018)

4.4.2. Household annual income and biogas adoption

Table 7 further indicated that majority of the respondents who had adopted biogas technology were from higher income households (53.3%). However there is also a high percentage (55.6%) of non adopters who have higher income but have not adopted the technology. This finding concurs with Schmitz (2007) who observed that rural people in Tanzania did not see the advantages of biogas technology to take up such a high risk of financing. He further observed that even richer people who could afford biogas installation were unwilling to invest in biogas technology. This suggests that people need to be educated more on the technology benefits and the necessity of adopting it as an alternative to the diminishing fuel wood resources and environmental benefits. This raises a question to whether income is a major determinant of biogas adoption. Though it is a fact that biogas technology involves high initial installation costs hence higher income earners are more likely to afford the costs.

4.5. Responsibility of household members in collecting fuel wood and biogas adoption

Table 8 presented the distributions of household members in collecting fuel wood in the study area. The result showed that husband is most responsible (29%) in collecting fuel wood among them 15% adopted biogas technology and 85% did not adopted biogas technology followed by wife (26.1%) of whom 33.3% adopted biogas technology and 66.7% did not adopt biogas technology. The reason could be wives are mostly engaged in home activities and children might go to school where collecting fuel wood is left for husband. In fact wife engagement is still high.

Table 8: Responsibility of household members in collecting fuel wood

Responsible body	Biogas adopters	Non-adopters	N=207
Wife	33.3(18)	66.7(36)	26.1(54)
Husband	15(9)	85(51)	29(60)
Children	33.3(6)	66.7(12)	8.7(18)
Wife and children	17.6(9)	82.4(42)	24.6(51)
Husband and children	12.5(3)	87.5(21)	11.6(24)
Total	(45)	(162)	100(207)

Source: Field survey (2017/2018)

4.6. Environmental characteristics and adoption of biogas technology

This section assesses the environmental potential of the study area for biogas technology adoption as summarized in table 9. In the literature (Rajeswaran, 1983) it is provided that biogas technology is viable when the prospective acceptor is driven to the necessity of encountering physical limit to the amount of fuel available from the traditional sources. In the study area fuel wood is the primary energy source hence its scarcity is assumed to be a driving force for people to adopt biogas technology as an alternative energy source.

Apart from finding a solution to firewood scarcity, biogas technology has got principal requirements without which it is impossible for a household to adopt the technology. These requirements include availability of feed-stocks and adequate supply of water for effective operation of biogas plants.

4.6.1. Fuel wood scarcity

The primary energy source for domestic use in the study area is fuel wood in form of firewood or charcoal. Findings in table 9 below indicated that 50.7% of respondents experienced shortage of fuel wood of whom 22.9% were biogas adopters and 77.1% were non-biogas adopters while 31.9% of respondents indicated that the fuel wood was no longer available in their area. Among these 77.3% of them adopted biogas technology and

22.7% of them did not adopt biogas technology. In study area due to fuel wood scarcity people have opted to use wastes like crop residues, and animal dung. In the study area researcher meet individuals carrying bundles of crop residues and animal dung value from the farms and open grazing fields for cooking. It is similar with, as the scarcity of fuel wood worsens, households have to collect fuel wood from further sources and utilize more and more proportion of dung and crop residues (Teketay, 2001). These wastes are seasonal, unreliable and heating value from these residuals as per users explanation is very minimal. The shortage of fuel wood implies that people will have to look for alternative energy sources which are more efficient for domestic use.

Table 9: Relationship of environmental factors and biogas adoption

Characteristics of study District	Biogas adopters	Non-adopters	N=207
Availability of wood-fuel			
Easily available	16.7(6)	83.3(30)	17.4 (36)
Not easily available	22.9(24)	77.1(81)	50.7 (105)
Not available	22.7(15)	77.3(51)	31.9 (66)
Total	(45)	(162)	100.0 (207)
Type of livestock management:			
Zero grazing	60(9)	40(6)	19.5 (15)
Semi grazing	66.7(2)	33.3(1)	3.9 (3)
Outdoor grazing	32.2(19)	67.8(40)	76.6 (59)
Total	(30)	(47)	100.0 (77)
Availability of water			
Available within less than1km	18.8(9)	81.3(39)	23.2 (48)
Available within 1 to 2km	20(15)	80(60)	36.2 (75)
Available within more than 2km	25(21)	75(63)	40.6 (84)
Total	(45)	(162)	100.0 (207)

Source: field survey (2017/2018)

In focus group discussion participants were asked the availability of wood fuel in their area. After discussion participants concluded that there is high deforestation and shortage of fire wood in their area. According to their response high population growth and lack of alternative source of energy like electricity and solar energy is the causes of fire wood scarcity. The findings above imply that the demand for an alternative energy source was high in the areas which were more affected by shortage of fuel wood. This result tallies with that of Adesina *et al.,* (2000) who observed that the adoption of alley farming was higher in areas with problem of fuel wood than areas with plenty of fuel wood. However these findings reveal the ignorance of people on what is about to happen in near future and for the coming generations due to the fact that the demand for resources are on increase while the supply is diminishing as a result of population growth. Generally, despite the shortage of fuel wood, in the study area hence demand for a solution of energy problem, biogas technology has not yet been accepted as an alternative energy source. This implies that there were other factors which strongly influenced adoption of biogas technology against the need to find a solution to energy problem.

4.6.2. Types of livestock management

The result in table 9 indicated that free grazing system is practiced in the community. Majority of respondents (76.6%) used outdoor grazing system, 19.5% used zero grazing system (cut and carry) and 3.9% of respondents used semi grazing system. This can be explained as when respondents used outdoor grazing, animal wastes the main input for biogas technology are not easily available. So that, households could hesitate to install biogas technology since their cattle are grazing far away from their home which cause shortage of biogas feed.

During field visit the investigator assured that cattle are in outdoor grazing system which is far away from home. In this case animal wastes the main input for biogas feed cannot be easily available.

