DETERMINANTS OF HOUSEHOLD BIOGAS TECHNOLOGY ADOPTION AND ITS IMPLICATION ON GREENHOUSE GAS EMISSION REDUCTION: A CASE OF ADA'A WOREDA, EAST SHEWA, ETHIOPIA

M.SC. THESIS

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DECLARATION

I declare that this MSc. thesis work entitled "Determinants of Household Biogas Technology Adoption and Its Implication on GHG Emission Reduction; A Case of Ada'a Woreda, East Shewa, Ethiopia" is my original work and has not been submitted for a degree of award in any other University and all sources of material used in this thesis have been properly acknowledged.

Leshan Tadesse ____________________ ____________________

Name of Student **Signature** **Date**

APPROVAL SHEET I

This is to certify that the thesis work entitled “Determinants of Household Biogas Technology Adoption and Its Implication on GHG Emission Reduction; A Case of Ada’a Woreda, East Shewa, Ethiopia” submitted in partial fulfillment of the requirements for the degree of master of science in Renewable Energy Utilization and Management, the graduate program of the Department of Environmental science, and has been carried out by Leshan Tadesse, under my supervision. Therefore, I approved that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Demamu Mesfin (PhD)	___________________________	____________________
Name of Advisor	**Signature**	**Date**

APPROVAL SHEET II

We, the Undersigned, members of the board of examiners of the final open defense by Leshan Tadesse have read and evaluated her thesis work entitled "Determinants of Household Biogas Technology Adoption and Its Implication on GHG Emission Reduction; A Case of Ada'a Woreda, East Shewa, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Utilization and Management

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Name of External Examiner	**Signature**	**Date**
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Name of Internal Examiner	**Signature**	**Date**
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Name of Advisor	**Signature**	**Date**
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Postgraduate Approval	**Signature**	**Date**

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ABBREVIATIONS AND ACRONYMS

BUS	Biogas user's Survey
CH4	Methane
CO_2	Carbon dioxide
CRGE	Climate Resilient Green Economy
EREDPC	Ethiopian Rural Energy Development and Promotion Center
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GHG	Greenhouse Gas
HH	Household
KII	Key Informant Interview
MoARD	Ministry of Agriculture and Rural Development
MoWE	Ministry of Water and Energy
NBPE	National Biogas Program of Ethiopia
NGOs	Non-Governmental Organizations
SPSS	Statistical Package for Social Science
SNV	Netherlands Development Organization
SSA	Sub-Sahara Africa
WHO	World Health organization

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ABSTRACT

In Ethiopia, majority of the rural population relies on biomass energy sources for day to day cooking. This heavy dependency on biomass fuel has resulted in deforestation, climate change, global warming, desertification and decrease in agricultural productivity. Adoption of biogas technology has great potential to supply clean and environment friendly energy source and results in reducing dependency on traditional biomass. This study was conducted to assess factors that influence the adoption of household biogas technology and its contribution on the greenhouse gas emission reduction, and biomass forest conservation. To do so, household survey was conducted on 356 households using simple sample random sampling design and logistic regression model is used to analysis the data. The result of analysis indicated that nine variables were statistically significant positively or negatively on the household's decision to adopt biogas technology. Variables such as number of cattle, distance to firewood sources, availability of reliable water source and awareness on biogas technology were have positive relation on biogas adoption with significance $p < 0.01$. However, variables such as land size, credit facility, household income status and technical service influence positively on decision to take biogas technology with $p <0.05$. Regarding biomass energy consumption, independent samples test results indicate that there is a significant mean difference in all bio-fuel energy consumption between adopter and non-adopter at $p < 0.001$. Hence, non-adopter households emitted about 8,247.88kg CO_2e per year per household whereas biogas adopter households emitted 3415.62 kg CO_2e per year per households which resulted in 4.84 tons CO_2e (58.69% reduction) by adopter households. Domestic biogas technology has also contributed on biomass forest conservation with annual woody biomass reduction of 51.5% by adopter households.

Key Words: Biogas technology adoption, Biomass energy, Greenhouse gas emission reduction, Forest conservation.

1. INTRODUCTION

1.1 Background

The Sub- Saharan African countries energy supply is heavily dominated by biomass which accounts above 90%, and the dominant cooking practice is three-stone open fire (Adkins et al, 2010; Schlag & Zuzarte, 2008). Like many other sub-Saharan African countries, Ethiopia's energy supply is heavily dependent on biomass which accounts for above 95% of the energy use (NCCSPE, 2011). Such reliance on biomass energy is one of the major causes of environmental degradation and a contributor to the greenhouse gases emissions, such as Carbon-dioxide, methane and nitrous oxide (Mano *et al*., 2017).

In many developing countries, particularly in sub-Saharan Africa (SSA), deforestation and degradation of forests contribute a huge amount of GHGs emission (Hosonuma et al., 2012). The consumption pattern of biomass has led to forest degradation and deforestation, atmospheric pollution from emissions of greenhouse gases (GHG) during the combustion of wood with its implications for climate change, and indoor air pollution leading to domestic health hazards particularly for women and children during cooking (WHO, 2005). To overcome these problems, alternative energy sources have recently become more and more attractive due to the increasing demand for energy, the limited resource for buying fossil fuel, the environmental concerns and the strategy to survive post-fossil fuel (Siltan, 1985).

Biogas is a renewable energy technology that utilizes organic wastes to produce a flammable methane gas suitable for cooking and lighting purposes (Lansing *et al.,* 2008). It also improves the environment at indoors and outdoors. The indoor environment is enhanced by reduction in the incidents of illness from burning of firewood and dung, outdoors by reduction in carbon dioxide and methane emission (Siltan, 1985).

Furthermore, it is also a proven technology that contributes to the reduction of the deforestation rate and helps to save the trees to sequester more carbon from the atmosphere and the local effects of trees being cut down that otherwise cause soil erosion, desertification, loss of soil fertility, and landslides (Marry et al, 2007). Biogas can be produced from locally available raw materials and harnessed in controllable, containable and usable quantities including all livestock feces contributed by livestock sectors (Walekhwa, 2009).

Ethiopia is one of the top-ranking countries in Africa and among the first ten in the world in terms of livestock resource (FAO, 2009). The majority of the rural population in Ethiopia is involved in some way in animal husbandry. So, the country has the greatest potential to the development of biogas technology (Zenebe et al; 2010).

Therefore, considering all these advantages, the rate of adoption of biogas plants is increasingly encouraged by Government and non-government initiatives. Nevertheless, it is difficult to specify the factors affecting the adoption of technologies in different parts of world due to differences in agro-ecological and socio- economic nature (Bekele et al., 2003). However, from my personal observation due to my exposure for the Ada'a woreda and Oromia region biogas program annual report of 2018, a number of households using biogas technology has been decreasing in the woreda. Therefore, this study is designed to assess and analyze determinants of household biogas technology adoption and its implication on GHG emission reduction in the district.

1.2 Problem Statement

Ethiopia has the largest cattle population in Africa and this indicates that the nation has higher potential to make use of biogas for rural energy supply (Tewelde et.al, 2017). Feasibility study has been conducted in 2006 at four regional states (Amhara, Oromia, Tigray and Southern Nation Nationality People's) for national biogas progarmme on domestic biogas technology in Ethiopia and the output of the study indicated that there are more than 1.1 million potential households for the technology (Esthete et.al, 2006). Following the positive outcomes of the study, in 2008 National Biogas Programme of Ethiopia was established and implementation started with the objective of improving the livelihood and quality of life of rural households from benefits of domestic biogas such as replacement of unsustainable utilization of wood and charcoal for cooking and lighting; use of the high value organic fertilizer from the bio-slurry; and improvement of health and development conditions for rural households.

The programme benefited about 25,219 households (NBPE, 2019) in the last one decade which is only 75% achievement of its plan. However, this figure is about 2.3% of the technical potential of the country and it is an indicator for less outreach and adoption of biogas technology in Ethiopia, particularly in Oromia region. This need assessment on why low dissemination rate of the domestic bio-digester technology. On the other case, biogas technology reduces greenhouse gases emission through replacement of firewood and charcoal used for cooking and this has been indicated in the national biogas programme objective. Some studies were conducted in the country such as studies by Shegenu & Seyoum (2017) at Aleta wondo woreda, Mengistu et al. (2016) at Northern part of Ethiopia and Berhe et al. (2017) at Tigray region on biogas adoption determinants. There is limitation on the geographical coverage of the study by researchers (no study in

Oromia region, in particular in this study woreda) and the mentioned researchers also didn't include in their study greenhouse gases emission reduction potential of biogas technology and impact on biomass forest conservation. Therefore, this study is to assess and analyze the factors for determining household's decision for bio-digester adoption and its role on GHG emission reduction.

1.3. Objective

1.3.1. General Objective

The General objective of this study is to examine determinants for the adoption of household biogas technology and the implication of biogas technology on the reduction of biomass consumption and GHG emission.

1.3.2. Specific Objective

- To assess the determinants of biogas technology adoption by farm households,
- To estimate biomass (firewood &Charcoal) saved and its interference on forest conservation in use of biogas energy by farm households.
- To estimate greenhouse gas emission reduction by household biogas technology.

1.4. Research Questions

The research questions basically designed to answer the following question:

- What are the determinants for Biogas technology adoption by farm household?
- What is the estimated amount of biomass fuel saving and forestry conserved by use of biogas energy by farm household?
- What is the role of biogas technology on reducing GHG emission?

1.5. Significance of the Study

The result of this study can be an input for different policy makers, planners and initiatives for developing and undertaking integrated plans, programs and projects which can have a significant involvement for ensuring sustainable renewable energy for rural households. The finding of this study also useful for researchers, stakeholders, and particularly individuals working in energy sector because it gives some insights on how to disseminate new technology like bio-digester for the rural households. Importantly, this study result can be an input for the biogas programme to focus on identified factors during promotion of the technology. On the other hand, the result of this finding can be used by the Oromia regional biogas programme office to deal with the concerned governmental body to have clear strategy/guideline for domestic bio-digester dissemination.

1.6. Scope and Limitation of the Study

The study was conducted at Ada'a woreda of East Shewa Zone, Oromia regional state at 5 kebeles to determine factors influencing biogas technology adoption and the roe of bio-digester owner households on reducing biomass energy consumption which result in GHG emission reduction. The study was conducted on sampled 356 households of which 96 are bio-digester owners and the rest non- adopter. The variables selected for the study are twelve for adoption assessment and five for biomass energy consumption. While dealing with role of bio-digester on biomass forest conservation, only two fuel type, firewood and charcoal, are considered because agricultural crop residues are seasonal and not available throughout the year and also kerosene is not considered for this as the source is fossil fuel.

