ROLES OF BIOGAS TECHNOLOGY ON CONSERVATION OF FOREST AND CLIMATE CHANGE MITIGATION IN SHEBEDINO DISTRICT, SIDAMA ZONE, SOUTHERN ETHIOPIA

M.Sc. THESIS

SEIFU WONAGO CHONCHE

HAWASSA UNIVERSITY, WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, WONDO GENET, ETHIOPIA

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SEIFU WONAGO CHONCHE

A THESIS SUBMITTED TO

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF THE MASTER OF SCIENCE IN RENEWABLE ENERGY UTILIZATION AND MANAGEMENT

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APPROVAL SHEET-I

This is to certify that the thesis entitled "Roles of Biogas Technology on Conservation of Forest and Climate change Mitigation in Shebedino district, Sidama Zone, Southern Ethiopia" is submitted in partial fulfillment of the requirement for the degree of Master of Sciences with specialization in Renewable Energy Utilization and Management. It is a record of original research carried out by Seifu Wonago Chonche Id. No. MSC/REUM/R018/10, under my supervision; no part of the thesis has been submitted for a degree in any other University or any other award. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended it to be accepted as fulfilling the thesis requirements.

Professor Tsegaye Bekele	___________	_____________
Name of major advisor	Signature	Date
_________________________	___________	_____________
Name of post graduate coordinator	Signature	Date

APPROVAL SHEET- II

We, the undersigned, members of the Board of Examiners of the final open defense by

Seifu Wonage have read and evaluated his thesis entitled "Roles of Biogas Technology on Conservation of Forest and Climate change Mitigation in Shebedino district, Sidama Zone, Southern 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.

______________________	__________________	_______________
Name of the chairperson	Signature	Date
Professor Tsegaye Bekele	___________	______________
Name of main advisor	Signature	Date
_______________________	___________	_______________
Name of internal examiner	Signature	Date
________________________	___________	_______________
Name of external examiner	Signature	Date
_________________________	____________	______________
SGS approval	Signature	Date

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DECLARATION

I declare that this thesis is my work and has not been presented for a degree in any other University or any other award. All sources of materials used for this thesis have been duly acknowledged.

Name: Seifu Wonago Signature…………………

Place: Hawassa University, Wondogenet College, Wondogenet

Date of Submission………………………

DEDICATION

This piece is especially dedicated to my beloved father Mr. Wonago Chonche and mother Ms. Tukule Chasa for their steadfast support in my education and for devoting their time to help me throughout their life.

LIST OF ACRONYMS AND ABBREVIATIONS

° C	Degree Celsius
AGWT	Anthropogenic Global Warming Theory
CH4	methane
CO2	Carbon dioxide
CRGE	climate resilient green economy
EU	European Union
GHG	Greenhouse gas
Gt	Giga tone
GtCO2e	Giga tone of carbon di oxide equivalent
GWP	Global warming potential
IAP	Indoor air pollution
IEA	International Energy Agency
KWh	Kilowatt hour
KWh/Sm3	Kilowatt-hour per second per meter cubic
LPG	Liquefied Petroleum Gas
M^3	Meter cubic
MtCO2e	Million tons of carbon dioxide equivalent
Mtoe,	Million tone of equivalent
NBPE	National biogas program of Ethiopia
NOx	Different types of nitrous oxide
OECD	Organization for Economic Cooperation and Development
UNEP	United nation environmental policy

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ROLE OF BIOGAS TECHNOLOGY ON CONSERVATION OF FOREST AND CLIMATE CHANGE MITIGATION, IN SHEBEDINO DISTRICT, SIDAMA ZONE, SOUTHERN ETHIOPIA

Seifu Wonago Chonche

Mobile: +251-916155302, Email:seifudo2@gmail.com

ABSTRACT

In Ethiopia, the dissemination of domestic biogas has been practiced at national level starting from 1979, however in the case of Shebedino district, Sidama zone, southern Ethiopia, its dissemination started in 2014. Consequently, there are limited empirical evidences concerning to the overall impacts of the technology on environment. Thus, this study examined roles of biogas technology on conservation of forest and climate change mitigation in Shebedino District, Sidama Zone, SNNPR, Ethiopia. The respondents were selected through stratified random sampling procedure. Thus, 199 households were surveyed (with 52 adopters and 147 non adopters), and 6 key informant interviews, 4 focus group discussions and direct observation technique were used for primary data collection. Participatory experimental research (KPT) was carried out using 40 selected household of both biogas adopters and non-adopters (20 for each category). Independent sample t-test and chi-square test were employed to analyze the collected data. Binary logistic regression model was used to predict factors that influenced biogas technology adoption and utilization. Experimental data was analyzed by using Excel spreadsheets of KPT software. Estimation of fuel wood saved, forest area saved and GHG emission reduced and sequestered can be determined through calculation. T-test result of the study showed that there was significant (at 1% and 5% significance level) mean difference between adopter and non-adopter for the variables like: age, educational status, household size, income, cattle size, land size, distance to water. χ^2test result on gender and awareness showed also statistically significant χ^2 value at 1% significance level. In a Shebedino district, majority of households were non-adopters of biogas technology, the factors that were found to be responsible for the low adoption of biogas in the district were: gender, educational status, age, household size, average annual income and cattle number. From KPT result, the annual fuelwood saving potential of the technology was found to be 1514.6 Kgs (34.71%) of fuel wood per biogas plant/year with an emission reduction potential of 2.2995 tons of CO_2e per biogas plant/year, forest area saving found to be 17 trees per biogas plant/year and 0.357 tons of CO2 sequestered per 17 tree (biogas plan t) /year. In total, from 63 functional biogas 95419.8 kg fuelwood saved/year, 144.9 tons of CO_2e reduced (mitigated)/year, 0.612hectare (1071) tree saved/year and 22.44 tons of CO2e sequestered/year by saved trees. From the result of this study it is evident that GHG emission into atmosphere has been reduced, and this led to minimize average global temperature which could result in climate change mitigation .Therefore biogas production plays important role on conservation of forest and climate change mitigation. As a result of the study, it was recommended tha,t upgrading the existing model of biogas technology to include different stove type which used to multi cooking purpose; this is supposed to reinforce adoption of biogas technology.

Keywords: *Fuelwood, Conservation, Forest, Greenhouse Gases, Biogas energy, Climate*

1. INTRODUCTION

1.1Background of the Study

Energy is the primary input for almost all economic activities and has become vital for improvement in the quality of life (Chandrakar, 2015). Generally there are traditional and modern energy sources. The modern energy sources are kerosene, Liquid Petroleum Gas (LPG) and electricity. Traditional energy sources are firewood, charcoal, crop residues and animal waste. (Bekele, *et al*, 2016). Biomass is a kind traditional energy sources of most promising and alternative renewable of energy. It is the main source of energy for rural households for cooking, lighting and heating purposes (Komala and Devi, 2016). The number of people who depends on traditional energy sources in the world is estimated to be 2.7 billion of the global population in 2009. Among these, 2.6 billion people are from developing countries, 653 million people of which are from Sub-Saharan Africa (Bekele et al., 2016). Ethiopia is one of the developing counties of sub-Saharan Africa, in which more than 67 million people are dependent on biomass energy to meet their cooking, heating, lighting and hygiene needs(Bekele *et al*., 2016). The Ethiopian energy sector is the highly dependent on biomass (firewood, charcoal, crop residues and animal dung). The bulk of the national energy consumption is met from biomass sources. Biomass accounts for 92% of total national energy consumption in 2010. About 81% of the estimated use firewood, 11.5% use leaves and dung cakes while only 2.4% use kerosene for cooking and the remaining group uses other energy sources(Ministry of water and energy , 2013)

Shebedino district is one of the Ethiopian districts found in the Sidama Zone, Southern Nation Nationalities Peoples Regional state (SNNPRS) whose nature of the energy consumption pattern is increasingly biomass for cooking, heating and some for lighting (SWWMEO, 2017).

Over reliance on fuelwood for cooking and heating is increasingly being associated with addition of harmful substance in to the environment from biomass cooking fires. These activity was recently found to be the largest environmental threat to health in the world, and it is associated with 4 million deaths each year (Lim et al., 2012). In addition to this, the use of inefficient and unsustainable energy sources leads to environmental degradation through deforestation of forests and woodlands, reduced agricultural productivity due to erosion and imbalanced rainfall regimes, and respiratory disorders due to smoke inhalation caused by the carbon originating from incomplete combustion of solid fuels (World Bank, 2006). Greenhouse gases (GHGs) mainly CO_2, N_2O and CH_4 emitted by the energy sector are the major contributors to climate change (IPCC, 2007). Climate change is an emerging issue and a global challenge induced by anthropogenic activities (IPCC, 2007). According to UNFCCC, climate change refers to a change of climate which is directly or indirectly caused by human activities that alter the composition of global atmosphere. Over dependence of households on biomass is caused by lack of modern energy system and technology. It is estimated that two billion people worldwide continue to lack access to efficient clean energy services. To address this situation United Nation Development Program, called for all nations to put special emphasis on renewable sources of energy (UNDP, 1997).

Renewable energy sources such as hydropower, wind power, solar photovoltaics, biogas, ethanol and biodiesel, and geothermal energy for heat and grid electricity are currently in wide use in some regions and being introduced in some areas in developing countries (Flavin & Aeck, 2005). According to Flavin and Aeck (2005), the use of renewable energy provides many benefits which include freeing women’s time from survival activities, allowing opportunities for income generation, as well as reducing exposure to indoor air pollution thereby improving health and providing lighting and cooking for households .

According to Thapa (2006), utilization of biomass based energy resources through appropriate technology interventions has become very important for environment conservation and sustainable rural development. Biogas technology is one biomass based technology of renewable energy in which energy is produced through anaerobic digestion process of biodegradable organic materials, such as manure, food processing residues, energy crops and waste water treatment sludge. Biogas is primarily a mixture of methane and carbon dioxide. It is among the environmental friendliest and cleanest of all cooking technologies (IRENA, 2017**)**. A biogas plant supplies energy and fertilizer, improves hygiene and protects the environment (Sasse, 1988). This benefits especially rural households. On the other hand the use of biogas by households contributes several indirect benefits such as health, environmental, agricultural and economic benefit through reduced deforestation and carbon trading that increase the adaptive capacity to climate change (Chand, *et al* 2015). This study therefore aims to assess the roles of biogas technology as the major option on conservation forest and climate change mitigating in Shebedino district, Southern Ethiopia. The study at the end will try to find policy recommendations which need to take the district out of its current energy crisis. It also will recommend ways to save the environment from hazardous substances which causes the climate to be changed.

1.2 Problem Statement

Domestic energy requirements in rural and urban areas in Ethiopia are mostly met from wood, animal dung and agricultural residues. At the national level it is estimated that Traditional Energy Sources (biomass fuels) meet 92 % of total energy consumed in the country and the remaining consumes modern energy (Ministry of water and energy, 2013). Even in urban areas, half of households rely on traditional biomass (wood, dung and agricultural residues) for cooking, and in rural areas, virtually all do (except for 0.2 per cent who use kerosene and 1.2 per cent who use charcoal), (Issa, 2016).

According to Nachmany et al., 2015 more than 80% of the country's population live in rural areas, and traditional energy sources represent the principal sources of energy. Some 95% of energy needs are derived from fuel wood, crop/animal waste, and human/animal power.

In Shebedino district majority of rural households use biomass energy for cooking and kerosene for lighting purpose (SWWIEO, 2017). While in high consumption of biomass, no one pay an attention to what these energy consumption habits contribute to the environment and how it wastage the natural resource. This over dependence on biomass causes adverse effects, such as emission of particulate matter that are harmful to health, causes deforestation and environmental degradation. Many studies have shown that consumption of energy in the rural areas is mostly inefficient and unscientific causing pollution and health related problems in rural area (Balakrishnan, 2004, Parikh, 2001 and Mishra, 2000). In addition to this there is no concern to how to conserve energy and the environment, as well as less attention is given to the adoption of renewable energy technology. According to national CRGE, (2011) improving crop and livestock production practices for higher food security and farmer income; protecting forests and promoting reforestation; expanding electricity generation from renewable sources; and leapfrogging to energy-efficient technologies in transportation, industry and buildings four base pillars of the policy and the strategy targets climate change mitigation and adaptation (FDRE, 2011). The green growth pathway envisages limiting national greenhouse gas emission levels to150 $MtCO_2e$ instead of 400 $MtCO_2e/a$ in 2030 under business as usual (BAU) scenario. To achieve this there are programs which works by replacing fuel wood for domestic use with less polluting fuels, as biogas. In addition to this, there are also plans to distribute 9 million stoves by 2015 and 34million by 2030 (Nachmany et al., 2015). CRGE policy goals that the large abatement of emission is expected through improving fuel efficiency and shifting fuels (from fuel wood to biogas) for cooking stoves (CRGE, 2011).

In order to reduce the adverse effect caused by fuel wood consumption and to fulfil Ethiopian CRGE policy goal, the adoption of biogas technology is one of the best option in the Shebedino district. According to SWWIEO, 2017 report, from 2013 the Shebedino district held under national biogas program and 122 biogas plants is constructed until 2018. From these 122 biogas plants, 63 is giving its function and households are using energy from it in their home. In the consumption of energy from biogas many people knows lighting and cooking benefits of it, but only few people knows another indirect side-benefits of the technology on environment; as well as there are a limited evidences of comprehensive research carried out on the role of biogas technology that can explain the contribution of biogas technology on protection of environment from harmful substance in Shebedino district. The study conducted in Kiambu County, Kenya by Wamuyu, M. S. (2014) found that a single household using biogas energy helped mitigate approximately 2.333 tonnes of CO2 from being released into the atmosphere from firewood avoidance. According to Renwick et al. (2007), the average amount of GHG emission reduction per each domestic biogas installation and it was estimated to mitigate 5 t of CO2e per annum. The average amount of GHG emission reduced per biogas installation was estimated to be about 2.4 t per annum (Shrestha, 2010). In addition to this, Poudel, Adhikari, & Singh, 2016 found that 7.61 tCO2eq per year of GHGs emission was reduced and the forest area protected per household per year was 0.0789 ha. Thus, this study was conducted to check out how the results of biogas technology adopters and non-adopters look like in the context of Shebedino district, Southern Ethiopia. Therefore, this study were focus to find out the roles of biogas technology on conservation of the forest and climate change mitigation in Shebedino district, Southern Ethiopia.

1.3 Objectives of the Study

1.3.1 General objective

The overall objective of the proposed study was to explore the contribution of the biogas technology as a tool for improving livelihoods of rural communities and also for forest conservation and climate change mitigation.

1.3.2 Specific objective

- ✓ To quantify the amount of greenhouse gas emission reduction though the use of biogas technology in the Shebedino district
- ✓ To estimate proportion of feul wood consumption reduction by the use of biogas technology in the Shebedino district
- ✓ To assess factors influencing adoption of biogas technology in the Shebedino district

1.4 Research Questions

1. How much fuel wood consumption is saved by the use of biogas technology in the Shebedino district?
2. What amount of the greenhouse gas reduced by the use of biogas technology in the Shebedino district?
3. What is the factor that influence the adoption of biogas technology in the Shebedino district?

1.5 Significance of the Study

These study findings would be of importance to governmental organization to provide adequate information about what biogas technology contributes for the rural community as well as to environment protection in the district. In addition to this, the study findings would be of importance to the Shebedino district water mine and energy office to provide information on indirect side benefit of biogas technology, and make the energy expert of the office work on target to the outcome of the research. The findings of this study would contribute to better understanding to cutout the future adverse effect and to show an ability of biogas technology to conserve forest and stabilize climate change. These study finding would also be of importance to Shebedino district environmental and forest protection office to provide information about the number of tree saved and amount greenhouse gas reduced by the use of biogas technology per year.

The findings would further come up with the sensitization and awareness action plan for the County on biogas technology which would be duplicated at the local and national levels to facilitate energy switch to achieve sustainable development. It is also anticipated that the study would also stimulate interest on more researches in the field of renewable energy sources as well as facilitate new technological improvements in biogas production, efficiency, quality, management of surplus gas.