Figure 3: Cattle in outdoor grazing

4.6.3. Availability of water

Water is another critical requirement for biogas technology because it serves both livestock keeping and biogas plants operations. An equal amount of water needs to be mixed with feed stocks like cow dung before it is fed into a biogas plant. Findings in table 9 above indicated that the majority of sample population 40.6% had access to water supply within a distance of 2km from homesteads. But only small proportion of sample respondents had access to water supply at less than 1km.

The finding corresponds to that of Schmitz (2007) who found that water is available to rural Tanzanian households to a share of 55% within 1 km even in dry season. For daily feeding of the biogas technology, the source of water was suggested to be within a walking distance of 20 minutes to 30 minutes away from home (Eshete *et al.*, 2006; EREDPC and SNV, 2008). Therefore, distance to water source from home was expected to have negative influence on adoption of biogas technology.

During focus group discussions, women in study area experiencing water shortages expressed their concern by stating that, time which was expected to be saved from firewood collection as a result of adopting biogas technology, is almost the same as the time spent for water fetching required for biogas plants hence the new technology makes no difference. Sasse (1988) asserts that if a biogas plant is far from water source and from the cow sheds, a house wife must perform additional work. According to Sasse (1988), the distance to water source should be less than a quarter of the distances to firewood collection sources. For households which experience shortage of water this could pose a barrier for biogas adoption.

Furthermore, findings in table 10 indicated that about 88.4 % experienced serious to moderate shortage of fuel wood which could be an opportunity for biogas adoption regardless of other inhibiting factors. Respondents were asked strategies they used towards solving problems of fuel wood. Based on their response, 72.5% of them agreed that the best strategy is planting trees.

Table 10: Shortage of fuel wood and strategies to solve

Shortage of fuel wood	N=207
Serious	17.4(36)
Moderate	71.0(147)
Small	11.6(24)
Total	100(207)
Strategies towards solving problems of fuel wood shortage	
Migrate to an area closer to source of fuel	10.1(21)
Planting trees	72.5(150)
Stop free range gazing	1.4(3)
Stop charcoal making	2.9(6)
Prevent bush fires	3.0(6)
Looking for alternative source of energy like biogas technology	2.9(6)
Using fuel saving stove	7.2(15)
Total	100(207)

Source: field survey (2017/2018)

4.7. Awareness about biogas technology.

From the findings of the study (figure 4), 44.93% of the respondents acknowledged that they had at least heard about biogas technology and 55.07% of them never heard about biogas technology. This implies that majority of people in the study area were not aware of the existence of the biogas technology in their area; this might have been caused by concerned bodies in the district did not well promote the existence of biogas technology. Awareness of the existence of biogas technology in the area does not necessarily mean awareness of the technology itself. Awareness of the technology involves people getting detailed information about the technology: what it is, how it functions, its advantages and its financial aspects, to influence people's decisions on its adoption.

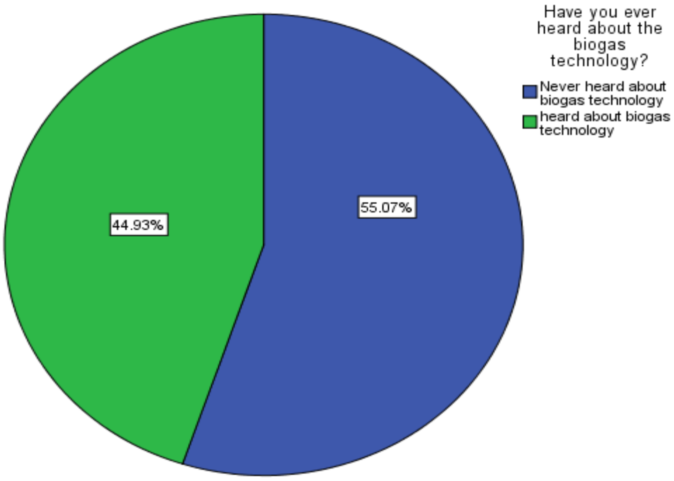

Figure 4: Awareness of biogas technology in the study area

Furthermore awareness alone is not enough to influence the adoption of an innovation. According to Rogers (1995), awareness is just the first stage of adoption process, and it has to be followed by accumulation of knowledge which in turn induces the perception of people on the technology. The accumulation of knowledge is a result of continuous efforts of acquiring information concerning the introduced innovation.

Besides, awareness of existence of alternative source of energy other than fire wood is presented in figure 5. Out of sample respondents, 81.2% of them knew about alternative source of energy other than fire wood like solar energy, charcoal and to some extent biogas technology.

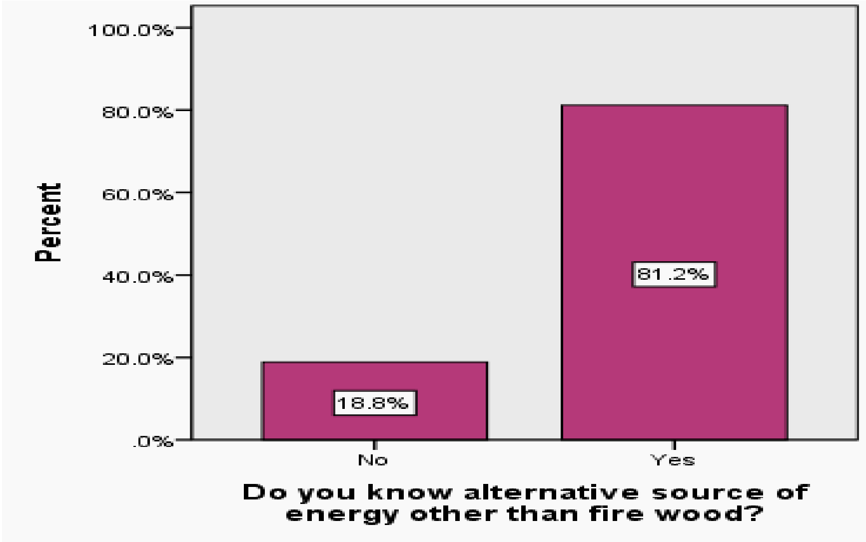

Figure 5: Awareness of respondents about alternative source of energy

4.8. Describing characteristics of biogas adopters.

Biogas adopters were interviewed separately to explore source of cash for biogas installation, ways of biogas adoption , how often project staff members visited installed biogas, weakness of biogas, accessibility of biogas technology, support and encouragement, technical assistance from extension workers, rewarding and use of good performers to train others and promotional activities.

