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THE IMPACT OF SMALL SCALE BIOGAS TECHNOLOGY ON HOUSEHOLD INCOME AND HEALTH IN ADA'A WOREDA, OROMIA REGION, ETHIOPIA.

BY

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The Impact of Small Scale Biogas Technology on Household Income and Health in Ada'a Woreda, Oromia Region, Ethiopia.

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This is to certify that the thesis entitled "*The Impact of Small Scale Biogas Technology on Household Income and Health in Ada'a Woreda, Oromia Region, Ethiopia."* submitted in partial fulfillment of the requirement for the degree of Master of Art in Environment and Sustainable Development from Addis Ababa University, and is a record of original research carried out by Woubakal Tesfaye Beyene Id. №. GSR/9020/09, under my supervision, and no part of the thesis has been submitted for any other Degree or Diploma. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended that it be accepted as fulfilling the thesis requirement.

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This is to certify that the thesis prepared by WoubakalTesfaye,entitled: "*The Impact of Small Scale Biogas Technology on Household Income and Health in Ada'a Woreda, Oromia Region, Ethiopia."* and submitted in partial fulfilment of the requirements for the degree of Degree of Master of Arts in Environment and Sustainable Development complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

The Impact of Small Scale Biogas Technology on Household Income and Health in Ada'a Woreda, Oromia Region, Ethiopia.

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Addis Ababa University, 2018

Access to modern energy is a key element in rural development. This thesis identified the Impact of Small Scale Biogas Technology on Household Income and Health in Ada'a Woreda, Oromia Region, Ethiopia. 9 kebeles were purposively selected where there are high numberof biogas users. The descriptive statistical significances and the association of the dummy and continuous variables with the dependent variable were tested using chi-square and t-test. Propensity score matching was used to assess the impact small scale biogas technology has on health and income of household. The study found out small scale biogas technology is favorable among users due to; subsidy form the government; relatively cheap comparing to other fuel sources; as it considers the health economic and environmental benefits; as it saves fuel; it being smokeless; its durability; the fact that it cooks quickly; as it effectively uses waste from farm and produces compost for farm use. The result from Propensity score matching indicated that small scale biogas technology has a significant and positive impact on health So, the impact of small scale biogas technology has an average treatment effect of 8249.2 ETB, 5968.5 ETB, 9961.5 ETB, 8652.3 ETB per annum to household income using nearest neighbor, radius, kernel and stratification methods respectively. Looking at the impact of small scale biogas technology on health, the study looked at three outcome variables; cost of the treatment for the victims in the households; the number of days spent for fuel collection per week and; total members of the household affected by indoor air pollution (IAP). The impact of biogas on cost of treatment has an average treatment effect of 320.2 ETB, 392.5 ETB, 339.2 ETB, and 332.8ETBusing nearest neighbor, radius, kernel and stratification methods respectively. The impact of biogas on number days spent for fuel collection has an average treatment effect of -1.5, -1.4, -1.3, and -1.3 days using nearest neighbor, radius, kernel and stratification methods respectively. Lastly the impact of using small scale biogas technology on total members of household that are affected by the illness -1.2, -1.2, -1.2, and -1.2, member using nearest neighbor, radius, kernel and stratification methods respectively. The result indicated the positive impact of small scale biogas technology on health. As the technology has a great potential in promoting sustainable and renewable energy, much effort should be done in promoting the technology, awareness raising to non-user household and peer education should be done.

Key words: Biogas, IAP,Income,Propensity Score Matching, Renewable energy

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List of Acronyms

AUC :	African Union Commission
AUC-ECA	African Union Commission- Economic Commission for Africa
CDM:	Clean Development Mechanism
CRGE:	Climate Resilient Green Economy
EREDPC:	Ethiopia Rural Energy Development and Promotion Centre
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
GTP II	Growth and Transformation Plan II
IAP	Indoor Air Pollution
IRENA	International Renewable Agency
MLP	Multilevel Perspective
MoWIE	Ministry of Water, Irrigation & Energy
NBPE	National Biogas Programme Ethiopia
NPVs	Net Present Values
SDGs	Sustainable Development Goals
SNM	Strategic Niche Management
SNV	Smart Development Works
TLU	Tropical Livestock Unit
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programs
WEF	Water Energy and Food Nexus
WSSD	World Summit for Sustainable Development

CHAPTER 1: INTRODUCTION

1.1. Background

Energy is essential for the economic and social development of a nation. People need affordable and reliable energy but there has to be an appropriate balance between the growing demand for energy and the vital need to protect the environment and climate globally. Nevertheless, the issue of balancing the growing demand for energy with the limited availability of fossil fuels with the need to protect the environment is the greatest challenge of the modern world. Energy in the form of charcoal, firewood, and crop residues plays a pivotal role in the basic welfare and economic activities in many households in the developing countries (Rahman et. al., 2017).

Energy being the crucial element in a country's economic development, it is a driving force to improve the standard of living. However, access to the reliable and affordable energy source is still a challenge for the majority of the people in developing countries. To make things worse, for the rural population access to modern fuels is limited due to low economic opportunities and access to better technology than the urban population. Energy is very critical to sustainable development and poverty reduction efforts. It affects all aspects of development; social, economic and environment, including livelihoods, access to water, agricultural productivity, health, population levels, education and gender issues. Thus the need for the development of renewable energy in households is crucial (Mulu, 2016).

The relationship between water energy and food (WEF) has become very important with the development of sustainable development. This nexus attracted attention at the Bonn 2011 Nexus conference held in the preparation for the United Nations (UN) Rio+20 conference. The Bonn conference shade some light on closely related sustainability issues connected to the sectors of water, energy and food security (M. Gulati et.al, 2013). To better understand and manage sustainably the limited natural resources, understanding the dynamics and complex interrelationship between water, energy, and food using a nexus approach is very necessary (FAO, 2014).

In Africa, bioenergy emerged as a suitable renewable energy alternative to hinder the impacts of the rising and falling costs of fossil fuel and environmental degradation. With that background, an inclusive consultative process to outline an Africa Bio energy Framework that promotes the development of a sustainable and modern bio energy sector in Africa was initiated by the African Union Commission (AUC) (AUC-ECA, 2013).

In Ethiopia currently, there are 2 types of energy sources: modern and traditional. Modern energy sources include electricity and petroleum while traditional sources of cover fuel wood, charcoal, dung cake, and crop residues which constitute 92% of the total household energy consumption. Despite Ethiopia's natural energy sources like hydropower, wind, geothermal, and bio fuels, the country faces huge crises. This problem is further intensified by very low per capita energy consumption and the dominance of conventional biomass fuel use. With increasing price of imported oil, the substitute for most Ethiopians remains on biomass fuels and dung cakes. In the northern part of Ethiopia as most natural vegetation depleted energy from dung cake constitutes 22.8% of the total household energy consumption in Tigray Region and 20.4% in Amhara Region (Mulu et.al 2015).

It is estimated that 89.6% of the total energy consumption in Ethiopia is composed of conventional biomass fuels from which 10.4% coming from modern energy sources (Afanador et.al. 2016). Most rural households in Ethiopia are highly dependent on biomass for their energy needs. Devereux (2000), stated with the increasing population pressure, the stress on firewood is increasing which leads to deforestation, land degradation, and loss of soil nutrients leading to food insecurity and energy crises. With the increasing shortage of firewood, households are turning to dung cakes and crop residues for energy. This new reliance creates additional environmental and food security problems as these residues are being used largely for energy purposes than being used as an organic fertilizer for crop production which in the long run affects the food security (Mekonnen and Köhlin, 2008).

Ethiopia has initiated the green growth policy by implementing Ethiopia's Climate Resilient Green Economy strategy which aims to achieve a middle-income economy with zero net emissions by 2025 (CRGE, 2012). The country is working to generate clean and renewable energy which is interlinked with the SDGs, of 1, 3 5 and 7. Goal 1 of SDG aims to end poverty in all its forms everywhere; Goal 3 aims to ensure health; Goal 5 stating gender equality which could be achieved by reducing women's time spent for the collection of energy sources. The last SDG that links with renewable energy is Goal 7, stating increased use of renewable energy which could be achieved by the use of small-scale biogas technology.

To abate the challenges of domestic energy and associated environmental and socio-economic challenges Ethiopia has launched the implementation of successive domestic biogas programs (CRGE, 2012). The biogas sector in Ethiopia started with the launch of The National Biogas Program (NBPE) in 2008. Although the NBPE started in 2008, previous initiatives already paved the way for the establishment, as documented by Ethiopia Rural Energy Development and Promotion Centre (EREDPC), of biogas technology. These initiatives were first introduced in Ethiopia as early as 1979. The biogas digester was built at the Ambo Agricultural College (EREDPC, 2008).

The program led to the building of over 17,000 bio digesters (Kamp and Forn, 2016). Initially, NBPE has installed 8,000 bio digesters but with the growing demand, each year and other favorable conditions has raised to 17, 000 bio digesters (NBPE-II, 2014). Although the need exists for the biogas technology currently 0.8 % households are using the technology. (NBPE, 2015). The Government of the Federal Democratic Republic of Ethiopia (GoE) has recognized the need by laying down the foundation in its Growth and Transformation Plan I (GTP-I) for the development of renewable energy by indicating biogas as one of the urgency. In GTP-I it is also specified the policies and infrastructures that are needed for the implementation. The GTP-I explicitly addresses the sustainability of growth: "Environmental conservation plays a vital role in sustainable development. Building a 'Green Economy' and ongoing implementation of environmental laws are among the key strategic directions to be pursued during the plan period." (GTP, 2011: p. 119).

Although there are policies and programs that promote the use of small-scale biogas technologies little is known about the impact of using the technology at the household level. Whether the adoption of small-scale biogas technology has significantly improved the livelihood of a given household. This research looked at households' food consumption patterns, health, income and the gender in relation to using small-scale biogas technology.

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1.2. Statement of the Problem

Biogas energy is utilized commonly for cooking, lighting, refrigeration, and running internal combustion engine (FAO, 1996). Biogas burns more efficiently as compared to fuelwood and dung. It burns at an efficiency of about 60 % whereas fuelwood burns at 5 % to 8 % efficiency in open fire place and dung burns at 60 % of that of fuelwood (FAO, 1997). Unlike the use of traditional biomass fuels, cooking with biogas is much easier because there is no need to keep the fire burning (Arthur et al., 2011).

Biogas energy production and use have been illustrated to have the potential to reduce wood fuel consumption, mitigate climate change and reduce indoor air pollution (Smith et al. 2013). Biogas is considered as one of the solutions to generate sustainable and clean energy. As a result country, particularly developing countries, are promoting the use of clean energy like biogas energy in their effort to attain the SDGs.

Access to modern energy is a key element in rural development. However, according to Getachew, et.al. (2006), despite all attention given to energy issues in Ethiopia in the past, rural communities continue to be deprived of basic energy services. Thus, modern forms of energy are not as available as they are in the urban areas and the conventional sources tend to deplete the natural resources.

Getachew and Stoop (2007), reviewed NBPE and stated that an increasing fraction of the population is being confronted with the difficult choice between eating its food poorly cooked and travelling long distances to collect fuel for cooking. Moreover, Dawit (2014), stated that fuelwood scarcity leads to malnutrition among children due to lack of dietary diversity. Hence, these studies stated the scarcity of fuelwood and its effect on dietary pattern.

In the developing countries collecting fuelwood is mostly the responsibility of women and children, with the scarcity of fuelwood their welfare highly depend on it as they have to travel long distances to collect fuelwood (Heltberg, 2004; Rehfuess et al., 2010).

Mulu (2016), examined the contribution of biogas technology to rural livelihood and the environment in Northern Ethiopia. The study found biogas technology reduced the weekly per capita energy consumption by 75.1 Mega Jules (MJ). Besides reducing the conventional energy sources it highly improves the health and sanitation conditions of the sample respondents. The author also argued that the major factors that influence households' decisions on adoption of the biogas technology are; sex and education level of household head, cattle size, household access to credit, income level, and the lack of biogas 'injera' mitad (stove). On the other hand, Nigussieet.al. *(*2016), examined the links between biogas technology adoption and health status of households in rural Tigray, Northern Ethiopia. The researchers found that households with small-scale biogas technology have significantly lower incidence of indoor air pollution (IAP) related illness compared to the non-adopter households.

Kamp and Forn (2016), analyze the current status of the domestic biogas unit in Ethiopia and the barriers and drivers that influence its development using multilevel perspective (MLP) and Strategic Niche Management (SNM) technique. Their findings suggest that economic stability, literacy and poverty has affected the sector. Furthermore, the poor coordination between the stakeholders has created a gap to attain the intended result.

Although there are ample literature in regard to the role of biogas on the livelihood of households, the researches done mainly focus on the factors that affects and influence the adoption of the technology. Studies done in regard to health and biogas focused on IAP, this study, besides IAP, looked at other illness that can be ameliorated by using small scale biogas technology. Furthermore, this study looked at the impact of small scale biogas technology on households' income in comparison with non-users. The study also identified the effect of using small scale biogas technology on gender at the household level.

1.3. Objective of the Study

1.3.1.General Objective

The overall objective of the study is to assess the impact of small scale biogas technology on households'welfare by comparing users with non-users in Ada'a woreda in Oromia Region.