1.6 Limitations of the Study

The study was limited to assess the role of biogas technology on conservation of the forest and climate change mitigation in only Shebedino district, Southern Ethiopia. The study was also limited on the sample 199 household which is the representative of whole population of the district. GHG Emission reduction from: fertilizer usage, energy consumption from lighting and cattle manure management, were not included in the study, due to complexity of the process.

2. LITERATURE REVIEW

2.1 Overview of Global Energy Consumption and Sources of Energy

A major challenge in 21st Century will be that of implementing sustainable development and meeting the energy needs of the ever increasing world's population. According to the International Energy Agency, (2008), about 2.4 billion people, (that is around a quarter of the world's population) have no access to electricity and rely heavily on unsustainable biomass energy to meet their energy needs (IEA, 2008). Moreover, under today's energy policies and investment trends in energy infrastructure, projections show that as many as 1.4 billion people will still rely on biomass in 2030 (IGAD, 2007). Statistics suggest that some 1.86 billion m3 of wood is extracted from forests for fuel wood and conversion to charcoal. Of this total, roughly one-half comes from Asia, 28% from Africa, 10% from South America, 8% from North and Central America and 4% from Europe,(Karekezi, 2002).

This scenario, where figures for Eastern and Southern African countries indicate that a high proportion of total national energy supply is derived from the diminishing biomass energy (Karekezi, 2002). Ethiopia one of the African country which is currently in an energy deficit position both for commercial and non-commercial energy. The challenge at hand is how to reduce over-reliance on wood-fuel among the rural poor who have limited access to alternative sources of energy. Biogas is an energy technology that has the potential to counteract many adverse health and environmental impacts connected with traditional biomass energy in the country.

2.3.2 Energy Consumption Patterns in Ethiopia

The current energy sources of Ethiopia can be categorized into two: modern and traditional. Modern sources of energy encompass electricity and petroleum while traditional sources of energy include fuelwood, charcoal, dung, and crop residues.

In 2009, traditional biomass fuels accounted for 92 % of the total energy consumption whereas modern fuels constituted the remaining 8 % (MOWE, 2011). The household sector is the major consumer of energy in Ethiopia. It makes up 89.2 % of the total national energy consumption while the remaining 10.8 % is shared among agriculture, transport, industry, and service sectors (EREDPC and MoARD, 2002). According to MoWE (2011), in 2009, the household sector accounted 92.6 % of the total energy consumption while all other sectors together constituted only 7.4 %.More than in any other sector, biomass fuel is important in the household sector. It makes up 98.6 % of the total energy consumption. Specifically, fuelwood, dung, crop residues, and charcoal account 81.4 %, 8.1 %, 7.8 %, and 1.3 %, respectively whereas electricity and petroleum together contribute 1.4 % of the total household energy consumption (EREDPC and MoARD, 2002). The contribution of biomass fuels is still greater in the rural households as compared to the urban counterpart. According to EREDPC and MoARD (2003), biomass fuels constitute 99.9 % of the total energy consumption of the rural HH.

2.2 Overview of Biogas Technology

Biogas is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and low amount of other gases ("FAO,1996) see table 2

Table 1: Composition of biogas

	Substances					
	Methane	Carbon di oxide	Hydrogen	Nitrogen	Water vapor	Hydrogen Sulphide
Symbol	CH_4	C_2O	H	N	H_2O	H_2S
Percentage	50-70	30-40	5-10	1-2	0.2	Traces

Source: Yadav and Hesse 1981

2.2.1 Uses of Biogas

Like any other fuel, biogas can be used for household and industrial purposes, the main prerequisite is applicable for consumer appliances (Ni Ji-Qin and Nynl, 1993).

2.2.1.1 Biogas for lighting

Biogas can be used for lighting in non-electrified rural areas. Special types of gauze mantle lamps consuming 0.07 to 0.14 m^3 of gas per hour are used for household lighting. Several companies in India manufacture a great variety of lamps which have single or double mantles. Generally, l-mantle lamp is used for indoor purposes and 2-mantle lamps for outdoors. Such lamps emit clear and bright light equivalent to 40 to 100 candle powers. These are generally strong, well built, bright, efficient and easy to adjust compared to stoves, lamps are more difficult to operate and maintain. The lamps work satisfactorily under a water pressure of 70 to 84 mm (Karki and Dixit, 2002). Until now, biogas lamps are not manufactured in Ethiopia and are imported from several companies in India.

2.2.1.2 Biogas for cooking

Cooking is by far the most important use of biogas in the developing world. Biogas burners or stoves for domestic cooking work satisfactorily under a water pressure of 75 to 85 mm. The stoves may be single or double varying in capacity from 0.22 to 1.10 m^3 gas of gas consumption per hour. Generally, stoves of 0.22 and 0.44 m^3 (8 and 16 cubic feet) capacity are more popular. A 1.10 m (40 cubic feet) burner is recommended for a bigger family with larger plant size (Karki and Dixit, 2002). Biogas is 20 percent lighter than air and has an ignition temperature in the range of 650° to 750° C. It is an odorless and colorless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is 20 Mega Joules per m^3 and burns with 60 percent efficiency in a conventional biogas stove.

These gases are produced by the methanogenic bacteria that act upon organic materials in the process of completing their life-cycle in an anaerobic condition (FAO 1996). The amount of heat released during the biogas combustion is approximately 6 kWh/Sm^3. In other words, the combustion of 1 standard m^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: It must be noted that the actual fuel consumption also depends on the fuel utilization efficiency, such as cooking stoves efficiencies. Table 2 & 3 summarizes typical efficiencies for the possible uses of biogas (FAO, 1996).

Table 2: Typical efficiencies for devices using biogas and Equivalence between biogas and other fuels in terms of heating value

	Biogas use			
	Heaters	Stoves	Engines	Lamps
Efficiency	88%	55%	24%	3%

Source: (FAO, 1996).

Table 3: Equivalence between biogas and other fuels in terms of heating value

Fuel	Unit	Value
Charcoal	Kg/Sm^3 of biogas	0.7
Firewood	Kg/Sm3 of biogas	1.3
Gasoline	liter/Sm^3 of biogas	0.75

Source: (FAO, 1996).

2.2.5 History of biogas technology in Ethiopia

Attention given to energy issues in Ethiopia in the past; rural communities continue to be deprived of basic energy services. Modern forms of energy are simply not available in rural areas while traditional sources are rapidly being depleted, thereby deepening the rural energy crisis (EREDPC, 2007).

Biogas offers an attractive option to replace unsustainable utilization of wood and charcoal and was introduced in Ethiopia as early as 1979 and the first batch type digester was constructed at the Ambo Agricultural College. In the last two and a half decades, around 1000 biogas plants were constructed in various parts of the country (SNV, 2010). In 2007 a joint EREDPC/SNV team was established to develop a program implementation document. An extensive stakeholders' consultation process at both regional and national level resulted in more than 120 representatives of the government, non-governmental organizations, and the private and financial sectors gaining awareness about the features and functions required for a national biogas program (NBP), and providing ample inputs for the development of the program. The first phase of the program will be implemented in selected woredas in Oromia, Amhara, SNNP and Tigray regional states (SNV, 2010). The selected woredas include: In Oromia: Adaà, Dugda Bora, Hetosa, Ambo and Kuyu; In Amhara: Bahir Dar Zuria, Dembia, Gondar Zuria, Fogera and Dangla; In SNNPRS: Dale, Mareko, Meskan, Arba Minch Zuria and Derashe Special Woreda and In Tigray: Hintalo Wajirat, Raya Azebo and Western Tigray (SNV, 2010)

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 SNNP regional state (Getachew, 2016).

2.2.7 Innovation Diffusion Theory and Biogas Technology

Diffusion research focuses on conditions which increase or decrease the likelihood that a new idea, product, or practice will be adopted by members of a given culture.

According to Rogers (1995), in a given technology, there are five categories of adopters, who are: (i) innovators, (ii) early adopters, (iii) early majority, (iv) late majority, and (v) laggards.

These categories follow a standard deviation curve. Very few (2.5%) (Innovators) adopt the innovation in the beginning. Early adopters make 13.5% a short time later, followed by the early majority (34%), and the late majority (34%).

Diffusion of environmentally sound technologies such as biogas is essential to realize sustainable development goals. However, the diffusion rates are context specific and depend largely on specific social, economic and technological factors. These factors that either hinder or facilitate, and drive the process are often interlinked, making diffusion a complex phenomenon. Renewable energy technologies (RETs) for instance are mainly driven by impending environmental and energy security considerations arising from use of fossil and wood fuels.

2.3 Energy Consumption and Climate Change Linkages

The bulk of global energy supply comes from carbon-based fuels, but whose emissions threaten the global climate, environment, human health and earth's very existence. Energy-related greenhouse gas emissions are the main drivers of anthropogenic climate change, exacerbating patterns of global warming and environmental degradation. Three major anthropogenic GHGs are carbon dioxide, methane and nitrous oxide (Wamuyu, 2014).Global emissions of carbon dioxide (CO_2) have increased by more than 46 % since 1990. The Intergovernmental Panel on Climate Change (IPCC) estimates that globally, agriculture contributes 10% of anthropogenic CO_2, 40% CH_4 and 60% N_2O.

Burning of fuel wood could result in net emission of CO_2, by decreasing the forest area and standing stock of carbon in forests. Fuel wood contributes to GHG emissions through unsustainable harvests and incomplete combustion of biomass. When one ton of dry wood burns or decays, 1833 kg of CO_2 is emitted. It is further estimated that traditional charcoal production emits nine tons of CO_2 for every ton of charcoal produced (Wamuyu, 2014).

Climate change, driven by fossil fuel combustion and deforestation, is a becoming threat to lives and livelihoods in every part of the world at this time (Ackerman, 2009).

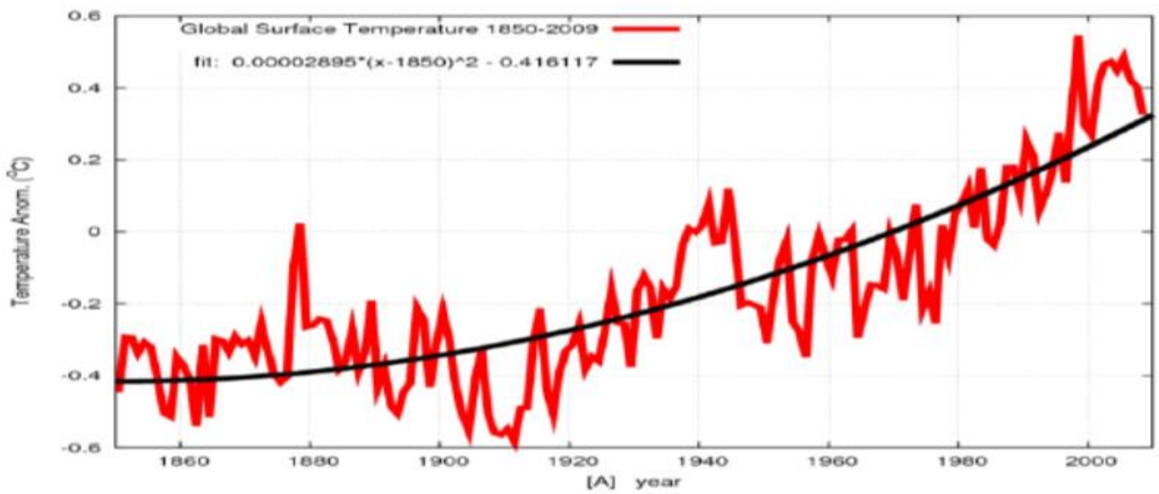


Figure 1: Global surface temperature increments (land and sea)

Source: Climatic Research Unit.

Emission of black carbon from biomass combustion may also exacerbate the effects of climate change (Wamuyu, 2014).

By 2030, with projected economic and population growth, the world's total energy demand is expected to be approximately 35% higher than 2005, despite significant gains in energy efficiency.

By 2010, IEA projects that global energy consumption and annual CO_2 emissions will have risen by almost 50 % from 1993 levels. The Developing nations' share of commercial energy consumption was expected to grow to nearly 40% by 2010.This is because of rapid industrial expansion and infrastructure improvement, high population growth and urbanization and rising incomes allowing purchase of energy-consuming appliances and cars, as a result CO_2 emissions would rise even faster to about 45% of global emissions.

More than two-thirds of harmful greenhouse gases are produced in the energy sector by activities such as transport, electricity generation, and heating and cooling for industrial and domestic purposes. This means that in the long term it will only be possible to keep global warming within the agreed limits by converting to low-carbon energy and improving energy efficiency (Federal Ministry, 2016). Greenhouse-gas emissions from the energy sector represent roughly two-thirds of all anthropogenic greenhouse-gas emissions and CO_2 emissions from the sector have risen over the past century to ever higher levels. Effective action in the energy sector is, consequentially, essential to tackling the climate change problem (IEA, 2015).

2.4 Biogas for reduction of Green House Gases (GHG) emissions

The use of unsustainable wood for heating or cooking results in positive GHG emissions, whereas the use of biogas is generally neutral with regards to GHG emissions (provided that organic materials used to feed the bio-digester are renewable and that there is no methane leakage from the plant) .As a consequence, in a country where wood production is non-sustainable, biogas plants can displace the use of firewood or charcoal, resulting in a reduction of GHG emissions (Rakotojaona , 2013).

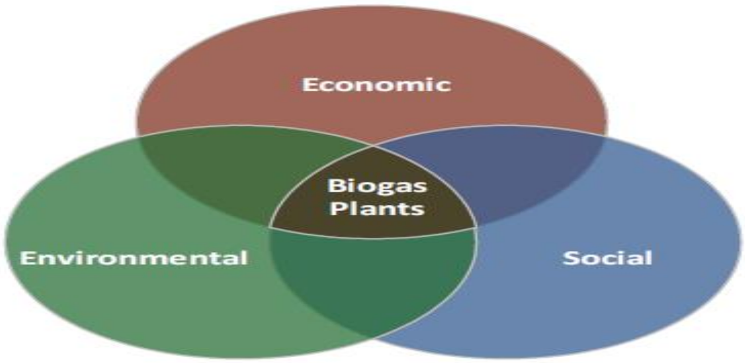


Figure 2**:** Biogas plant triple win

Source: (Rakotojaona .L, 2013).

2.4.1 Digester Size and Emissions Reduction

Agricultural bio-digesters reduce GHG emissions and generate clean energy (Clean Development Mechanism). Emissions reduction depends on many factors, including digester design and size. Studies by Winrock and Eco-Securities (2004), in Nepal, found that a biogas plant measuring 6m^3 was able to mitigate 5 tons of CO_2-equivalent per year (Biogas Support Programme, 2000). According to Shrestha *et al*. (2003), biogas plants of sizes 4, 6 and 8 m3 mitigated about 3, 4 and 5 tons respectively of CO_2 per year. Further, a study by Winrock and Eco-Securities (2004) shows carbon reduction per digester at 4.6 tons of carbon dioxide equivalent. Similarly, AEPC (2008), found GHGs reduction rate of biogas is as 4.99 tons.

2.4.2 Roles of biogas to reduce fuel wood consumption and climate change mitigation

Biogas is alternative or substitute energy sources. As viable eco-friendly alternative technology, it can substitute firewood for cooking, heating and lighting fuel. So, it reduces the dependency on forests and increases greenery leading to an improved environment (Adhikari, 2014).

Adopting biogas technologies can take place at micro (e.g. household) as well as macro levels (Hamlin, 2012, Arllette and Franziska, 2012, Eba'a Atyi et al., 2016). Apart from cooking, biogas can potentially reduce indoor air pollution, produce energy for lighting, heating, and improve sanitation by reducing pathogens, worm eggs and flies (Urmila et al., 2008). Adopting biogas technologies can potentially reduce workload, as the need for firewood collection reduces. Its usage is accompanied by environmental benefits such as fertilizer substitution, less greenhouse gas emission, improved indoor air quality; and economic benefits, as it reduces expenses on fuel and fertilizer (Buysman, 2009).

Moreover, the Forest Law Enforcement, Governance and Trade (FLEGT) mechanism, is joining forces with REDD+ activities in many countries for common action to address deforestation and strengthen forest governance. This action, can be tacken through the adoption and dissemination of biogas technology.

2.5 Empirical Review

Different study was conducted on biogas technology, from these the finding of study group are: Wang et al. (2011) and Fei & Yu (2011) found that biogas use in China is affected by family size, age, gender, education level and knowledge and awareness. Support from government in terms of finances and policy also affected use of biogas in China (Jian, 2011).