The study limited to twelve factors for adoption and couldn't consider others determine factors like availability of infrastructure (such as road, electricity), availability of incentive for the user, availability of construction materials in the locality and others .Also during estimation of GHGs reduction, only energy aspect of the technology was considered and the role of bio-slurry, which is an organic fertilizer replacing chemical fertilizer, is not taken into account in emission reduction calculation.

2. LITERATURE REVIEW

This chapter explores basic concept about biogas, benefits of biogas, factors affecting biogas Technology, adoption and experiences of biogas technology as well as Ethiopia's experiences and steps towards adoption. The chapter further reviews literature related to adoption process, benefits of using biogas bio gas for greenhouse gases emission reduction by household biogas technology.

2.1. Biogas composition and properties

Biogas is a mixture of gases evolved from digestion process of organic matter by anaerobic bacteria at anaerobic conditions (i.e. without oxygen) (Mattocks, 1984). Most studies about biogas indicate that methane (CH_4) and carbon dioxide (CO_2) are the main components, where the ratio of methane ranged between 50 - 80% and the ratio of carbon dioxide range is 20 - 50% (EREC, 2002). Other components of biogas that may be found in small amounts (traces) are: Hydrogen (H_2), Nitrogen (N_2), Hydrogen Sulfide (H_2S), Carbon monoxide (CO), Ammonia (NH_3), Oxygen (O_2) and water vapor (H_2O) (Schomaker et al., 2000).

Table: 1 Composition of biogas

Substances	**Chemical formula**	**Percentage**
Methane	CH_4	50-70
Carbon dioxide	CO_2	30-40
Hydrogen	H_2	5 – 10
Nitrogen	N_2	1 – 2
Water vapor	H_2O	0.3
Hydrogen sulfide	H_2S	traces

Source: EREDPC and SNV Ethiopia (2008)

2.2. History of biogas technology in Ethiopia

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

2.2.1. Benefits of Biogas technology

Biogas as an alternative to the use of biomass for energy was introduced in Ethiopia since 1979.Households directly benefit from domestic biogas; reduced use of fuel wood, improved living condition, time saving, Reduction of workload, mainly for women, improved soil fertility through the use of bio-slurry. Additionally, biogas contributes to the reduction of greenhouse gases and to job creation (PID, 2008). As an effort to counteract environmental, indoor air pollution and social problems arising from wood fuel combustion and use, and waste management, numerous efforts by several development organizations in Ethiopia through the Ministries of water & energy and Environmental protection, to introduce and disseminate biogas technology in the area, to provide affordable, clean and sustainable domestic biogas to the residents is very low (NBPE, 2013).

Biogas is mainly composed of methane (CH_4), and is thus a flammable gas. It can therefore be used as a fuel for heating, cooking and lighting. Biogas can also be used to feed engines to produce electricity. The heating value of biogas – the amount of heat released during the biogas combustion – is approximately 6kWh/Sm^3. In other words, the combustion of 1 standard m^3(sm^3) of biogas produces the equivalent of 6 kWh of heat. For information, the following table compares the equivalence between biogas and other possible fuels in terms of heating value:

Table: 2 Equivalence between biogas and other fuels in terms of heating value

Fuel	Unit	Value
Charcoal	kg/Sm^3 of biogas	0.7
Firewood	kg/Sm^3 of biogas	1.3
Gasoline	liter/Sm^3 of biogas	0.75

Source: GTZ, Bio-digester installation manual 2008.

2.3. Impact of Biogas on Firewood Saving and Forest Conservation

As per the study investigated by Amare (2015), 60% biogas reduced the firewood, compare to 40% who believed that biogas has nothing to do with forest conservation. Upon interview with key informants revealed that 62% of the biogas impact on the environment reduces the firewood leading to the forest conservation. In addition to this before the installation of biogas plants, households used 3,596.4 kg of fuel wood /HH annually, after installation of biogas plant each household uses an average of 1062 of fuel wood/HH/year which is reduction of 2,534.4 kg (70.47%) per hhs per year. According to Muriuki (2015) most non-adopter households heavily relied on firewood and charcoal for their domestic energy needs. Average monthly firewood consumption for non-adopter households was 228.5 kgs, compared to an average of 187.5 kgs consumed by biogas adopter households before the installation of biogas plants. About 82 kgs of charcoal was consumed on average by non-adopter households. Comparing fuel consumption for the non-adopter households and adopter households after biogas installation, the observable mean difference could not be over-emphasized. With the non-adopters using 228.5 kgs of firewood monthly, biogas users consumed only 60.8 kgs. The reduction in charcoal was also huge with the non-adopter households using 81.8kgs per month per household, whereas 18.3 kgs consumed by households that have adopted biogas.

2.4. Carbon Emission Savings and Climate Change Mitigation

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

Fuel wood consumption is a major cause to environmental degradation, and may lead to energy insecurity for rural African households, especially where the resource is commercialized (Hiemstra-van der Horst and Hovorka, 2009). The high dependence on wood fuel in the sub-Saharan Africa has resulted in an alarming rate of tree felling and deforestation (cited in United Nations Economic and Social Council, 2007). This would create a great challenge for Africa unless renewable energy sources, which are clean and environmentally friendly energy sources, can't be given a great attention in the future. The use of alternative energy such as biogas has a potential to reduce the demand for wood and charcoal use, hence reducing greenhouse gas emissions improving water quality, conserving of resources, particularly trees and forests, and producing wider macroeconomic benefits to the nation (Amigun and Blottnitz, 2010) due to reduced deforestation.

2.5. Factors affecting household biogas technology adoption

There are several issues that consumers consider before rejecting or adopting an innovation and technology. Cost is one of the major considerations. Consumers particularly in regions where credit and/income access is low households go for technologies that have low initial cost than those that are likely to reduce operation costs which may extend for a long period of time (Mwirigi et al., 2014).

According to (Lionbergen & Gwin, 1991), innovation uptake relies upon different factors that vary from one place to another. To a greater extent, households' demographic traits, environmental elements, institutional support services, and technology usefulness as perceived by the consumers have been found to greatly influence adoption and dissemination of a new technology.

The relative advantage of a modern energy technology may be evaluated in financial phrases, social status, convenances, and satisfaction (Mengistu et al., 2015). To support this argument Gebreegziabher (2007) noted that the greatest threat to significant biogas uptake in Ethiopia remained to be the high initial investment cost. Rogers (1983) indicated the potential of subsidies to speed up technology uptake.

A study by Mwirigi k. Erick (2018) on adoption of biogas technology and its contribution to livelihoods and forest conservation in Kenya revealed that household income and education level significantly influenced the technology uptake. Another study by Bundi M. Bonnke(2010) in Kisii County ,Kenya, on factors influencing the choice and adoption of biogas technology among the peri-urban residents indicated that starting from the most influential to the least as: high installation costs of plants, multiple use of household fuels, level of income and education ,promotion of the technology, lack of facilities and appliances such as stoves and lamps ,minimal coordination between stakeholders and lack of a central coordinating body.

Uhunamure et al. (2019) conducted study on correlating the factors influencing household decisions on adoption and utilization of biogas technology in South Africa and the finding of the study that have statistical significance ($p < 0.01$) were household head level of education, age of household head, number of cattle owned, distance to fuel wood source, crop production, credits, loans and subsidies, income, gender, water availability and awareness. With significant ($p < 0.05$) household size, technical availability and distance to fuel wood source positively influence the adoption and utilization of biogas technology.

A study by Anna Wawa and Shadrack Mwakalila (2012) on factors affecting the adoption and non-adoption of biogas technology in semi-arid areas of Tanzania indicated weakness promotion efforts, little involvement of the government, poor performance of biogas plants associated to technical problems, high installation costs, unreliable feed stocks and water shortage as the major barrier for the adoption. Melaku Berhe et al. (2017) conducted a study on factors influencing the adoption of biogas digesters in Northern rural part of Tigray region, Ethiopia and reached on conclusion the size of cattle holding, working age, gender, access to electricity, access to credit services, and livestock mobility as a factors on choice of the household biogas technology.

Sufdar Iqbal et.al. (2013) did research on factors leading to adoption of biogas technology in Faisalabad district, Pakistan and found positive association between the adoption and the number of livestock, age and land. Shegenu and Seyoum (2018) conducted study on determinant of biogas technology adoption and its implication on environmental sustainability in Aletawondo woreda, Ethiopia, and concluded that proximity to water, access to credit, cattle size, availability of trained mason, land size and annual income as a significant determinant. On their study, they also indicated that an average of 1066.80kg biomass and 25.2-liter kerosene reduced resulted in reduction of 2160.93kg CO_2 equivalent GHG emissions to the atmosphere annually per adopter households. Lixiao Zhang and Changbo Wang (2014) conducted a study on household biogas digester of size $8m^3$ in China and concluded GHGs emission mitigation of 50.45t CO_2 equivalent in its life span of 20 years.

2.6. Technology adoption

Rogers (1995), defines technology adoption as the level at which an innovation is chosen to be used by a person or an organization. In keeping with (Abukhzam& Lee, 2010), adopting a technology depends on numerous elements which purpose a targeted user to adopt or reject. They include; perceived usefulness and ease of use, facilitating conditions e.g. availability of government support and managerial support, technology readiness and social influence. These factors can make a positive or negative contribution towards technology adoption. Customers may also reject some technologies due to the fact that technologies are not in line with their values, beliefs and past experiences. Davis et al., (1989) argues that the successful implementation of any innovation is primarily determined by user's attitude. However, factors such as technology characteristics (e.g. perceived usefulness and ease of use, compatibility, reliability, security), organizational and managerial characteristics have been found to be key instrumental factors affecting users' attitude towards adoption or rejection of a particular technology.

Getting a new idea adopted, even when it has obvious advantage, is difficult (Rogers, 2003). Many innovations require a length period of many years from the time when they become available to the time when they are widely adopted (Rogers, 2003). Diffusion of innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. Rogers defined the adopter categories as "the classifications of members of a social system on the basis of innovativeness" This classification includes innovators, early adopters, early majority, late majority and laggards. Innovators are the first individuals to adopt an innovation and they are very few (2.5%) followed by early adopters (13.5%). Early adopters consist of younger generation with high social status and finances to invest. Early majority and late majority (34%) follow later and finally the laggards up (16%) as the last group to adopt. In addition to the gatekeepers and opinion leaders who exist within a given community, change agents may come from outside the community. Change agents bring innovations to new communities through the gatekeepers, then through the opinion leaders, and so on through the community.