The finding is shown in appendix 1. The result shows that majority of respondents got money for installation from their own money and subsidy from biogas project (an external donor of the African Biogas Partnership Programme) (33.3%) and the government (26.75%). In addition 26.7% of respondents installed the project fully sponsored by biogas project office. But least number of respondents (13.3%) installed the biogas technology with their own money. The explanation for this is almost all of respondents installed biogas with money obtained from other source like project or government office. During focus group discussion the respondents underlined that regardless of the maintenance cost, at least 12,000 birr is required to install and most of residents in the study area cannot afford this cost. Instead they used source of energy like solar for lighting and fire wood, animal dung and crop residuals for cooking.

Respondents were also interviewed how they adopted biogas plant. For majority of adopters (40%) it was planted without their interest. This could be a first task for project runners to introduce biogas technology for the first time in the study area so that others will learn from them and adopt it. Second majority of respondents (26.7%) adopted the technology due to extension workers encouragement in (appendix 1).

Respondents complained that biogas project officers did not come back and visit often biogas plant once they are installed. Unreliable technical services were a common problem reported by respondents during household interviews and in focus group discussions. There was little or no technical assistance given for biogas users from extension workers or from the project staff. During focus group discussion non adopter households who have interest to adopt the technology said that they have a doubt or issues in getting technical supports like procedures for construction, operation and maintenance.

The result in appendix 1 showed limitation of biogas technology. Majority of respondents (26.7%) agreed the biogas technology can't produce enough energy for cooking like the absence of biogas enjera stove. Improving the existing biogas model with addition of enjera stove can be an impetus to the adoption and dissemination of biogas technology. Figure 6 shows the biogas energy used for stove is not good enough.

Figure 6: Biogas used for stove

Other respondents complain that the technology is difficult to operate (20%), unavailability of feed stocks (20%), high maintenance cost (13.3%) and (20%) difficulty to get maintenance service. With these limitations it could be difficult to expand biogas adoption in the study area.

Regardless of these constraints biogas technology was not easily accessible. Respondents perceived that, the technology is not or negligibly available (37.8%), low available (33.3%), satisfactory (15.6%) and highly available (13.3%) (appendix1).

Since the number of households who installed biogas plant with their own money (13.3%) of the respondents pointed out the need for financial service for biogas installation. In this regard, households were asked about access to financial services for biogas installation. According to their response most of them (53.3%) perceived there is no access to financial service, 20% perceived the access is low. This tells us there was no adequate access to financial service source specifically to biogas installation (appendix 1). Access to financial service enables the poor to be able to afford adoption of biogas technology. Provision of subsidy to biogas construction is a temporal solution but to scale up adoption and dissemination of biogas technology over a wider market, access to financial service is quite essential (Ghimire, 2013). Adoption studies on improved maize (Feleke and Zegeye, 2006) and potato (Abebe *et al.*, 2013) varieties in Ethiopia showed similar statistically significant positive associations between access to financial service and adoption of those improved crop varieties.

Officials from district administrative or project offices were expected to support and encourage households to adopt biogas technology. Having such premises, respondents were interviewed level of support they got from officials. The study finding in appendix 1 indicated 46.7% of respondents did not get support, 13.3% respondents said they got low level of support and 20% said it was satisfactory. This indicated that level of support by officials was at most satisfactory where only 6.7% said it was high (appendix 1). The biogas technology is somehow new to the study area and much has to be done to support and encourage adopters so that others will adopt.

Rewarding of good adopters and using them as a model to train others are supposed to play a role to make more households adopt biogas technology. However, the result that was not the case (appendix 1). The technology has faced high resistance to adopt and making them as a model is a useful approach for uptake of the technology but was not done in the study area.

Furthermore advertisement and promotion of biogas plant in various ways play a great role to expand biogas adoption. But the study result in appendix 1 conveyed advertisement and promotion were not carried out or negligibly done. Figure 7 revealed functionality status of biogas plants among adopted households. It is shown 80% of installed biogas plants were working at the time of survey and 20% of installed biogas plants stopped working.

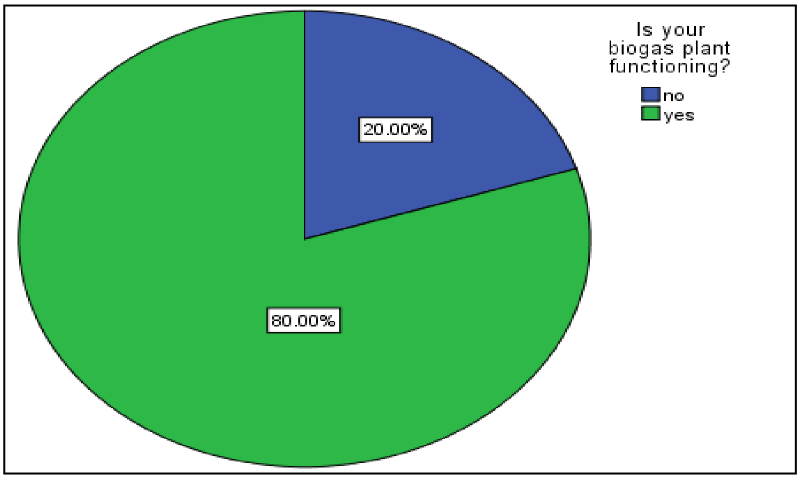

Figure 7: Working status of biogas

After biogas plants were installed they should not stop working so that it must not discourage non adopters. Much of the reason for the failure was due to lack of technical support and frequent visit by extension workers as described above.