1.3.2.Specific Objectives

- To examine the effect of small scale biogas technology on household income
- To analyze the health benefits of using small scale biogas at the household level.

1.4. Significance of the Study

As Ethiopia aims to leap frog to a middle income country, with an ambitious zero net emission by 2025, the country is working strenuously on renewable and clean energy. But on the other hand rapid economic growth and population expansion are putting high demand for energy, water and food. Energy plays a central part in Ethiopia's effort to the reduction of poverty and to achieving sustainable development, since it touches all features of development; economic, social, and environment, including household welfare, health, population levels, and education and gender issues. In addition none of the SDGs can be met without access to clean and efficient energy services.

It is difficult to achieve any of the SDGs without improving the quality and availability of energy services in the developing countries. United Nations Secretary-General's Sustainable Energy for

All (SEforAll) initiative and the 2030 Agenda for Sustainable Development has recognized energy as the main factor central to sustainable development and aims to achieve access to modern energy services by 2030.Therefore, amongst the 17 SDGs goal 7 “access to affordable, reliable, and sustainable modern energy for all” is interlinked to women’s empowerment, goal 5. This is because rural women and girls are primarily responsible for the most of the household work and easy access to energy makes a noteworthy difference to their health and well-being. It is worthy to mention although access to clean and renewable energy doesn’t assure gender equality but will provide extra time for women to focus on their education and income generating activities (UNDP, 2016).

That being said, this study has both policy and academic significance. The research looked at and brought to forefront the positive effect of small scale biogas technology in the everyday life of households. Although this looks like a drop in the ocean, the comparison with the non-users highlights the mega effect biogas technology has on the health, women and income of user households. Moreover, assessing what has been done so far paves the way for policy makers and academicians on what to focus.

1.5. Scope and Limitation of the Study

The paper looked how small scale biogas technology has affected the welfare of households. It mainly focused on the health, household income and the gender aspect. The paper identified the effects by comparing small scale biogas technology users with non-users in Ada’a woreda, Oromia regional. This research faced limitations of resource like time and budget.

1.6. Ethical Consideration

As ethical considerations are one of the most important aspect of this research, the paper strictly followed procedures. The researcher obtained the proper cooperation letter form Environment and Sustainable Development Department at Addis Ababa University and offices that were visited. Besides the researcher ensured the voluntary participation of respondents in the research and vehemently avoided use of offensive, discriminatory, or other unacceptable language needed to be avoided in the formulation of Questionnaire/Interview/Focus group questions. The research acknowledged the works of other authors and researchers. Most importantly the researcher maintained at most level of objectivity during the study.

1.7. Organization of the Paper

This thesis is composed of five chapters. Chapter Two reviews theoretical and empirical literatures as well as conceptual frame work of the research. Study area description, research design, sampling methods and procedure, and methods of data analysis are included in chapter three. In chapter four the results of the study and discussions are included. Chapter five, the last chapter, is conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1. Energy, Sustainable Development and Biogas

2.1.1. The Concept of Energy

Energy is essential to the welfare of human beings. The creation of new energy sources started when communities learned to control and use fire (Gadonniex, 2010). Energy deeply influences the life of communities. It is fundamental to all aspects of human welfare, including access to clean water, health care and education and increasing agricultural productivity (Rahman *et. al.* 2017).

2.1.2. Interface between Energy and Sustainable Development Goals

The world population is rising and the energy consumption is increasing and will be at startling rate in the coming years. To secure the ever demanding of energy the scope of energy should be expanded from oil and coal to a more diverse energy supply structure. As it is mentioned in World Bank, 2013 report the World Summit for Sustainable Development (WSSD) (2002) and United Nations Conference on Environment and Development (UNCED) (1992), placed energy in focus for poverty eradication and development agenda.

Energy has been recognized as instrumental in improving third world livelihoods. Modern energy resources, such as nuclear energy, wind energy, solar, geothermal heat, bioenergy, etc. shall be developed, and development and utilization shall be boosted (IRENA, 2015). Goal 7 of the SDG states to promote a vast option of energy access and to increase and encourage use of renewable energy sources through greater international cooperation and expanded infrastructure and technology for clean energy. (UN, 2016).

2.1.3. What is Renewable Energy?

An energy which comes from a natural energy source such as; sun, wind, rain, tides and geothermal heat and which are replenished naturally are usually referred as renewable energy (Sambo, 2010). Renewable energy utilization has expanded greatly over the past decade. 120 giga watts (GW), in the power sector of renewable energy capacity was deployed in 2013. This is estimated to be all of Brazil’s electricity generation capacity (IRENA, 2015).

Globally renewables generated 22.1% of electricity in 2013. In the heat and transport sector vigorous growth is shown. Currently the position of renewable energies in meeting the global heat demand is 10% and it is rising. As it was stated in REN21, 2014 global status report 0.8% of the global transport fuel that was used in 2013 was derived from renewable energy sources such as Liquid biofuels (including ethanol and biodiesel) (REN21, 2014).

Biogas is a sustainable and clean substitution energy to biomass produced by anaerobic fermentation of animal dung and other waste in a subterraneous digester built from locally available materials (SNV, 2015). It is a combination of gases (methane and carbon dioxide) produced through the anaerobic breakdown of organic matter (e.g., animal or human waste, food waste or plant material) ultimately creating energy. Biogas energy can be used for cooking, heating, electricity and even transportation. Biogas is also considered favorable from a financial perspective as it has generally low capital requirements, especially when compared to "conventional centralized power systems" (Mwirigi et al., 2014; Karekezi, 2002).

Biogas technology is form of renewable energy that uses various organic wastes in the absence of oxygen to harvest combustible mixture of methane and carbon dioxide gases, mineralized water and organic fertilizer (bio-slurry) (Gautam et al., 2009). This technologyrecuperates biogas by collecting anaerobic degradation pathways controlled by micro-organisms. The gas is a mixture of methane (CH4) and carbon dioxide (CO2), and other gases like hydrogen sulphide (H2S) (Singh and Sooch, 2004; Shin et al., 2005). The gas is flammable as the presence of Methane. Being one of the most decentralized renewable energy technology,small-scale biogas technology is highly promoted for rural people.

Some African countries have also been working on the dissemination of biogas technology with renewed interest. The total numbers of biogas installations constructed up to 2011 in nine African countries, namely, Rwanda, Ethiopia, Tanzania, Kenya, Uganda, Burkina Faso, Cameron, Benin and Senegal summed up 24,990 (SNV, 2013). ABPP, which was created by SNV and HIVOS, planned to construct 70,000 biogas installations in six African countries (Kenya, Burkina Faso, Ethiopia, Tanzania, Uganda, and Senegal) with the aim to provide sustainable source of energy for about half a million people by the end of 2013 (AFREA, 2011). HIVOS manages the programme, SNV provides technical assistance whereas national agencies take the responsibility of implementing the programmes with a range of partners. The major source of funding for ABPP is the Dutch Ministry for Development Cooperation (DGIS).

Currently, ABPP is active in five countries with the dropped out of Senegal at the beginning of 2012 (ABPP, 2012).

Most African countries are endowed with abundant renewable energy sources and can provide a major breakthrough solution to Africa's energy crisis (Bugaje, I.M., 2006). Biogas comes from anaerobic digestion of biomass, it is widely grouped into public sewage and solid waste, agro and livestock waste, and energy crops. Compared to other renewable energies biogas technology is more advantageous as combines and stores energy (gas) and it produces bio-slurry which can be used as fertilizer (Janssen and Rutz, 2012).

2.1.4. Energy and Biogas in Ethiopia

In Ethiopia access to modern energy is one of the key element in rural development. Though in the past due attention was not given to it. As only 2 % of Ethiopia's rural households have access to the national grid and 85 % of the population live and work in rural areas, the lack of energy is expected to severely restrict Ethiopia's social and economic development. Woody biomass represents the principal form of cooking and lighting fuel in Ethiopia's rural areas. The scarcity of fuel wood in these geographies has led to an increased utilization of cow dung and agricultural residues as primary sources of household fuel which otherwise would have been used to enhance the nutrient status and texture of the soil and contribute positively to agricultural production (NBPE, 2015).

2.1.5. Biogas in Context of Ethiopia's National Development Agenda

Biogas technology has been implemented in Ethiopia since 1979, however due to technical, logistical and other reasons it didn't develop as planned (Zereay,et.al, 2013). In 2009, National Biogas Program of Ethiopia (NBPE) was launched with the aim of constructing 14,000 biogas plants in the first phase while exploring the potential for the development of a commercially viable biogas sector, which was later revised to 10,000 plants. A total of 8,161 biogas units were installed within the Phase I period (2009-2013). The programme started under the multi-country Africa Biogas Partnership Programme (ABPP). The Ethiopian Rural Energy Promotion and Development Centre (EREDPC) was the national partner. The project was later placed under the supervision of the Ministry of Water, Irrigation & Energy (MoWIE). SNV/Ethiopia carried out a feasibility study in 2006 for implementing a nationwide program on the development of household biogas units.In the second phase of the program (2014 – 2017), it targeted to install

20,000 biogas plants. In 2014 alone, a total of 1,762 plants have been constructed raising the total number (NBPE, 2015).

The National biogas programme Ethiopia promoting domestic biogas was launched with the support of the Netherland Development Organization. It is hosted and co-financed by Ministry of Water, Irrigation and Electricity (MoWIE) with financial and technical support of the Directorate General for International Cooperation (DGIS) of the Netherlands managed by the Humanist Institute for International Development Cooperation (HIVOS). It is also gets technical support from the Netherlands Development Organization (SNV). Ethiopiabeing rich in livestock and as the majority of the rural inhabitants are involved in various forms of animal husbandry is therefore logical that the GTP recognizes biogas as one of the potential feasible sources of renewable energy for domestic use. This program is designed to upscale the National Biogas Program undertaken by the Ethiopian Rural Energy Promotion and Development Center (EREDPC). This program is in line with the GTP and CRGE's plan of expanding clean and renewable energy (ECA, 2015).

According to Ethiopia Clean Cooking Energy Program, which adheres a shift from conventional fuel sources to renewable energy sources, 39,178 unit small scale biogas digesters are and will be initiated in the period of 2015 to 2020. Development Bank of Ethiopia (DBE) in collaboration with Ministry of Water, Irrigation and Electricity (MoWIE) are supervising this program. The program is sustained by the World Bank managed Clean Initiative for Development (Ci-Dev) to maintain suitability after the project has phased out (NBPE, 2015).

2.2. Theoretical LiteratureReview

2.2.1. Household Energy Transition in Developing Countries

2.2.1.1.The Energy ladder

The energy ladder was developed as a model to explain the household energy choice in developing nations (Kowsari and Zerriffi, 2011). The energy ladder notion takes as its standing point the differences in energy - use patterns between households with differing economic status. This model assumes households tend to maximize their utility with the neo-classical consumer manner implying they will move to more refined energy sources as their income increase (van der Kroon et.al., 2011). Fuel switching is a central notion in the energy ladder concept, meaning a move to a new type of energy is a moving away from the previously used one (Heltberg, 2005).

Martin (2005), mentioned the energy ladder model provides a partial glimpse of the actual reality. Recent empirical evidences on the transition of energy transition found out different than the simple energy ladder model that portrays the adoption of fuel in a progressive manner (Kowsari and Zerriffi, 2011). This raised to the issues that different types are used for different types of tasks, households can choose or mix different energy sources rather than simply abandoning the conventional energy sources. (Davis and Mark, 1998; ESMAP, 2003; Heltberg, 2004; Leiwen and O'Neill, 2003; Masera et al., 1997, 2000; Pachauri and Spreng, 2003). This notion brought about another energy model, energy stalking.

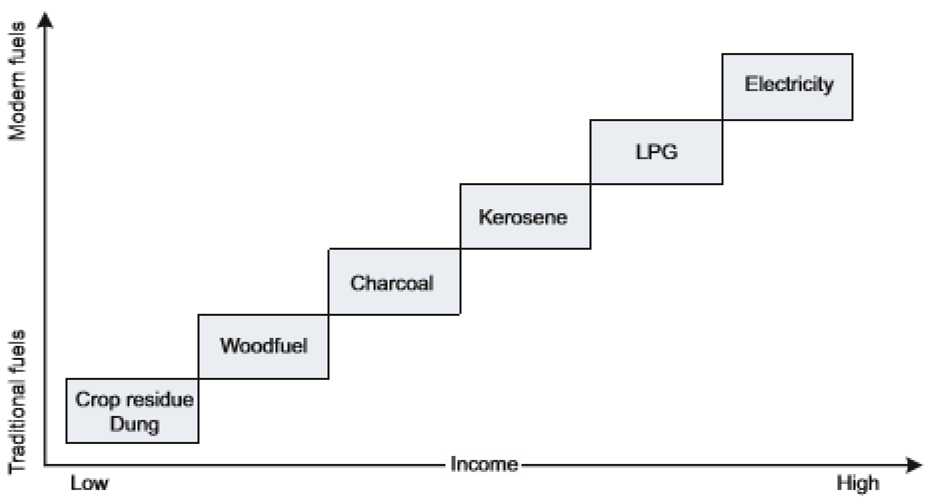

Figure 1 the classic Energy Ladder (Three dimensional energy profile: A conceptual framework for assessing household energy use Reza Kowsari and Hisham Zerriffi)

2.2.1.2.Energy Stacking Model

When households use different fuels at the same time it is called energy stacking. Households stack fuels for several reasons as; keeping the conventional energy systems when the modern forms of energy show prices increment, as a form of insurance when there is a shortage of modern energy form, as an insurance against modern energy supplier failure, based on the type of food being cooked (ESMAP, 1999, Leach, 1992; Thom and Cecile, 2000, Masera et al., 2000).