2.7. Conceptual Framework of the study

The factors that could likely affect the Biogas technology divided into five interrelated categories which are technical, economic, infrastructural, cultural and social aspects (Agarwal, 1983; Masera et al., 2000). Accordingly, the conceptual framework tries to show a diagrammatic representation of the determinant factors for the adoption of Biogas technology in the study area. Adoption of Biogas technology in this study is the dependent variable defined as to accept or decide to use the Biogas technology and is influenced by various explanatory variables that are interconnected. Herein below is the conceptual diagram that illustrates the factors that determine the Biogas technology adoption and may help in data analysis and discussion part in future.

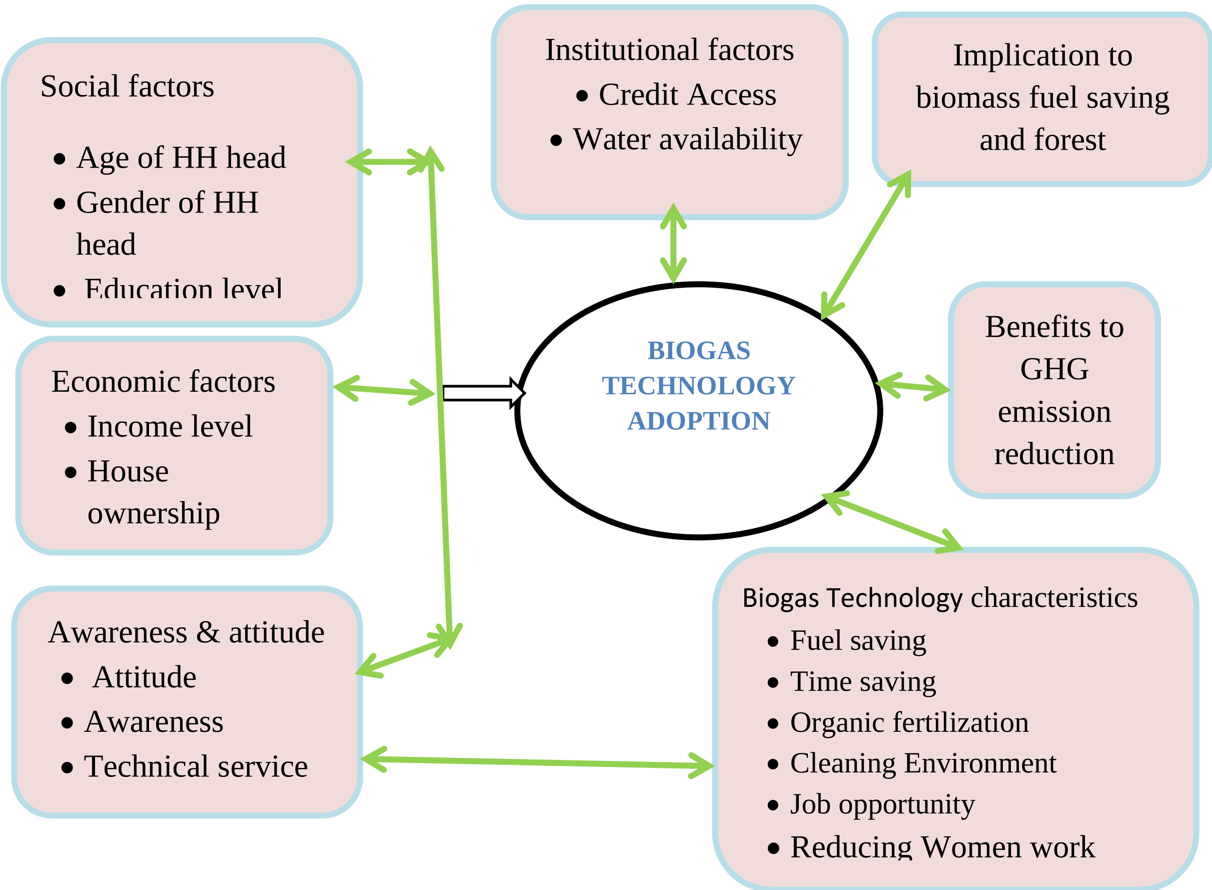


Figure 1: Conceptual framework of the study

Source: Developed by myself.

The conceptual framework indicates that demographic and social factors such as age of household head, educational level of household head, gender of household head, House hold size; economic factors such as annual cash income level of household, house ownership, no of Cattle; institutional factors such as water availability, credit access and Biogas technology characteristics include fuel and time-saving, organic fertilizer, cleanest

Environment and job opportunity can influence the decision to adopt biogas technology in Ada'a woreda. Furthermore, knowledge and awareness could also affect the adoption of Biogas technology. Adopting Biogas technology has a positive implication for a biomass fuel saving, forest conservation and greenhouse gas emission mitigation.

3. MATERIALS AND METHODS

This Chapter describes how the research was carried out. It includes the description of the study area, sampling techniques, and sample size determination, method of data collection and analysis, and definition of variables and their unit of measurement

3.1. Description of the study area

The study was conducted in Ada'a woreda which is found in Oromia regional state on the East of Addis Ababa. Geographically, the woreda is found in between longitudes 38º51' to 39º04' East and latitudes 8º46' to 8º59' North covering a land area of 1750 km^2 (AWRLAO, 2019). The Woreda is bordered on the South by Bora woreda, on the West by South West Shewa zone, on the North West by Akaki Woreda of Oromia special zone around Finfinnee, on the North East by Gimbichu Woreda and on the East by Lume Woreda

Ada'a was mostly plain highland ranging between 1600 to 2000 meters above sea level. The agro-ecology in the woreda was best suited for various agricultural productions. Rivers and crater lakes are used for agriculture particularly for horticultural crops production. Ada'a is known countrywide for its finest quality 'teff' production which dominates the agricultural production system of the area. Wheat was also cultivated in sufficient amount. Pulse crops and chickpea are grown in the bottomland. Cattle, sheep, goat, and poultry production was a very common practice in the woreda.

According to the information obtained from Ada'a Woreda Water and Energy office, there are 27,264 total households in Ada'a woreda from which 306 households had domestic biogas technology.

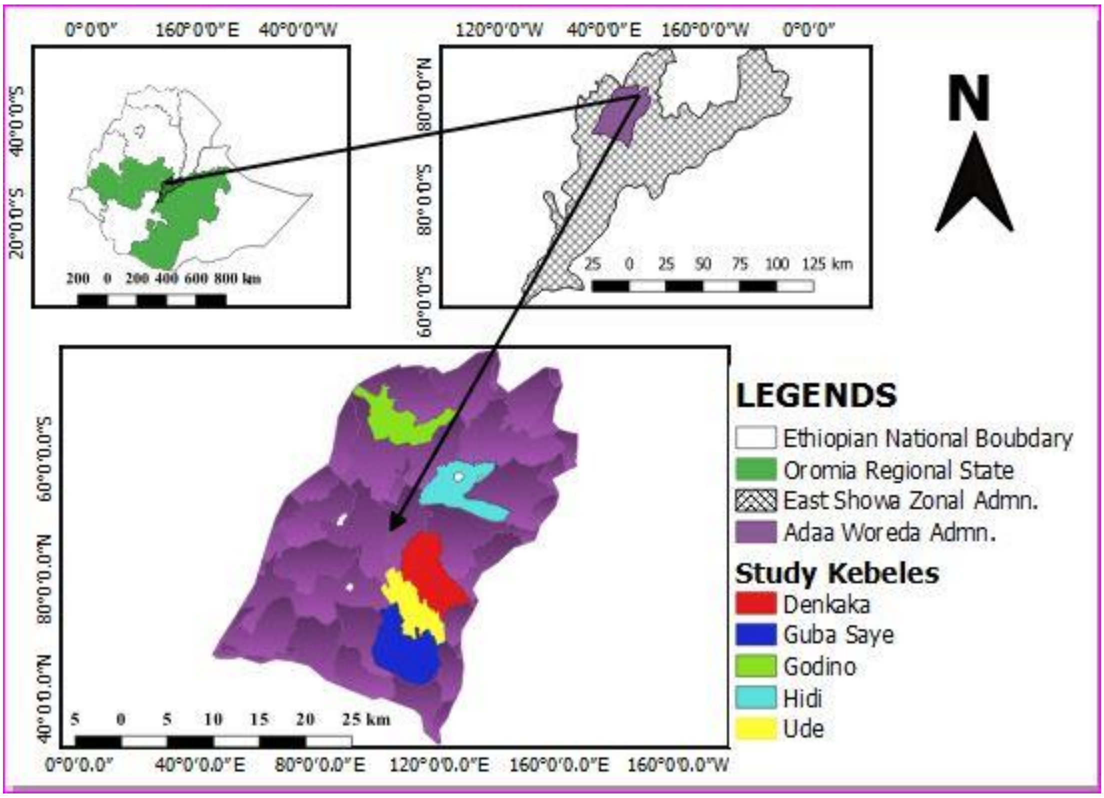


Figure 2: Map of the study Area

3.2. Data collection Methods

To collect the essential data for this study, a cross-sectional survey method was employed. Cross-sectional survey was preferred for this study because of its flexibility and its simplicity in collecting several data. Cross-sectional data also selected due to the constraint of budget and time as well as shortage of longitudinal data. Both qualitative and quantitative approaches were employed due to the nature of the study. The study involves assessing several factors that influences individual household to adopt biogas technology. The qualitative approaches is used to make an in-depth investigation of the variables related to adopter and non-adopter of biogas technology (Anna, 2012).

The primary data was collected using a structured questionnaire through interviewing the household head, key informant and focus group discussion. Secondary data was gathered by reviewing different published and unpublished sources relevant to this research topic.

3.2.1. Questionnaire

A set of closed ended and open-ended questionnaires was developed and administered to respondents. The questionnaires were developed in English and translated into Afan Oromo. The questionnaire was useful in collecting general information about rural households' socio-economic characteristics, Awareness, knowledge and Attitude toward of biogas technology adoptions as well as experience on biogas technology. The questionnaires were held with the household's head (Male or Female).

3.2.2. Field observation

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

3.2.3. Focus group discussion

A focus group discussion was organized to help issues which needed more clarification after administration of questionnaires. A focus group discussion composed of ten members was adequate, one group was consisted of both biogas users and non-biogas users and it offered general opinions on factors influencing biogas adoption.