In addition Arthur et al. (2011) contended that biogas minimizes GHG emissions, and hence assists the world climate change mitigation efforts via capturing methane and reducing use of fossil fuels.

In Nepal, it was found that the total GHG emissions from biogas users and non-users were 3.7 t and 6 t of CO2e per household per annum, respectively. The average amount of GHG emission reduced per biogas installation was estimated to be about 2.4 t per annum (Shrestha, 2010).

The overall assumption of this study is that inadequate support from stakeholders particularly the government institutions has got an influence on adoption and non-adoption of biogas technology. Government institutions and other stakeholders ‘support involves among others; effective information dissemination and promotion strategies through communication channels such as media which assumed to influence awareness and peoples ‘attitude towards the technology adoption.

2.6 Conceptual Framework

A conceptual framework could be a simple list of concepts and their likely associations or a more illustrative schematic diagram of important factors, expected relationships, and possible outcomes of the research problem. It enables the researcher to critically consider multiple facets of the research problem; identify key factors, and depict their logical interrelationships in a scheme. Thus, a thoughtfully developed conceptual framework can serve as a vital compass.

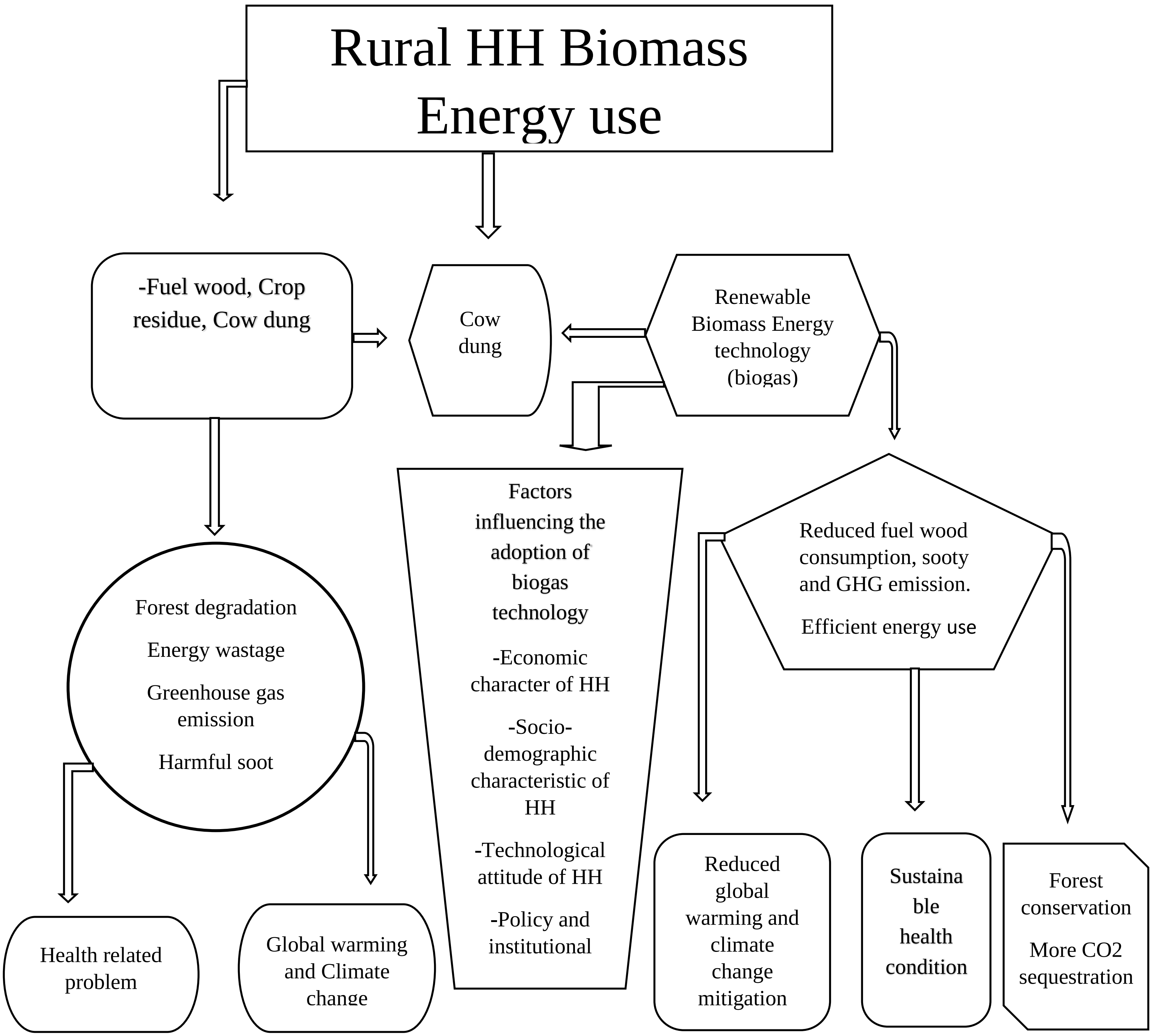


Figure 3: Conceptual frame work

Source: Own sketch

3. MATERIALS AND METHODS

3.1 Description of Study area

3.1.1. Location

The study were conducted in Shebedino district .Shebedino district is the one of the district in the Sidama Zone, Southern Nations, Nationalities, and Peoples' Region of Ethiopia. It is located 27 km from Hawassa city and found in the geographical coordinate 6° 49′59.99″ latitude in the North and 38° 29′ 59.99″ longitude in the East (SWOFED, 2017). Shebedino district is bordered with four Sidama zones district: from North with Hawela Tula sub city, from South with Dale district, from East with Gorche district and from West with Boricha district. It comprises 35 Kebele administrations; among these, three of them are urban Kebeles and 32 of them are rural Kebeles and main town in Shebedino is Leku. According to 1994 Census, this district had a population of 420,976, of whom 214,000 were men and 206,976 women; 10,669 or 2.53% of its population live in urban areas (SWOFED, 2017).

3.1.2 Topography

The study area district is located in Great Rift Valley and has a total area of 276.9 square kilometer. The altitude of the study district varies from 1500-3000m above sea level.

3.1.3 Climate

In Shebedino district there are two agro climatic zones of which is (84.4%) is Woina dega and (15.6%) is Dega. Hot climate zone dominated in the district and it covers 30% of total area. Its mean annual temperature ranges from 16 ^{0}c to 25 ^{0}c .The mean annual rainfall of the Shebedino district ranges from 800mm to 1600 mm. The cool climate condition of the district is known as Alicho or Dega which occurs in mountainous highland (SWOFED, 2017).

3.1.4. Farming system

3.1.4.1 Crops practiced

In the study area, more than 90% livelihood of the population earned from crop production and livestock rearing, and the rest 10% earn from petty trade and other livelihood activities (SWOFED, 2014). The area has two cropping seasons. These are Belg (Starting from February to May) and Meher (starting from June to September). The farmers dominantly practice garden coffee farming systems that include intercropping of various crops (enset, maize and haricot bean), vegetables, fruits, and khat and field crops such as teff, potato and sweet Potato. Coffee and khat are major cash crops in the area (SWAO,2017).

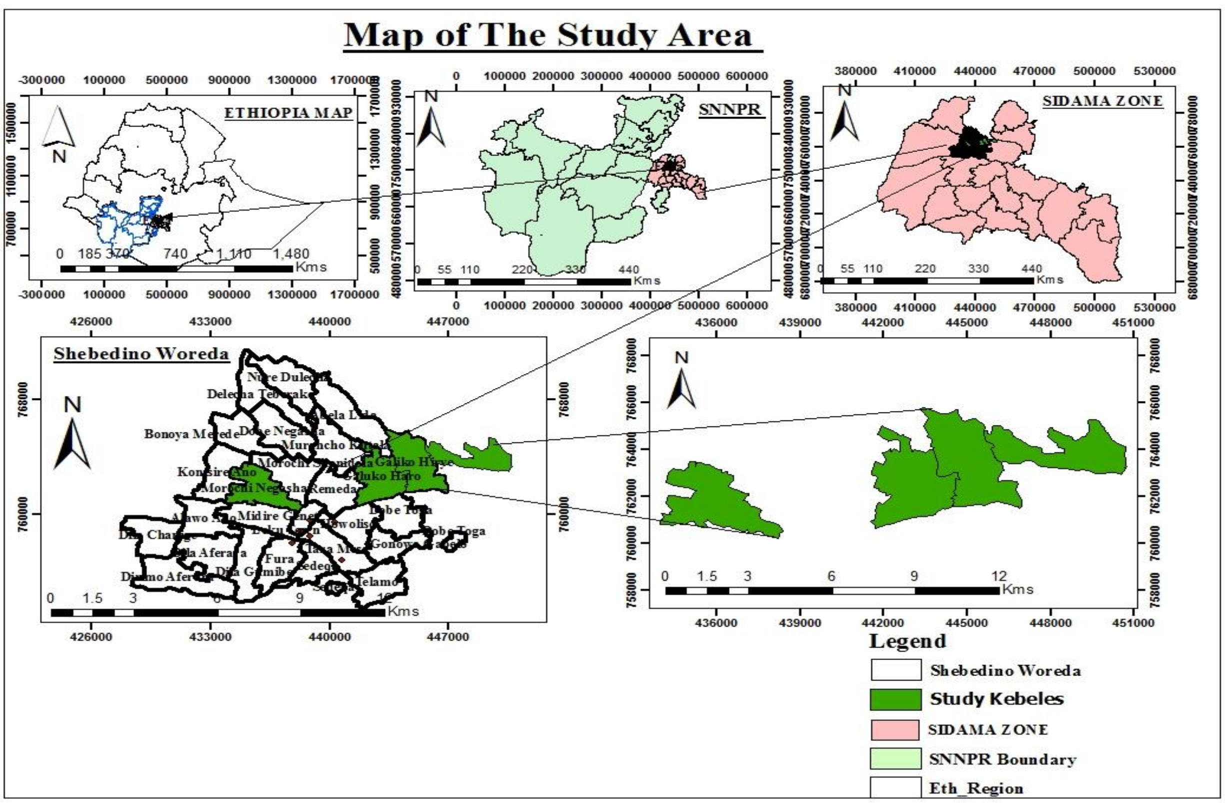


Figure 4: Location map of the study sites

Source: Office of Agriculture, Shebedino district, 2017

3.2 Research Design

This study adopted a cross-sectional survey design (Gray, 2004; Lewin, 2005), which comprises qualitative and quantitative research approaches. This is because, the presence of various specific research objectives and data types. The data was collected to study the role of biogas technology on conservation of forest and climate change mitigation in Shebedino district, Southern Ethiopia. This study utilized kebele's people who were in different socioeconomic status, and educational background.

3.3 Sources of Data

3.3.1 Primary source

Primary data was collected in different ways. A primary data mainly related to respondents' demographic characteristics, peoples' attitude towards biogas technology, type of fuel used and biogas consumed per households was collected through households' survey by using questionnaire. In addition to this data were also collected through, key informant interview focus group discussion, field observation and photography, as well as kitchen performance test(KPT) was carried out .

3.3.2 Secondary source

The secondary data was collected from recent literature such as published and unpublished books, journals and reports. Other data's available at kebele or district were also used. Different websites were visited for the purposes of literature, as well as for general analysis of the document.

3.4 Sampling technique and Sample size Determination

3.4.1 Sampling technique

To achieve the objectives of the study, respondents were sampled through stratified sampling process which involved classifying households into two groups, namely, the adopters and non-adopter households. Households that owned a biogas were classified as “adopters “while those that never owned one classified as “non-adopters”.

Samples are selected from four kebeles of the district on the basis of adoption of biogas technology. These were: Garagalo, Galuko-hireye, Galuko-haro Morocho-nagasha kebele’s. According to SWWIEO, 2017 the total number of biogas technology adopter in the district is 122 households. There are 2590 total number of house hold in selected four kebeles. From these 78 house hold were adopter and 2512 were non-adopter. The house hold list was also obtained from administration of each kebele.

3.4.2 Sample size determination

The rural households of Shebedino district were considered as population for this study. Therefore sample size comprised of 199 respondents (52 were biogas adopters who were purposively selected and 147 were non-adopters who were randomly sampled) from four kebeles of Shebedino district.

This sample size was obtained from population by using Yemane formula.

$n = N/1+N(e)^2$ ………………… (1) Yemane (1967), Where; n = desired sample size for adopters and non-adopter households N = population of registered daily farmers e = margin of error 8%.

Table 4: Distribution of sample sizes in each selected kebeles

Kebele's	Total number of households		Sample size taken	
	Adopter	Non adopter	Adopter	Non adopter
Galuko-haro	14	633	10	37
Garagalo	17	753	11	44
Galuko-hireye	18	625	12	37
Morocho-nagasha	29	501	19	29
Total	78	2512	52	147

Source: Own computation, 2019

Kebele is the smallest administrative division in Ethiopia

3.5 Data Collection Methods

For this study both qualitative and quantitative approaches were used. The quantitative approaches used for collecting data from households, though Semi-Structured Interview and energy quantification (from KPT); whereas, the Qualitative type of primary data was collected using key informant interview, focus group discussion, and personal observation.

3.5.1 Household survey (HHS)

The general description of the location of the persons who responded to the questionnaire in the households was 47(23.62%), from Galuko-haro, 55(27.64%), from Garagalo 49(24.62%), from Galuko-hireye and 48(24.12%), from Morocho-nagasha kebele. This in total makes 0.24% of households of Shebedino district. The household's survey was conducted with sample HHs through semi structured questionnaires. A detailed and well-designed structured questionnaire were developed in English language and translated it in to Sidama language in a way that enables to gather full information about the study objectives.

All questionnaire were distributed for expected 199 households and 100% of households' survey data was recorded. Questionnaire survey gathered information on demographic characteristics of households (household size, land size, education level and livestock number), household fuel consumption (consumption of dung cake, fuel wood and kerosene). The questionnaire were pre-tested among seven randomly selected households from sampled kebeles to detect misunderstandings, ambiguities, or other difficulties of participants.

3.5.2 Key informant interview (KII)

For this study the interview was carried out on governmental institute and stakeholders who work on biogas technology promotion and dissemination. The sample population for the interviews included 6 KII partner in total, (2 KII partner from biogas technology promoter energy expert and 4 KII partner from local authority representatives).

The interview guide used consists of both open and closed ended questions. Open ended questions were designed to solicit information relating to actual and expected returns on respondents and study area characteristics, and their relations to adoption of biogas technology. Closed ended questions on the other hand were intended to capture information relating to respondents 'attitude towards the role of biogas technology. The questions that would asked to all respondents were identical, in order to obtain homogeneous information.

3.5.3 Field Observation.

Field observation was used to gather additional information and counter-check information provided by household respondents and focus group discussion participants. In addition to this, a direct observations were used to evaluate existence of biogas plants, functionality of biogas plants, designs and care of biogas plant, and types of feeds used to confirm functioning of biogas plants. Moreover, the camera was used to capture some events and structures of interest to this study.

3.5.4 Focused Group Discussion (FDG)

The members of focus group discussions in this study were selected from both adopter and non-adopter households of biogas in each selected kebeles. FDG were conducted using four focus discussion group, each group with 11 members. Some open-ended questions were prepared for discussions, to play a vital role in addressing the objectives of the study.

3.6 Kitchen Performance Test (KPT)

Kitchen Performance Test (KPT) is the principal field based procedure to demonstrate the effect of stove interventions on household fuel consumption. In this study the kitchen performance test were used to estimate amount of fuel wood saved by the use of biogas technology. In addition to this it was used to estimate the amount of greenhouse gas reduced (mitigated), forest conserved, CO_2 sequestrated from saved fuel wood by the use of biogas technology.

According to Bailis & Edwards, (2007) one must choose families to act as the comparison group from a community that is similar in socioeconomic status, livelihood options, and climatic or environmental conditions. So that, Morocho Nagasha kebele was selected for KPT in this study.