4.9. Factors affecting adoption of biogas technology

The discussion under sections 4.2 through 4.8 is a descriptive analysis to investigate the relationship between the individual factors and adoption of biogas technology. This section presented the empirical analysis which shows how these factors behave when they are put together. This is due to the fact that no individual factor acts in isolation; one influences the other and in turn influences adoption of biogas technology. Empirical results of econometric model used to determine factors influencing adoption of biogas technology are presented in Table 11. From the table, the fitness of Logit model is measured by Mc Fadden (R2), 55.3% Mc Fadden value provides a good predictive ability of the model implying that the variables included in the model explain about 55.3% of the variation in the dependent variable. The chi-square statistics show that the model is highly significant at 1% and 5% confidence levels with $p \leq 0.01$ and $p \leq 0.05$ respectively. In addition 79.69% of adoption was correctly classified where the cut point is 50%. This indicates goodness of the model.

Table 11: Estimation of factors influencing adoption of biogas technology

Variables	Coefficient	Std Error	|P[|Z|>z]	Odds ratio
Sex				
Female	0.106	898	0.991	1.011
Male(ref.)				
Age				
Between 36-45 years	-2.204	0.901	0.014*	0.110
between 46-55 years	-0.545	0.893	0.542	0.580
Above 56 Years	-0.853	0.103	0.407	0.426
Education				
Below grade seven	1.17	00.574	0.014*	3.23
Grade 8 and above	2.478	1.039	0.017*	11.91
Occupation				
Livestock keeping	2.28	0.932	0.014*	9.79
Farming and livestock keeping	3.288	0.661	0.000**	26.80
Income	1.000	0.000024	0.996	1.00
Number of cattle	0.4	0.102	0.001**	1.49
Source of fuel				
Firewood and charcoal	0.572	0.135	0.000**	1.77
Alternative				
Yes	-2.045	1.675	0.002**	0.13
Cons	5.092	1.676	0.001**	162.715

*** indicates significant at 1% and * indicates significant at 5%*

Source: own survey 2017/2018

Chi-squared	73.71
P-value	0.0000
Pseudo R-squared (McFadden)	0 .553
Correctly classified	79.69%

The result in table 11 shows the effect of demographic, economic and environmental factors on biogas adoption.

Sex: Sex has no influence on adoption of biogas technology that is there was no difference between male and female headed households to adopt biogas technology. It is true that in most cases men control the household resources in Ethiopia (Lim *et al.,* 2007). It is also men who primarily made final decisions both at household and community levels (EREDPC and SNV, 2008). However, a different result was obtained by Kabir *et al.* (2013) in which female-headed households were found to have more favorable biogas technology adoption behaviors than the male-headed households. Contrary to this result, in the same document, it was described that males mostly dominate the decision process over the household matters in Bangladesh.

Age: When a household heads were in age group between 36-45 years, they were less likely to adopt biogas technology (OR=0.110).This result tallies with that of Simon (2006) who reported that there was a positive relationship between household age and adoption of rotational woodlot technology. However the present result differs from what Sebyiga (2007) reported; where younger people were more likely to adopt formalized land conservation approaches compared to older farmers. This difference is explained by Shiferaw and Holden, (1997) that if adoption has any relationship with age, it might be due to individuals experience or education, or a reflection of authority, labor availability or sources of income. Relating to the findings of this study, adoption of a capital-intensive technology like biogas can be explained by the fact that aged people have more resources including ownership of cattle, ownership of land and houses hence likely to adopt biogas technology than younger people are.

Education status: Table 11 further shows education was positively affecting adoption of biogas technology. The likelihood of household head whose education level was up to grade seven was 3.23 times that of never attended household heads (reference).The same is true for grade 8 and above completed households whose probability to adopt biogas technology was increased by 11.91 compared with never attended household heads. This implies that people with lower education were less likely to adopt biogas technology more than people who attained higher education. This observation is similar with what was expected and also supported with other studies (Simon, 2006; Hawassi, 2007; Sebyiga, 2008,) who reported that educated people were more likely to adopt innovations than those who spent few years in schooling.

Occupation: Occupation of household head was significantly affecting adoption of biogas technology. When a household's occupation was livestock keeping and farming, and livestock keeping the likelihood of adopting biogas technology was increased by 9.79 and 26.80 respectively as compared to crop farming only (reference). The plausible explanation for this could be if a household reared cattle commercially households' income could increased as compared to farming only. On the other hand the main feed of biogas technology is animal dung and if a household had this input, there will not be shortage of biogas feed.

Income: The result in table 11 shows income was not significant in affecting adoption of biogas technology. This finding differs from other studies (Kambele, 2003 and Ng'wandu, 2009) which showed that higher income earners were likely to adopt biogas technology than lower income earners. The probable explanation for this difference could be the subsidy approach used by the biogas project (which is 6,000 birr per each biogas technology) to introduce the technology in the study area, where those who decided to adopt the technology contributed part of installation costs and the remaining part was subsidized by the biogas project.

Number of cattle: The result showed that number of cattle owned in the household was significant to adopt biogas technology implying that when extra cattle was owned in the household, the likelihood of adopting biogas was increased by 1.49. It is consistent with cattle dung is the primary input for biogas digesters in Ethiopia. Consequently, the NBPE has targeted households with a minimum of four heads of cattle. Four heads of cattle are supposed to produce a minimum of 20 kg dung daily input needed to feed the minimum size biogas digester of the programme (EREDPC and SNV, 2008).

Source of fuel: When a household's main source of fuel is wood and charcoal, it was more likely to adopt biogas technology than using cow dung and crop residuals. This could be firewood is running out without substitution and people in the area are suffering from lack of fire wood. This was approved with direct observation at the time of survey. Availability of alternative source of energy was significantly negatively affecting adoption of biogas technology. This implies that if the household has/used alternative source of energy the probability of adopting biogas technology was 0.13. This is reasonable that if a household has alternative source of energy like solar energy, it was unlikely to adopt biogas technology because of its limitation explained in table 11.

4.10. Discussion of information obtained from stakeholders

To triangulate results obtained from households, stakeholders in biogas technology were asked about the extent of adoption, technical and material supports, financial service access, and limitation of the technology and access of spare parts.