3.3. Sample Techniques and Sample size determination

3.3.1. Sample Techniques

Simple random sampling is one in which each member in the total population has an equal chance of being selected for the sample and random sampling always produces the smallest possible sampling errors (Renckly, 2002). In this study, both purposive sampling and simple random sampling techniques were employed. A simple random sampling technique was used to select five Kebeles, namely Ude, Dekaka, Gubasaye, Hiddi, and Godino from the total of 27 rural Kebeles within the woreda. Moreover, a simple random sampling technique was also used to select the number of household heads who didn't adopted the biogas technology and purposive sampling technique is used for adopter households. Purposive sampling is used to get properly functioning bio-digesters in that locality and why less dissemination rate of biogas technology.

3.3.2. Sample size determination

The unit of analysis for this study was both the Biogas technology adopter and non-adopter households in the study area. To determine a representative sample size for a simple random sampling design by Yamane (1967) formula was adopted. Accordingly, a total sample size of **356** household heads were selected using the equation (1) herein below.

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

Where "n" was the sample size, "N" was the population size (total household heads size), and "e" was the level of precision., P= 0.05and±5% level of precision (*e*) and 95%

confidence level. Finally, to determine the sample households from each kebele were selected using a proportional sampling technique. Based on this, the sample size of each kebele was computed as follows (Table 3).

Table 3: Proportional sample size determination of biogas and non- users' households in each kebele

No.	Kebeles	Household number	sample size	percent	Number of adopters	Number of non-adopters
1	Ude	614	67	18.82	14	53
2	Gubasaye	549	60	16.85	12	48
3	Denkaka	617	67	18.82	13	54
4	Hiddi	726	79	22.19	27	52
5	Godino	762	83	23.31	30	53
	Total	**3268**	356	100.00	96	260

Source: Ada'a woreda Water and energy resource office 2020

3.4. Data Analysis Method and Model Specification

All the quantitative data collected from different sources were coded and entered into ($SPSS_v20$) statistical tools and excel for statistical analysis. To reduce problems related with incompleteness and other related inappropriate responses, the row data was cleaned, edited, coded, grouped, tabulated and summarized with the help of SPSS software version 20 statistical tools. The results of the analysis were interpreted and discussed using descriptive statistics, and econometric models.

3.4.1. Descriptive Statistics

Descriptive statistics was employed for analysis of data using mean, percentage, frequency, standard deviation, chi-square test and t-test that give statistical summaries related to variables of concern. Chi-square test, independent and paired samples test were employed to identify variables that vary significantly between adopters and non-adopters. The chi-square test was used to see the association between some categorical variables of adopters and non-adopters. The t-test was used to see if there is a statistically significant difference between the mean of adopters and non-adopters with respect to continuous variables, for example, fuelwood consumption.

3.4.2. Econometric Model Specification for Biogas Adoption

To identify the major determinant factors for the household's decision on the adoption of biogas technology, a logistic regression model was employed. Since the outcome of the dependent variable is binary and the explanatory variables are in any form of measurement scale (Peng et al., 2002), the dependent variable in this study was a binary variable with values 1 for adopter and 0 otherwise. The model can be written mathematically as follows.

$$\mathrm{p} = \mathrm{E}(\mathrm{Y} = 1|\mathrm{x})\mathrm{a}b\mathrm{x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where Y= 1 means a given household adopts Biogas technology, x is the explanatory variable, ‘a' and ‘b’ are parameters to be estimated.

$$P = \mathrm{E}(\mathrm{Y} = 1|\mathrm{x}) = \frac{1}{1+e^{-(a+bx)}} = \frac{\mathrm{e}^{\mathrm{a+bx}}}{1+\mathrm{e}^{\mathrm{a+bx}}} \ldots\ldots\ldots\ldots\ldots 2$$

As P is the probability of adopting Biogas Technology, 1-P is the probability of not adopting the Biogas technology. Therefore

$$1 - p = (Y = 0|x) = \frac{1}{1+\mathrm{e}^{\mathrm{a+bx)}}} \ldots\ldots\ldots\ldots\ldots 3$$

Where Y = 0 is the non-adopter. Therefore, by dividing equation 2 to equation3 we can write the model mathematically as follows.

$$\frac{p}{1-\mathrm{p}} = e^{a+bx} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where $\frac{p}{1-p}$, is the odds ratio of certain events to have occurred which is the ratio of the probability of a given household to adopt Biogas Technology to the probability of households that will not adopt.

By taking the natural logarithm of equation (4) on both sides, one can derive an equation to forecast the odds ratio of certain events to have occurred as follows:

$$Ln\left(\frac{p}{1-\mathrm{p}}\right) = Ln(e^{a+bx}) = a + bx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..5$$

Therefore, by extending the simple logistic regression into multiple predictors and by considering the residuals, the logit model is written as:

$$logit(Y) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon_i \ldots\ldots\ldots\ldots\ldots 6$$

Where βo is constant term, x_1, x_2…x_k are explanatory variables that are expected to affect the adoption of Biogas technology and β_1, $\beta_2 \ldots \beta_k$ are the parameter's that is estimated corresponding to each explanatory variable and ε_i is the error term. Before performing the logistic regression analysis, the data will be checked for the existence of multicollinearity problem between the independent variables using a correlation matrix and the variance inflation factor (VIF). There were no variables that have a strong correlation.

3.5. Explanatory variables of the model

The following explanatory variables will be hypothesized to influence the adoption decision of household to the biogas technology:

Dependent Variable: In this study, the dependent variable had a dichotomous nature which denotes the adoption of Biogas Technology. In this case, households using Biogas technology for cooking, lighting and slurry for soil fertility were considered as adopters whereas those who not use the technology were considered as non-adopters. The major independent variables included in the model are defined as following.

Independent Variables

A) **Age of the household:** Age of household head was expected to affect adoption of biogas either positively or negatively. Older household heads will be expected to have more resources particularly cattle as compared to younger people and hence, potentially capable of adopting biogas technology. This was due to the nature of the technology where cattle ownership was a prerequisite to ensure availability of feed-stocks for operation of biogas plants. On the other hand, older households may be more risk- averse and less likely to be flexible than younger household and thus have a lesser adoption rate for biogas technology.

B) Gender of the headed household: Sex of household head was assumed to affect adoption positively or negatively. It is assumed that male headed household are more likely adopt new technology because male headed household are often considered to get more information about new technology and take on risk than female headed household (Temesgen et al., 2008). On the other hand, Biogas technology was expected to lessen woman's workload particularly firewood collection task and hence it may be more adopted by women headed household than male headed household.

C) Number of cattle owned: It will be expected to influence adoption of biogas positively. Households that owned a greater number of cows had a high probability of adopting the technology.

D) Land size: Land was one of the important economic factors that measure adoption of new technology. Households with larger hectares of land would have enough area for cattle grazing and bio-digester construction site, and they have more chance to adopt the biogas technology. Therefore, it will be expected to influence adoption of biogas positively.

E) Education Level: More educated household heads were expected to adopt the technology. Therefore, it will be hypothesized that education influence adoption of biogas technology positively.

F) Size of household: It will be expected to influence adoption of biogas positively as bio-digester construction and operation is more or less a labor intensive in nature. So, household with more productive labor force was assumed to adopt in a better way than the household who has few or no productive labor force.

G) **Access to technical services**: Access to technical services will be expected to influence adoption positively. Areas where there is access of technical service for biogas plant, potential households will be motivated to install biogas plant.

H) Awareness on biogas technology: It will be expected to influence adoption of biogas technology positively. Households those have heard and had information about uses of biogas technology will be motivated to have the technology.

I) Availability of water: water was one of the factors that determine the adoption of biogas technology because it was used during construction of the plant and daily operation of the bio-digester. Therefore, it will be hypothesized that the availability of water can influence biogas adoption positively.

J) Distance to firewood source: As the distances to firewood sources increases, women are expected to look for other alternative energy such as biogas technology. Therefore, it will be expected to influence biogas adoption positively.

K) Availability of credit: Households who want to have bio-digester but do not have money at that time need some source of financing such as credit. Therefore, it will be hypothesized that availability of credit can influence adoption of biogas technology positively.

K) Income status: Defined as total amount of annual income gained from all sources/activities measured in money and categorized as high, medium and low-income level households. Households that have higher income may have a higher probability to adopt new technologies (Lewis and Pattanayak, 2012). Comparatively, households with better incomes tend to take risks than poor one. Thus, the income was expected to have a significant positive contribution to adopt Biogas technology.

Table 4: Specification of variables included in logit model for adoption of biogas technology

Variable	Description of the variable	Measurability	Expected sign
AGE	Age of the head of household	Years	±
GENDER	Sex of household head (1=male,2=female).	Proxy/categorical	±
HHSIZE	Number of household members (“1” stands for who do provide labor and ”0” for who do not provide labor)	Proxy/categorical	±
EDUC	Education of household head (0’’ for Not educated, ‘1’ for 1st Cycle education, ‘2’ for 2nd Cycle education and ‘3’ for Collage and above)	Years	+
NCATTLE	No of cattle Owned	Number of cattle owned by HH	+
LANDSIZE	Total area of land owned by the household	Hectares	+
FWDIST	Distance to firewood sources	Kilometers	+

BIOAWARE	Awareness of households towards bio-gas technology ("1" stands for aware and "o" otherwise)	Idea of bio-gas technology	+
TECHAVA	Availability or non -availability of technical services (1=available,0=not available)	Binary	+
WATERAV	Availability of reliable water services ("1" stands for water available and "o" otherwise)	Proxy/categorical	+
CREDIT	Availability of reliable credit services ("1" stands for credit available and "o" otherwise)	Proxy/categorical	+
INCOME STATUS	Households income ("2" stands for high, '2' stands for medium and "o" low)	Proxy/Categorical	+

In general, the explanatory variables included in the empirical models are summarized in Table 4. The selection of explanatory variables to be included in the empirical model was based on the adoption theory and empirical findings from previous research elsewhere.

3.6. Estimation of household fuels used and GHGs emission saved due to biogas technology

The major types of energy sources used in the study area were identified based on the data obtained from the structured questionnaire. The questionnaire also provided quantitative information on the amount of fuel consumption for domestic use at the rural household level for different purposes. To obtain the amount of biomass fuel consumption, data in kilograms at rural household level was difficult. Therefore, the amount of biomass fuel consumption was requested in terms of local measurement units such as the number of bundles for wood, a sack for charcoal and dung, and a bundle for crop residue per week. This method of measurement was expected to improve the reliability of information obtained from respondents and was also used by Gebreegziabher et al. (2007) and Zerihun, (2015) on other similar studies.