According to Bailis et al., 2007, as a rule of thumb, if the target population is very small (e.g. less than 200 families), then the number of families covered by the initial survey between should be at least 20. There were 29 adopters of biogas technology in Morocho nagasha kebele, so that 20 test subjects were selected from adopter households. An equal amount of test subjects were also selected from non-adopter households of biogas for a cross sectional study. Sample sizes needed to be larger if there is a lot of variation in the amounts of fuel used and saved, which is often the case in KPTs. For this study KPT was to be performed as a cross-sectional study. Random sampling was not possible for the selection of families, because all families did not agreed to participate in the test.

Therefore families were selected as local circumstances allow (Bailis & Edwards, 2007). Before the KPT have to be carried out, one day visits was done on each selected households .This was done to arrange or to order households to be ready to the next day KPT. Then the uniform firewood from similar tree species was supplied for each biogas adopter and non-adopter households, and then initial supply of wood was weighed and counted. The provision of uniform fuel wood were to fulfil the want of researcher and in order to make all selected household to use fuel woods from similar tree species. The test subjects were informed households to cook normally as usual cooking manner and ordered to use fuelwood only from a designated stock during the tests. The aim was to capture their usual behavior in the kitchen.

The fuel wood used in the study was acquired from local sellers in the town of the Shebedino district. The sellers was purchasing fuel wood composed of different plant species. Then the researcher ordered the sellers to prepare the fuel wood only from eucalyptus tree species, which was the preferred wood type in the study communities.

After provision of fuel wood, the tests were carried out for a period of three consecutive days and times like festivals or holidays were avoided, since more cooking is done than an usual. This is least testing period of KPT in according to Bailis et al., 2007.

For undertaking of KPT the participant households were visited twice a day (1hour after breakfast and 1 hour after the lunch mass), and the remaining fuelwood were weighed. The primary tools and hardware used in the KPT were: spring balance with 0-50 kg range, 1 m resolution rope, cart for wood transport, digital wood moisture meter and GPS 72H to obtain the coordination of participant household home position.

Wood digital moisture meter spring balance with 0-50 kg GPS 72H

Figure 5: Tools and hardware used in the KPT

Source: Own photographing

Finally statistical analysis was conducted on the test results to estimate the mean fuel savings.

Since the project and baseline samples are independent, then the standard error of the estimate is:

$$SE_y = \sqrt{\frac{s_b^2}{n_b} + \frac{s_p^2}{n_p}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Source: Harvey, A., & Uk, O. (2011.).

Where: n_b is a baseline Sample size, n_p is a project sample size, s_b^2 is baseline standard deviation of the sample and s_p^2 project standard deviation of the sample

$$SE_y = \sqrt{\frac{(0.41625)^2}{20} + \frac{(0.2285)^2}{20}} = 0.106$$

The sample of size of n, the estimated precision is given by the formula

$$Precision = 1.6 \times \frac{SE_y}{\bar{y}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Precision $= 1.6 \times \frac{0.106}{0.84} \times 100 = 20.22\%$

Where: $\bar{y}$ is the estimate of mean fuel savings calculated from the sample

SE_y is the standard error of the estimate

Here 1.67 is used as an approximation to the critical value t $_{0.95, -1}$, which will vary between 1.75 and 1.64 as the sample size n increases from 15 to very large. In this KPT, CV for daily fuelwood consumption of biogas technology adopters and non- adopters were 0.14 and 0.17, respectively. Moreover, the precision attained was 20.22%. This indicates that the sample size satisfy the 90/30 rule. Therefore, no additional sample size was required for KPT.

Then the minimum required sample size is obtained by:

$$\tilde{n} \geq \left(\frac{s_b^2+s_p^2}{\bar{y}_b-\bar{y}_p} \times \frac{1.67}{x/100}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(4)}$$

Source: Harvey, A., & Uk, O. (2011.).

$\tilde{n}$ Is the sample size needed, $\bar{y}_b$ is baseline mean of the sample and $\bar{y}_p$ is project of the sample

The total required sample size in this case is thus $2n$

$$\tilde{n} \geq \left(\frac{0.416^2 + 0.228^2}{2.42 - 1.58} \times \frac{1.67}{30/90}\right)^2 \quad , \tilde{n} \geq 9.9 = 10$$

Total sample size would be 2x10=20, but, the sample size used for this, study was 40 households which is greater required sample size, this is more enough and more useful to obtain more precise and accurate result.

3.7 Data Collection Procedures

Before data collection, the energy consumption behavior of the district households were obtained from the Shebedino districts water mine and energy office.

According to the SWWMEO, 20017 report, about 69%, households in the district consume fuelwood, 23% crop residue, 0.12% biogas 4% dung cake, the remaining households used other source of energy for cooking, whereas about 63% household in the district used kerosene, 15 % solar, 10% electricity, 0.082% biogas and the remaining households uses other sources of energy for lighting. The data was collected by eight data collectors (two data collectors in each kebele). All of data collectors can speak both Amharic and Sidamic language. To administer the questionnaire, data collectors were trained for 3 hour in order to make them to be aware about the topic of the study and to clarify the entire content of questionnaire. The data was collected within eight weeks. Enumerators scheduled and decided data collection moment to be, in the morning (7-9 o-clock) and afternoon (4-6 o-clock) on Monday to Friday; whereas in the weekends, morning to afternoon would be the data collecting time. The enumerators chosen these time because of the respondents are farmers and that the chosen time was the data collectors would probably get the respondents free of work at home.

3.8 Data analysis and Presentation

The data that was collected through questionnaire, was coded and keyed into the Statistical Package for Social Scientist (SPSS 20.0) and exported to Stata, while experimental data was entered into Excel spreadsheets and exported to KPT statistical software. After thoroughly cleaning the data and checking for any erroneous entries, detailed statistical analysis were carried out to establish relationships between variables and draw conclusions. The data analysis involved both quantitative and qualitative methods. Qualitative data was analyzed based on content analysis, while quantitative data analyzed using descriptive and inferential statistics.

3.8.1 Descriptive statistic

Descriptive and inferential statistics was used to analyze Quantitative data. Descriptive statistics was employed to assess the following aspects: respondents' demographic and socio-economic characteristics and their attitude towards biogas technology, and to identify the type of most commonly used tree species for energy consumption. The descriptive statistics included: averages, percentages, and Pearson's product moment correlation (some sources categorize it as inferential statistics). Inferential statistics encompassed binary logistic regression and independent samples t-tests. Before detailed analysis, frequencies, mean, standard deviations and cross tabulations were used to display the data.

Tests of significance, specifically T-tests and Chi-Square (χ^2) were used. Significant differences were estimated using Duncan's multiple range tests in SPSS and strata for windows. P-values were instrumental in informing the results of this study in which Significance difference was set at $p<0.05$. The degree of correlation (r) or association between continuous independent variables and dependent variables was measured by use of Karl Pearson's' coefficient, while spearman correlation was used between discrete (dummy) variables. The collected data was presented using statistical techniques which included percentages and frequency distribution tables. Tables, pie-charts and graphs were also used to present the analyzed data.

3.8.1.1 Econometric model

For this study econometric model was used. In general, one of the objectives in modeling is to have a simple model to explain a complex phenomenon. The most commonly used econometric models in adoption studies are the binary logistic regression model. Binary Logistic regression model was used to predict factors that influenced biogas adoption and utilization. The model is used when the dependent variable is a dichotomy and the independent variables are of any type.

It applies maximum likelihood estimation after transforming the dependent into a logit variable (Garson, 2008). It estimates the odds of a certain event occurring. The dependent variable is a logit, which is the natural log of the odds.

The model is given as;

$In\left(\frac{P}{1-P}\right) = a + bx$ ……………………………………………………………(10)

$P = e^{a} + bx$……………………………………..………………………..(11)

$1 + e^{a} + bx$……………………………………………………………………(12)

Where P is the probability of the event occurring, x are the independent variables, e is the base of the natural logarithm, a and b are the parameters to be estimated by the model.

The empirical form of the model is

$Pry = \frac{1}{1+e^{-(a+bx)}}$…………………………………………………………….. (13)

Where Y is the logit of the dependent variable

The logistic prediction equation:

Y= In (odds (event)) = In (prob (events)/prob (nonevent))

=In (prob (event)/1-prob (event) 1

$=b_0+b_1X+b_2X_2+b_3X_3+b_4X_4+b_5X_5$…….$b_nX_n$ ……………………………………(14)

Where b_0 is constant term, X_1, X_2, X_3, X_4, X_5........Xn are independent variables likely to affect the probability of adopting biogas technology and b_1, b_2, b_3, b_4, b_5.b_n are the coefficient to be estimated.

The dependent variable Y= adoption of biogas technology

=P(Y) = (1 if household adopt and use biogas, and 0 if not)

X_i represent the following variables: X1 = GENDER (Binary, M/F), X_2 = AGE (Continuous, Yrs.), X_3= INCOME (Continuous, Average annual income of households in ETB (ksh)), X_4 = HHSIZE (Continuous, Number of household members), X_5 = No. CATTLE (Continuous, Number of cattle owned by households), X_6= FLWODIST (Continuous, Time taken to bring fuelwood to resident), X_7= LANDSIZE (Continuous, Total area of land owned by households in Hectares), X_8= EDUSTAT (Continuous, Educational status of households head in years), X9=AWARENESS (Binary, aware/not aware), X_{10} = DSTWATSR (Continuous, Time taken to take water to home in minute), ε = Error term. In the present study, the observations was coded "1" for adopters and "0" for non-adopters and used as a dependent variable. The general formula for adoption of biogas technology will be specified as follows:

$$Y=b_o+b_1(AGE)+b_2(GENDER)+b_3(INCOME)+b_4(HHSIZE)+b_5(No.CATTLE)+b_6(FLWODIST)$$
$$+b_7(LANDSIZE)+b_8(EDUSTAT)\ b_9(AWARENESS)+b_{10}(DSTWATSR) \ldots\ldots\ldots\ldots(15)$$

3.8.1.1.1 Multicollinearity test for continuous variables

When using binary logistic regression, the data were checked for the existence of multicollinearity for both dummy and continuous variable. Multicollinearity may arise due to a linear relationship among explanatory variables. It might cause smaller t-ratios for many of the variables in the regression, high R^2 value, large variance and standard error with a wide confidence interval.

For continuous variables VIF is used to test whether there is multicollinearity between variables by using the formula:

$$VIF\ (X_i) = \frac{1}{1+R^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Where, R^2 is the squared multiple correlation coefficient between X_i and other explanatory variables.

3.8.1.1.2 Multicollinearity test for discrete variable

Contingency coefficients test is used for dummy variables and it can be obtained by using the following formula.

$$C=\sqrt{\frac{\chi 2}{\chi 2+n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Where C is contingency coefficient, $\chi 2$ is the chi-square value and n=total sample size.

Table 5: Definition of Explanatory Variables for Biogas Technology Adoption Model.

Variable	Type	Description	expected sign
AGE	Continuous	Age of household head in years	+/-
GENDER	Dummy	Sex of household head(1=male,0=female)	+/-
INCOME	Continuous	Average annual income of household(Ksh)	+
HHSIZE	Continuous	Number of household members	+
No. CATTLE	Continuous	Number of cattle owned by household	+
LANDSIZE	Continuous	Total area of land owned by household in hectares	+
EDUSTAT	Continuous	Educational status of household head	+
AWARENESS	Dummy	Awareness of household head on biogas	+/-
DSTWATSR	Continuous	Average time(in minute) taken to reach water source for biogas feeding	-
FLWODIST	Continuous	Average time in minute taken to collect fuel wood	-

Source: own computation

3.8.1.2 Variables explaining adoption of biogas technology:

The households' decisions on adoption of biogas technology were expected to be the outcomes of interactions of multiple factors.

Based on examination of various related studies (Bhatia, 1990; Bhat et al., 2001; Mwirigi et al, 2009; Walekhwa et al. 2009; Kabir et al., 2013; Qu et al., 2013), the major determinants influencing adoption of biogas technology revolve around 1) demographic, 2) social, 3) economic, 4) institutional and 5) biophysical factors. The, selection of plausible explanatory variables involved both examination of the existing related literature and field observations and experiences.

3.8.1.2.1. Dependent variable and Independent variable

Adoption of biogas technology: is owning biogas technology and using energy from it. Adoption of biogas is independent variable while, independent variables are listed and defined as follows:

Age of household: The young household heads are likely to be more flexible and liable to accept new technologies, but at the same time, they are likely to have less capital accumulations and have lower economic status than the old farmers. Hence, the age of the household head was expected to have either positive or negative influence on adoption of biogas technology.

Sex of household head: Men dominantly control the household resources (Lim et al., 2007) and often make final decisions both at household and community levels in the country (EREDPC and SNV, 2008). Thus, sex of the household head was expected to have either positive or negative influence on adoption of biogas technology.

Educational status of household head: Household heads with higher educational levels were indicated to be less conservative, more informed, more knowledgeable, and more vigilant to the environment (Walekhwa et al., 2009).

Thus, household heads who passed through greater number of schooling years were anticipated to have a greater probability of adopting biogas technology.

Household size: is a number of household member who included in one house. Large household size have sufficient labor required to manage and operate biogas technology. Thus, household size was hypothesized to have either positive or negative influence on adoption of biogas technology.

Cattle size: Number of cattle owned by households.It is one of the most variable because of this the primary input for biogas digesters in Ethiopia is cattle dung.

Thus, households who have more number of cattle, was expected to have positive influence on adoption of biogas technology.

Household income: amount in ETB in which household earned per year.Construction of biogas needs a cost covered by the farmers, either through own income sources or loans. It is in the form of Ethiopian birr. Thus, household with high income source have more probability to adopt biogas technology.

Size of farmland: is sizes of land in hectare which households owned. Households with larger size of farmland were supposed to have better income. Hence, it was hypothesized to have positive influence on adoption of biogas technology.

Distance to fuelwood sources: is the time taken to collect fuelwood from source to resident,thus, the distance to the main fuelwood source away from resident was expected to have negative influence on adoption of biogas technology.

Distance to water sources: For daily feeding of the biogas technology, the source of water was suggested to be within a short walking distance away from home. Therefore, distance to water source from home was expected to have negative influence on adoption of biogas technology.

Awareness: Awareness is level of knowledge of household acquired on biogas technology from different sources of information.

Awareness affect the adoption of biogas technology both negatively and positively, in which more aware households adopt biogas than non-aware households.

3.8.2 Determination of fuel wood saved

According to SNV (2010) 1m^3 of biogas has fuelwood replacement value for different fuels as shown in Table 3. Fuel wood consumed by households in both adopter and non-adopter can be measured by recording daily fuelwood consumption and dividing the amount by number of adult equivalent served.

$F_a = \frac{fuelwood\ consumed}{No\ adult\ served}$ Where F is fuelwood consumption per capta and coefficient "a" represent adopter and non-adopter…………………………………………………………….... (5)

$$F_{saved} = \frac{fuelwood\ consumed\ by\ non-adopter}{No\ adult\ served} - \frac{fuelwood\ consumed\ by\ adopter}{No\ adult\ served} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where F_{saved} is saved amount of fuelwood.

3.8.3 Determination of total GHG reduction per unit of useful energy for cooking

Greenhouse Gases (GHGs) can be measured by recording emissions at source by continuous emissions monitoring or by estimating the amount emitted by multiplying activity data (such as the amount of fuel used) by relevant emissions conversion factors. In estimation of emission, all GHG converted into CO_2e. CO_2e is a universal unit of measurement that allows the global warming potential of different GHGs to be compared (DEFRA, 2012).The mass of GHG emissions from the use (consumption) of fuel wood in CO_2e were calculated according to as follows.

Emission factor and GWP of GHG are obtained according IPCC, 2007 and The mass of GHG emissions GHG reduction in CO2e is calculated according to as follows:

$$E_a = \sum_{i=1}^{n} (C_i \times EF_{CO_2} \times GWP_{CO_2} + C_i \times EF_{CH_4} \times GWP_{CH_4} + C_i \times EF_{N_2O} \times GWP_{N_2O}$$

$$= \sum_{i=1}^{n} \left(C_i \left(EF_{CO_2} + 25 \times EF_{CH_4} + 298 \times EF_{N_2O} \right) \right)$$

Where E_a= GHG emissions reduction in kg from the combustion of fuel type 'a'; n= total number of sample households; Ci= amount of fuel saved by a sample adopter households 'i'; EF CO_2 = CO_2 emission factor for fuel type 'a'; EF CH_4 =CH_4 emission factor for fuel type 'a'; EF N_2O =N_2O emission factor for fuel type 'a'; GWP=Global warming potential for the GHG indicated.