The East Gojjam Zone Water, Irrigation and Energy officer told to the investigator that extent of biogas adoption in the East Gojjam Zone is low. The regional biogas project office subsidizes 6,000 birr for purchase of materials and mason for each biogas installation. This is in line with the result obtained in section (4.8) and appendix 1 most of biogas adopters installed with money obtained from either project or government. In addition, the officer stated that trainings and technical services were given in limited extent. This supports the finding in section (4.8) in that most biogas adopters complain they don't get training and technical service after installation.

The Gozamin District Water and Energy officer stated that even though there is financial service access for biogas installation, households are not willing to take it. This could be households' fear of its proper functionality and its power for cooking and lighting. As a result installing biogas with financial service will not be profitable. Furthermore the officer briefed that in addition to regional biogas project, the district water and energy office offer training and material support for model adopters though it is not adequate.

Secondary data about number of installed biogas was obtained from Gozamin District and East Gojjam Zone Water and Energy office since 2012. The data obtained is presented in figure 8 and 9 below. In Gozamin District the number of biogas installed in starting from 2012 was not uniformly increasing like in 2013 it was 7 and in 2014 it was 4. The maximum number of biogas installed was in this budget year (2017/2018) (fig 8)

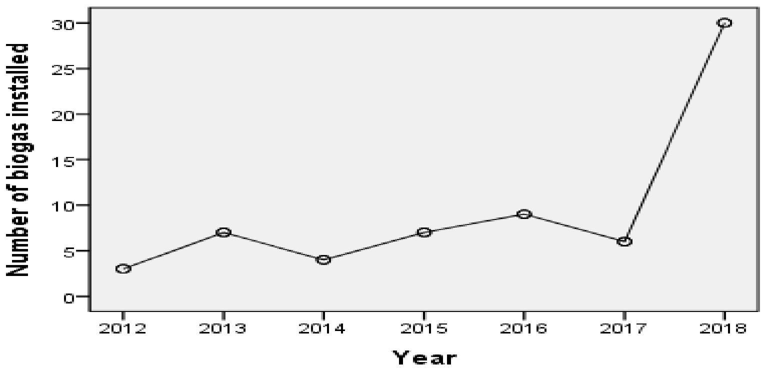

Fig 8: Graphical display of number of biogas installed in Gozamin District

When we see East Gojjam Zone where Gozamin District is found the number of biogas installed was not consistent in each year. The maximum number (145) was observed in 2013 followed by 106 in 2017 (fig 9).

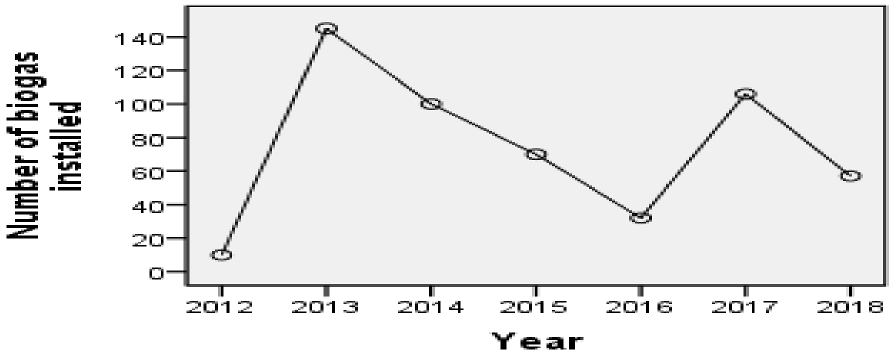

Fig 9: Graphical display of number of biogas installed in East Gojjam Zone

5. Conclusions and Recommendations

5.1. Conclusions

This study was conducted in Gozamin District East Gojjam Zone. The study employed cross sectional survey. Data were collected from 207 rural households listing in 4 purposefully selected kebeles where 45 were adopter of biogas technologies and the remaining households' were non-adopters. All adopters (45) in selected kebeles were included in the sample and the remaining 162 non-adopted households were selected randomly. Probability proportional to size sampling allocation technique was used to allocate samples in each kebele. Qualitative, descriptive and quantitative analysis were used in order to extract relevant information about socio-economic, demographic and environmental characteristics and their potential effect on participation of households to biogas adoption.

From the evidence gathered in the present study, it can be concluded that despite the potential and existence of favorable conditions for technology adoption and despite the existing a biogas project in the study area since 2012, the adoption rate of biogas technology has been at a low level. The major factors for low level adoption rates as revealed in the study can be categorized into demographic, economic, environmental and awareness. Demographic characteristics include gender, education level, age of household heads and family size. Majority of biogas adopters were male headed even though it is not significant in the model. The age group 36-55 years was an active age group to adopt biogas technology. Education level was an important variable to affect biogas adoption where as someone has high education level he/she was more likely to adopt biogas technology.

Among economic characteristics livestock keepings, both farming and livestock keeping were more important occupation categories as compared to crop farming only to adopt biogas technology. Since most biogas technologies were installed with fully sponsored or subsidy from biogas project and government, annual household income was not significantly affecting adoption of biogas technology.

Among environmental factors using fire wood and charcoal as main source of energy was one of the factors influencing household decision to adopt biogas technology. On the other hand using alternative source of such as solar energy and number of cattle were decreasing likelihood of adopting biogas technology.

Larger proportion of households never heard about biogas technology implying that awareness of biogas technology in the study area was low. Both respondents and government officials asserted that lack of promotion of biogas technology, technical supports, training and follow up of installed biogases were in not carried to the required level. Among installed biogas technologies some of them were stopped working due to lack of adequate feed and maintenance service.

5.2. Recommendation

In view of the major findings and conclusions drawn from the findings, the following recommendations are made for actions to be taken in order to promote and raise levels of adoption rates of biogas technology as an alternative energy source for rural populations.

- **Promotion of biogas technology**. The study has revealed that there has been low and declining adoption rate of biogas technology associated with inadequate promotion by the government institutions and the biogas project operating in the study area. This calls for biogas programs to use effective promotion approaches and continuous education to the community about biogas technology.