A measurement was made to know the average weight of a bundle of wood, a sack of charcoal, a sack of dung and a bundle of crop residue by taking 20% of the sample households. This method was also used by Zerihun Amare (2014).

3.7. Greenhouse gas Emission Estimation Equation

The GHG emission from stationary fuel combustion can be calculated by multiplying the amount of fuel consumed by the corresponding emission factor. The fuel consumption data in mass or volume units must be first converted into the energy content of these fuels (IPCC, 2006). In this study only three important gases such as CO_2, CH_4, N_2O are considered in the GHG emission estimation. The global warming potential (GWP) of these three gases over a 100 years' time horizon is 1, 25, and 298 respectively (IPCC, 2007). To estimate the GHG emission from combustion of a given fuel type 'f' by adopter and non-adopter households were calculated using IPCC guideline for tier one method as follows.

$$\boldsymbol{E_{\mathrm{f}} = \sum_{i=1}^{n}(A_i * EF_i)} \ldots\ldots \quad (7)$$

Where E_f=GHG emission in kg from the burning of fuel type f;

n= total number of adopter or non-adopter sample households;

A_i= amount of fuel consumed by sample household i;

EF_i = default emission factors for gas type i

To estimate the total amount of GHG emissions of the adopter and non-adopter households, first, it is converted into CO_2e via multiplying by its global warming potential of each gas. The equation is as follows.

$$\boldsymbol{E_{\mathrm{CO2e}} = \sum_{i=1}^{n}(A_i * EF_i * GWP_i)} \ldots\ldots \quad (8)$$

Where E_{CO2e} =total emission in carbon dioxide equivalent**,** GWP_{i}= the global warming potential of gas type 'i'

Table 5: Global warming potentials (GWP) selected GHGs

Pollutant Name	Chemical formula	100-year GWP
Carbon dioxide	Co_2	1
Methane	CH_4	25
Nitrous oxide	N_2o	298

Source: IPCC, 2007

3.8. Independent sample t-test

To compare mean differences of biomass consumptions for adopter and non-adopter households', independents t-test model was used. In independent sample t-test, the groups in a two-sample t-test are usually fixed by design, and the grouping variable has one value for each group. However, there are occasion when assignment to one of two groups can be made on the basis of an existing scale variable.

With the independent-Samples t-test procedure, all you need to provide is the cut point. The program divides the sample into two at the cut point and performs the t-test. The virtue of this method is that the cut point can be easily changed without the need to recreate the grouping variable by hand every time.

The Independent-Sample t-test procedure tests the significance of the difference between two sample means. Also displayed are:

- ✍ Descriptive statistics for each test variable
- ✍ A test of variance equality

- ✍ A confidence interval for the difference between the two variables (95%)

4. RESULT AND DISCUSION

Adoption of any technology in general and biogas technology in particular, depends on various factors and varies from place to place. Adoption and dissemination of technologies can be determined by demographic, environmental, institutional setup, and related socio-economic factors. Technology that is perceived to be more important than the other one is usually adopted earlier (Mengistu et al., 2015). Considering the hypothesized determinant factors influencing the adoption rate of biogas technology in the study area, the overall socio-economic characteristics of the sampled households, factors influencing biogas technology adoption and biogas technology and its implication on GHG Emission reduction were discussed as follows.

4.1. Socio-Economic Characteristics of the Respondents

The descriptive statistics data of both continuous and dummy variables considered as determining the adoption of biogas technology were analyzed and the computed results were presented in table 6 below. From 356 sampled households of biogas users and non-user of the technology, the analysis showed that 83.2% households were male-headed, while the rest 16.8%were female-headed. A noticeable fact about the low participation of the female was the barrier in the male as the household head. The average age of the respondents was 52 years, ranging from the highest age of 88 years to the lowest age of 27 years. The average HH size of the respondents was approximately 5 members.

Almost all farmers in the study area undertook mixed agriculture as their major occupation. The average land holdings of these farmers were 2.11 hectares and the average livestock holding was 5 cattle. This shows that there is no scarcity of land allocation for biogas plant and thereby operating their agricultural activities including livestock raring. Both biogas technology user and non-user must walk 1.7 to 20km to collect fuel wood from their resident which was 11.85km in average (Annex 1).

The education level of the respondents may be helpful to adopt new technology. From the total respondents, 41% of the respondents had a 1st cycle education 19% 2nd cycle and 5% college and above education whereas 35% respondents have no education (table 6).

Furthermore, there is limited access to availability of reliable water sources, credits access as well as income status for both users and non-users of the technology counted 62%, 68% and 61.5% respectively. Among the users and non-users of the technology, 42% of respondent had information about the use of biogas technology.

Table 6: Frequency on socio economic of Dummy Variables.

Variables	**Freq.**	**Percent**
Male respondents	296	83.2
Female respondents	60	16.8
Education level		
Not educated	125	35
1st Cycle education	147	41
2ndCycle education	68	19
College and above	16	5
Availability of reliable water sources	221	62
Awareness on bio gas technology	151	42
Credit facility	242	68

Income status	219	61.5
Technical service	104	29
Biogas Adoption	96	27

Source: own data ,2020

4.2. Factors influencing biogas technology adoption

Before analyzing the variable in the set problem, multi collinearity among the explanatory variables was tested using variance inflection factor and multi collinearity was not detected. (See Annex 2). The estimated results of the binary logistic regression model indicated that the estimated values fit the observed data reasonably well. The LR $\chi2$ test was based on the assumption that at least one of the coefficients of the regression predictor was not equal to zero. The estimated LR $\chi2$ test value was 361.35, which indicated that the predictors' coefficients were different from 0. Furthermore, the complete model comprising the full number of predictors was found to be highly significant (Prob > $\chi2$ (DF = 11), p = 0.00), with a high Pseudo R^2 value (87%). Measures of goodness-of-fit of the model results indicated that the independent variables were simultaneously related to the log odds of bio gas adoption.

Table 7: Logit model result of determinants of adoption of biogas technology

Biogas Adoption	**β**	**Exp β**	**S/ E**	**P>z**	**[95% Conf. Interval]**	
Gender	-2.163	0.115	0.99	0.029*	-4.103	-0.223
Age	0.039	1.04	0.034	0.245	-0.027	0.106
Education level	1.003	2.728	0.559	0.072	-0.091	2.098
HHF size	0.04	1.041	0.323	0.901	-0.593	0.673
No of Cattle	0.511	1.667	0.161	0.001**	0.196	0.826
Land size hectare	0.764	2.147	0.381	0.045*	0.017	1.511
Distance to firewood sources (Km)	0.229	1.257	0.073	0.002**	0.085	0.372
Availability of reliable water source	3.749	42.48	1.406	0.008**	0.993	6.505
Awareness on biogas technology	2.584	13.246	0.938	0.006**	0.744	4.423
Credit facility	2.785	16.192	1.229	0.023*	0.376	5.193

Income status of HH	1.759	5.805	0.876	0.045*	0.041	3.476
Technical service	2.464	11.75	1.215	0.043*	0.082	4.846
_cons	-19.118	0	4.144	0	-27.24	-10.996
***and* represent significance at 1% and 5% confidence level respectively*						

Source: Own survey, 2020

The chosen independent variables were predicted households' biogas adoption conditions for the entire observed data. The binary logistic regression results showed in table 7, which help to identify the determinants of biogas technology adoption, were discussed as follow.

Among the 12 explanatory variables identified, 9 variables had a significant influence on the household's decision to adopt biogas technology. Number of Cattle, Distance to fire wood sources , Availability of reliable water source and Awareness on biogas technology were significant variables in influencing the decision to adopt biogas technology (p <.01) (table 7) whereas, Gender, Land size, Credit facility, household income status and Technical service were significant variables at (p <0.05) (table 7).The influence of these variables on the household's decision to adopt biogas technology is inconsistent with previous findings (Abadi et al., 2017 and Kelebe et al., 2017) in Ethiopia. More importantly, these results showed that households' socio-economic and biophysical characteristics were key determinants in decision-making to adopt or not to adopt biogas technology.

I. Gender

Households' gender has negative significant impact on adopting biogas technology. The results in Table 7 showed that sex of household has meaningful impact on adopting biogas technology at 5% significance levels with coefficient of variation, odd ratio and P-value (-216. 3%, 0.115and 0.029) respectively. The negative results show that the odds of being female-headed household increased the probability of adopting biogas technology by 0.12 units (table 7). The fact is that females provide for and dominate most of the domestic household tasks of the house, such as preparing meals, fuel wood collection and waste management, and home maintenance and has made them to adopt the technology than their counter parts males. It is believed that the adoption of the biogas technology will reduce the burden of their non-productive works in the home and the result is in line with that obtained by Kabir et al. (2013) in their studies in Bangladesh in which households headed by females were more expected to adopt biogas technology than their male counterparts.

II. Number of Cattle

The primary raw material considered for biogas digesters for gas production is cow dung. So, the number of cattle owned by households increases the chances of adopting the technology. In addition, focus group discussion participants indicated that approach by the biogas progarmme in the country targets households with a minimum of four or more cattle. Significantly, an increase in heads of cattle owned by households positively increases the chances of adopting the technology by a factor of 1.7 at 99% significant level (table 7). This result is consistent with the outcomes of (Mengistu et al, 2016 and Kabir et al, 2013) that the numbers of cattle owned have a significant relationship with the intention of a household to adopt biogas technology.

III. Land size

Given the space requirement of biogas technology in terms of area for installing the biogas plants as well as providing pastures for the cattle and their farming activities, the area of land owned by the household becomes a crucial factor in the adoption of biogas technology. This study revealed that the odds of having one additional hectare of land increases 2.147 units of biogas adoption at 0.045 P-value (table 7). This result is in line with the study done by Shegenu and Seyoum (2018) at Aleta wondo on determinant of Biogas Technology Adoption.

IV. **Distance to firewood sources**

There was a significant and a positive association between the distance to firewood sources and biogas technology adoption (table 7). As the distance to firewood sources from the residence increased by 1km, the likelihood of households to adopt biogas technology increase by a factor of 1.3 at α 0.002. Similar findings have been reported by (Mengistu et al. 2016 and Berhe et al. 2017). When the source of firewood is far from the residence, household members spend a significant amount of time and labor on firewood collection that would in turn affect the opportunity for performing other agricultural activities. More importantly, since the source of firewood has been declining rapidly in recent times, those households foresee biogas technology as an alternative source of energy.