From the empirical studies done by byLeiwen in rural Chinain2003) indicate that some forms of traditional energy are still used by the wealthiest households. Barnes proposed a ‘‘rural energy ladder’’ that illustrates the steps through which rural households generally move from traditional biofuels and human and animal power to a mix of traditional and modern fuels (Barnes et al., 1996).

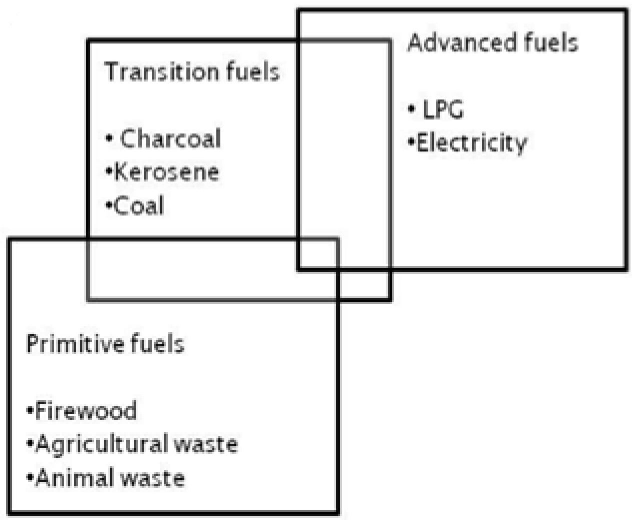

Figure 2 Energy Stacking Model- Source Schlag and Zuzarte, 2008.

2.2.1.3.Energy Leapfrogging

This theory about access to energy is a recent trend, it evolves around the idea that developing countries have access to a set of efficient technologies that was not available to developed countries in the past. As mentioned by Goldemberg, 1998 the idea often features in the energy debate assuming that developing nations have access to energy saving technologies that were not existent when developed countries were at a similar stage of economic development.

2.3. Empirical Related Review

This section will provide empirical review on the impact of small scale biogas technology on the livelihoods/ well-being of households.

2.3.1. Health benefits of Biogas

The utilization of biogas innovation has various wellbeing and social advantages. The medical advantages incorporate: lessening in smoke borne illnesses, for example, migraine, eye-consuming, eye-contamination, and respiratory organ disease; change in family sanitation by means of latrine association with bio digesters and nonattendance of sooth and fiery remains in the kitchen; and lessening in consuming mishaps (Ghimire, 2008). Essentially, Bajgain and Shakya (2005) uncovered that usage of biogas extraordinarily enhances the nature of indoor air. It consumes neatly with the goal that its utilization limits eye diseases which comes about because of consuming of conventional biomass powers. In addition, it helps looking after sanitation of zones encompassing families by means of fertilizer administration and clean toilets associated with biogas digesters. Consequently, it brings down the likelihood of development of infectious maladies. At the end of the day, as expressed by Aggarangsi et al. (2013), biogas innovation gives medical advantages not exclusively to its clients yet in addition to the entire network in its environs. To be sure,Bajgain and Shakya (2005) too remind that smoke free rooms may not generally be profitable. The smoke is constantly used to keep out creepy crawlies. Be that as it may, the smoke free biogas stoves can't fend off mosquitoes.

All inclusive, around two million passings per year from pneumonia, unending lung illness, and lung malignancy are connected to indoor air contamination from the utilization of strong powers. In slightest created and Sub Saharan Africa nations, the greater part of the considerable number of passings from these three infections are related with strong fuel utilize while it is simply around 38 % for the general creating nations (Legros et al., 2009). Hence, clean vitality mediations, for example, scattering of biogas innovation in these locales can significantly lessen passings because of indoor air contamination.

Biogas innovation has likewise different social parts. It enhances social relations by means of limiting terrible scents and natural contaminations of natural squanders which would have been generally fill in as a wellspring of grievance among neighbors and contrarily influence social relations (Aggarangsi et al., 2013). It spares time for social exercises; it enhances societal position in the network; it diminishes ladies and youngsters' work weight; and it offers brighter light that helps quality instruction and family obligations (Ghimire, 2008). Additionally, ENERGIA (2010) expressed that the utilization of biogas establishment curtails time spent on fuelwood accumulation, cooking, and cleaning utensils and kitchens. This spared time is used for rest and recreation, tutoring, social exercises or potentially gainful purposes which unquestionably enable ladies and advance ladies and young ladies' instruction.

The splendid biogas light likewise helps with prevailing in kids' instructive exhibitions. In Nepal, because of the utilization of biogas, ladies can save money all things considered three hours day by day from the general time required for cooking, cleaning pots, and gathering fuelwood (Winrock International, 2007). Another examination in Nepal uncovered that biogas clients by and large spare 96 minutes for each day for cooking when contrasted with customary stove clients. Also, biogas is a spotless cooking fuel.

Thus, the time put something aside to wash cooking utensils is assessed to be all things considered 39 minutes every day (Renwick et al., 2007). This time spared might be used for tutoring or other beneficial purposes. Kids who have been firmly possessed with fuelwood gathering could inspire time to go to class. Along these lines, the utilization of biogas limited the hole in instructive status between guys and females (Arthur et al., 2011).

Nigussieet.al. 2016 in their study of the links between biogas technology adoption and health status of households in rural Tigray, Northern Ethiopia. The researchers used propensity score matching to analyze the matched data and revealed that the households using small scale biogas technology have a lower chance of acquiring IAP-related illness than the non-users. Subsequently, small-scale biogas adopters paid less money for medication, the number of sick days are limited and time spent of fuelwood collection are less compared to non-users. All in all, the study found small-scale biogas technology to improve the health conditions of households.Zerihun in a study conducted in 2015 in Fogera District, Amhara Regional State on benefits of using biogas energy in rural areas found out the technology users benefited from reduced IAA and improved sanitary conditions

2.3.2. Biogas and Household Income

Wamuyu (2009), in a study he conducted in Kenya, Kimbu County found out the using of biogas technology has uplifted the livelihoods of the households in that county. Households have saved up to 445 USD annually due to the technology, time was significantly saved and respiratory diseases from IAP were reduced significantly.

In Gwavuya, Abele, Zeller & Muller's article (2012) titled Household Energy Economics in Rural Ethiopia: A Cost-Benefit Analysis of Biogas Energy, the authors identified biogas plants yield positive net present values (NPVs) for households collecting their own energy sources but even higher NPVs for households that purchase all of their energy needs as they benefit from cost savings through the use of biogas technology

In a study done in Pakistan by Ali et.al, (2013) the researchers evaluated the use of biogas in developing areas. The result is biogas technologies have created green jobs and have increased the revenue from rural economy. Besides that, biogas technology is helpful in transforming organic wastes into high quality fertilizer. As a result of proper waste management, the hygienic conditions of the area were upgraded. They also mentioned in the study, the use of biogas technology has greatly reduced work load mainly on women.

For an improved economic and social wellbeing and poverty reduction energy plays a pivotal factor. In this regard biogas plays a vital role in the sustainable development of rural communities (IAEA, 2005). In a study done in South Africa by M. Gulati et.al. in 2013 showed biogas production contributed to the reduction of household costs for fertilizer and energy. The saved income has been used for other purposes such as school fees andnutritious food items adding significantly to the households' welfare and to the economy.

2.4. ConceptualFramework Model

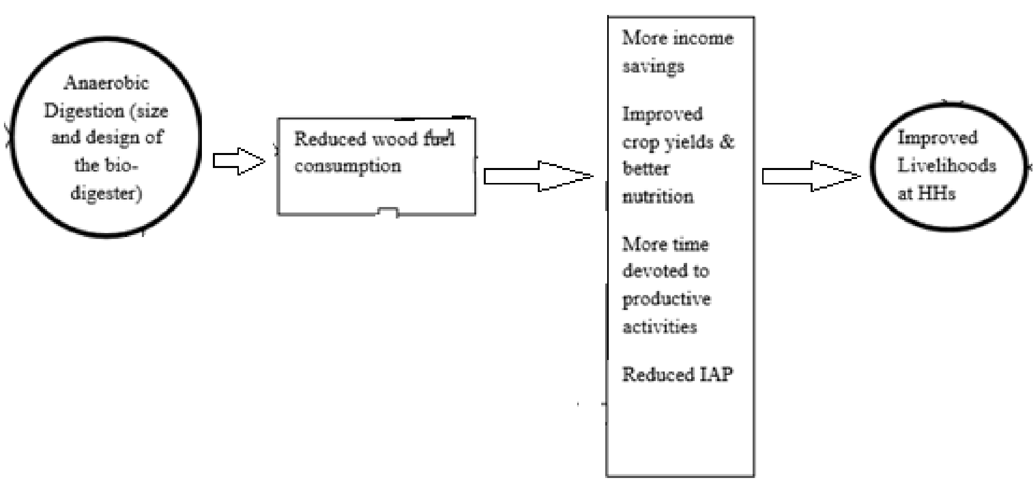

Figure 3 Conceptual framework (own construction)

Conceptual framework lists of concepts and their associations and possible outcomes of the research problem. This enables the researcher to analytically consider numeroussidesof the research problem; recognize key factors, and portray their rational interrelationships in a system.

In perspective of the above thought, the visual portrayal of the reasonable structure has been created based on articulation of the issue and survey of related writing. Consequently, the diagrammatic type of the reasonable structure that presentations interrelationships among key factors and their presumable results is portrayed in Figure 3.

Reception and scattering of biogas innovation in a given society relies upon various factors. A portion of the central point include: socio-statistic characters of families; monetary characters of families including access to elective wellsprings of vitality like power and photovoltaic; biophysical factors, for example, access to woody biomass, arrive, and water assets; legitimate and institutional factors, for example, advancement work, backings, and endowments; private segment interest in advancement, development, and assembling and supplies of machines and extra parts; and traits of the innovation itself.

Here it ought to be noticed that appropriation of biogas innovation is family unit specific. It requires family units to have adequate size of domesticated animals to sustain biogas digester, adequate and dependable water sources inside sensible separations, and work to work the biogas establishment. It moreover needs families either to approach credit or adequate claim budgetary cash-flow to cover the full or fractional cost of biogas speculation (incomplete in the event that where there is sponsorship).

In this manner, in view of the interchange of all the previously mentioned factors, family units can procure learning and mindfulness on biogas innovation, assess its significance, and create demeanor towards utilizing the innovation, lastly may choose to receive and begin the genuine utilization of the innovation.

Once biogas innovation is embraced, managed and productive use of the innovation can lead to different advancement results. A portion of the major feasible advancement results may include: addressing vitality needs, spared time, diminished workload, lessened wellbeing hazard, decreased use, expanded salary and openings for work, expanded efficiency, decreased deforestation, lessened GHG discharges, enhanced soil richness, decreased indoor air contamination, and enhanced sanitation.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Description of the Study Area

Ada'a woreda is found on the east of Addis Ababa which is in between longitudes 38º51' to 39º04' East and latitudes 8º46' to 8º59' North covering a land area of 1750 km^2. Ada'a is mostly plain highland ranging between 1600 to 2000 meters above sea level. The agro ecology in the woreda is best suited for diverse agricultural production.Rivers and crater lakes are used for agriculture particularly for horticultural crops production. Ada'a is countrywide known for its finest quality teff production which dominates the agricultural production system. Wheat is also cultivated in ample amount. Pulse crops and chickpea are grown in the bottomland. Cattle, sheep, goat, and poultry productionis a very common practice. On average a household owns a farm size varying from 1 to 2.5 ha and oxen is the major farming operation.

Ada'aexperiences annual temperature ranging from about 8–28ºC.There are 3 agro-climatic zones known in the woreda. The two cropping seasons in the woreda are "belg" (short rainy season) March to April and and "meher" (main rainy season) from June to September. Form the information obtained from Ada'a Woreda Water, Mine and Energy office,there are 27,264 (CSA, 2007) households in Ada'aworeda from which 306 households use small scale biogas technology.