Table 6: Emission factor value for greenhouse gases

Fuel type	CO2 (kg/kg)	CH_4 (kg/kg)	N2O(kg/kg)
Wood and Wood Residuals	1.64(1,640 kg/t)	126×10^{-6} (126 kg/t)	63×10^{-6} (63 kg/t)

Source: IPCC, (2007)

Table 7: Global warming potential of greenhouse gases

Gas	GWP in 100 years
CO2	1
CH4	25
N2O	298

Source: IPCC, (2007)

3.8.4 Determination of the total forest area saved

Forest area saved can be obtained from amount of fuel wood saved and calculate as follows. Small sized eucalyptus tree, which is planted for construction and fuelwood purpose, has average height and diameter of 18 m (50.055 ft) and 12cm (4.7244 inch) respectively (Fantu et al., 2005). According to Scott et al. (2005), the total biomass of the tree can be calculated by using the equation below that could be considered as an average of all species.

For trees with $D < 11$ inches, the following equation is applied to calculate number of tree saved.

$W_{\text{of one eucalyptus tree}} = 0.25 \times D^2 \times H$………………………………………………………… (8)

To determine the dry weight of the tree, multiply the weight of the tree by 72.5 %.

$DW = W \times 72.5\ \%$..(9) (Scott et al., 2005).

Where: W = Above-ground weight of the tree in kilogram, D = Diameter of the trunk at breast height in centimeter, H = Height of the tree in meter, DW= Dry weight of the tree in kilogram.

According to Oballa, P.O et al. (2010), Eucalyptus tree seedlings are planted within2m×2m spacing so that it has 2500 tree seedlings per hectare for fuelwood purpose and out of this 70% will become mature trees.

3.8.5 Determination of the weight of CO_2 sequestered in the saved tree per year

Carbon sequestration is the process of capture and long-term storage of atmospheric carbon dioxide to mitigate global warming and to avoid dangerous impacts of climate change. In other words, it also refers to the process of removing carbon from the atmosphere and depositing it in a reservoir (Dhanwantri et al., 2004). This process works as tree take carbon from atmosphere, utilize it in the process of photosynthesis, as well as they store it in the form of biomass or wood.

This is to say, activities that increase photosynthesis and/or decreases respiration is regarded of great advantage in the global carbon reduction (Toochi, 2018). CO_2 sequestered in the saved tree by biogas per year can be calculated according to Myers and Goreau, that tropical tree plantations of pine and eucalyptus can sequester an average of 10 tons of carbon per hectare per year.

To determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

4. RESULTS AND DISCUSSION

4.1 Socio-economic and Demographic Characteristics of Respondents and Econometric model results

Before applying binary logistic regression model multicollinearity test was conducted to check whether a linear relationship among explanatory variables.

According to Gaur (2009) a value of variance inflation factor (VIF) greater than five reveals the existence of multicollinearity. However, the maximum VIF value for this study was 1.57 and no serious problem was found (see appendix 4)

For dummy variables, if the value of contingency coefficient is greater than 0.75, it is an indication of the existence of the multicollinearity among the variables, however, the maximum VIF value for this study was 0.718 and no serious problem was found(appendix 2).

4.1.1 Household Characteristics Predicting Biogas Technology Adoption

A Binary logistic regression analysis was conducted to predict adoption of the biogas technology and to validate the above noted observations. The variables used in parameter were sex of household (GENDER), age of household (AGE), educational status of household (EDUSTAT), household size (HHSIZE), average annual income of household (INCOME), number of cattle owned by household (No cattle), land size of house hold (LANDSIZE), time taken to bring fuelwood to resident (FLWODIST), awareness of household on biogas (AWARNESS) and time taken to fetch water and bring to residents (DSTWATSR) were fitted in the model as a predictors. The findings were used to test the hypothesis of the study which stated that household socio-economic factors significantly influence rapid adoption of biogas technology. The findings supported this hypothesis and established that these social-economic factors significantly influenced adoption of biogas technology.

Below is a discussion on how these factors influenced adoption of biogas. The complete model comprising the full number of predictors was found to be statistically significant, where χ^2 (df =10) =112.155 and p<0.001. Indicating that the predictors set as reliably distinguished between adopters and non-adopters of the technology (Table 7). In other words, the estimated values fitted the observed data reasonably well. Measures of goodness of fit of the model results indicated that the independent variables were simultaneously related to the log odds of adoption.

The model correctly predicted 69.2 %of the biogas adopters, 92.5% of the non-adopters, and 86.4% % of the overall sample households.

The Cox and Snell R-squared and Nagelkerke R-squared values, which merely mimic the R-squared value in linear regression (Pallant, 2011) were 43.1% and 63.1%, respectively. Therefore, Nagelkerke R-squared value 63.1% is fairly adequate in supporting the quality of the model. Among the ten independent variables included in the model, six variables were in the main effects and statistically significant at ($p<0.05$).

Age of household (AGE), Educational status of household and Number of cattle owned by household (No_cattle) were found to be significant ($p<0.01$) on adoption; Sex of house hold (GENDER), Household size (HHSIZE) and Income of household (INCOME) were found to be significant at ($0.01<p\leq0.05$). Land size of house hold (LANDSIZE), Time taken to take fuelwood to home (FLWODIST), Awareness of household to biogas (AWARNESS) and Time taken to take water to home (DSTWATSR) were insignificant ($p>0.1$)factor. This revealed that considerations of socio-economic characteristics of the households is essential in promoting and dissemination of biogas technology. This finding gives the direction what someone consider the cause of low adoption of the new technology, thus in promotion of new technology the socio-economic characteristics of the community should be considered.

Table 8: Binomial Logistic Regression Estimates of Biogas Adoption Model in Shebedino district

Factors likely to influence biogas technology adoption.

Variables	B	Std. Err.	Wald	P>z	Odds Ratio
GENDER	1.610792	.7578613	4.518	0.034**	14.04012
AGE	.0738527	.0280347	6.940	0.008***	1.076543
EDUSTAT	.3531918	.1033078	11.688	0.001***	1.423749
HHSIZE	.4674585	.206599	5.120	0.024**	1.550853
INCOME	.0000723	.0000339	4.552	0.033**	1.000066
NO_CATTLE	.7399393	.1978615	13.985	0.000***	2.0849
LANDSIZE	.0061716	.6132551	.000	0.992	1.003238
FLWODIST	-.0142822	.0265208	.290	0.590	.9840299
AWARNESS	1.112967	.7826991	2.022	0.155	3.54005
DSTWATSR	-.0538707	.033936	2.520	0.112	.9486699
_cons	-12.53497	2.185911	32.884	0.000	1.60e-06

****, **, and * significant at $p<0.01$, $0.01<p\leq0.05$, and at $0.05<p\leq0.1$, respectfully. -2 Log likelihood =116.464,* χ^2(df=10) =112.155, *Pseudo R-Squareds (Cox and Snell R2=43.1% and Nagelkerke R2 =63.1%), Percentage of correctly predicted biogas adopters=69.2;*

Percentage of correctly predicted non- adopters =92.5; and Overall percentage of correctly predicted sample households=86.4.

Source: Own computation from field survey results.

4.1.1.1 Gender

The respondent's gender was essential for the researcher to understand how different people adopt biogas technology based on their sex. This was analyzed and the findings were presented in figure 4 below. From figure 6, about 49(94.23 %) of adopters household were male headed and 3(5.77 %) were female headed, while 99(67.35%) and 48(32.65 %) of non-adopters were male and female respectively. The chi square test showed significant (χ^2 =14.57, P= 0.000) at 1 % significant level shown in appendix 11. Gender can therefore be argued to have relationship with biogas adoption.

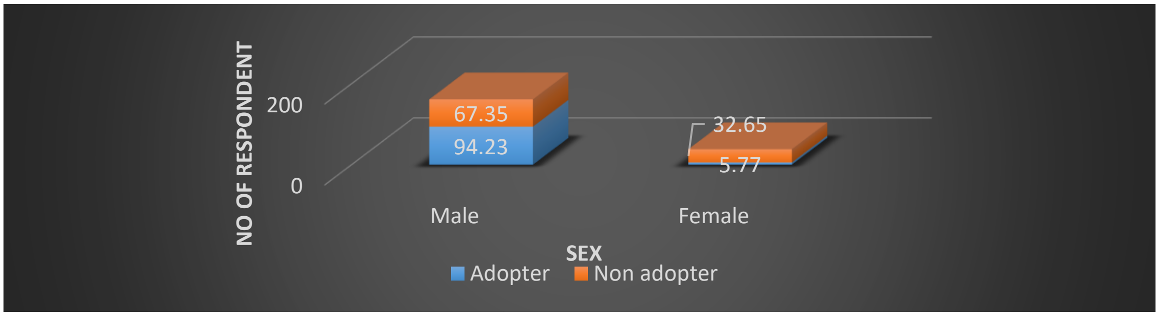


Figure 6: Gender of adopter and non-adopter households

From binary logistic regression model result, it was found that gender of the household head had positive sign towards adoption and a statistically significant ($0.01<p\leq0.05$) relation with the households' decision on adoption of biogas technology (see table 9 in above). Male headed households appeared to have higher probability of adopting biogas technology than the female-headed households. Accordingly, odds ratio of Gender (14.04012), Male -headed households were high to adopt biogas technology by a factor of 14.04 as compared to the female-counterpart. This finding related to simple comparisons and observations, evidence consistently suggests that energy-saving technologies can have huge potential to reduce considerable time burden of women and increase labor productivity in general.

Empirical studies show that biogas use and adoption among rural women has rarely been high and usually much lower than men (Pender and Gebremedhin 2006; Horrell and Krishnan 2007; Oladele and Monkhei 2008; Babatunde et al., 2008; Carr and Hartl 2010.From the findings, it is clear that more men adopted the biogas technology than female. Similarly the study found that sex of household heads influence the adoption of biogas technology (Mengistu,, 2016). The results are also consistent with results by Njenga (2013) and Kabir et al., (2013) who found out that male headed household adopted the technology since they own resources and they control decision making in the household. Therefore this study found that gender influenced adoption of biogas technology. The implication of these results in regard to biogas adoption is that, if women headed household are empowered to make decisions and control resources it may be easy for them to adopt biogas. In cases where female was heading a household and she was empowered financially she could make a decision.

4.1.1.2 Age

The sampled respondents were asked to indicate their ages in order to help the researcher to understand how different age segments of the population perceived investing in biogas technology, and the responses were summarized in table 6 below. The age of the sample household heads of adopter ranged from 38 to 71 years old with an average of 49.27 years, while age of non-adopter household heads ranged from 29 to 66 years with average of 43.25 years. The independent sample t-test on age of household indicated that significant t-value at 1% ($P<0.000$) significant level (see in table 9 below). Therefore this indicated that significant mean differences between the ages of sample biogas adopter and non-adopter households.

In addition to this binary logistic regression result of this study found out that, age of households' head had a significant ($p<0.01$) positive relationship with biogas technology adoption (from table 8 in above).

The probability of households adopting the biogas was higher in household heads were middle aged to elderly, compared to those headed by youths. The probability of adoption of biogas technology increases by a factor of 1.08, as the household head's age increases by one more year. This result tally with the finding by Sufdaret al., (2013), reported that the probability of adopting biogas increased with increasing age, because older people have resources for construction of biogas plants in terms of finances and land ownership. Focus group discussion indicated that further the young people were put off by the process of mixing dung with water which they felt is dirty and time consuming. The findings are similar with those of Wawa (2012) who revealed that the young people disliked holding cow-dung because they feel uncomfortable and fear that they might contract skin infection. The adoption of biogas technology projects by older households in Shebedino district seems to be propelled by experience of elderly people about usage of various sources of energy. This result showed that as a number of the year of household increase the probability of adopting biogas technology also increased. Finally therefore, this study found that age affects adoption of biogas technology. Similarly Somda et al., (2002), Rubas (2004), found that age influence the adoption of biogas technology. The implication of these results is that, if the biogas technology with dung mixer and low cost are designed and promoted, the youths are able to decide and to adopt it.

4.1.1.3 Educational status of household head

Education is number of years that household arrived at school. It increases understanding deciding, accepting or rejecting, interpreting and perceiving ability of some ones to new sort of information.

An analysis of extent to which level of education influences adoption of biogas technology was done. The respondents were asked to indicate their level of education and whether or not they possessed biogas technology projects in their homesteads. The educational levels of the sample biogas adopter and non-adopter household heads varied from Illiterate (who are not able to read and write) to literate (who are able to read and write). The educational level of both adopters and non-adopters ranged from 0 to 13 years in school, but the mean school year of adopters and non-adopters is 4.4 and 2.5 educational year respectively. The independent sample t-test on education level of household indicated that significant t-value at 1% (P<0.000) significant level (see in table 9 below).

Therefore this indicated that significant mean differences between the education level of sample biogas adopter and non-adopter households.

Educational level was among the factors that was contributed to the adoption of biogas technology. Education level of the household head had a significant positive relationship with adoption of biogas technology at (p<0.01), from table 8 above. The probability of adopting biogas technology increases by a factor of 1.42 as s the household head's educational level increases by one more year of schooling. The results agrees very well with adoption studies by Kebede et al., 1990; Brush and Taylor, 1992; Adesina and Baidou Forson, 1995, Mengistu ,M.G,2016 and Fleke and Zegeye 2006; which all revealed a positive correlation between education and probability of adopting new technology. Mwakaje (2008), attributed to the fact that perhaps low literacy levels would hinder information absorption needed for substantive decision making on new technologies. Song (2012) showed that highly educated workers tend to adopt new technologies faster than those with less education. Low levels of literacy are associated with difficult in flow and comprehension of information which is likely to affect adoption of biogas (Uaiene et al., 2009).

In general, from this it was found that, majority of households in the study area were less educated, such that dissemination of the biogas would not be fast and many households couldn't be adopted it. Finally educational status influenced the adoption of biogas technology in Shebedino. The result showed that more educated households have the greater probability of adopting biogas technology. The result implied that for households to adopt biogas, individuals should be encouraged to attain higher level of education by staying in school longer than that they currently do. In addition, to establish biogas technology as a viable and long lasting option, it is quite essential to make (find) viable way to promote biogas for less educated households with in equal manner to more educated households.

4.1.1.4 Household size

The household sizes is the number of people consisted in one house. Household peoples are converted into standard adult equivalents (appendix 11) for both adopter and non-adopter of sample households, thus, the household sizes of the sample households ranged from 2.3 to 10, with average household size of adopter 5.41 and 4.8 for non-adopter, (see table 6 below). This average is much higher than the national level which is 4.7 persons (IPCC, 2008).The independent sample t-test on household size indicated that statistically significant mean differences between household size of the sample biogas adopters and non-adopters at 1%($P<0.004$) significance level (table 9).

From binary logistic regression result, household size had a significant positive relationship with adoption of biogas technology at ($0.01<p\leq0.05$) significant level, (from table 8 above). The probability of adopting biogas technology increases by a factor of 1.55 as the household size increases by one. Increased number of households size increase adoption of biogas technology. The results are in agreement with the study in China which indicated that, biogas adoption was facing challenges due lack of labor as a result of rapid urbanization (Zuzhang, 2014).

An excess labor in families were positively correlated with household's willingness to adopt biogas (Wang et al., 2011). Household labor is an important factor in adoption of biogas plants. Household's size had implication on labor provision since biogas requires regular feeding and collection of dung, however, presence of sufficient households' labor power, which is denoted by the household size, is vital for both biogas digester construction process and post-construction management activities. After the completion of the construction, household-labor is also required for feeding the biogas digester daily as well as taking care of the cattle (livestock) to ensure sustained digester feeding.

The biogas plants require collection of cow dung, bringing water, mixing the dung with a water, feeding the plant, cleaning the cow shed and transporting the slurry to the farm (Wawa, 2012). Without enough people in the family to carry out all of the above activities it is difficult for biogas plants to run efficiently. This study therefore found that households' size influences the adoption of biogas technology. Increased number of households size increase the probability of adopting biogas technology. This result is similar with the research findings of Waleahwa et al. 2009, who indicated that households size and biogas adoption have a significantly positive interrelationship with each other.