V. Availability of Reliable Water Source

As hypothesized, there was a positive and significant association between the adoptions at p-value 0.008, as expected. If there is a one-unit increment in availability of reliable water source in the rural households, the odds of adopting the biogas technology were more likely increase by an odds ratio of 42.5 times (table 7). This result is supported by key informant and focus group (FGD) during discussion. Access to reliable water source is mandatory for biogas production and, hence, biogas technology adoption (Mwirigi et al., 2014). To avoid a shortage of water, and hygiene and sanitation most adopters connected their toilets to the biogas digesters, which are also supported by an earlier finding in northern Ethiopia (Kelebe et al., 2017).

VI. Awareness on biogas technology

Awareness was statistically significant for the adoption of the technology at household level in the study woreda. Increased awareness of the technology concerning the benefits of biogas energy also increased the probability of adopting the technology. Information and know-how from family, friends and media is a key in promoting the technology. This indicates that, as individuals become more aware of the benefits of new technology, the probability of adopting that technology increases. Similarly, the result indicated that those households who are aware of the benefits of the biogas technology are more likely 13.3times at 0.006 P-value to adopt the technology than those households who were not aware of the benefits of the biogas technology (table 7). During discussion with focus group, they also confirmed that gap of awareness and information slowed the outreach of the bio-digester to the far rural areas. A similar finding was found by Sheha and Makame (2017), lack of awareness was among the potential factors that hinder the adoption of improved energy sources to the wider community. Therefore, raising the awareness level of the rural households would help them to decide for adoption and sustained use of the bio-digester.

VII. Access to credit

Access to credit had significantly and positively influenced biogas technology adoption (table 7). Having access to credit by households increased the likelihood of biogas technology adoption by a factor of 16.2 at α 0.023 compared to their counterparts (table 7). Thus, access to credit is a key factor in enhancing the poor households' affordability of biogas technology. This finding is supported by previous studies conducted in Ethiopia by Mengistu et al. (2016) and Berhe et al. (2017), which described the existence of a significant positive relationship between access to credit and biogas technology adoption. Both studies stated that the availability of credit services in rural areas is likely to ease the financial constraints for managing bio-digesters. Therefore, access to credit services is an important variable in biogas technology adoption, particularly through motivating households to adopt technology, increase the financial capacity of households for bio-digester installation and enable faster maintenance services.

VIII. Household income status

There was a significant positive association between household income status and biogas technology adoption. Accordingly, an increase in household income level by one unit was found to increase the probability of biogas technology adoption by a factor of 5.8, at 0.045 p-value (table 7). This finding is inconsistent with the findings (Kabir et al, 2013) in Bangladesh and (Walekhwa et al., 2009) in Uganda. More annual income might provide more economic capacity and legibility for a bio digester installation and affordability of buying spare parts for maintaining an installed biogas digester operational.

IX. Technical service

There was a significantly positive association between access to technical support availability (table 7) and the household decision to adopt biogas technology. As indicated by this study, having access to technical support increases the likelihood of adopting biogas technology by a factor of 11.750 at p-value 0.043 as compared to their counterparts. This means that households with technical support would have better utilization of biogas technology and good reputation on the technology. The unavailability and slow response from concerned body to solve technical problem associated with bio-digester has led to many of these digesters performing under their capacity and sometimes abandoned due to non-functionality issues. This has discouraged other prospective users from considering the technology. My result is similar with (Uhunamure, et al, and 2019) which states the importance of technical support for biogas user in solving major problem to expand biogas technology.

4.3. Role of Biogas Technology on GHG Emission Reduction

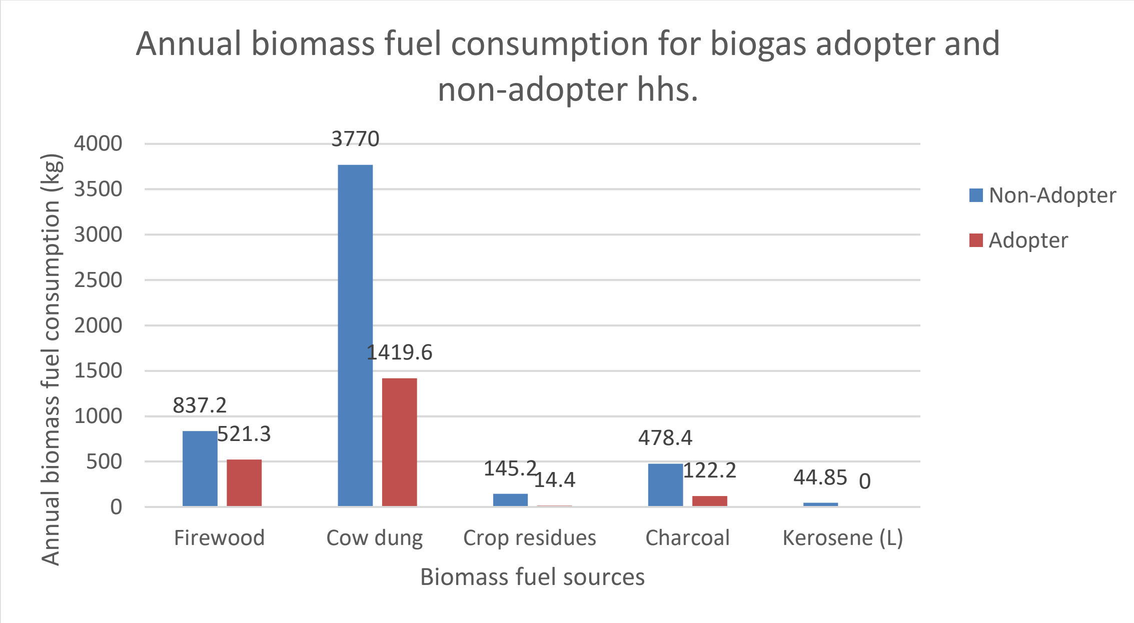
4.3.1. Sampled household biomass energy consumption pattern

It is obvious that rural households rely on large quantities of traditional energy sources, commonly obtained from firewood, charcoal, animal dung and crop residues for their primary energy requirements. In this research it was intended to know types and the amount of energy sources consumed by biogas adopter and non-adopter households in the study area. The results of the household survey indicated that almost all households of both biogas adopters and non-adopters consume biomass-based energy source for cooking and heating. However, the level of consumption is different from household to household depending on family size and biogas adoption. Although both biogas adopters and non-adopter households consume considerable amounts of biomass energy for cooking and heating, the amount consumed by non-biogas adopters is much higher than that of biogas adopters with 3153.3kg per annum per household (figure 3), which means adopter household saved 60% biomass fuel per year per household.

Table 8: Average Biomass Used Per Week per sampled households.

Fuel type	Non-Adopter	Adopter
Firewood (kg)	16.1	10.0
Cow dung (kg)	72.5	27.3
Crop residues (kg)	9.1	0.9
Charcoal (kg)	9.2	2.4
Kerosene (L)	0.86	0

Source: Field survey data, (2020)



Source: Field survey data, (2020)

Figure 3: Fuel types and amount used per households per year

4.3.2. Estimation of GHGs Reduction by domestic biogas technology

To estimate the amount of greenhouse gases emission reduction by bio-digester owning households, data was collected on amount of biomass fuel used per week per household and the result is indicated in table 8 above.

From the above table the data was converted to annual for the sake of annual estimation. Therefore, each non-adopter households used 837.2, 3770.0, 145.2 and 478.4 kg of firewood, cow dung, crop residue and charcoal per year whereas adopters used 521.3, 1419.6,14.4 and 122.2 kg per year respectively (table 8). When we see the difference on each fuel's types: adopter household reduced 37.7%,62% and 74.4% on firewood, dung cake and charcoal respectively. During interview with sampled households, both adopter and non-adopter households responded that they use firewood for "injera baking", a staple Ethiopia food, because the energy from biogas is not able to bake injera yet. This is why less difference on firewood consumption than other fuel type. In case of kerosene, non-adopters used 44.85 liters annually where biogas user households used biogas for lighting instead.

To calculate emission reduction, each consumed fuel types by adopter and non-adopter households per year is converted into carbon dioxide equivalent using equation on (Smith et al., 2000) and detail calculation was attached in annex I.

The result of the study on GHGs emission for non-adopter and adopter households per year and net emission saved by adopter households are illustrated in table 9 as follow.

Table 9: Amount of GHGs emission per fuel types and reduction per biogas adopter in CO_2e

s/n	Fuel type	GHGs emission per hh per year (tCO_2e)		Emission reduction (tCO_2e/hh/yr)	Emission reduced in %
		Non-adopter	Adopter		
1	Firewood	1.58	0.98	0.6	37.97
2	Dung Cake	4.75	1.99	2.76	58.11
3	Crop residue	0.14	0.01	0.13	90.00
4	Charcoal	1.65	0.42	1.23	74.55
5	Kerosene	0.1	0.0	0.12	100.00
	Total	**8.24**	**3.40**	**4.84**	**58.69**

Source: Field survey data, (2020)

From table 9 above, by deducting emission caused by non-adopter from adopter households, the net emission reduction by biogas adopter households per year is 4.84 tons CO_2e from saving of biomass fuel and kerosene.

A study conducted by Zerihun Yohannes Amare (2014) at Fogera woreda of Amhara region on 30 households obtained GHGs emission reduction of 3847kg (3.85 tons) CO_2e per household per year. This figure is almost similar with my finding of 4.85 tones CO_2e

per household per year. In his study he also indicated biogas adopter households didn't use kerosene which is the same as my result. Another similar study carried out by Njana Sharma et.al (2019) to analyze the role of biogas in climate change mitigation and adaptation on 108 households at Nepal showed greenhouse gas emission reduction by 3820 kg (3.82 tones) per household per year and this result also support my result. Another study by Gosaye Shegenu & Abrham Seyoum (2018) on determinant of Biogas Technology Adoption and its Implication on Environmental Sustainability at Aleta wondo Woreda on 196 households found 2160.93 kg (2.16 tones) CO_2e emission reduction per biogas adopter per year. When compared to my result, their finding is less by 55%.

The difference on the result can be due to many factors such as size of bio-digester assessed, sample size, energy demand of the households and others.

4.3.3. Impact of Biogas on Firewood Saving and Forest Conservation

The annual firewood and charcoal consumption of non-adopter households was estimated to 0.84 and 0.48 tons per year per household. whereas for adopter households 0.52 and 0.12 tons respectively (table 9). This shows that the average amount of firewood and charcoal reduced by biogas users is 0.32 tons (38%) and 0.36 tons (75%) per household per year respectively. From this figure, it was clear that biogas user households saved 38% firewood and 75% charcoal than non-user households and contributed significantly to biomass forest conservation.