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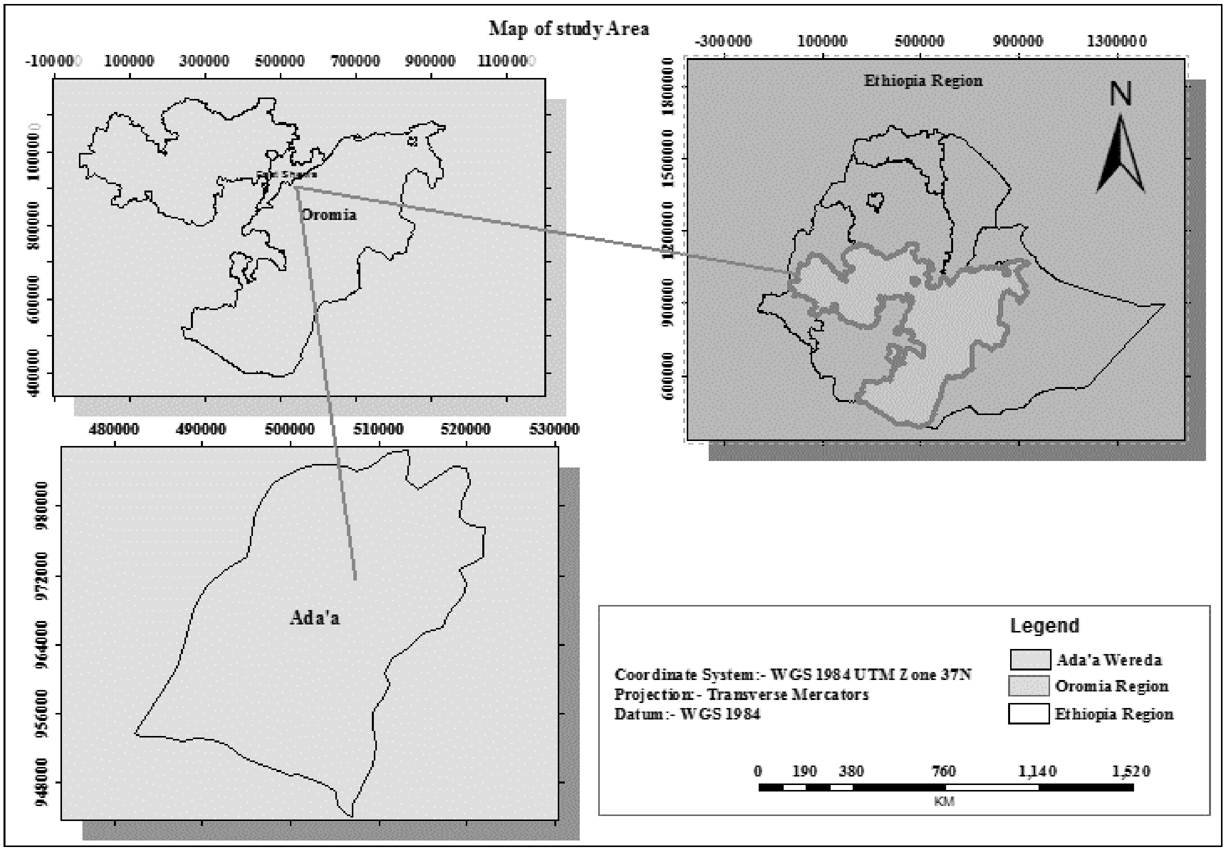

Figure 4: Study Area Map

Like many parts of the country, energy source for Ada'a woreda is mainly from traditional biomasses; and, firewood constitutes a greater coverage of domestic energy supply both in rural and urban areas.

3.2. Study Design

The study design used in this research is a cross sectional study design. This design was considered as the limited time the research had and as the data has to be collected at one point in time. Itcombined both quantitative and qualitative research methods. The study employed quasi-experimental research design as the comparison will be those households who are using small scale biogas technology, treated group and the control groups, non-users.

3.3.Data Sources

For this study both primary and secondary sources of data were employed to gather reliable and valid information. The primary data was collected from both small scale biogas technology user and non-user householdsby structured questionnaires, and key informant interview. While secondary data was collected through review of documents, small scale biogas technology user databases, books, journals, reports, websites etc.

3.4. Sample Size Determination and Sampling Techniques and Procedures

3.4.1. Sample Size Determination

The units of analysis for this study were both biogas users and non-user households. From the data obtained from National Biogas Programme Coordination Office database and SNV, there are a total of 306 households in Adea woreda. Biogas user households who started using the technology before 2015 were used as sampling frame. The main purpose for selecting households that has been using the technology before 2015is to better understand the impacts of biogas on the welfare of the household.

That being said; the study used Cochran formula.

$$\mathrm{n} = \frac{Z^2}{e^2} pq$$

Where,

n $=$ Sample size required

$p =$The estimated proportion of an attribute that is present in the population, (expected prevalence).

$q = 1 - p$

$Z =$ Z- Score associated with appropriately chosen level of confidence (95%) with the table value of 1.96.

$e =$ The desired level of precision

Therefore, assume p= 0.3. Accordingly, the desired level of precision 5% with 95% level of confidence the Z value equals 1.96. The estimated sample size will be:

$$\mathrm{n} = \frac{(1.96\,)^2}{(0.05)^2}[0.3(0.7)] \approx 322$$

From the data obtained from NBPE office as seen in Table 1 there are 37 kebeles in Ada’a woreda with households that have small scale biogas technologies.

Table 1: List of kebeles and number of biogas users in Ada'a Woreda. (Source: NBPE, 2017)

No.	Kebele	No. of users
1	Dire Sheiri	4
2	Dutelu	1
3	G/Gorba	53
4	Galedhertu	1
5	Garbicha	2
6	Gice	8
7	Gobasaye	11
8	Godino	8
9	Golba	1
10	Hidi	9
11	Kajima	4
12	Katila	21
13	Koftu	4
14	Kurkura	6
15	Tadacha	6
16	Ude	26
17	Wajitu	6
18	Y/Silase	1
19	Yatu	3

No.	Kebele	No. of users
20	Kebele 12	4
21	Kebele 14	3
22	Kebele 01	35
23	Kebele 02	17
24	Kebele 03	1
25	Kebele 05	12
26	Kebele 06	2
27	Kebele 08	3
28	Kebele 11	6
29	Kebele 12	1
30	Kebele 14	2
31	Kebele 15	2
32	Bakajo	3
33	Dambi	9
34	Dandi	4
35	Dhankaka	18
36	Dire	8
37	Dire Ararti	1

The study initially planned to collect data from 368 which is calculated by the sampling formula. From the 37 kebeles, the study purposively selected 9 kebeles with significant numbers of small scale biogas user households. As the researcher was bound by time and money constraints, the study was forced to choose 9 kebeles among the 37 kebeles in Ada'aworeda with relatively high number of biogas users from the other kebeles. From the selected 9 kebeles the researcher took all the 116 small scale biogas user households, keeping the criteria of currently active and users before 2015, for the purpose of this research. Unfortunately, during data collection phase of the research, information could only be obtained from 100 user households. As the study used propensity score matching to assess the impact of small scale biogas technology by comparing user and non-user households, the research doubled the number of non-users. It is however unfortunate the research couldn't keep the set sample size. This is as a result of some adopters has seized using the technology in the selected kebeles, and due to time, and budget constraints.

3.4.2. Sampling Techniques

9 kebeles were purposively selected where there are high number of biogas users. The study selected all the 116 small scale biogas technology users from the 9 kebeles. Using information obtained from NBPE, user households' kebeles were purposively selected. After obtaining the population size of the selected kebeles from Ada'a Woreda Water Mine and Energy Bureau, sample non-user households were selected using proportional sample determination. Each individual non-user household has been selected using simple random sampling method. The researcher selected 200 non-users using judgmental sampling by doubling the number of users.

Table 2 Proportional Sample Size determination in each sample kebeles.

Selected Kebeles Based on Biogas Users	Total Number of Households	How to Compute	Sample Size
01	17982	17982*200/53707	≈67
G/gobra	1437	1437*200/53707	≈5
Ude	4980	4980*200/53707	≈19
Gobasaye	5327	5327*200/53707	≈20
Katila	6227	6227*200/53707	≈23
Dankaka	6427	6427*200/53707	≈24
Godino	3499	3499*200/53707	≈13
Gice	2751	2751*200/53707	≈10
Dire	4961	4961*200/53707	≈19
Total	**53707**		**200**

3.5.Tools of Data Collection

The research used both quantitative and qualitative methods of data collection method. Quantitative data was collected directly from respondents using structured questionnaire. The researcher developed the questionnaire in English and translated into Oromo language. Qualitative information of the study was obtained through interview and focus group discussions. Secondary data was also obtained through the respective woreda's data base, review of relevant literature from internet and publications.

3.6. Data Processing and Analysis

Quantitative data obtained through survey questionnaire was entered in to computer for analysis using Microsoft Excel 2013. Accordingly, the data was edited, coded, and cleaned. The analysis part was conducted using both descriptive and econometric analysis. The propensity score matching model was analyzed using STATA 13.

3.6.1. Descriptive Data Analysis

Descriptive statistics mean, standard deviations, frequency and percentages were used using STATA software version 13. In addition to this, the statistical significances and the association of the dummy and continuous variables with the dependent variable were tested using chi-square and t-test. Moreover, data collected through key informant interviews and focus group discussions were analyzed using textual analysis.

3.6.2. Econometric Analysis

Propensity Score Matching (PSM)

When random assignment of treatment is not practicable to subjects, propensity scores are used as an alternate to approximate the effect of the treatment received (Thavaneswaran, 2008). In this study, this technique is used to analyze the data. PSM isused to identify the difference in outcome variable between biogas users and non-user households assuming the covariate have the same characteristics.

Rubin,(2011) defined PSM as the coupling of treatment and control components with comparable values on the propensity score, and other covariates, and removing the unmatched components. The primary use of PMS is compare two groups but can also be applied to more than two groups. As Li, (2012) defines it “PSM refers to a special procedure that uses propensity scores and matching algorithm to calculate the causal effect.”

PSM depend on identifying a group of treated individuals similar to the control. In this paper the main difference remains between households who use small scale biogas technology and non-user households.

Statistically the estimated propensity score $e(x_i)$, for subject $i,(i = 1,\dots, N)$ is the conditional probability of being assigned to a particular treatment given a vector of observed covariates x_i (Rosenbaum and Rubin, 1983):

$$e(x_i) = \Pr(z_i = 1|x_i) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1)$$

and

$$\Pr(z_1 \ldots\ldots z_n|x_1 \ldots\ldots x_{n)=} O_{i=1}^{N} e(x_i)^z \{1 - e(x_i)\}^{1-z} \_\_\_\_\_\_\_\_\_\_\_\_ (2)$$

Where:

$z_i = 1$ for treatment

$z_i = 0$, for control

x_i = the vector of observed covariates for the i^{th} subject

And

In randomized studies, covariates are variables that are not affected by the allocation of treatments to subjects.

Since the propensity score is a probability, it ranges in value from 0 to 1.

The main objective of the PSM is to substitute the many confounding covariates in an observational study with one function of covariates. The function (or the propensity score) captures the possibility of study participants receiving a treatment based on observed covariates. The projected propensity score is then used as the confounding covariate to adjust for all of the covariates that go into the estimation (Li, 2012).

When applying the matching estimate, two assumptions are made to estimate the average treatment on effected on the treated (ATT). Heckman *et al.*,(1997) proposed the conditional independence assumption (CIA), which implies that selection into the treatment group is solely based on observable characteristics (selection on observables).

One can estimate the ATT by subtracting the average treatment effect of the treated group from that of the control group at a particular propensity score.

$$ATT = E\{Y|T = 1, e(x)\} - E\{Y|T = 0, e(x)\} \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (3)$$

Under this method, a user household is compared with a nonuser household having the same characteristics and the difference in outcomes is evaluated. The study used a probit to estimate of observable characteristics will use predicted values from probit to generate propensity score $p(x_i)$ for all treatment and comparison group members (Pattanayak, 2009).

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + e \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (4)$$

As it is mentioned by Negussie et. al. (2016) “the challenge in any program evaluation is to quantify what would have happened to an actor's welfare or other outcome of interest had the program not been in place. In a randomized experimental design, the impact of a programmecan be estimated by a simple difference in means between treatment and control outcomes” (page 286).In before and after comparison the impact of program on the outcome indicators are measured by calculating the difference in outcome indicators before and after the intervention using statistical models (Rahman, 2017).

To see the impact biogas has on income and health of user households in comparison with non-users PSM was employed. As mentioned above PSM operates in 3 steps; first it finds the propensity scores then choses and appropriate matching algorithm then lastly estimate the effect of the treatment. The study used different matching algorithms, these are; nearest neighbor, radius, Kernel and stratification matching algorithms.

The nearest neighbor matching algorithm evaluates the difference between propensity scores of user and non-user households by taking the k nearest neighbors in the match. So more formally, define Aik as a set of k non-treated nearest neighbors.

$$A_i^k min \parallel p(X_i) - p(X_j) \parallel \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (5)$$

The treatment effects is then

$$E(Y_i^1 - Y_i^0 | p(X_i), T_i = 1) = \frac{1}{n^1} \sum_{i=1\{T_i=1\}}^{n^1} \left[Y_i^1(X_i) - \frac{1}{k} \sum_{i=1\{j \in A_i^k\}}^{k} w_{ij} \, Y_j^0 \right] \_\_\_\_\_\_\_\_\_ (6)$$

The other matching method instead of matching the nearest neighbors, this can match i to all controls within a certain radius r from p(xi)

$$A_i^k min\{p(X_i)| \parallel p(X_i) - p(X_j) \parallel < r\} \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (7)$$

The choice of r is arbitrary, but should be very small. The treatment effects is calculated:

$$E(Y_i^1 - Y_i^0 | p(X_i), T_i = 1) = \frac{1}{n^1} \sum_{i=1\{T_i=1\}}^{n^1} \left[Y_i^1(X_i) - \frac{1}{k} \sum_{i=1\{j \in A_i^k\}}^{k} w_{ij} Y_j^0 \right] \text{\_\_\_\_\_\_\_\_\_\_\_\_} (8)$$

Where is the relative weight of the matched unit in the set A_i^k:

$$W_{ij} = \frac{1}{k} if j \in A_i^k and W_{ij} = 0 \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (9)$$

The third matching method matches i to all controls in the range of common support. By specifying a weight for control units that is inversely proportional to the distance $\parallel p(xi) - p(xj) \parallel$. the treatment effects is then;

$$E(Y_i^1 - Y_i^0 | p(X_i), T_i = 1) = \frac{1}{n^1} \sum_{i=1\{T_i=1\}}^{n^1} [Y_i^1(X_i) - w_j(p(x_i))Y_j^0] \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (10)$$

Where $w_j(p(x_i))$ is determined by a kernel function

3.7. Description of variable

Dependent Variable (s):

Income: The first dependent variable is income of the household, the annual income of households messured in birr.