4.1.1.5 Cattle size (in TLU)

Cattle dung is the primary input for biogas digesters in Ethiopia. Consequently, the National Biogas Program of Ethiopia (NBPE) has targeted households with a minimum of four heads of cattle. Four heads of cattle are supposed to produce a minimum of 20 kg dung daily input needed to feed the minimum size biogas digester of the program (EREDPC and SNV, 2008).

The sample households possessed various livestock types: cattle, sheep, goats, donkeys, horses, Mules, pigs, chicken, and bee hives, but for this study only Cows, ox and Calves were used.

This is because cattle is used as first pre condition for construction of the biogas technology in the study area. Then the types of cattle owned by the sample households were converted into Tropical Livestock Unit (TLU, appendix3) to compare cattle holding size between adopter and non-adopter households.

An average cattle size for adopters and non-adopter households was 4.3 and 2.44 respectively (shown in table 9 below). Then t-test result indicated that significant mean difference between Cattle size of adopter and non-adopter at 1 %($P<0.000$) significance level (see table 9 below).

Binary logistic regression model result however, showed that heads of cattle was found to be a significant factor that positively affected adoption of biogas technology at ($p<0.01$) significant level. For each additional unit of cow or cow equivalent, the likelihood of adopting biogas technology increases by a factor of 2.08, (from table 8 above).

The results in Table 6, above reveal that the mean cattle size of the respondents who had adopted biogas owned was 4.2, that almost all adopter had more than four cattle. The result is consistent with the findings of Walekhwa et al. (2009) and Kabir et al. (2013), in which cattle size was reported to have a significant positive association with that of adoption of biogas technology. Similar to this Iqbal et al. (2013), reported that an increase in number of cattle increased the probability of a households adopting biogas technology since they would provide sufficient cow dung. However owning cattle may not in itself make one adopt biogas technology. As observed in the field during the study, there were non-adopter household who owned more than five cattle but, they do not adopted a biogas plant. The surveyed households have the minimum number of cattle required to feed the optimum sized biogas 6 m3. Thus, households with a lesser number of cattle may not have sufficient cattle dung required for feeding the biogas digester on daily basis.

Therefore cattle size influences the adoption of biogas technology. Increased number of cattle size increase the probability of adopting biogas technology. The finding is similar with the finding of Walekhwa et al. (2009) and Kabir et al. (2013), found that cattle size is factor influencing the adoption of biogas technology.

4.1.1.6 Households Income Levels and adoption of biogas

Households in the study area depended on a range of activities to earn their living, but the major economic activity was agriculture, basically dairy and crop production. In addition to farming some households were employed in either formal or informal sectors or engaged in business of some kind.

Income is the total amount of Ethiopian birr (ETB), which household earned per year. In this study it was found that, adopter households earned income ranged from 4500 birr to 78000 birr, while non-adopter earned up to 1300 to 37000 birr with average annual income 17546.15 and 9013.605 birr for both adopter and non-adopter households respectively. About 77.5% of non-adopter household earned below 10,000 ETB, while only 40.4% adopter household earned that amount. In addition to this 30.8% of adopter earned 10000-20000 ETB, while 16.3 % of non-adopter household earned that, (see figure 7). The independent sample t-test indicated that, the significant mean differences between the income of the sample biogas adopter and non-adopter households at 1 %($P<0.000$) significance level, shown in table 9 below.

The study sought to determine whether household's income levels influence investment on biogas technology. The respondents were requested to indicate the sources of their income as well as the range on their annual income. Then from binary logistic regression result, it was found that a statistically significant positive association between the total annual income and adoption of biogas technology at ($0.01<p\leq0.05$), significant level (see table 8 above).

The analysis gave an odds ratio of 1.97. Thus, when the households' income increases by 1.0 ETB, the adoption of biogas technology increases by a factor of 1.97.So, biogas adoption increase with an increased income level of households. The findings correlate with findings by Sufdar et al., (2013), Walekhwa et al., (2009Gupta and Ravindranath (1996), who found that households with high income are more likely to adopt biogas technology as compared to households with low income. Household's income could be an indication of their ability to own a biogas plant. Those with high income are thought to have the ability to own a biogas plant unlike those with low income.

Given the high initial cost of construction of a 6m3 biogas plant which was estimated at ETB 13000- 2000 for fixed dome system according to. Those households that had adopted the technology were earning more than 14,000 ETB on average (SWWMEO, 2017). During focus group discussion it was established that most of the respondents were subsistence farmers and earned very little income.

It was therefore difficult for them to have adequate funds to invest in such projects such as biogas plants given that their income is barely enough to meet various basic needs for the family members. So this study found that income influences adoption of biogas technology. Similarly Arthur et al., (2011) and Walekhwa et al., (2009), found that household who had more average annual income have more probability of adopting biogas technology than that have less average annual income. Therefore improving the household income and arranging credit facilities can boost adoption of biogas technology.

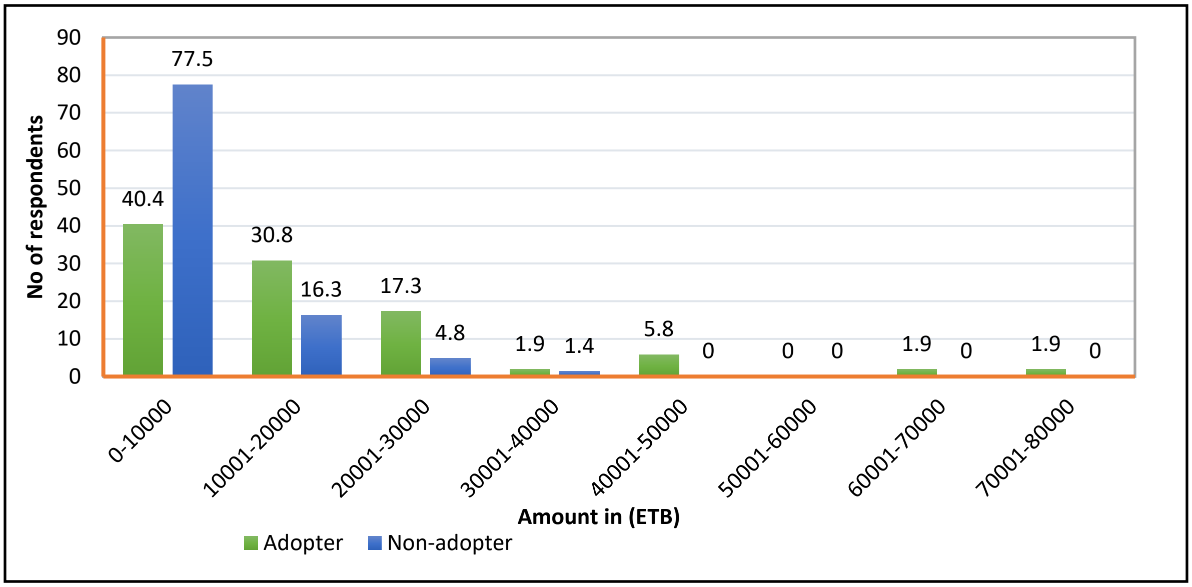


Figure 7: Income levels for adopter and non-adopter households.

Source: Own computation from field survey results.

4.1.1.7 Farm land size

In a country like Ethiopia where agriculture employs the vast majority of the population and land is an important economic resource for the development of rural livelihoods. The average farmland size of adopter and non-adopter sample population was 1.218 hectare and 0.881hectare, respectively, in which non-adopter sample population result is almost similar with the national level land use survey, which shows that the average household farm size in Ethiopia is 1.22 hectares,(CSA, 2012a). From table 6 below, the t-test result indicated, significant mean differences between the land size of the sample biogas adopter and non-adopter households at 1% ($P<0.0040$) significance level(shown in table 9 below).

From binary logistic regression result, land size couldn't affect adoption of biogas. The results were contradict to those of Gulbrandsen (2011), Brush and Taylor, (1992), who posits that more households with larger sizes of land had adopted the technology as opposed to households with smaller sizes of land in Tanzania.

4.1.1.8 Fuel wood distance (in minute)

The opportunity cost of gathering fuelwood increases with the increasing distance of its source away from resident (Heltberg et al., 2000; Guta, 2014). As the scarcity of fuelwood worsens, households have to collect fuelwood from further sources and utilize more and more proportion of dung and crop residues (Teketay, 2001). The study found that the maximum time that households had taken to collect fuel wood was 45 minute. The average minute that adopter and non-adopter had taken to collect fuel wood was 21.13 and 19.80 minutes respectively (shown in table 9 below). This finding differ with the finding of Jebesa, 2017 that, on average households traveled 0.5hr, with minimum and maximum 0.1hr and 2hr to collect firewood. In an increase a distance to fuelwood, the probability of adopting biogas technology decreases. The independent sample t-test on fuel wood distance further indicated an almost fair distribution of wood distance between the households who had adopted biogas and not adopted, with insignificant level ($P<0.3497$); similarly binary logistic regression result showed that insignificant relationship of fuel wood distance with biogas adoption.

4.1.1.9 Distance to water source (in minute)

Distance to water source is the average distances from the residence to the source of water and the time taken to travel it. In table 6 below, t-test indicated that there were insignificant mean differences between distance to water of the sample biogas adopter and non-adopter households at 5% (P<0. 0.0317) significant level.

In increase a household distance from residence to water source, the probability of adopting biogas technology decreases; however binary logistic regression result showed that insignificant relationship of distance to water with biogas adoption.

The result contradict with the finding of Wawa, (2012) who reported that water availability was found to have an inverse relationship with adoption of biogas technology.

Table 9: Distribution of respondents by HH characteristics

	Adopter		Non-adopter		t-value	Pr(|T |>|t |)
	Mean	Std. Dev.	Mean	Std. Dev.		
Age	49.26923	9.305523	43.2517	8.413007	-4.3101	0.00***
Educational stat (yrs)	4.423077	3.637205	2.489796	1.874001	-4.8804	0.00***
Household size	5.415385	1.05466	4.773469	1.125746	-3.5913	0.00***
Income in ETB	17546.15	14867.58	9013.605	6301.485	-5.6809	0.00***
No of cattle (TLU)	4.293269	1.379117	2.926382	1.747775	-7.3988	0.00***
Land size (Hectare)	1.218269	0 .481727	0.881972	0.3904662	-5.0101	0.00***
Wood Dstnce (min)	21.13462	8.312591	19.80272	8.973049	-0.9373	0.3497
Distance water(min)	15.23	3.281	18.4898	10.6664	2.1642	0.03**

***and ** shows significant variation at 1% and 5% significance level respectively.

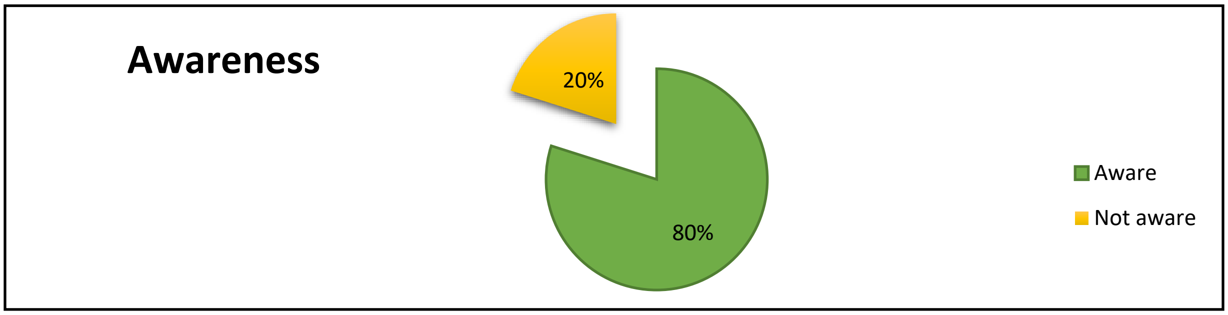
Source: Own computation from field survey results.

4.1.1.10 Households level of awareness

The data collection tool was designed to ask if the respondents have heard about biogas technology. The diffusion of knowledge, ideas and innovations is a significant departure towards regional socio-economic growth and development. As the result, 80% have heard (aware) of the technology, 20% have never heard (not aware) of the technology (see figure 8 below).

From this statistics, it implied that efforts by the various stakeholders to sensitize people about this technology through various channels has been done satisfactorily, but the question remains, why the low technology uptake?

Awareness can therefore have significant chi square at 1 %(χ^2 =9.0024, P≤0.003) significant level shown in appendix 12. Therefore chi-square test result indicated that awareness relationship with adoption of biogas, however binary logistic regression result indicated insignificant relationship with biogas adoption. This finding contradict with the Wawa, (2012), which revealed that awareness on biogas technology had an inverse relationship with adoption, implying that people with low awareness adopted biogas technology.



Source: Own computation from field survey results.

Figure 8: level of awareness of household on biogas technology.

4.2 Biogas technology functional status in Shebedino district.

In this study, it was revealed that 40(76.92%) biogas plant was functional from the sampled biogas adopter households and the remaining 12(23.08%) were nonfunctional (see table10). The proportion (percentage) of non-functional biogas plant of this study is smaller than the finding of Wawa, A.I., (2012) in Kongwa and Bahi districts of Tanzania, which showed that about 47% of installed biogas plants in the study area were not functioning.

From field observation of this study it was found that, non-functionality were caused by different reasons, these were: households missing regular daily feeding, spending above one month during initial feeding, poor construction of whole biogas plant, poor construction of dome cast section, unfinished construction, leakage on gas pipe, missing of removing water from water drain, lack of spare part, lack of adequate technical service, leaving gas controller opened in non-using time, see figure 9 below.

Table 10: Functional status of biogas frequency distribution

Functional status of biogas	Frequency	Percent
Functional	40	20.1
Non Functional	12	6.0
No biogas	147	73.9
Total	199	100.0

Source: Own computation from questionnaire data

Fig: i) less or no daily feeding to biogas plant ii) Installation exposed to gas leakage iii) Broken glass lamp that are non-functional

iv) Unfinished construction v) Gas controller left open

Figure 9: i, ii, iii, iv, v Non-functionality causes of biogas plant.

4.3 Most commonly used tree species for domestic energy use

From this study it was found that most commonly used tree species by both adopter and non-adopters in study area was *Eucalyptus camaldulnsis* (bahr zaf in local name) for source of fuel wood , thus 56% of respondents used as fuelwood sources. This finding have conformity with a previous study that pointed out that many people in Ethiopia are absolutely dependent on the Eucalyptus as a source of fuelwood (Teketay, 2000). There were also other types of tree species used by sample households and it accounts small percent (see fig 10 below). Key informant interview from local authority representatives witnessed that, the major reason of households to prefer *Eucalyptus camaldulnsis* were its accessibility, availability and its fast-growing rates relative to other tree species in the area. From field observation it was found that the majority of tree species in the study area and on farm lands of households were *Eucalyptus camaldulnsis* any house had it on its own land. This result tally with Bekele et al, 2013, found that *Eucalyptus* is the dominant tree species planted in the homestead.

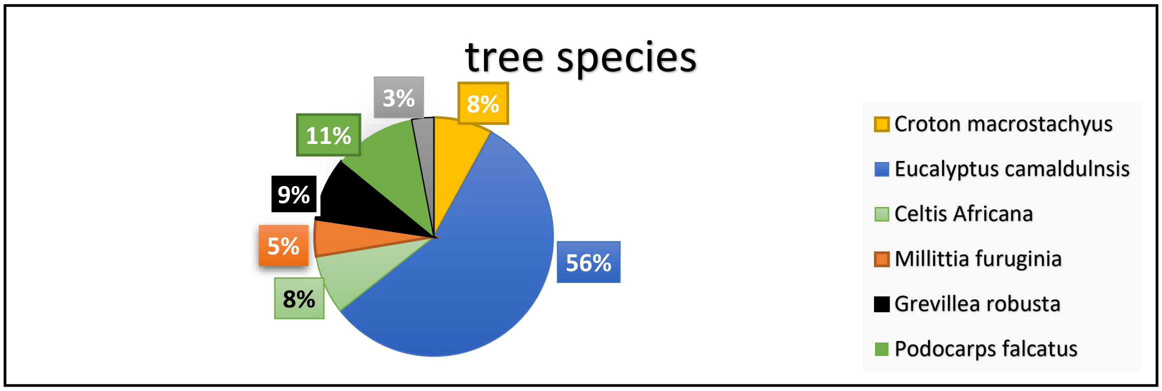


Figure 10: Most commonly used tree species for domestic energy use

Source: Own computation from field survey result.