- **Awareness creation on biogas technology.** The study indicated that awareness about biogas technology was low. Any project office, political leaders, development agents and any other concerned bodies have to do more to raise awareness on biogas technology.
- **Continuous technical supports and training.** The respondents emphasized that unavailability of technical supports and lack of training after installation of biogas technology. Stakeholders also assured the existence of these problems. Therefore, continuance technical support and training should be given.
- **Financial support.** Installation cost is high which is not affordable by rural households alone. High installation cost forced households to find other alternative source of energy but cheaper than biogas technology. As a result NGOs and governments should subsidize installation cost.
- **Technological improvements.** Biogas adopters stated that biogas technology is not effective in cooking and lighting as compared to other alternative energy sources. Therefore to ensure sustainably expansion of biogas technology the technology has to be improved for effective use in cooking like enjera baking and lighting.

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Appendix 1: Characteristics of biogas adopters

Characteristics	Number (N=45)	Percent
Source of cash for biogas installation		
Own money	6	13.3
Fully sponsored from biogas project	12	26.7
Own money and subsidy from biogas project	15	33.3
Own money and subsidy from government	12	26.7
Total	45	100
Way of biogas adoption		
Without my interest	18	40
Due to shortage of fire wood	9	20
Encouragement by extension officer	12	26.7
Due to given or promised incentives	3	6.7
High cost of other energy source	3	6.7
Total	45	100
Visit of biogas plant by biogas project staff members		
Often	3	6.7
Not often	21	46.7
Never come back after installation	21	46.7
Total	45	100
Weakness/limitations of biogas technology		
Difficult to operate	9	20
Unavailability of feed stocks	9	20
High maintenance costs	6	13.3
Difficult in getting maintenance services	9	20
Can't produce enough energy for cooking	12	26.7
Total	45	100
Accessibility of biogas plant		
No or negligible access	17	37.8
Low level of access	15	33.3
Access is satisfactory	7	15.6
High level of access	6	13.3
Total	45	100

Access of financial service for biogas installation		
No or negligible access	24	53.3
Low level of access	9	20
Access is satisfactory	3	6.7
High level of access	3	6.7
Total	39	86.7
Support and encouragement from officials		
No or negligible	21	46.7
Low	6	13.3
Satisfactory	9	20
High	3	6.7
Total	39	86.7
Technical assistance from extension workers		
No or negligible	12	26.7
Low	24	53.3
High	3	6.7
Total	39	86.7
Rewarding of good performers		
No or negligible	30	66.7
Low	6	13.3
Satisfactory	3	6.7
High	0	0
Total	39	86.7
Use of good performers as a model to train others		
No or negligible	12	26.7
Low	18	40
Satisfactory	6	13.3
High	3	6.7
Total	39	86.7
Use of kebele leaders in promotion of the technology		
No or negligible	9	20
Low	27	60
Satisfactory	3	6.7

High	0	0
Total	39	86.7
Advertisement and promotion activities		
No or negligible	24	53.3
Low	12	26.7
Satisfactory	0	0
High	3	6.7
Total	39	86.7

APPENDICES

1: Households questionnaire on assessment of promotion and adoption of household biogas technology in Gozamin District; East Gojjam Zone.

Part: 1

A. General identification

1. Date of interview……………………………….
2. Name of the respondent……………………….
3. Kebele ………………………………………….

B. Household/Institution information

4. Sex of the head of household; 1 = Male, 2 = Female ( )
5. Age of the head of the household (Years) ( )
6. Fill the number of people in each age group in your household;

Age group	Number /quantity/	Those who do provide labour
Below 25 years old		
Economically active 26– 35 years old		
Economically active 36- 45 years old		
Economically active 46- 55 years old		
Aged more than 56 years old		

7. What is your level of education?

   (i) Never attended formal education ( )

(ii) Below standard grade seven ( )

(iii) Standard grade 7-8 ( )

(iv) Grade 9 and above ( )

8. Main occupation of the head of household;

(i) Crop farming ( )

(ii) Livestock keeping ( )

(iii) Farming and livestock keeping ( )

(iv) Petty business ( )

(v) Wage employment ( )

(vi) Others (identify)

9. Secondary occupation of the head of the household;

(i) Crop farming ( )

(i) Petty business ( )

(ii) Big business ( )

(iii) Livestock keeping ( )

(iv) Others (identify)

C. Household income

10. What are the sources of income for your household?

(i) Farm production ( )

(ii) Livestock keeping ( )

(iii) Farm production and livestock keeping ( )

(iv) Business ( )

(v) Wage employment ( )

(vi) Others (identify)

11. What is your average income per year in birr?

D. Livestock keeping

12. Indicate number, and management system of the various livestock types in your farm.

Type	Number	Management system	Management system (key)
Cattle			1 = Zero grazing
Goats			2 = Semi grazing
Sheep			3 = Free grazing
Others (identify)			

Part 2: Availability of important resources

13. Are the following resources available in your area?

Resource	Availability (use key)	Distance towards the resource (kms)
Water for household use		
Fuel wood for cooking		
Grazing land for livestock		

Key on availability of resources

(i) Readily available
(ii) Is in short supply
(iii) Not available

14. What is the major source of fuel for household uses?

(i) Fuel wood and charcoal
(ii) Cow dung ( )
(iii) Crop residues ( )
(iv) Electricity ( )
(v) Solar energy, wind power ( )
(vi) Biogas ( )
(vii) Others (Identify)

15. If the source is fuel wood indicate where you get the fuel wood.

(i) Public forest ( )
(ii) Planted trees ( )

(iii) Virgin land ( )

(iv) Trees on farmland ( )

(v) Private forest ( )

(vi) Fallow areas ( )

(vii) Neighbor's village land ( )

(viii) Market ( )

16. What was the distance near the source of fuel wood in 10 years ago? (km)

17. How long does it take to search fuel wood from the source to home place? (hrs)

18. Average number of fuel wood bundles, bags or charcoal used per month in kg

19. Who is responsible for energy availability in your household?

(i) Wife ( )

(ii) Husband ( )

(iii) Children ( )

(iv) Wife and children ( )

(v) Husband and children ( )

20. How do you rank the problem of fuel wood shortage in your area?

(i) Serious ( )

(ii) Moderate ( )

(iii) Small ( )

21. What do you think is the best strategy toward solving the problem of fuel wood?

(i) Migrate to an area closer to the source of fuel wood ( )

(ii) Plant trees ( )

(iii) Stop free range cattle ( )

(iv) Stop charcoal making ( )

(v) Prevent bush fires ( )

(vi) Looking for alternative sources of energy ( )

(vii) Fuel saving stove ( )

(viii) Others (specify)

22. Do you know any alternative energy other than fire wood and charcoal?

(i) Yes ( )

(ii) No ( )

23. If yes, mention them

24. For the alternative energy sources you mentioned above, which ones do you use?

Part 3: Awareness and promotion of adoption of biogas technology.