Health: The second dependent variable is health, it is represented by number days spent for fuel collection and total members of household that are victim by the illness

Cost of treatment: treatment of respiratory illness caused by IAP and chronic back pain related to heavy load.

Adoption of small scale biogas technology: is the third dependent variable**.**

Independent Variable (s):

Age of the household head- Young household heads tend to be more open to using new technologies rather than the older generation. Age will have a positive influence to adopt the technology.

Gender of the household head- In rural house household level energy women dominate the use of energy (Karekezi, 2002). Female headed households tend to be more open to adopt small scale biogas technology than the male headed ones. But the ownership of property plays a great role in rural areas as men tend to have property rights than women. It is expected sex of the head of the household to have either a positive or negative effect,

Household size- Large household may put greater pressure on the household resources. Thus, household size is expected to have positive influence on adoption of biogas technology.

Marital status of household head-Young couples will be more open to adopting new technology.

The number of livestock owned- The bio digesters need, four or more local breed cattle (two in the case of hybrid), (NBPE, 2014). In this regard the number of cattle will positively or negatively affect the adoption of the technology.

Education level of the head of household-. With the advancement of education there is a greater chance of adopting small scale biogas technology. Thus, the education level of the household head is expected to have a positive influence.

Farm land size- The bigger the size of the farm land owned by the household, there is high probability of adopting the technology. It is expected to have a positive influence on the dependent variable.

CHAPTER 4: RESULT AND DISCUSSION

In this chapter the results of the findings are interpreted and discussed in detail. In order to see the relationship between independent and dependent variables the study used both descriptive as well as econometrics analyses. Chi^2 and T-test were used to show if there is a statistical association or significant relationship between dependent and independent variables. To calculate the significant mean difference between small scale biogas technology user households and non-user households, if there is any, propensity score matching was used.

4.1. Descriptive Statistics and Discussion

4.1.1. Social-economic and Demographic Characteristics of Respondents

Table 3: Sample size of user and non-user households

Adoption	Number of household	Percent
User households	100	33.33
Non-user Households	200	66.67
Total	300	100

Source: own survey data (2018)

The above table shows the sample size of the selected households. A total of three hundred (300) households from 9 kebeles of Ada'a Woreda formed the sample of this study, and information was obtained from them. Among these, 200 (66.67%) comprised of households that had not adopted small scale biogas technology (non-user households) while 100 (33.33 %) households had taken up the technology (user households).

Table 4Descriptive Statistics of Dummy/Categorical Variables

Variable name	Users (n=100)	Non-users (n=200)	P-value
	Frequency (%)	Frequency (%)	
Gender of the Household			
Male	92 (92%)	184 (92%)	0.00***
Female	8 (8%)	16 (8%)	
Education Level			
Illiterate	10 (10%)	29 (14.5 %)	0.00***
Primary School	57 (57%)	113 (56.5%)	
Secondary School	24 (24%)	18 (9%)	
TVET and above	3 (3%)	2 (1%)	
Read and Write	6 (6%)	38 (19%)	
Marital Status			0.18
Married	92 (92%)	179 (89.5%)	
Separated/divorced	3 (3%)	2(1%)	
Widowed/widower	5 (5%)	19 (9.5%)	

Source: Own survey data (2018)

NB: ***p<0.01, **p<0.05, *p<0.1

From Table 5 it can be observed that, from the 100 small scale biogas technology user 92 (92%) households are headed by male member of the household while the remaining 8 (8%) are headed by female head households. Looking at the non-users from the total of 200 respondents, 184 (92%) household heads are male and while 16 (8%) are headed by female. Most households, both for users and non-users are male headed.

Comparing the educational status of user and non-user households, user households tend to be in a better educational position than that of non-users. Looking at the educational status of both user and non-user households from 100 user respondents 10 (10%) are illiterate, 6 (6%) can only read and write 57 (57%) have attended primary education 24 (24%) have reached secondary school and 3 (3%) are TVET level and above. On the other hand looking at the non- users 29 (14.5 %) are illiterate, 113 (56.5%) respondents halt their education at the primary level 18 (9%) have attended secondary school and 2 (1%) are at TVET level and above. While 38 (19%) respondents can only read and write. The above table also displays the marital status of the selected households. From 100 user households 92 are married, 3 are divorced/separated and 5 are widowed/widower. Looking at the non-users from 200 sample households 179 (89.5%) are married, 2 (1%) are separated/divorced and 19 (9.5%) are widow/widower.

The study looked at the continuous/discrete variables in more detailed manner. The following table listed the continuous variable in comparison between user and non-user households.

Table 5Continuous/discrete Variables

	Total Sample		**Adopters**		**Non-Adopters**		
Variable name	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	T-Value
head_age (year)	44.72	11.93	40.80	12.15	46.68	11.35	4.13***
H_hsize (number)	5.37	1.27	4.55	1.08	5.78	1.16	8.82***
Income	81010.93	38051.78	102057.1	37376.83	70487.87	33862.48	-7.35***
Livestock _TLU	4.04	2.17	5.30	1.87	3.40	2.03	-7.82***
Distance to market (KM)	5.65	3.63	3.16	1.46	6.89	3.75	9.58***
Agriculture land size	1.25	-850718	1.35	-6203071	1.19	-9420674	-1.5314

Source: Own survey data (2018)

NB: ***p<0.01, **p<0.05, *p<0.1

Variables that provides information to explain respondents' personal and demographic characteristics (age, gender, marital status, level of education and occupation) and socio-economic characteristics (income, livestock, etc.) are called household characteristics. This characteristics may have positive or negative influence on the adoption and use of small scale biogas technology. Below is a detailed description of each variable in terms of using small scale biogas technology.

Household age and using small scale biogas technology

The average household age of the total 300 sample households is 44.72. The mean age of the user household heads (40.8 years) differed significantly with the mean age of non-users household heads (46.68 years). The mean age of user households is quite less than that of the non-users. This mean variation was found to be statistically significant with t-value of 4.13; and, this t-value shows there is significant difference between the mean age of users and non-users at ($P<0.01$) level of significance. Age can therefore be argued to have been a key in using small scale biogas technology. As it can be seen user households are relatively younger comparing to their counterparts.

Household size and using small scale biogas technology

From Table 6it can be seen that the average family size for the 300 sample households is 5.37. Average family size is 4.55 and 5.77 for the user and non-user households respectively with standard deviation of 1.08 for users and 1.16 for non-users. The mean difference was found to be statistically significant with t-value of 8.82. The t-value implies that there is a significant difference between the mean family size of the small scale biogas technology user and non-user households at ($P<0.01$) level of significance.

Household income and using small scale biogas technology

Table 6 revels the mean annual income of user households (102057.1 ETB) is much higher than that of the non-users (70487.87 ETB). Income of household head was found to be a significant factor in the adoption of the biogas. As rearing of animals is an important source of income, the survey results show that small-scale biogas technology users have a large number of livestock than that of non-user, making their income higher.

Household Livestock and small scale biogas technology

The survey results show, small-scale biogas users have an average of 5.3 livestock owned, while the figure for non-users is 3.4. This mean difference in livestock ownership is significant at the 1% level. The mean livestock ownership for the total 300 user and non-user households is 4.04, indicating both biogas users and non-users own at least four or more cattle. The mean difference between user and non-users was found to be statistically significant with t-value of -7.82 implying the the mount of livestock owned by a household determines the adoption of small scale biogas technology. This finding aligns with NBPE requirement of at least four cattle to start establish a biogas plant at a household level.

Distance to market and using small scale biogas technology

The average distance travelled by a household to reach to the nearest market place is 5.65 km. while it is 3.16 km. for users and 3.75 km. for non-users. The result of sample t-test shows that there is statistically significant mean difference between users and non-users with a t-value of 9.58 with 1% significant level. The closer a household is to a market place the more informed the household becomes. The result of the survey shows that users are closer to market place than the non-users indicting they are more close to information and technology.

Household agricultural land size and small scale biogas technology

Table 6 shows the average agricultural land size for the total sample household is 1.25 hectare while being 1.35hectare and 1.19 hectare for users and non-users respectively. The result revealed, agricultural land size don't have any significance in using small scale technology. This finding is contrary to several studies which holds land size farm statistically significant to adopting biogas technology.

4.1.1. Reasons for adopting and not adopting small scale Biogas technology

Sample households were asked the reason why they chose to install small sale biogas technology, what they like most about it and why they dislike most about the technology. Below the discussion is presented in detail.

Table 6 Reasons to installation biogas technology

Reasons	Responses	
	Number	Percent
Subsidy	2	0.7%
Affordable	23	8.4%
Health benefit	30	10.9%
Environmental benefits	21	7.7%
Economic benefit	23	8.4%
Saves fuel	66	24.1%
No smoke	71	25.9%
Durability	6	2.2%
Cooks quickly	12	4.4%
To use farm wastes	10	3.6%
Bio slurry	10	3.6%
Total	274***	100.0%

Source: Own survey data (2018)

*** Multiple response of reasons to install

User households were asked what motivated them to install the small scale biogas technology. The reasons for adopting small scale biogas technology includes; subsidy form the government; relatively cheap comparing to other fuel sources; considering the health, economic and environmental benefits; as it saves fuel; as a result that it doesn't produce smoke; its durability; the fact that it cooks quickly; as it effect uses waste from farm and produces compost for farm use. From the 100 user household respondents, the majority 71 (25.9%) installed small sc.ale biogas technology as the technology doesn't produce and smoke. 66 (24.1) respondents install the technology as it saves time. Same number of respondents, 23 (24.1%) chose to install small scale biogas technology for its economic benefit and relatively cheaper to other fuel sources. Considering the health benefits 30 (10.9%) respondents were interested to adopt the technology. Looking at the environmental benefits 7.7 % (21) respondents were motivated to adopt the technology. 3.6% (10) respondents chose to adopt the small scale biogas technology to properly make use of the the animal wastes and to make use of the bio-slurry. As a result of the durability of the technology 6 (2.2%) of the respondents chose to install the technology. 4.4% (12) households preferred the technology as it cooks quickly comparing to the conventional fuel source. From the hundred sample households 2 households (0.7%) adopted the technology as a result of subsidy.

Table 7 Reasons for liking small scale biogas technology

Reason	Responses (Yes)	
	N	Percent
Cooks quickly	19	7.7%
Saves firewood	62	25.2%
Saves time from collecting firewood	32	13.0%
Portable	48	19.5%
Durability	14	5.7%
No smoke	34	13.8%
Provide clean environment	12	4.9%
Doesn't itch eyes	19	7.7%
Safe to use	6	2.4%
Total	246***	100.0%

Source: Own survey data (2018)

*** Multiple response

When user households were asked about what they like most about the small scale biogas technology majority, 62 (25.2%) mostly like it as it saves firewood. As the biogas stove can be moved easily 48 (19.5 %) respondents like the portability of the technology. Considering the time saved collecting fire wood 32 (13.0%) user households preferred the technology. 13.8% (34) user households like using the technology as it doesn't create smoke while in use. The technology providing a clean environment and the fact that it is safe to use was liked by 12 (4.9%) and 6 (2.4%) respondents respectively. 7.7 % (19) user households like how the technology cooks meals quickly and the same amount of respondents like how it doesn't cause eye itching as a result of a smoke while cooking. 14 (5.7%) like the technology as it is very durable and long lasting.

Table 8 reason for disliking small scale biogas technology

Reasons	Responses	
	N	Percent
It is expensive	204	27.8%
Does no save firewood	35	4.8%
It cooks slowly	18	2.5%
There is nowhere to repair	104	14.2%
It requires attention	40	5.5%
It requires dung	51	7.0%
It is prone to accidents	6	0.8%
Dislike technology	15	2.0%
Produces insufficient energy	260	35.5%
Total	733	100.0%

Source: Own survey data (2018)

Both users and non-users were asked why and what they don't like about the technology. It was found out producing insufficient energy has made the technology unfavorable by 35.5 % of the respondents. The other limiting factor with 27.8% respondents reported that the technology is expensive. Respondents who are using the technology mentioned that, even though they are using biogas they are still mixing it with other fuel sources like wood and crop residues. 104 respondents (14.2%) don't like it as it is difficult to maintain it when the stove or the digester broke down. The small scale biogas technology is also unpopular as a result it doesn't save fire wood, cooks slowly and requires due attention among 4.8%, 2.5 % and 5.5 % of user and non-user households respectively. As the digester needs dung and the dang needs to be mixed with water 7% (51) respondent households dislike that about the digester. Only 6 respondent households does not like the technology fearing that it likely to cause accidents. From the total 300 sample user and non-user households 15 (2%) households like everything about the small scale biogas technology.