Table 10: Fuel types and amount used per year per household

Category	Average Fuel types and amount used per year per hhs		
	Firewood (tons)	Charcoal (tons)	Total Woody biomass used(tons)
Non-adopter	0.84	0.48	1.32
Adopter	0.52	0.12	0.64
Saved biomass	0.32	0.36	0.68

percentage saved	38.1	75.0	51.5

Source: Field survey data, (2020)

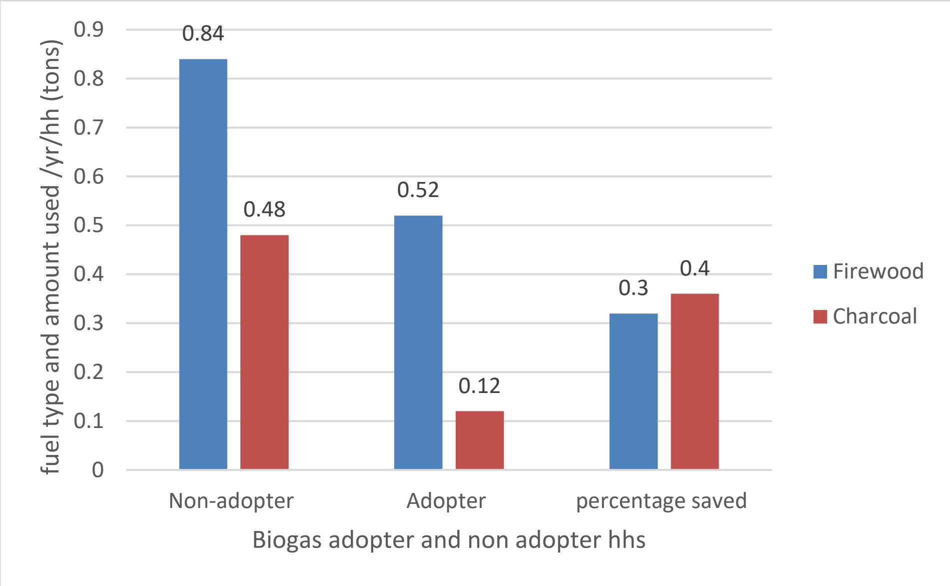


Figure 4: Firewood and Charcoal consumption per biogas adopter and non-adopter hhs.

Comparing my results with other similar studies and discussion as follow: The study conducted by Ararsa Seboka (2019) indicated 35.7% annual reduction of firewood (2278.8kg to 1465.2 kg) and charcoal by 33.3% (432. to 288 kg) per households for biogas users). From this, firewood finding was in accordance with my result of 38% reduction whereas his charcoal result was less by 41.7% than my result. A study done by Maheshwor Poudel et.al (2016) on Potentiality of Biogas as Renewable Energy Technology and its role for the Conservation of Environment in Nepal indicated biogas user household save 46.67% of fuelwood which is almost close to my result. Another finding in China by Christiaensen and Heltberg (2014) indicated 26.8% reduction on firewood by biogas adopter and this result is less by 11.2% than my study result. Another study finding at Northern Tigray by Kelebe HE, Olorunnisola A, (2012) showed reduction of 45% on firewood by biogas adopter household, which is also inconsistent with my finding. Zebider A (2011) obtained 64% reduction on firewood per household and this is greater than my result by 26%. On the other hand, Biogas User Survey (BUS) conducted by SNV (2019) showed reduction on charcoal and firewood of 75.3% and 17.1% respectively by biogas adopter households and the result of charcoal reduction is very much in accordance with my study result but firewood result is less by 21%.

4.3.4. Adopter and Non-adopter Households Biomass Energy Consumption

The result in this study showed that energy consumptions of the adopter sample households had relied on traditional biomass energy. The average weekly fuel wood, dung, crop residue, charcoal and kerosene consumption of each biogas adopter sample households was 6kg, 24.2kg, 0.97kg, 0.43kg and 0.03L, respectively. While the average weekly consumption of each non-adopting household was 21.5kg, 79.7kg, 10.1kg, 10.1kg and, 0.74L respectively. The independent samples test results indicate that there is a significant mean difference in all bio fuel energy consumption between adopter and non-adopter at p-value < 0.001 (Table 11). Therefore, there was saving of 15.5kg of firewood, 55.5kg of cow dung, 9.1kg of crop residue, 9.7kg of charcoal and 0.71L of kerosene as a result of using biogas technology.

Table 11: Mean biomass energy consumption and equal variances assumed (n =356)

Energy sources	t-test for equality of Means								
	F	T	Sig.	Mean		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
				Non-adopter	Adopter			Lower	Upper
Firewood (kg)	24.203	5.999	0.000	21.457	6.000	15.457	2.577	10.315	20.599
Cow dung (kg)	18.198	7.594	0.000	79.714	24.171	55.543	7.314	40.948	70.138
Crop residues (kg)	15.787	6.528	0.000	10.057	0.971	9.086	1.392	6.309	11.863

Charcoal (kg)	16.229	14.314	0.000	10.057	0.429	9.629	0.673	8.286	10.971
Kerosene (L)	51.982	8.905	0.000	0.743	0.029	0.714	0.080	0.554	0.874

Source: Own survey, 2020

This implies biogas technology have a significant contribution to achieving the climate resilient green economy strategy as one of the mechanisms to abate GHG emissions due to burning of biomass fuels for household energy use. A study conducted in wondo genet by (Soboka, 2019) shows that there is a significant difference ($p < 0.05$) in the level of consumption of biomass fuels between the two categories of households.

5. CONCLUSION AND RECOMMENDATION

Cattle number, distance to firewood sources, availability of reliable water source and awareness on biogas technology were have positive relation on biogas adoption with significance of $p < 0.01$ whereas land size, credit facility, household income status and technical service were influence positively on decision to take biogas technology with $p < 0.05$ significance. So, for mass dissemination of bio-digester technology for rural households, focus should be given first on those parameters. From feasibility study done in 2006 in Ethiopia, cattle number and availability of reliable water source are technically mandatory for any households to have a bio-digester. Therefore, intensive promotion is needed for rural community even for those who had access to water and enough number of cattle to create awareness and change their mind to decide to invest on bio-digester technology. On the other hand, post construction technical service like repair and maintenance on biogas pipeline and appliances are crucial as it create bad reputation among non-adopter households which make promotion of the technology difficult.

Adopter households saved about emission of 4.84 tons CO_2e (58.69%) per year per households and reduced 38% and 75% on firewood and charcoal. "Injera baking" took a considerable amount of biomass fuel because domestic biogas technology couldn't bake injera yet and biogas owners are using firewood for this purpose.so if energy from domestic bio-digester could bake injera, its' benefit on GHGs emission reduction will be increased which resulted in significant decreasing on global warming and also on biomass forest conservation by minimizing biomass fuel use and lessen forest degradation.

5.1. Recommendations

Based on the study findings the following courses of action have been proposed.

- ✍ The biogas programme in coordination with concerned governmental body should pay due attention to improve living standard of rural households by increasing access to clean energy biogas technology through focusing on determinant factors such awareness creation, facilitation of credit and after construction technical service (such as biogas pipeline and appliances repair)
- ✍ Since biogas technology is a multi-benefit technology, coordination and promotion of the technology need active involvement of different stakeholders at different level, particularly involvement of key stakeholders like office of agriculture, climate and environment.
- ✍ To increase the role of biogas in mitigate the GHG emission due attention should be given on using biogas energy for' baking injera 'as much biomass energy was used for this purpose.
- ✍ During the assessment, participants on group discussion raised the issues of wrong promotion such as biogas is used as electricity, run television and charge mobile and, this affected the uptake of the technology in that locality. So, the programme should revisit the information flow to the grass root level during promotion.

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Annexes

Annex I

Summery statistics on socio economic of respondents for continues variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Age	356	51.88	12.98	27	88
HHF size	356	4.71	1.34	1	8
No of Cattle	356	5.25	3.51	0	16
Land size hectare	356	2.11	1.16	0	7
Distance to fire wood sources (Km)	356	11.85	6.07	1.7	20

Annex II Collinearity Statistics

Variables	Tolerance	VIF
Gender	0.96	1.04
Age	0.72	1.39
Education	0.67	1.48
HHFsize	0.90	1.12
NoCattle	0.67	1.50
Lsize	0.88	1.14
Timefirewood	0.85	1.17
Timewater	0.78	1.29
Awarness	0.76	1.32
Credit	0.82	1.22
Income	0.85	1.18
Technical Service	0.61	1.65

Annex I: Emission calculation

For Non-adopter household

- **Emission from firewood**

Amount of firewood used per household per year is 837.2kg

Co$_2$e = (837.2kg*1.7472kg CO_2/kg *1) + (837.2kg*0.00468kg CH_4*25) + (837.2kg*0.0000624kg NO_2/kg *298) = **1576.22kg** CO_2e /year / household.

- **Emission from dung cake**

Amount of dung cake used per household per year is 3770.0kg

CO_2e = (3770kg*1.38 kg CO_2/kg *1) + (3770kg*0.000414kg CH_4*25) + (3770kg*0.0000552kg NO_2/kg *298) = **4751.63**kg CO_2e /year/household

- **Emission from crop residue**

From collected data, amount of crop residue used per household per week is 9.1 kg. Since the availability of crop residue is seasonal, for this calculation it is assumed available for 4 months in a year. So, the amount used is 145.2kg

CO_2e = (145.2kg*0.975 kg CO_2/kg*1) + (145.2kg*0.000264kgCH_4/kg*25) + (145.2kg* 0.000035kg NO_2/*298) = **144.04kg** CO_2e/year per household.

- **Emission from charcoal**

Charcoal consumed per household per year is 478.4kg and GHGs emission from it is calculated as:

CO_2e = (478.4kg*3.304 kg CO_2/kg*1) + (478.4kg*0.0059kg CH_4/kg*25) + (478.4kg* 0.0000295kg NO_2/*298) = **1655.4kg** CO_2e/year per household.

- **Emission due to kerosene use**

Amount of kerosene used per year is 44.85 liters and GHGs emission will be:

CO_2e = (44.85 L*2.68kg CO_2/L *1) + (44.85 L*0.0001 kg CH_4/L*25) + (44.85L*0.000021 kg NO_2/L *298) = **120.59kg** CO_2e per year per household.