A. Awareness

25. Have you ever heard about the biogas technology?

(i) Yes ( )

(ii) No ( )

26. Have you adopted biogas technology?

(i) Yes ( )

(ii) No ( )

27. Who gave you the information about biogas technology for the 1st time?

(i) Biogas researcher ( )
(ii) Extension officers ( )
(iii) Politician ( )
(iv) Neighbor, relative, friend who adopted bio.tech. ( )
(v) Biogas Project staff ( )
(vi) Others (Specify) ……………………………………..…

28. If you have not adopted biogas technology gives reasons;

(i) Do not see the benefit of biogas technology ( )
(ii) Shortage of household labor ( )
(iii) Plenty of fuel wood in the area am living ( )
(iv) High technology costs ( )
(v) Not aware of the technology ( )
(vi) I find it not appropriate ( )
(vii) Others (specify)

B. Experience on biogas technology. FOR BIOGAS USERS ONLY or Key Informants

29. When did you start using biogas technology as source of energy (year)?

30. Who/ which company built you a biogas plant (name)?

31. Where did you get cash for biogas Installation and maintenance?

(i) Own money ( )

(ii) Financial service /Loan ( )

(iii) Fully sponsored by biogas project ( )

(iv) Own contribution and subsidy from biogas project ( )

(v) Own contribution and subsidy from the Government( )

(vi) Other sources (specify)

32. What influenced you to adopt biogas technology?

(i) Out of my own interest ( )

(ii) Severe problem of fuel wood for domestic use ( )

(iii) Encouraged by extension officer ( )

(iv) Influenced by friends/neighbors who have already adopted biogas technology ( )

(v) Given/promised some incentives (specify) ( )

(vi) Awareness of environmental problems ( )

(vii) By- laws against tree cutting ( )

(viii) High costs of other energy sources ( )

(ix) Sensitized by the media ( )

(x) Others (specify)

33. Is your biogas plant functioning?

(i) Yes ( )

(ii) No ( )

34. If yes what are the benefits of using the technology:

(i) Easy and fast in use ( )

(ii) Clean, no soot as compared to fuel wood ( )

(iii) Low running cost after installation costs ( )

(iv) Saving time used for firewood collection ( )

(V) Others (specify)

35. If your biogas plant is not functioning, for how long? (Months)

36. What are the reasons for none functioning of your biogas plant?

(i) Technical problems ( )

(ii) Feeding related problems ( )

(iii) I don't know ( )

(iv) Others (specify)

37. How frequent are the biogas project staff visit you to see the progress of the plant?

(i) Often ( )

(ii) Not often ( )

(iii) Never came back since installation of the plant ( )

38. Are technical services available when needed?

(i) Easily available ( )

(ii) Available but not frequent ( )

(iii) Not available ( )

39. Is your household labor able to accomplish the activities required to run a biogas related activities?

(i) Yes ( )

(i) No ( )

40. If no, what do you do to solve the problem of shortage of labor?

(a) Use hired labor (fulltime) ( )

(b) Use hired labor (part time) ( )

(c) Use of own off-work hours ( )

(d) Others (specify) ( )

41. What are weaknesses/ limitations of biogas technology?

(i) High costs of installation ( )

(ii) Difficult to operate ( )

(iii) Unavailability of feed stocks ( )

(iv) High maintenance costs ( )

(v) Difficult in getting maintenance services ( )

(vi) Not producing enough energy for cooking ( )

(vii) Others (Specify)

C. Gender in Biogas technology

42. Who is the owner of the biogas plant?

(i) Husband ( )
(ii) Wife ( )
(iii) Both husband and wife ( )
(iv) Other family member (specify)

43. Who influenced the household decisions on establishing biogas plant?

(i) Husband ( )

(ii) Wife ( )

(iii) Both husband and wife ( )

(ii) Others family member (Specify)

44. What are the advantages of biogas to females? Related to health, efficiency and others

45. What is the gender division of labor for the following biogas related activities?

Gender	Type of activity		
	Fetching water	Cleaning the plant	Collection of feeds & ferrying slurry
Male			
Female			

46. Apart from biogas do you use any other energy sources?

(i) Yes ( )

(ii) No ( )

47. What kind of energy source do you use?

48. Why continue using other energy sources while you have a biogas plants?

D. Biogas technology Promotion

49. Are there any campaigns, seminars for promotion of biogas technology in your area?

(i) Yes ( )

(ii) No ( )

50. If Yes how many times were the campaigns/seminars in last year

51. Have you ever attended any of the following?

(i) Training workshop on biogas technology ( )

(ii) Biogas village campaign ( )

(iii) Public/Political biogas campaign ( )

(iv) Visited biogas project for consultation ( )

52. Which promotion ways/strategies are being used biogas disseminators?

53. Which weaknesses do the ways/strategies mentioned above has?

54. In your opinion, does the district fully involved in promoting biogas technology?

(i) Yes ( )

(ii) No ( )

55. The following are the factors assumed to promote adoption of biogas technology. Indicate the level of peoples' access to the factors in your area.