4.2. Econometrics Analysis

4.2.1. Propensity Score Matching method for the impact of biogas technology

4.2.1.1. Model Diagnosis Test

To compare the outcome of treated and non-treated groups, propensity score matching is the best option for the observational survey. Because the observational survey considers the same characteristics in both treated and non-treated group. Thus, before estimating the impact of biogas technology on household income and health, a good balancing and common support (overlapping) of the covariate variables is necessary.

Variable name	Coefficient	P-value
Age of the household head in years	.0070762 (.0095257)	0.458
Gender of the household head	.4792297 (.410461)	0.243
Household size	-.7792267 (.112306)	0.000***
Marital status of household head	-.11584 (.1568421)	0.460
Number of livestock owned by the household in TLU	.3474374 (.0500453)	0.000***
Educational status of household head	-.0066889 (.003379)	0.048***
Agricultural land size in hectare	-.0042543 (.1247697)	0.973
Constant	1.43621 (.6155342)	0.020**
Number of observation	300	
Pseudo R^2	0.3821	
LR-chi-square	145.94	
Log Likelihood	-117.98584	

Table 9 Estimation of propensity score: Probit Model

* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

According to Table 14 the estimation of propensity score using probit model result revealed, there is a good overlap indicating the common support condition is satisfied. Based on the estimated propensity score result in each covariates such as, household size, number of livestock,owned educational status of household headandby the household in TLU, with the P-value of 0.000 and 0.048. It is statistically significant.

As it can be observed from the figure below every treated and non-treated groups have a common support between each other. Hence, there is an overlap between treatment and non-treatment groups. The other assumption to estimated propensity score matching is that the balancing property should be satisfied. Here the balancing property is satisfiedforthe estimated propensity score. (See the appendix). Both balancing and overlap of the covariate variables between treated and non-treated groups are the same for both income and health aspect of small scale biogas technology as they have the same independent variables for income and health aspects. Accordingly, these common covariate variables are age of household, family size, education level, TLU (tropical livestock unit), and land size are used under these models.

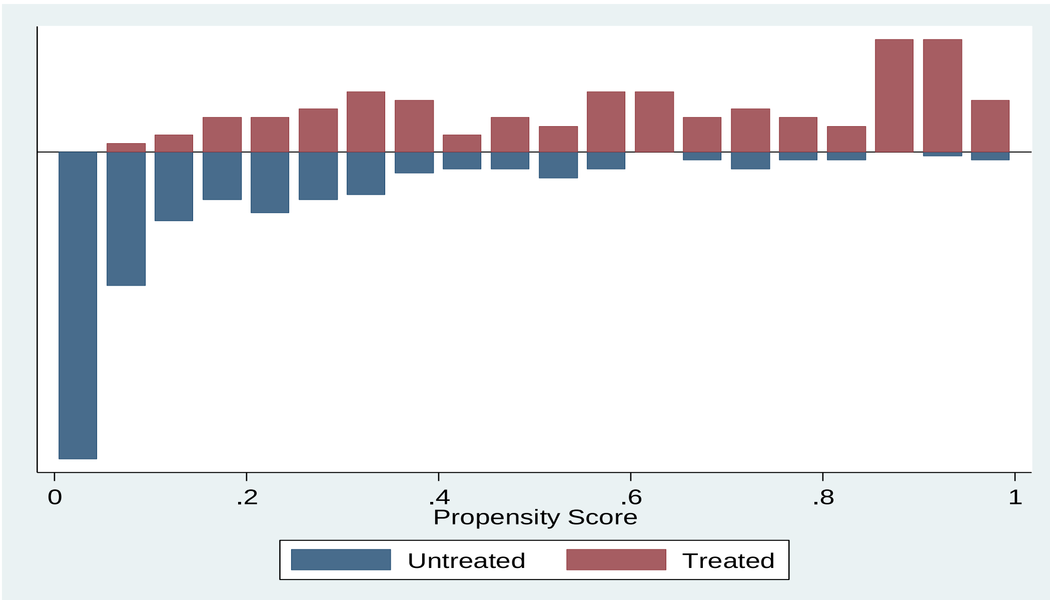

Figure 5 common support treatment and untreated group

4.2.2. Impact of biogas technology on income level of the household

Biogas technology have an advantage on the income level of the household. Many researches focus on the factors affecting biogas technology adoption; however,in this research the researcher is saw the impact of biogas technology on household income. In this section, to see whether the adoption of small scale biogas technology has an impact on user and non-user households or not, the researcher used propensity score matching method. The propensity score matching shows whether the treatment have positive impact or not. The below table below shows the average treatment effect on treated group as result of adoption of biogas technology.

Table 10 The average Treatment effect on Treated (ATT)-Income.

Type of matching method	Users	Non-users	ATT	Std. Err.	T-value
Nearest Neighborhood	100	43	17672.1	8249.2	2.1*
Radius matching	100	113	25442.7	5968.5	4.3*
Kernel matching	100	113	17920.2	9961.5	1.8
Stratification method	100	113	18686.1	8652.3	2.2*

Source: computed from own survey (2018)

NB: *statistically significant

To identify the impact of biogas technology on households' income four matching methods were used. These methods are; nearest neighborhood, radius, kernel and stratification matching methods. As we observe in Table 15, the average treatment effects on treated with nearest neighborhood matching method; the treatment group is 100, while the number of control is 43 after matching. Neighborhood matching method reveals the difference of average income of 100 treatment groups and the average income of 43 control groups is 17672.1ETB annually. Therefore, 17672.1 ETB is the average treatment effect on treated group which is the effect of biogas technology on income level of the households. Thus, user households can earn additional income than that of non-user household. The average treatment effect of the treated group shows positive impact. This implies adopting small scale biogas technology increases the income of a household. This result is also statistically significant at t-value of 2.1. Therefore, adopting biogas technology have a positive impact on the income of households with neighborhood matching method.

The same result is obtained from radius matching methods. Under this method, the total number of treated group is 100 while the number of control is 113 after matching. The difference in average income between treated and non-treated group 25442.7ETB per annum. This result is the average treatment effect on the treated group. This implies adopting small scale biogas technology has a positive impact.According to this result, user households earn more income than that of non- users. It is also statistically significant at t- value of 4.3. Therefore, under radius method adoption biogas technology have a positive impact in increasing income level of households.

The other matching method to see the impact of biogas technology on household income is with kernel matching method. It also shows adopting biogas in the study area has a positive impact on household income. Under this matching method, the average treatment effect of biogas on treated group, on average, earns additional income of 17920.2 ETB yearly. Meaning, the difference in average income between the control and the treatment group is the effect of adopting small scale biogas technology. So this method shows positive impact even if it is statistically not significant.

The final method to see the impact of adopting small scale biogas technology on household income is stratification matching method. This method reveals, the adoption of small scale biogas technology has a positive impact on the income level of the household. It is also statically significant at T-value 2.2.This indicates that, the difference in the average income between the 100 treated group and 113 non treated group shows the treatment group has difference in average income.

Consequently, the result from the four matching methods reveals, adopting small scale biogas technology has a positive impact on the households' income. This might be as a result of households engaging in different livelihood diversification activities like petty trade, allocating more time on agricultural activities; engaged in selling local alcohol selling or generate income from bio-slurry and so on.

A study done by SNV (2013), in Uganda supports the finding of this study where by biogas user households are selling bio slurry and earing extra income. Also they are using the bioslurry to improve farm production. A study in Bangladesh Chakrabarty et al. (2013) found out that by using small scale biogas technology women were able to engage in income generating activities that boosted the household's income. Ramani and Rajshekar (2010) in a study done in India it wasfound out women started engaging in income generating activities since start they start using biogas, as it has has reduced their time of wood collection. Gulbrandsen (2011), in her study about the development and sustainability of biogas found out farmers in Njombe District, Tanzania, has increased their income by saving kerosene expenses, which in turn led to increased purchase power.

4.2.3. Impact of small scale biogas technology on health

To see the health benefit of biogas technology, three outcome variables were taken into account. These three outcome variables are estimated independently to estimate biogas's impact on health. For example, to estimate the average cost of treatment, firstly the study estimated the propensity score matching of being medically treated for the control groups. After that, the four matching methods were undertake to see whether adopting small scale biogas technology has positive impact or not. The outcome variables are; cost of the treatment for the victims in the households; the number of days spent for fuel collection per week and; total members of the household affected by indoor air pollution (IAP). These outcome variables are directly related with the health status of the household. The estimation of average treatment effect on the treated group is based on four matching methods such as nearest, radius, kernel, and stratification as seen in table 16.

Table 11 Average Treatment Effect on Treated- health

	Kind of matching method	treat.	contr.	ATT	Std. Err.	T-value
Cost of treatment	Nearest	100	43	-320.2	80.9	-4.0*
	radius	100	113	-392.5	65.2	-6.0*
	Kernel	100	113	-339.2	44.3	-7.7*
	stratification	100	113	-332.8	41.5	-8.0*
Number days spent for fuel collection	Nearest	100	43	-1.5	0.3	-5.9*
	Radius	100	113	-1.4	0.1	-9.9*
	Kernel	100	113	-1.3	0.2	-5.4*
	Stratification	100	113	-1.3	0.2	-5.6*
Total members of household that are victim by the diseases	Nearest	100	43	-1.2	0.2	-7.2*
	Radius	100	113	-1.2	0.1	-12.8*
	Kernel	100	113	-1.2	0.1	-8.6*
	Stratification	100	113	-1.2	0.2	-7.4*

Computed from own survey (2018)

*Statistically significant

As it is shown in the Table 16, the total number of treated group after matching 100 while for control group 43. Under nearest matching methods, the difference in average cost for treatment between treated and non-treated is 320.2 ETB. This is obtained from the data gathered from households regarding illnesses related with reparatory disease, diarrhea, backbone pain, eye in the last 12 months. Additionally, if households have incurred cost of treatment as a result of diseases associated with indoor air pollution. Sample households were asked if the mentioned illness have occurred in the last 12 months and if they have incurred costs for treatment or not. Thus, the result shows that non-users are more prone to indoor air pollution and they have also incurred additional cost of treatment. This implies user households have in curredless cost of treatment than non-user for indoor air pollution. The nearest matching method shows that about 100 treatment groups while 43 control group after matching. The effect is negative 320.2 ETB. This implies the users saved 320.2 ETB as a result of using small scale biogas technology. While non-users incurred an average of 320.2 ETB. This shows the impact of not adopting small scale biogas technology on non-users. This could be the result of users houses are less smoky than that of non-users. This result is the same for radius, kernel and stratification matching method. So as it is shown in the Table 16 the average treatment on treated group shows the difference of average cost of treatment between the control and treatment group is a negative result. Moreover, the average treatment on the treated group is 392.5, 339.2 and 332.8 per annum under radius, kernel and stratification matching method respectively. The result is statistically significant at t-value of 6.0, 7.7 and 8.0 respectively under the three matching methods. Therefore, the negative sign implies less cost of treatment for those of user households than non-users of small scale biogas technology. Finally, adoption of small scale biogas technology, besides reducing medical cost of a user household it also mitigates the likelihood to be affected by different diseases. With the reduction in medical cost a household might shift the saved cost to other household expenses like food expenses.

While one of the major cause of chronic disease is the number of days spent on fuel collection. And backbone pain can be related to the number of days spent for fuel collection and carrying heavy loads. To see if there is a mean or average difference in the outcome variables between treated and non-treated groups the four matching methods were utilized. As it is see from Table 16, in the four matching cases the average difference in number of days spent for wood collection for treated and control groups have difference. The average treatment on the treated group has a difference, implying that the propensity score matching reveals, the mean difference between the treated and non-treated is -1.5, - 1.4, - 1.3 and -1.3 using nearest, radius, kernel and stratification method of matching respectively. The negative sign implies that the treated group spent less days collecting fuel wood than that of the control group. In other terms, on average the treated group saves 1.5, 1.4, 1.3 1.3 days per week spent on wood or fuel collection as a result of small scale biogas technology. The treated group spends less time collecting fuel wood reducing their probability of being affected by chronic diseases than that of the control groups. Therefore, the average treatment on the treated group reveals that biogas adoption has a positive impact on the health status of the household. It is also statistical significant at t-value of 5.9, 9.9, 5.4 and 5.6 under nearest, radius, kernel and stratification method of matching respectively.