Therefore, total GHGs emission by non-adopter households is **8,247.88** kg CO_2e per households per year.

Similarly, calculating GHGs emission from biogas adopter households as follow:

Emission calculation for adopter households

- **Emission from firewood**

Amount of firewood used per household per year is 521.3kg

Co_2e = (521.3kg*1.7472kg CO_2/kg *1) + (521.3kg*0.00468kg CH_4*25) + (521.3kg*0.0000624kg NO_2/kg *298) = **1321.71kg** CO_2e /year / household.

- **Emission from dung cake**

Amount of dung cake used per household per year is 1419.6kg

CO_2e = (1419.6kg*1.38 kg CO_2/kg *1) + (1419.6kg*0.000414kg CH_4*25) + (1419.6kg*0.0000552kg NO_2/kg *298) = **1997.09**kg CO_2e /year/household

- **Emission from crop residue**

From collected data, amount of crop residue used per household per week is 0.9 kg. Since the availability of crop residue is seasonal, for this calculation it is assumed available for 4 months in a year. So, the amount used is 14.4kg

CO_2e = (14.4kg*0.975 kg CO_2/kg*1) + (14.4kg*0.000264kg CH_4/kg*25) + (14.4kg* 0.000035kg NO_2/*298) = **14.29kg** CO_2e/year per household.

- **Emission from charcoal**

Charcoal consumed per household per year is 122.2 kg and GHGs emission from it is calculated as:

CO_2e = (122.2kg*3.304 kg CO_2/kg*1) + (122.2 kg*0.0059kg CH_4/kg*25) + (122.2kg* 0.0000295kg NO_2/*298) = **289.69kg** CO_2e/year per household.

- **Emission due to kerosene use**

Biogas adopter do not used any kerosene and no emission from it.

Therefore, total GHGs emission by adopter households is **3415.62** kg CO_2e per households per year.

Finally, by deducting emission caused by non-adopter from adopter households, the net emission reduction by biogas adopter households per year is 4832.26kg CO_2e (4.8 tons CO_2e).

Annex II: Emission factor for selected fuels

s/n	Fuel type	CO_2 (kg/ton)	CH_4 (kg/ton)	NO_2 (kg/ton)
1	firewood	1747.2	4.68	0.0624
2	charcoal	3304	5.9	0.0295
3	Crop residue	975	0.264	0.035
4	Dung cake	1380	0.414	0.0552
		CO_2 (kg/l)	CH_4 (kg/l)	NO_2 (kg/l)
5	Kerosene	2.68	0.0001	0.000021

Source: MoWE (as cited in Guta,2012) and IPCC (2006)

Annex III: House hold Questionnaire

My name is Leshan Tadesse. I am MSc student of Renewable Energy Utilization and Management program at Hawassa University, Wondo Genet College of Forestry and Natural Resources. I am studying my Master Thesis research on 'Determinants of Biogas Technology Adoption and its Implication on GHG Reduce in Ada'a Woreda, Ethiopia'. To this end you are kindly requested to answer the following questions regarding this title. Your response will be highly appreciated and will be treated with confidentiality and it will only be used for academic purposes. I would like to extend my special appreciation for your cooperation and commitment during my work.

Thank you!!!

Part 1: General Identification

Date of interview: ________________________

Name of respondents: _____________________

Name of Kebele: _________________________

Part 2. General Information of Household (HH)

Sex: Male ☐ Female ☐

Age of household head ___________________

Household head Level of education of ___________________

Household family size ___________________

Part 3: Economic characteristics:

1.Income Activity of households

a) Farming ☐ b) Business ☐ c) Wage employment ☐ d) Other- Specify ____

2. Do you have your own livestock? 1) No ☐ 2) Yes ☐

3. **If answer of 2 is yes**, indicate number of livestock you have. A) Cattles ____________B) Goats ______ C) Sheep_____ D) Donkeys_____ E) Chicken/ducks_____ F) others_____

4. Do you have your own farm land? 1) No ☐ 2) Yes ☐

If your **answer is yes**, indicate your farm size in hectare _______________

Part 4; Institutional and social factors (the Availability of important sources)

1. Are the following resources available in your area?

Key on availability of resources 1) Readily available 2) Is in short supply 3) Not available

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

2. Main Sources of energy for cooking? A) Kerosene B) Charcoal C) Firewood D) Electricity E) Biogas F) agricultural residuals G) dung cake

3. What is the source of power you use for light? A). Kerosene B). Electricity C). Firewood D) Biogas

4. If the source is fire wood and or charcoal, from where do you get these fuels? A. from forest B. from trees around the home C. Bought from market D. Other

5. Has the time you spent on gathering fuel wood. A) increased B) decreased C) stayed the same over the last 5 years?

6. Has the distance you travel to gather fuel wood

A) Increased B) Decreased or C) Stayed the same over the last 5 years?

7. If the source of power you use is fuel wood and or charcoal, indicate an average number of fuel wood bundles and or bags of charcoal used per week.

A. Firewood (Donkey load) ______ B. Man (load)______ C. charcoal (kg) ______

D. Cow dung (kg) __________

Part 5: Awareness and Attitude toward of biogas technology adoption

8. Have you ever heard about the biogas technology? A) Yes B) No

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

i) Biogas researcher ii) Extension officers iii) Neighbor iv) Relative

v) friend who adopted BT vi) NGOs vii) Others (Specify)

10. What are reasons for not adopting biogas technology? use a tick

a. Do not see the benefit of biogas technology ☐

b. Number of cattle owned	☐	g. Gender of household head	☐
c. Lack of space (land size)	☐	h. Shortage of household labor	☐
d. High Technology costs	☐	i. Lack of loans and subsidies	☐
e. Education of household head	☐	j. Age of household head	☐
f. Not aware of the technology	☐	k. Any other	☐

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

a) Is Suitable technology b) Is Not suitable technology

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

A. Very expensive to install D. Requires large land size

B. Requires technical skills E. Very complicated

C. Requires education F. Labor intensive

13. If you are given 10,000 birr, what will be your priority investigation?

A. Invest in biogas technology B. Farm production

C. Livestock production D. Petty businesses enterprise e. others (specify)____

14. Are there regular promotions, seminars for promotion of biogas technology in your area?
A) Yes B) No
If **No**, how can biogas production and utilization be promoted in your Kebele?

____.

PART 6: Experience on biogas technology. FOR BIOGAS USERS ONLY

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

2. What is the size of your digester? a) 6m3 b) 8m3 c) 10m3 d) other__

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

4. Who initiated the idea of biogas to you? a) Government extension officer

b) NGOs c) Friend d) relative

e) neighbor f) Politician g) other (specify) _______

5. What was the major reason for starting a biogas plant? a) NGOs

b) Own interest c) Own interest & Encouraged by extension officer

d) Acute problem of fuel wood for domestic use

e). Influenced by friend with biogas plant

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

a) Own save d) Own contribution and subsidy from NGOs

b) Credit /Loan e) Own contribution and subsidy from the Government

c) Fully Sponsored by NGOs f) Other sources (Specify) __________

7. Is your biogas plant functioning? a) Yes b) No

8. If **yes**, what are the benefits of using the technology: a) Easy and fast in use

b) Clean, no soot as compared to fuel wood c) Low running cost after installation costs d) Saving time used for firewood collection e) Others (specify). _____

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

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

10. How frequent are the Biogas project staff visit you to see the progress of the plant?

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

11. Are technical services available when needed? a) Easily available

b) Available but not frequent c) Not available

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

PART 7: Question for mitigation part

1 Did you have biogas? Yes _______ No.______

2. If you don't have/ if you have biogas digester, what was/is the fuel you use most of the time?

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

3 How much fuel did you consumption in a week?

No	Type of fuel	Amounts of fuel Consumption per week	Remark

.		Donkey load	Man load	Number/cake	quintals	Litter	
1	Fire Wood						
2	Cow Dung						
3	Crop residues						
4	Charcoal						
5	Kerosene						

Appendix 2: -Field Observation

1. Biogas plant A) Present B) Absent

2. Status of plant A) Complete B) Incomplete

3. Structural problems. A) Cracked digester B) Chocking of outlet/inlet
   C) Broken or leaking pipes D) Shortage of cow dung.

4. Presence of cattle A) yes B) No

5. Cattle rearing method A) Free range B) zero grazing

Appendix 3: - Focus Group Discussion Guide

1. What are the major energy sources in your area? ______________________________

2. Do you see a need for alternative energy sources? If yes which alternatives do you think are appropriate to you are____

3. What is the acceptance status of biogas technology in your area, do you think the technology has been adapted to the expected level? ______________________________

4.If you think adoption is low what are the reasons _______________________________

5.Some people adopted the technology and stopped using it in the way. What could be the reasons ____

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

7. For adopters; do you have enough knowledge about biogas to the extent of being able to share the information with others? A) yes B) no. If not, what areas do you think need more education / training ____

8. In your opinion what kind of strategies can be put in place to enhance adoption of biogas in Ada'a woreda?

A) ____

b) ____

C) ____

9. Is there sufficient water in this region for biogas production?

10. List in order of importance what factors affect biogas adoption

a) Age of household head	g) Number of cattle own
b) Size of household	h) Size of land
c) Economic status of house hold	i) Lack of technical service
d) Education level of household head	j) Gender of household head
e) Water problems	k) attitude/awareness
f) Credit/loan	l) Income

Appendix 4: - Interview Guide for Key Informants Dealing with Biogas Technology

1. When did your organization start disseminating biogas Technology in Ada'a? ___ (Year)

2 What motivated your organization to engage into biogas technology?

3 How many biogas plants you installed are functioning?

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

5 What technical problems affecting functioning of biogas plants?

6 Did your organization give any support/ contribution to people who adopted or who intend to adopt biogas technology? a) yes b) no

7 If yes, what kind of support and at what level?

Kind of support	Level of contribution (%)
(i) ______________________________ _____	____________
(ii)_________________________________	____________
(iii) ________________________________	____________

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

____

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

10 What is your opinion on Governments' involvement in biogas technology Dissemination?

____

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

____

12. Do you think many people are aware of biogas technology in District? A) yes B) no

13. What percentages of population were afforded awareness? _____________________

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

15 What is the percentage of adopters as per population of the area? _______________

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

17 What percentage of biogas plants installed in District is functioning? ___________

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

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

a) Rural b) Sub-urban c) Urban d) Both

Reasons for your response ____

20. Key point for not adopting biogas technology on rural area and how to promote the technology for adaptation? ____