Levels of access

1. If no or negligible access
2. If low level of access
3. If access is satisfactory
4. If access is relatively high

Factor assumed to influence adoption of biogas technology	Level of access
Strong demand from people for a solution to energy crisis problem	
Awareness and knowledge of the technology	
Access to credits and other sources of funds for affordability	
Subsidies and other assistance to people	
Support and encouragement from civic council officials	
Availability of technical assistance and experienced extension officers	
Rewarding of good performers	

Use of good performers as models and to train others

Use of kebele leaders in promotion of the technology

Advertisement and promotion activities

2: Interview guide for Organizations dealing with biogas technology

1. Name of Organisation …….................…………………………

2. When the organisation did started disseminating biogas technology in Gozamin District? ………………. (Year)

3. Is there any other organisation in Gozamin District dealing with biogas technology? If yes mention them;

4. What motivated your organisation to engage into biogas technology?

5. What were the project's main objectives? At what level (%) are the objectives met?

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

7. At what extent does the targeted group met? If not met as expected, what do you think are the reasons?

8. How many kebeles in this district have you reached for biogas technology?

9. Do you think many people are aware of biogas technology in Gozamin District? What percentage of population?

10. How many households in a district have adopted the technology?

(i) In Libanos kebele …………………………

(ii) Chmbord kebele …………………………

(iii) Wenka kebele…………………………….

(iv) Enerata kebele ……………………………

(v) Others...

11. Table, on number of biogas plants installed per year Gozamin District.

Year	Number of plants installed	Targeted number	Reason for variance if any	Districts covered

12. What is the percentage of adopters as per population of the area?

13. If the adopters' percentage is small compared to the expected, what do you think are the factors for people not adopting biogas technology?

14. What percentage of biogas plants you installed is functioning?

15. How much does the biogas plant cost from year 2005 up to 2009 in E.C for $4m^3$............, $6m^3$......., and 8m3........, and 10m..........in birr.

16. Apart from animal dung what other materials can be used as feed-stocks for biogas plants?

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

18. What technical problems affecting functioning of biogas plants?

19. What have you done or you suggest as remedy to the problems you mentioned in your responds to question 17 and 18 above?

20. Did your organisation give any support/ contribution to people who adopted or who plan to adopt biogas technology?

21. If yes what kind of support and at what level?

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

22. Are the technical assistance/services available when needed by biogas adopters? How frequent do your technicians visit people who adopted the technology?

23. What are the strategies your organisation use to disseminate biogas technology?

24. What are the problems facing your organisation in disseminating the technology?

25. What is your opinion on Governments' involvement in biogas technology dissemination?

26. What support does your organisation receive from the Government in technology dissemination efforts?

27. What have you lean as organisation about; and your suggestion to the Government on:

(i) Promotion of technology ……….………………………

(ii) Affordability of the technology …..…………………….

(iii) Sustainability of the technology ……….……………

(iv) Plant types and sizes …………………………………

28. Can you summarize the roles supposed to be played by the following Institutions/ organisations /individuals in Promotion of biogas technology, and indicate the level you think played by each?

Institution/Organization/ Individuals	Role to be played in dissemination of biogas technology	Level participation (%)
Zone Water, Irrigation and Energy responsible		
Non Governmental Organisations		
District Water and Energy Office		
Politicians		

29. Any comment on sustainability of your project as far as biogas dissemination is concerned?

30. From your experience in which setting does biogas technology is more appropriate?

(i) Rural, ( )

(ii) Sub-urban, ( )

(iii) Urban ( )

(iv) Both ( )

Reasons for your response ………..…..

3: Check list to the District Government departments/Institutions dealing with biogas technology

1. Policy statements and strategies on alternative energy sources versus its implementation status.
2. Data on energy situation and specifically rural energy in Gozamin District.
3. Renewable energy technologies so far implemented in Gozamin District.
4. Please if you can provide data on the following;
    - Government organizations dealing with biogas dissemination (Years established, location over the District.
    - Non Governmental organizations dealing with biogas technology, biogas plants so far installed by regions and by years of installation.
5. Who monitors the operations of NGOs dealing with energy issues and what are the reporting mechanisms or channels used by both projects owners and the public (beneficiaries of the technology)?
6. What are the promotion strategies and support services offered by the District/Government organizations to Biogas projects and the community to facilitate promotion of biogas technology?
7. What are the challenges facing the District department/Organization on promotion of renewable energy technologies particularly biogas technology?

4: Check list for focus group discussion

1. What do you comment on deforestation status in your area and what are the major causes?

2. Is there energy problem in your area? If yes to what extent

3. Do you see a need for alternative energy sources? If yes which alternatives do you think are appropriate to your area? Think of environment, costs, availability of raw materials, technical services and technological know-how and cultural acceptance to the surrounding community.

4. What is acceptance status of biogas technology in your area? Do you think the technology has been adapted to the expected level?

5. If you think adoption is low what are causes?

6. For biogas users; what were you expectation from biogas technology. Are the expectations met?

7. How Biogas technology did reached this area, what were the dissemination strategies used by disseminators?

8. The following are biogas stakeholders; rank them according to how you perceive their participation level in promotion of biogas technology as alternative energy source.

Biogas stakeholders:

SN	Stakeholder	Perceive participation level
1	Zone Water, Irrigation and Energy Office	
2	Extension officers at District level	
3	Political leaders	
4	Non Governmental Organizations dealing with biogas technology	
5	Respective community (biogas adopters and Potential adopters)	

9. For biogas adopters do you have enough knowledge about biogas to the extent of being able to share the information with others? If not what areas do you think need more education/training?

10. The survey on biogas in this area has shown that most of installed biogas plants are not functioning, what are the major causes and suggest their remedies?

Biographical sketch

Adem Ahmed was born in Debre Elias District, Amhara Regional State in 1965. He learned his elementary and secondary education at Debre Elias Tigilferie Primary School and Dembecha High School respectively. He graduated with a Debre Birahan Teacher Training Institute in1986, Wondo Genet Forestry with Diploma of Forestry in 1993, Bahir Dar Polytechnic with Degree of Natural Resource and Management in 2003. Currently, he joined the MSc. Degree program in Renewable Energy Utilization and Management Wondo Genet College of Forestry and Natural Resource, Hawassa University on 2011.