4.4 Fuel wood collector

It was found that women's and daughters were more participated on fuel wood collection in both adopter and non- adopter house such that, 39(26.53%) of non-adopter household and 25(48.08%) adopter households, women's were participated in fuel wood collection, (shown in table 11). Daughters of household accounts the next percent of the result, thus 61 (41.50%) non-adopter and 11(21.15%) of adopter households daughter participated in fuel wood collection. This indicated that females are more participant of fuel wood collection. Generally, more adult females are involved in fuel collection than adult males .This is because females are more tasked with kitchen work than males. This finding tally with the finding of Singh, 2014, who found that women and girls are traditionally responsible for collecting fuelwood for domestic purposes in many parts of developing countries. Therefore adopting technology like biogas replace fuel wood would needed to minimize the work load of females and to save time of females which females spent to fuel wood collection.

Table 11: Fuelwood Collector in household

Fuelwood Collector in Household	Non-adopter		Adopter	
	Freq.	Percent	Freq.	Percent
Women	39	26.53	25	48.08
Men	11	7.48	7	13.46
Boys	36	24.49	9	17.31
Daughters	61	41.50	11	21.15
Total	147	100.00	52	100.00

Source: own computation from questionnaire data

4.5 Energy consumption pattern in Shebedino district for cooking and lighting

The questions were asked households in order to arrange the energy sources in the form: most important, important, and moderately important, less important and not used energy source. As a result 162 (81.4%) household responded that they used fuelwood as most important source of energy, while 33 (16.6%) used crop residue, 1(0.5%) dung cake and 1 (0.5%) electricity as most important source of energy for cooking. Among the various fuels considered, fire wood and crop residue turned out to be the prominent energy sources of households in the study area. This finding tally with the finding of Jebesa, 2017 that, among the various fuels considered fire wood and crop residue turned out to be the prominent energy sources of households in the study area. Even though in comparing crop residue and fuel wood consumption of households in the study area, majority of surveyed households consumed fuel wood for cooking. The findings conformed to government study in Ethiopia, which reported that fuel wood in Ethiopia constitutes 81.4% of energy consumption in the rural (EREDPC and MoARD, 2002).

Due to this preference/prevalence, deforestation, felling of trees and a low forest cover have become a growing and serious challenge to the district as well as in the country.

About 28(14.1%) of the adopter households responded that they used biogas as important source of energy, while 10 (5 %) of household used as moderately important and 2 (1%) as less important for cooking (see appendix 10). This statistics revealed that, low adoption of biogas technology with in Shebedino district, could be caused by an increase in terms of utilization forest products such as firewood.

91(45.7%) of households used kerosene, 44(22.1%) used solar, 20(10.1%) used biogas and the remaining household used other energy as most important source for lighting (see Appendix 13).This finding have some difference with the finding of Jebesa, 2017 that about 55% the respondents uses kerosene and the respondents' uses small size solar only about 20% for purpose of lighting. In this study, the amount of kerosene saved by use of biogas from lighting were not included, because of complexity of the process, and many biogases in the study area were not giving lighting function (only cooking function).This situation was caused by maintenance related problem; if the plants are maintained successfully its lighting function would be safe .Therefore, someone who are working on the biogas technology should check up the problem of non-functionality of biogas plant, and should order the way that plants to be maintained.

4.6 Cook stove type used in Shebedino district

In the consumption of fuel wood, the frequency of cook stoves used across the surveyed kebeles were checked. It was found that,68.8 % of households used open thee stone stove and 20.1 % used both open three stone stove and biogas stove, the remaining household used improved cook stove.(see figure 11).

Respondents pointed out that they used the all type of cooking stove, three or four times per a day for cooking. Three-stone cook stoves that are most preferred model stove of rural households for cooking. This stove is exposed to energy wastage and indoor air pollution.

Using open three stone results, in inefficient use of energy that exposed to energy wastage, health related problem, time wastage, extra fuelwood expenditure and more indoor air pollution. So investing on energy efficient technology and energy efficient cook stove to be essential way to eliminate the emerging energy wastage in a case of Shebedino district.

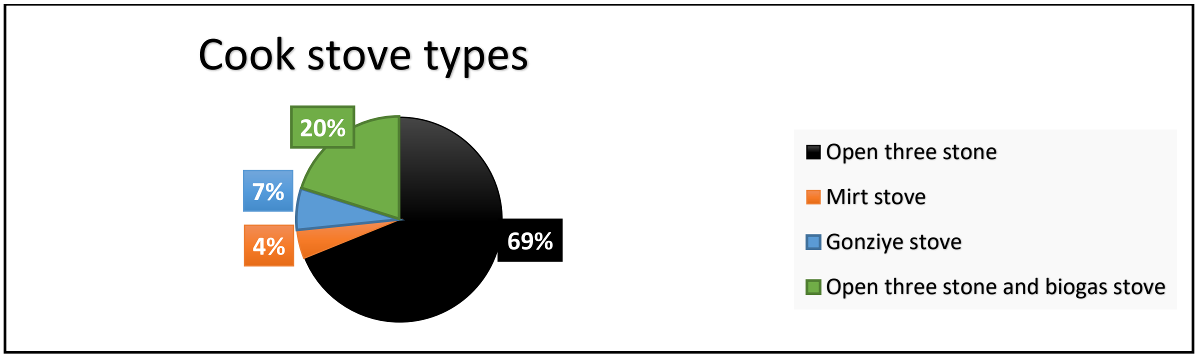


Figure 11: Cook stove type used by households in the Shebedino district

Source: Own computation from field survey result.

4.7 Roles of Biogas Technology in Fuelwood Saving, Emission Reduction and climate change mitigation

4.7.1 Households Biogas energy consumption pattern in Shebedino district

The sampled households were asked how often they use biogas per a day, and accordingly 61.54 % households responded that, they used biogas three times per a day (morning, afternoon and evening) .From the KPT, it was found that, about 34.71% firewood consumption per year was reduced in adopter households with acquisition and use of biogas.

This finding had almost some difference with a Study by Xiaohua et al. 2007, which showed that, biogas digesters used in different regions of rural China reduced the use of biomass fuel by 40% (Xiaohua et al., 2007). Adopter households in the study area used biogas especially for cooking wot, making coffee and tea. In the focus group discussion the group member reflected that they want to use the technology to different cooking purpose (making kocho and bread, and baking injera).

Table 12: Adopter household's number of cooking period by biogas per day

Number of cooking by biogas per day	Freq.	Percent
Once	2	3.85
Twice	1	1.92
3 Times	32	61.54
4 times	5	9.62
Not used	12	23.08
Total	52	100.00

Source: own computation from questionnaire data

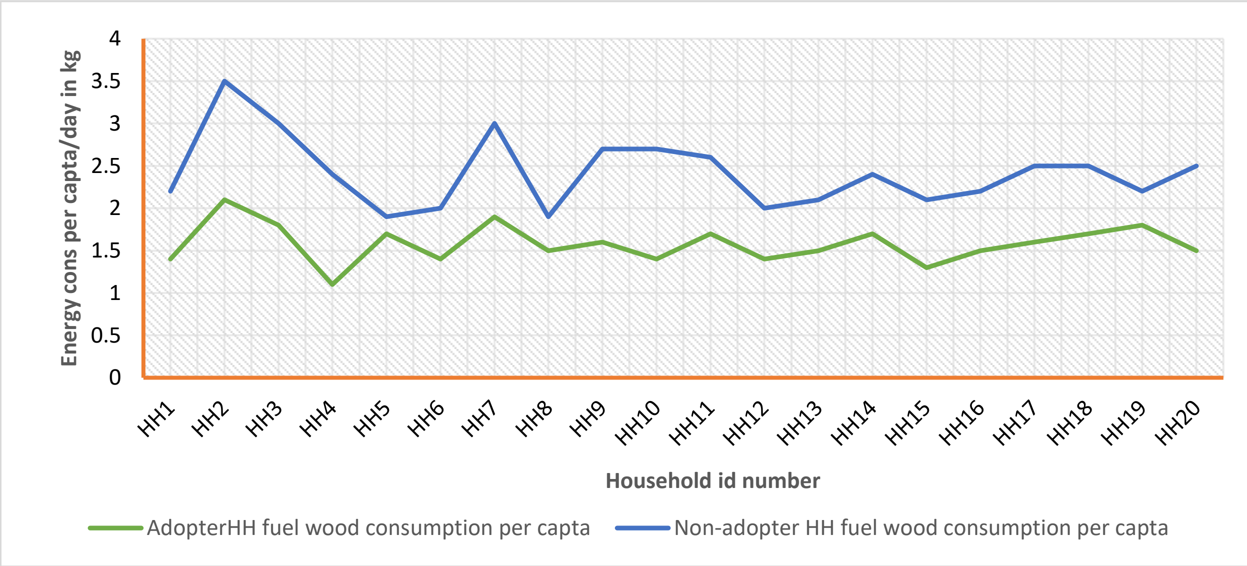
4.7.2 Comparison of fuelwood Consumption between biogas Adopter and Non-Adopter

Based on kitchen performance test (KPT) results, fuel wood consumption between adopter and non-adopter households were estimated and found to be different. The adopter household fuel wood consumption per capta/day ranges from 1.1 to 2.1 kg, while the non-adopter household fuel wood consumption per capta/day ranges from 1.9 to 3.5 kg (see appendix 14). The results are illustrated in fig 12 below. The y- axis indicate fuel wood consumption in per capta /day in kilogram while, x-axis indicates both adopter and non-adopter household and the coefficient 1, 2...20 indicates households number for both adopter and non-adopter households.

The figure showed that there are a fuel wood consumption difference between adopter and non-adopter households. Blue (graph of non-adopter HH) and green (graph of adopter HH) line of the graph, is increasing to the right with household id; indicating that both adopter and non-adopter households are continuing to depend on fuel wood consumption.

In contrast to this there are a gap/area between blue (graph of non-adopter HH) and green (graph of adopter HH) line of the graph, indicating that there are fuel wood consumption difference between adopter and non-adopter households even though both households depend on fuel woods. This shows that non adopter households are over depending on fuel woods than adopter households. The area between the green (graph of adopter HH) fuelwood consumption and blue (graph of non-adopter HH) fuelwood consumption in fig 12 below showed that, fuel wood saved per capta by adopter households.

This fuel wood consumption difference between adopter and non-adopter household cause's social and economic difference between adopter and non-adopter households.



Source: own computation from KPT

Figure 12: Fuel wood consumption in adopter and non-adopter households per capta.

4.7.3 Estimation of fuel wood saved by the use of biogas

The, adopter and non-adopter households per capta fuel wood consumption was 1.58 kg and 2.42 respectively (see appendix 11). The mean fuel wood saved per capta (kg/person) in this study was 0.84 kg/person per day and the average family size of sampled households was 4.94 adult equivalent.

An estimated average yearly fuelwood consumption for single non-adopter households/year was 4363.5 Kgs, while fuel wood consumption by single adopter households/year was 2848.9 kg. From this 1514.6 kg fuel wood is saved by adopter households per year.

Almost Similarly Wamuyu, 2014, found that approximately, 1519.2 Kgs of wood fuel and 1147.2 Kgs of charcoal were saved annually by those households using biogas. In the Shebedino, there are 63 functional biogas plants and an estimated amount of fuelwood saved from these 63 biogas plant was 95419.8 kg/year (See appendix 5).

Therefore household who owned biogas technology could save more fuel wood compared to non-adopter households, thus increasing dissemination of biogas in the district reduces fuel wood consumption and overcomes energy crisis. So the result of this finding showed that biogas play key role in saving fuel wood.

4.7.4 Estimation of GHG emission reduction through biogas

Over dependence on fuel wood consumption is being one of the leading causes of deforestation, and increased emission of CO_2 in to atmosphere. Biogas technology has the potential to remarkably conserving forests.

In this study, net amount of an estimated GHGs emission reduction per biogas plant/day was found to be 6.896 kg CO_2 e. This was estimated for yearly GHG emission reduction and gives 2.517 tons CO_2 eqv per biogas plant/year.

The finding was much more less than the findings of BSP (2012), Winrock Eco Securities (2004), and Shrestha et al. (2003). BSP (2012), estimated that, GHGs emission reduction was 3 tons per plant annually, while Shrestha et al. (2003) found that biogas plants of sizes 6 m^3 mitigated about 4 tons of carbon dioxide per plant annually.

From 63 functional biogas in Shebedino it was estimated that, 144.9 tons CO_2 e saved in total. Based on these emission reduction habit, a household mitigated approximately 2.517 tons of CO_2e or 63 households mitigated (reduced) 158.58 tons CO_2e, being released into the atmosphere (See appendix 6).

Reduction in CO_2 emission directly helps to minimize global warming which result in climate change mitigation and has positive impacts, higher at global level rather than at local level. Therefore the result of this finding indicated that, biogas technology has the potential to remarkably reduce emissions by reducing fuelwood consumption. This plays a role in minimizing average global temperature and mitigated climate changes.

4.7.5 Estimation of forest area Conserved

Conservation of forest is a financially viable technique to reduce emission from atmosphere. It could also bring significant benefits to the local communities involved, and consequently helps in reducing poverty at the same time. After installation of biogas plant, there was 34.71% reduction in fuel wood consumption but, Still 62.29 % of fuelwood is being used by the biogas users because of sufficient availability of fuelwood in the area.

From the result of this study, number of trees saved per biogas plant/year was estimated to be 17 trees. This finding is greater than the finding of BSP in small extent, BSP in Nepal estimated that a single biogas plant can save 11.6 trees per year.

From this study total forest area saved from 63 functional biogas energy consumption in shebedino was, 1071 tree and this is equivalent to 0.612 hectare forest cover (see appendix 7). This finding have difference with the finding of Winrock and Eco-Securities , thus, the forest area saved due to the reduction of fuelwood consumption was estimated to be 0.063 hectare .

The result of this study indicated that biogas technology has the potential to remarkably conserving forests. After the forest resources are conserved, water resources will be available, clean air to breathe will be safe and income can be generated by selling the forest products. It may also help to increase the adaptive capacity of local people and help in climate change mitigation.

Therefore switching to biogas is often assumed to automatically result in reduced deforestation (reduce the pressure on deforestation). If the dissemination of biogas technology increased in Shebedino district more conservation of forest area achieved.