Lastly, the study looked at member of households affected by illnesses in the last 12 months. To see the impact of biogas technology, the researcher asked whether there are affected people in the household or not. And the total number of people affected in the past 12 month. As it is shown in Table 16 the number of treated groups are 100 while the number of control groups are 43 under nearest and 113 for radius, kernel and stratification matching method. The average treatment on the treated groups shows negative effect. The difference of the average victims of the household members for treated and non-treated group gives average treatment effect on the treated group. Thus, the average treatment effect on the treated group under nearest methods is 1.2 and it is also negative. Which is, about 1.2 members in the household are affected by disease for the control groups. Or 1.2 peoples or members in the households are less affected by illnesses as a result of IAP in the households for biogas user. This result is the same under radius, kernel, and stratification matching method. Therefore, adoption of biogas technology decreases the number of affected peoples by IAP in households. It is also statistically significant at t-value of 7.2, 12.8, 8.6 and 7.4 under nearest, radius, kernel and stratification matching methods.

The findings of this survey correspond with Bajgain and Shakya (20005), study in Nepal where households decreased IAP greatest by using biogas technology. Mulu, 2016 in a study in Northern Ethiopia, Ofla and Mecha woredas found out that using biogas technology significantly improved the health and sanitation of the sample households. Negussie et. al. (2016), investigated in their study in Northern Tigray that the average treatment effect results showed small scale biogas technology users immensely reduced of IAP related illness in relation to non-user supporting the finding of this study. Grabham (2015), investigated renewable energies as a driver for grassroots development in rural Rwanda and found out biogas plants significantly reduced IAP. This was specially observed in young children and elderly people. Ramani and Rajshekar (2010) in their report on Renewable Energy for Rural Livelihoods Project in India indicated households using biogas technology have saved time and cash and avoided IAP caused by fuel wood. They also found out women started engaging in income generating activities since using biogas has reduced their time of wood collection.

Chapter 5: CONCLUSIONS AND RECOMMENDATION

5.1. Conclusions

As Ethiopia is striving hard to maintain a net zero emission by 2025, working on renewable energies is worthwhile. Achieving the SDGs can be done by assessing what has been done at the ground level and learning from what has been accomplished so far. Biogas energy has a huge potential to minimize the drudgery of women, the impacts of health that comes from fuel wood collection and conventional fuel related illnesses at the rural areas. As biogas generates clean and renewable energy, it can be a tool to achieve the sustainable goals. Goal one states to eradicate poverty form its root, in this regard biogas can play and is playing a considerable role as user households saved time and using the saved time to engage in income generating activities and allocating time to work on their farm for better production. From the result obtained by this survey the health of user households has improved significantly since they start using small scale biogas technology. Looking at the gender aspect, Goal 5, using small scale biogas technology has reduced the work load of women as a result diverted their time to IGA or social matters.

This study was conducted to see the impact of small scale biogas technology on house welfare particularly focusing on the health, income and gender aspect, in Ada'a woreda, Oromia region. The research is a quasi-experimental study where it compared user and non-user households. In total the study took 300 sample households, 200 non-user and 100 user households from 9 kebeles of the woreda.

Different characteristics and factors were considered for user and non-user households to determine the effect biogas has on user households. These characteristics were categorized as personal and demographic, gender factors, income, and health were analyzed accordingly. The result of the study showed most of the households, both user and non-user households, are headed by male member of the family and influence the decision to adopt small scale biogas technology. The user households are relatively younger comparing to their counterparts

The survey results show that small-scale biogas technology users have a large number of livestock than that non-user making their income higher making this finding aligns with NBPE requirement of at least four cattle to start establish a biogas plant at a household level. From the findings distance to market plays a great role in dissemination of information, users are closer to market place than the non-users indicting they are more close to information and technology.

User households were asked why they chose to adopt the technology, most users chose to adopt as a result the technology doesn't produce smoke followed by time saving. Respondents mentioned reasons like economic benefit and relatively cheaper compared to other fuel sources, health benefits, and environmental benefits, to properly make use of the animal wastes and to make use of the bio-slurry, durability of the technology as reasons why they chose the technology.

Looking at the gender aspect of using small scale biogas technology, the finding reveled that, using the technology has improved the lives of women by reducing the time spent in the kitchen, by reducing the work load and diverting the newly invented time to their families and income generating activities. However they are still using crop residues for baking injera as they don't have biogas mitad although, there is enough energy to go around. This lines up with the energy stacking theory as they are using also crop residue along with biogas.

To identify the impact of biogas technology on households' income the study used propensity score matching model. The model used four matching methods; these methods are; nearest neighborhood, radius, kernel and stratification matching methods. The four matching methods reviled small scale biogas technology has an impact on income. For example neighborhood matching method reveals the difference of average income of 100 treatment groups and the average income of 43 control groups is 17672.1 ETB annually. Therefore, 17672.1 ETB is the average treatment effect on treated group which is the effect of biogas technology on income level of the households. The average treatment effect of the treated group shows positive impact. This implies adopting small scale biogas technology increases the income of a household. This result is also statistically significant at t-value of 2.1. Therefore, adopting biogas technology have a positive impact on the income of households with neighborhood matching method.

Like income, to see the health benefit of biogas technology, three outcome variables were taken into account; cost of the treatment for the victims in the households; the number of days spent for fuel collection per week and; total members of the household affected by indoor air pollution (IAP). Based on the estimation of the four methods, small scale biogas technology as an impact on health. Looking at nearest neighborhood matching methods, the difference in average cost for treatment between treated and non-treated is 320.2 ETB. per annum. This indicates non-users incur an average of 320.2 ETB compared to their user counterparts.

5.2. Recommendation

Based on the findings of this study, the following recommendations are forwarded.

- As the innovation has an extraordinary potential in advancing manageable and sustainable power source, much exertion ought to be done in advancing of the innovation.
- Linkage between NGOs, donors and policy makers should be created and/or be strengthen to benefit from the full potential of biogas.
- Mechanisms and techniques should be in place for the rural poor to take advantage of benefits of biogas technology.
- Setting up easy referral systems where user households can go when they face difficulties, maintenance issues and spare parts.
- For encourage advancement of the biogas innovation, consideration ought to be given towards engaging females and female-headed families, enhancing instructive levels of the family heads, and families' entrance to credit and salary levels.
- Ada’a Woreda Water, Mine and Energy Bureau should work with stakeholders to provide users with biogas injera mitad (stove) to use the full potential of the biogas, as this can be seen as a motivator to attract non-user households.

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Appendix

Appendix 1: Propensity Score Matching (PSM) and Average Effect with Matching Effect

```
. pscore adopter head_age sex hhsize marital final_TLU education agland , pscore(psincome) blockid(blockf1) comsup level(0.001)


****************************************************
Algorithm to estimate the propensity score
****************************************************


The treatment is adopter

    adopter |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |        200       66.67       66.67
          1 |        100       33.33      100.00
------------+-----------------------------------
      Total |        300      100.00


Estimation of the propensity score

Iteration 0:   log likelihood = -190.95425
Iteration 1:   log likelihood = -125.68834
Iteration 2:   log likelihood =  -118.4383
Iteration 3:   log likelihood = -117.98863
Iteration 4:   log likelihood = -117.98584
Iteration 5:   log likelihood = -117.98584

Probit regression                                 Number of obs   =        300
                                                  LR chi2(7)      =     145.94
                                                  Prob > chi2     =     0.0000
Log likelihood = -117.98584                       Pseudo R2       =     0.3821

------------------------------------------------------------------------------
     adopter |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    head_age |   .0070762   .0095257     0.74   0.458    -.0115939    .0257463
         sex |   .4792297    .410461     1.17   0.243     -.325259    1.283719
      hhsize |  -.7792267    .112306    -6.94   0.000    -.9993425   -.5591109
     marital |    -.11584   .1568421    -0.74   0.460    -.4232449    .1915649
   final_TLU |   .3474374   .0500453     6.94   0.000     .2493504    .4455244
   education |  -.0066889    .003379    -1.98   0.048    -.0133117   -.0000661
      agland |  -.0042545   .1247697    -0.03   0.973    -.2487987    .2402896
       _cons |    1.43621   .6155342     2.33   0.020     .2297853    2.642635
------------------------------------------------------------------------------


Note: the common support option has been selected
The region of common support is [.06778348, .97458351]
```

```
Description of the estimated propensity score
in region of common support

                 Estimated propensity score
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0724205       .0677835
 5%     .0931231       .0710018
10%     .1107681       .0724205       Obs                 213
25%     .2163202       .0729904       Sum of Wgt.         213

50%      .373821                      Mean           .4544803
                        Largest       Std. Dev.      .2814882
75%      .700061       .9664445
90%     .8997541         .96913       Variance       .0792356
95%     .9416067       .9700513       Skewness       .4244037
99%       .96913       .9745835       Kurtosis       1.869123


******************************************************
Step 1: Identification of the optimal number of blocks
Use option detail if you want more detailed output
******************************************************


The final number of blocks is 5

This number of blocks ensures that the mean propensity score
is not different for treated and controls in each blocks



**********************************************************
Step 2: Test of balancing property of the propensity score
Use option detail if you want more detailed output
**********************************************************


The balancing property is satisfied


This table shows the inferior bound, the number of treated
and the number of controls for each block
```

Inferior of block of pscore	adopter 0	adopter 1	Total
.0677835	42	7	49
.2	40	22	62
.4	18	19	37
.6	8	18	26
.8	5	34	39
Total	113	100	213

```
Note: the common support option has been selected


*******************************************
End of the algorithm to estimate the pscore
*******************************************

.
end of do-file
```

Neighbor Matching

```
. attnd averageincome adopter,pscore(psincome) consup


 The program is searching the nearest neighbor of each treated unit.
 This operation may take a while.



ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT    Std. Err.         t
---------------------------------------------------------

      100          43   17672.124     8249.191     2.142

---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches

.
end of do-file
```

Radius matching

```
. attk averageincome adopter,pscore(psincome) comsup bootstrap


 The program is searching for matches of each treated unit.
 This operation may take a while.



ATT estimation with the Kernel Matching method

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

      100         113   17920.145           .           .

---------------------------------------------------------
Note: Analytical standard errors cannot be computed. Use
the bootstrap option to get bootstrapped standard errors.




Bootstrapping of standard errors

command:      attk averageincome adopter , pscore(psincome) comsup bwidth(.06)
statistic:    attk       = r(attk)

Bootstrap statistics                              Number of obs    =       300
                                                  Replications     =        50

------------------------------------------------------------------------------
Variable      |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
--------------+---------------------------------------------------------------
         attk |    50  17920.14 -2912.105  9961.516   -2098.27   37938.56   (N)
              |                                      -4461.353   32243.53   (P)
              |                                       -1480.64   34541.95  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected


ATT estimation with the Kernel Matching method
Bootstrapped standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

      100         113   17920.145    9961.516       1.799

---------------------------------------------------------

.
end of do-file
```

```
. attr averageincome adopter,pscore(psincome) comsup radius (0.1) bootstrap


 The program is searching for matches of treated units within radius.
 This operation may take a while.



ATT estimation with the Radius Matching method
Analytical standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

      100         113   25442.676    5003.591       5.085

---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius




Bootstrapping of standard errors

command:      attr averageincome adopter , pscore(psincome) comsup radius(.1)
statistic:    attr       = r(attr)

Bootstrap statistics                              Number of obs    =       300
                                                  Replications     =        50

------------------------------------------------------------------------------
Variable      |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
--------------+---------------------------------------------------------------
        attr  |    50  25442.68   -136.94  5968.463    13448.6   37436.75   (N)
              |                                       12825.23   35497.75   (P)
              |                                       12825.23   35497.75  (BC)
------------------------------------------------------------------------------
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected



ATT estimation with the Radius Matching method
Bootstrapped standard errors

---------------------------------------------------------
n. treat.   n. contr.         ATT   Std. Err.           t
---------------------------------------------------------

      100         113   25442.676    5968.463       4.263

---------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius


.
end of do-file
```

Average treatment efffect with kernel matching

Average treatment effect with stratification method

```
. atts averageincome adopter,pscore(psincome) blockid (blockf1) comsup bootstrap
```

ATT estimation with the Stratification method
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
100	113	18686.138	9622.999	1.942

Bootstrapping of standard errors

```
command:      atts averageincome adopter , pscore(psincome) blockid(blockf1) comsup
statistic:    atts       = r(atts)
```

Bootstrap statistics		Number of obs	=	300
		Replications	=	50

Variable	Reps	Observed	Bias	Std. Err.	[95% Conf.	Interval]	
atts	50	18686.14	3360.415	8652.254	1298.783	36073.49	(N)
					5739.94	38123.78	(P)
					4325.277	31637.61	(BC)

```
Note:  N   = normal
       P   = percentile
       BC  = bias-corrected
```

ATT estimation with the Stratification method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
100	113	18686.139	8652.254	2.160

Appendix 2: Conversion factor for TropicalLivestockUnit (TLU)

AnimalCategory	**TropicalLivestockUnit (TLU)**
Ox	1.10
Cow	1.00
Heifer	0.50
Bull	0.60
Calves	0.20
Sheep	0.01
Goat	0.09
Donkey	0.50
Horse	0.80
Mule	0.70
Poultry	0.01

Source:Storck,etal.(1991)

Appendix 3: Questionnaire for Biogas User Households

Name of interviewer…………………………………………………………………….

Date of interview…………………………..

Duration of the interview………………………….

Kebele: ……………………………..