4.7.6 Estimation of the weight of CO2 sequestered by forest.

In the trees which were saved by the use of biogas, there are carbon pool stored in it. The process of carbon sequestration to be succeed, it is essential that carbon must not return to the atmosphere from burning. Trees have an ability of trapping CO2 from the atmosphere and converting into useful forms of biomass through the process of photosynthesis. From this study it was estimated that 21 kg CO_2 e sequestered per tree/year. One biogas plants saved 17 trees and this sequester 357 kg CO_2 e. Finally 1040 tree were saved from 63 functional biogas pants in Shebedino, and that in total 21.8 tons C_2O e would be sequestered per year, (see appendix 8). This finding have some difference with the studies cited in Science Daily, that natural African tropical forests absorb about 600 kg carbon (2199.6 kg C_2O e) of per hectare per year thus, 25 kg carbon (91.65 kg C2O e) of sequestered per tree per year. Sequestration could play an important role in reducing anthropogenic greenhouse gas from the atmosphere, and minimize global warming, which results in climate change mitigation. Therefore, conservation of existing forest sequestered and store GHG, this resulted in mitigation on climate change.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Energy is central or a back bone of all economic, social and industrial development. Access to sustainable and reliable energy like renewable energy is very critical in the economic development, environment protection, health improvement and empowering women and the youth of a nation. Energy scarcity is arguably one of the challenges that the world faces today in the quest for better livelihoods. Worldwide there have been efforts to develop alternative energy supplies from renewable sources such as solar tidal waves, geothermal, wind and biogas. Biogas forms a viable source of alternative energy for the rural households. The rural households use the technology especially for cooking, lighting and bi-product as fertilizer. It offers an attractive option to replace unsustainable utilization of wood and Charcoal. Majority of Shebedino district households had awareness on a biogas technologies and knows its benefits, however, the adoption level of the technology in the district was quite low. Many factors were found to be responsible for this low adoption levels. The factors influencing the biogas technology adoption in the study area were combination of the independent variables like: gender, educational status, age, household size, average annual income, cattle size. Even though, some households were adopted and using energy from it. Most of adopter and non-adopter households in Shebedino district have believed that biogas is an alternative domestic and efficient energy source to alleviate fuelwood scarcity; improves women's health, save fuelwood expenditure and save the time which women spent to collect fuelwood and prepare food. In the district biogas is applicable especially for cooking, lighting and to use bi product as fertilizer, so that, adopter households in the study area consumes less fuelwood than non-adopter households of equal family size. In the reduced consumption of fuelwood, there are reduced in GHG emission in to atmosphere. In addition to this less consumption of fuel wood increase number of trees saved and this resulted in increase in the forest area covered by trees. Then the saved forest area sequester carbon di oxide from atmosphere and converted it into useful forms of energy (into biomass). Thus, forest is viable technique to reduce emission from atmosphere. Therefore forests can be an essential component when designing well-balanced, which contribute adaptation and mitigation strategies against climate change. This process further plays a considerable role climate change mitigation through reducing GHG emission in to/from atmosphere and minimizing average global temperatures that resulted in less global warming. The results of these all processes shows that using energy from biogas reduces fuel wood consumption, reduce GHG emission into atmosphere, reduce indoor air pollution, save woman's work time, conserve the forest and creates the way to manage the waste . This led to conservation of forest and climate change mitigation. In general biogas plays an important role on conservation of forest and climate change mitigation. Therefore, switching of the household's energy consumption pattern in to alternative energy sources like biogas would be acritical issue of the study area in order to overcome emerging energy crisis, to conserve forest and to protect environment.

5.2 Recommendations

1. Upgrading the existing model of biogas technology to include different stove type which used to multi cooking purpose; this is supposed to reinforce adoption of biogas technology.
2. In addition to this, introducing and promoting less costly and with low capacity technologies such as the Plastic tubular design to encourage farmers who cannot afford and who have less livestock to install biogas.
3. Creating enterprise group in near to household's resident area, who provide spare parts of biogas technology.
4. To make biogas technology acceptable and adopted in young households, the biogas with dung mixer should be promoted and disseminated. In addition to this material like hand glove should be supported from biogas dissemination organization (program).
5. To disseminate the biogas without gender difference, shifting technology promotion to strategy that works by giving affirmative action for households headed by female; like: more subsidized in construction cost and more guidance from installation to functioning

5.3 Areas for Further Research

1. Studying the roles of biogas technology on improving soil fertility by using fertilizer only from biogas bi product.
2. Studies are also needed to investigate cattle feed regimes influences on methane yield, as well as how jumping of daily feeding of biogas affect functionality rates of biogas plant.

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APPENDICES

Appendix 1: Household Survey Questionnaire

I am student at Hawassa University Wondogenet College of Forestry and Natural resource. As a part of my study program, I am undertaking a study to Roles of biogas technology on conservation of forest and climate change mitigation.

Dear Respondents:

The main purpose of this interview questionnaire is to acquire information relevant for a research entitled "Roles of biogas technology on conservation of forest and climate change mitigation".The research outcome is expected to be helpful for the improvement of biogas dissemination program and other energy and environment related interventions. Therefore, your genuine answer to the interview questionnaire is a necessary condition for the reliability of this research outputs. The information is meant only for academic purpose. The responses you give will not have a negative impact on anybody. I honestly assure you that, your personal information will be kept confidentially. Hence, just feel free to provide the correct answer.

I am very much grateful to the favorable contribution of your time and energy tothe success of this study.

N.B:

- ✓ For some tabular questions, please put tick mark (□) where needed.
- ✓ For questions that request ranking, please write the ranks1, 2, 3, in the boxes only for choices applicable to your case by giving value 1 for the best choice, 2 for the 2nd best, etc.

Name of interviewer: __________ *Name of respondent*__________*Kebele* ________ *Date:* _________

Section one: Socio-economic and demographic characteristics of households

1) Sex of household head a) Male☐ b) Female ☐

2) Age of household head a) Below 25☐ b) 25-35☐ c) 36-45☐ d) 46-55☐ e) above 55☐

4) Marital status a) Married☐ b) Single ☐ c) Divorced☐ d) Widow☐

3) Educational Status of household head a) Can't read and write ☐ b) Primary☐

c) Secondary☐ d) Tertiary (Certificate, Diploma, and Degree) ☐

5) Size of household a) 1-4☐ b) 5-8☐ c) Above 8☐

6) Occupation of household head

a) Farmer☐ c) Civil servant☐ b) Business☐ d) Other-specify…………

7) Average annual income in birr (Ksh)

a) Less than 5,000 ☐ b) 5,000-15,000 ☐ c) 15,001-25,000 ☐ d) Above 25,000 ☐

8) Number of cattle owned

Fill the table below (indicate by using number 1, 2, 3, 4…).

Types of livestock	Number Kept	TLu
Calf		
Heifer		
Bull		
Ox		
Cow		
Total		

9) Land size in hectare--------------------------------------

Section two: Domestic energy sources

11) On average, how many minutes takes to reach the place where you collect fuelwood in minute? ------------------

13) Who is mostly participating in fuelwood collection in your family?

a) Women ☐ b) Men ☐ c) Boys ☐ d) Daughters ☐

Section three: Households' awareness and attitude on biogas technology

14) Do you have awareness about biogas technology? A. Yes ☐ B. No ☐

15). If your answer for Q16 is yes, who initiated the idea about biogas?

a) Energy experts of the district ☐ b) Neighbors/relatives/friends ☐ c) Radio ☐

d) Television ☐ e) NGOs ☐ f) Biogas researcher ☐ g) other, specify ------------------

Section four: Utilization and Adoption of Biogas

16) Do you have biogas plant? a. Yes ☐ b) No ☐

17) If your answer in Q17 is no what are the major reasons for not having biogas plant? If yes jump Q19.

a) Less Number of cattle owned ☐ b) Lack of space (land size) ☐ c) Lack of initial cost of construction ☐ d) Awareness gap of household head ☐ f) Unavailability of technical service ☐

h) Unavailability of household labor ☐ i) Lack of loans and subsidies ☐

18) Do you have access local material for biogas plant construction? a) Yes ☐ b) No ☐

Section five: For biogas users

19) What was the major reason for starting a biogas plant?

a) High cost of other energy sources b) Problem fuel for domestic use

c) Encouraged by extension officer d) Influenced by friend with biogas plant

Section six: Promotion of biogas technology

20) In your view how can biogas production and utilization be promoted in Shebedino district?

....

Section seven: Observation Schedule

1. Biogas plant a) Present b) Absent

2 is its construction status a) Complete b) Incomplete

3) Status of plant a) functional b) non-functional

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

c) Broken or leaking pipes d) Shortage of cow dung e) No gas

4) Presence of cattle a) Present b) Absent

Focus Group discussion Guide

1) What are the major energy sources in your area?

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

3) Do you see a need for alternative energy sources? If yes which alternatives do you think are appropriate to your area?

Section nine: Checklist for KII

1. Which tree species are most commonly used for domestic energy consumption in your locality? Why?
2. What is your view on the current status of fuelwood sources? Why?
3. Is charcoal production common in your locality?
4. When was dissemination of biogas technology started in in the kebele?
5. What are the problems that have been faced to on dissemination biogas?

Section ten: Kitchen Performance Test Format

1. Name of Household Head----------------------------
2. GPS reading---
3. Moisture meter reading-------------------------------
4. Adoption of Biogas Technology: a) Adopter b) Non-adopter
7. Household size (Number) ________________

Day 1-3

Weight of dry wood collected in last 24 hours ________ kg

Weight of dry wood used in last 24 hours ________ kg

Number of people served in last 24 hours

Children 0-14 years ________ Women over 14 years________ Men aged 15-59 years ________

Men over 59 years________

Appendix 2: Multicollinearity test for discrete variable

Variable	χ^2-value	CC	P-value
Gender	14.57	0.718	0.000
Awareness	9.0024	0.538	0.003

Appendix 3: Conversion factors used to estimate tropical livestock units (TLU)

Cattle	**Conversion factor**
Cow	1
Calf	0.25
Heifer	0.75
Bull	0.6
Ox	1.1

Source**:** Storck, *et al.*, 1991

Appendix 4: Multicollinearity test for continuous variable

Variables	VIF
Age of household head in years	1.052
Educational status of household head	1.039
Number of household members	1.070
Average annual income of household head in birr	1.316
Number of cattle owned by household	1.377
Land size owned by household in hectare	1.570
Average distance in minute to reach fuel wood source	1.040
Time(in minute) taken to reach water source for biogas feeding	1.043

Source: Own survey result (2019)

Appendix 5: Calculation of Fuel wood saved from biogas

The total fuel wood saved per household = Mean fuel Wood saved per cap x average family size

= 4.94 x 0.84=4.1496 kg/household per day.

Annual fuelwood saved per household: 365 x 4.1496 kg/day=1514.6 kg/year

There are 63 functional biogas plant in Shebedino district

Total wood saved by 63 biogas plant per year = 1514.6 kg/year x 63 biogas plant= 95419.8 kg

Average household size from survey result =4.94

Per capta fuel consumption by adopter =1.58 kg

Per capta fuel consumption by non-adopter =2.42

Yearly fuel consumption by adopter = 4.94 x 1.58 x 365 =2848.9 kg/year

Yearly fuel consumption by non-adopter = 4.94 x 2.42 x 365=4363.5 kg/year

Appendix 6: Calculation Emission reduction

GHGs Emission Reduction = Amount of fuelwood saved × GHGs emission per kg of fuelwood

$GHG_{\text{reduction per household perday}}$ = 4.1496 x 1.518 = 6.3 kg CO_2 eq per household /day

$GHG_{\text{reduction per } \textit{household} \text{ /year}}$ =365 x 6.3 kg CO2 eq per household/day

=2299.5 CO_2eq per household/year = 2.2995 CO2eq per household/year

There are 63 functional biogas in the district

63 x 2.2995 CO2eq per household/year

= 144.9 tons CO2 eq

Appendix 7: Calculation Forest area saved

W = 0.25 x (4.7244 inch)^2 x 50.055 ft ------ for one Eucalyptus tree = 279.306 Ibs=126.7kg

The amount of fuel wood saved by biogas per household/year is 1441.75kg

C = 1514.6 kg= DW of fuel wood saved by biogas plant per household/year

$W\ saved\ fuelwood\ = \frac{DW}{0.725} = \frac{1514.6}{0.725}$ =2089.103kg

Total tree saved per household/year = $\frac{W\ saved\ fuelwood}{W\ of\ one\ eucalyptus\ tree} = \frac{2089.103kg}{126.7kg}$

=17 trees per household/year

From 63 fictional biogas in the study area, No of tree saved can be calculated: 63 x 17=1071 tree

If one hectare holds =1,750 trees,how many hectare can 1008 tree can holds?

$=\frac{1071}{1750}$ = 0.612 hectare tree saved

Appendix 8: Calculation of CO2 sequestration

CO2 sequestered in the saved tree by biogas per year can be calculated according to Myers and Goreau, that tropical tree plantations of pine and eucalyptus can sequester an average of 10 tons of carbon per hectare per year.

To determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

1 hectare = 10 tons C

The forests area saved by the use of biogas in this study was 1040 tree (0.594 hectare tree).

Therefore C sequestered can be:

$$= \frac{0.612\ hectare\ tree \times 10\ tons\ of\ C\ per\ hectare/year}{1\ hectare}$$

=6.12 tones C sequestered per year

To convert this in to CO2 eq it should be multiplied by 3.6663

$\frac{6.12\ tones\ C\ X\ 3.6663\ CO2}{1C}$= 22.44 tones CO2 eq per /year.

Appendix 9: Frequency distribution table of Energy consumption pattern for cooking.

Level of importance	Electricity		fuel wood		Kerosene		biogas		crop residue		dung cake	
	Fre	Per	Fre	Per	Fre	Per	Fre	Per	Fre	Per	Fre	Per
Most important	1	0.5	162	81.4		0	0	0	33	16.6	1	0.5
Important	1	0.5	14	7.0		0	28	14.1	28	14.1	16	8.0
Moderate	4	2	18	9.0	3	1.5	10	5	24	12.1	19	9.5
Less important	0	0	5	2.5	0	0	2	1	45	22.6	10	5.0
Least important	0	0	0	0	1	0.5	0	0	29	14.6	16	8.0
Not used	193	97	0	0	195	98	159	79.9	40	20.1	137	68.8
Total	199	100	199	100	199	100	199	100	199	100	199	100

Source: Own computation from questioner survey result

Appendix 10 Conversion factor for adult equivalent

People	Conversion factor
Child: 0-14	0.5
Female: over 14	0.8
Male: 15-59	1.0
Male: over 59	0.8

Source: Cohen, J (1992)

Appendix 11Gender of household and chi square test

Adoption status of household	Gender of household		Total	χ^2	P-value
	Female	Male			
Non-adopters	50	97	147	**14.57**	**0.000**
Adopters	1	51	52		
Total	51	148	199		

Appendix 12 Awareness of household and chi square test

Adoption status of household	Awareness of household head on biogas		Total	χ^2	P-value
	Not aware	Aware			
Non-adopters	37	110	147	9.0024	**0.003**
Adopter	3	49	52		
Total	40	159	199		

Appendix 13 Frequency distribution table of Energy consumption pattern for cooking.

Level of importance	electricity		fuel wood		kerosene		biogas		crop residue		solar	
	Fre	Per	Fre	Per	Fre	Per	Fre	Per	Fre	Per	Fre	per
Most important	40	20.1	0	0	91	45.7	20	10.1	0	0	44	22.1
important	0	0	0	0	51	25.6	9	4.5	2	1	3	1.5
moderate	0	79.9	6	3	48	24.1	0		3	1.5	1	0.5
Less important	0	0	16	8	7	3.5	2	1	5	2.5	0	0
Least important	0	0	11	5.5	0	0	0	0	15	7.5	0	0
Not used	159	0	166	83.4	2	1.0	168	84.4	174	84.4	151	75.9
total	199	100	199	100	199	100	199	100	199	100	199	100

Appendix 14: Average daily per capita fuelwood consumption

	Subject	Non Adopters	Subject	Adopters
	Code	HH fuel wood consumption per capta	Code	HH fuel wood consumption per capta
	NH1	2.2	AH1	1.4
	NH2	3.5	AH2	2.1
	NH3	3	AH3	1.8
	NH4	2.4	AH4	1.1
	NH5	1.9	AH5	1.7
	NH6	2	AH6	1.4
	NH7	3	AH7	1.9
	NH8	1.9	AH8	1.5
	NH9	2.7	AH9	1.6
	NH10	2.7	AH10	1.4
	NH11	2.6	AH11	1.7
	NH12	2	AH12	1.4
	NH13	2.1	AH13	1.5
	NH14	2.4	AH14	1.7
	NH15	2.1	AH15	1.3
	NH16	2.2	AH16	1.5
	NH17	2.5	AH17	1.6
	NH18	2.5	AH18	1.7
	NH19	2.2	AH19	1.8
	NH20	2.5	AH20	1.5
Mean fuel use(kg)		2.42		1.58
SD (kg)		0.416		0.228
CV		0.17		0.14
Sample Size		20		20
Mean fuel saving (kg) / adult equivalent				
SE (kg) /biogas plant				0.106
What is the precision attained?				20.22%
Does the sample size satisfy the 90/30 rule?				Yes
What fuel saving may be claimed?				Mean value
Additional samples required for 90/30 rule?				No

Source: Own KPT result (2019)

Thank You!

Biography

Seifu Wonago was born on October 17, 1989 in Sidama zone, Southern Nation Nationalities and People Regional State, Ethiopia. He attended primary school at Dila Afarara Elementary and Secondary School at Leku, and Yirgalem High school. He joined Wolaita Sodo

University in 2010 and graduate with degree in Applied Chemistry. He has been working in Shebedino District Water, Mine and Energy Office from 2013 until he joined Hawassa University Wodogenet College of forestry and natural resource school of graduate studies in 2018/19. He is unmarried.