This questionnaire is prepared to collect data for the research paper entitled: *"The Impact of Small Scale Biogas Technology on Household Welfare in Ada'a Woreda, Oromia Region, Ethiopia."* The overall objective of the study is to assess the outcome of small scale biogas technology on the welfare of rural households by comparing users with non-users in Adea woreda in Oromia Region

The researcher, after receiving informed oral consent from you, would like assure that the confidentiality of the information shared and your name will be kept anonymous.

Direction: you are kindly requested to provide the right answer for the following questions. You have the right to fully /partially refuse or withdraw from participation. All your responses will not to be disclosed. Thank you for expressing your interest again.

A. HOUSEHOLD DEMOGRAPHIC INFORMATION

No	Name	Sex	Age	Educational Status	Marital Status

Sex- (Male 0 Female 1) Education-(Illiterate 0, read and write 1, Grades) Marital status- Married

B. Sample Households' Assets and Income Sources

Livestock Type	**Total livestock available on hand rightnow**	**Quantity sold**	**Distance to productmarket (km)**	**Value of productssold (Birr)**
Cow				
Ox				
Heifer				
Bull				
Calf				

0, Single 1 separated/divorce 2, widowed/widower 3

1. livestock (Last one year)

Goats				
Sheep				
Poultry				
Donkey				
Dairy Products (liters sold per				
Eggs (crates sold perweek)				
Others				

2. Crop production

Main crops/vegetables	Plot size per crop in hectare	Production (last season)	Consumption (quintals)	Sold amount (quintals)	Value of products sold

3. Additional income

Source of income	Amount	
	monthly	Yearly
Remittance:		
private business:		
Salary:		
Pension:		
Daily labour:		
Others		

C. FUELWOOD SOURCES AND CONSUMPTION PATTERNS

1. Sources of fuelwood

Energy Type	Average daily consumption	Amount used in

Firewood Sources	Amount in Kg	Average distance to source of fuel per KM	Number of trips per week to each sources
Collected from Forests			
Purchased			
Charcoal			

2. Energy consumption

	Amount	Unit	Price	Cooking	Lighting	Others (Specify)
Biogas (hour)						
Firewood (Kgs)						
Charcoal (kgs)						
Crop Residues						
Dry animal Dung						
Electricity						
LPG gas						
Kerosene (Litres)						
Others (Specify)						

D. ACCESS TO WATER RESOURCES

1. Which is your main source of water?

0=Private well water 1=Private hand pump water 2=Private tap water 3=Community well water 4=Community hand pump water 5=spring water

6=River 7=Pond water 8=others, specify ________________________________

2. On average, how many minutes do you walk from home to water source per trip? ______
3. Is the water source reliable? 1=Yes, 0=No

E. Biogas Installation Decision

1. Are you currently using biogas technology? 1=Yes 0=Not
2. Are you aware of what biogas technology is? 1=Yes 0=No
3. If No to Q. 2 are you aware of its benefits? 1=Yes 0=No
4. If No to Q. 2, why are you not using the biogas? 0= lack of awareness 1= lack of initial capital 2=access to loan facilities 3=not enough cattle 4= lack of information 4=other (Specify)
5. How did you learn about biogas technology? (more than one choice is allowed)

   0= Government/NGO, 1 =TVs/Radio/ Newspapers, 2= Friend/neighbor, 3 = Exhibition/promotion, 4= one to five network 5=other: (specify)
6. Do you have access to credit services? 1=Yes, 0=No
7. Did you take a loan to install biogas plants? 1=Yes, 0=No
8. If yes to Q 7 who provided the loan to you?

   0=Family member or friend 1=Bank/ (micro finance institutions) MFIs 2=Savings + Credit Union 3= Government

   4=Other_____________________________________

9. If not taken loan, why did you not take a loan to help pay for your biogas system?
   0=You had enough cash already so didn't need loan 1=You don't like to take any loans 2=Interest rate is too high 3=Application and approval process is difficult 4=Application process is expensive 5=There was no loan available 6=You assumed your loan would not be approved 7=Other:__________________________
10. Why did you buy and install the biogas? (answers can be more than one)

    0= Subsidy, **1=** its cheap energy source, **2=** Health benefits, **3=** Environmental benefits **4=** Economic benefits, **5**=It saves fuel, **6**=It produces no smoke, **7**=It lasts long (durable), **8**=It cooks quickly, **9**=It makes use of farm wastes, 10= compost for the agriculture **11**= Other: (specify)
11. What do you like most about the biogas plant?

    0=It cooks quickly, **1**=It saves firewood and other fuels consumption, **2**=Saves time on gathering fuel wood, 3= It is portable, 4=It is durable, **5**= It does not create smoke 6=It provides a clean cooking environment, **7**=It does not cause eyes to itch, 8=it is safe to use, **9**=Other (specify)
12. What do you dislike most about biogas plant?

0= It is very expensive, **1**= It does not save on firewood and other fuels, **2** =It cooks slowly, 3=Nowhere to repair, 4=It requires too much labour and attention, **5**=It requires too much dung, **6**=its prone to accidents **7**=Do not dislike anything about the technology, 8= it produce insufficient energy 9=Other (specify)

13. Have you experienced any problems with your biogas plant? Yes=1 No=0
14. If yes to Q 11 what problems____
15. Do you have an injera mitad connected to the biogas technology? Yes=1 No=0

F. GENDER AND BIOGAS

1. Who has taken initiative to install the biogas plant? 0=Head (male), 1=.head(female), 2=spouse (female) 3= both 4=male child 5=female child
2. Who took the decision to install the biogas plant? ?0=Head (male), 1=.head(female), 2=spouse (female) 3= both 4=male child 5=female child
3. Do you think use of biogas saves time? Yes=1 No=0 3=I don't know
4. If yes, for Q 2,
   a. How do you utilize the saved time?
   0=Children have been attending in the school, 1=Reduce workload/stress for women and children, 2=women are engaging more on agricultural activities, 3=women are engaging more on income generating activities, 4= Reduce the need to get up earlier in the morning for cooking, others, specify__________________________________
   b. If women are engaged in income generating activity what type of activity and amount earned per month

Type of activity	**Income earned/month**
Petty trade	
Selling bio slurry	
Producing and selling Local alcohol	

Peddling	
Poultry	
Professional employment	
Others specify	

5. Division of household tasks and time allocations by gender and age

Activities	In the last 7 days in hours				
	Husband	Wife	Daughters	Sons	Hired labour (M/F)
Cooking					
Baking injera					
Cleaning the house					
Child care					
Washing clothes					
Fetching water					
Collecting dung					
Feeding the digester					
Collecting fire wood					
Collecting crop residue					
Maintenance and cleaning					

of digester					
Livestock care					

G. HEALTH AND BIOGAS

1. What type of energy source were you using before installation of biogas?

Open=0 Charcoal=1Kerosene=2 stove=3other… … … … … …

1 . Compared to the old energy source did the new system produced smoke. 0=More 1=Less **2=**The same **3=** Not sure

2. Has the amount of smoke in the kitchen reduced after biogas installation?

   0=Reduced to some extent 1=Reduced to greater extent 2= No change

   3= completely avoided

3. Is the biogas plant connected to the latrine yes =1 no =0
4. If yes to Q. 4 have you observed improvement in the sanitation? yes =1 no =0
5. Do you still use other energy sources after biogas installation? Yes= 1, 0=no
6. If yes to question 6, which energy sources do you use?

Energy Sources	decreased significantly	to certain extent,	stayed the same,	increased,	increased significantly
Firewood					
Dung					
Charcoal					
Crop Residue					
Kerosene					
Electricity					

0=decreased significantly, 1=to certain extent, 2=stayed the same, 3=increased, 4=increased significantly

7. If yes to Q 6 why? 0= biogas energy is not sufficient 1= still mixing biomass energies 3= others specify ______________________
8. What are the major health problems before and after the installation of the biogas technology

Major health problems	Has anyone in your family been affected by these diseases	Victims- 0= Male adults, 1= female adults, 2= Male children, 3= female children 4= infants less than 5 years]	Before installation of biogas	Cost of treatment	After installation of biogas	Cost of treatment
Respiratory problems						
Itchy eye						
Burns						
Diarrhoea as a result of water borne diseases						
Injury/violence during collection						
Back pain due to heavy load						

I. FOOD CONSUMPTION AND BIOGAS

1. Fuel type and use

Fuel type	Purpose					Expenditure/month
	Baking injera/bread	Cooking	Boiling water	Lighting	Others, specify	

Biogas						
Electricity						
Fuelwood						
Charcoal						
Animal dung						
Crop residues						
Kerosene						
Dry cells						
Others, specify						

2. Household expenditure

Item lists	Measurement	Quantity	Expenditure/ month
1. Education			
2. Food items			
Teff			
Maize			
Sorghum			
Wheat			
Barley			
Different beans			
3. Salt, sugar, soap oil and other			
4. Grain mill services			
5. Clothing female			
6. Clothing male			
7. Furniture			
8. Communication			
9. Transport			
10. Ider			
11. Donation to religious institutions			
12. Pesticide			
13. Veterinary service			

3. How many times do you eat per day? ___________

4. How many meals do you cook on average per day? ________________________
5. Is the biogas enough for cooking and lighting? 1=Yes, 0=No
6. If not sufficient, what are the main reasons?

   0=Small plant size, 1=Under-fed plants 2=Over-fed plants, 3=Plants not regularly fed, 4=Less gas production due to defective construction, 5=Less gas due to defective operation and maintenance, 6=Less gas production during winter months, 7=others (specify) 8=Do not know
7. Has there been any change in the type of food you cook since you installed the biogas? [1= Yes, 0= No]
8. If Yes, please explain
9. Do you save time by cooking with your biogas stove instead of wood or charcoal?

   0=No, 1=Yes, I save time, approximately _______________________ minutes per days
10. With the installation of biogas do you diversify your meals when you cook 1=yes 0=no
11. With the installation of biogas are the meals timely and warm when consumed 1=yes 0=no
12. Do you use bio-slurry for fertilizer? 1=yes 0=no
13. If Yes to Q 12 for which crops do you apply bio-slurry? 0 = Cereals 1=Oil crops 2=Pulses 3= vegetables 4=others, specify _______________
14. Do you think the fertilizer quality of bio-slurry is better than the traditional manure?1=yes 0=no
15. If yes to Q 12, what better qualities does it have? 0=.Provides more yield 1=Has less weeds 2=Prevent pests 3=More fragile and easier to apply 4=Has less smell 5=Other, specify ______
16. If No to Q 12 specify ____
17. If you don't use bio-slurry for fertilizer, please, state why. _________________________
18. How much money have you saved from the reduction of chemical fertilizer? ________

Thank You

Appendix 4: Questionnaire for Non-User Households

Name of interviewer…………………………………………………………………….

Date of interview…………………………..

Duration of the interview………………………….

Kebele: ……………………………..

This questionnaire is prepared to collect data for the research paper entitled: *"The Impact of Small Scale Biogas Technology on Household Welfare in Ada'a Woreda, Oromia Region, Ethiopia**.**"*The overall objective of the study is to assess the outcome of small scale biogas technology on the welfare of rural households by comparing users with non-users in Adea woreda in Oromia Region

The researcher, after receiving informed oral consent from you, would like assure that the confidentiality of the information shared and your name will be kept anonymous.

Direction: you are kindly requested to provide the right answer for the following questions. You have the right to fully /partially refuse or withdraw from participation. All your responses will not to be disclosed. Thank you for expressing your interest again.

A. HOUSEHOLD DEMOGRAPHIC INFORMATION

No	Name	Sex	Age	Educational Status	Marital Status

Sex- (Male 0 Female 1) Education-(Illiterate 0, read and write 1, Grades) Marital status- Married 0, Single 1 separated/divorce 2, widowed/widower 3

B. Sample Households' Assets and Income Sources

2. livestock (Last one year)

Livestock Type	Total livestock available on hand rightnow quantity	Quantity sold	Distance to product market (km)	Value of products sold (Birr)
Cow				
Ox				
Heifer				
Bull				
Calf				
Goats				
Sheep				
Poultry				
Donkey				
Dairy Products (liters sold per				
Eggs (crates sold per				
Others				

3. Crop production

Main crops/vegetables	Plot size per crop in hectare	Production (last season)	Consumption (quintals)	Sold amount (quintals)	Value of products sold

4. Additional income

Source of income	Amount	
	monthly	**Yearly**
Remittance:		
private business:		
Salary:		
Pension:		
Daily labour:		
Others		

C. FUELWOOD SOURCES AND CONSUMPTION PATTERNS

1. Sources of fuelwood

Energy Type	Average daily consumption			Amount used in		
	Amount	Unit	Price	Cooking	Lighting	Others (Specify)
Firewood (Kgs)						
Charcoal (kgs)						
Crop Residues						
Dry animal Dung						
Electricity						
LPG gas						
Kerosene (Liters)						
Others (Specify)						

2. Energy consumption

Firewood Sources	Amount in Kg	Average distance to source of fuel per KM	Number of trips per week to each sources
Collected from Forests			
Purchased			
Charcoal			

D. ACCESS TO WATER RESOURCES

1. Which is your main source of water?

0=Private well water 1=Private hand pump water 2=Private tap water 3=Community well water 4=Community hand pump water 5=spring water

6=River 7=Pond water 8=others, specify ________________________________

2. On average, how many minutes do you walk from home to water source per trip? ______
3. Is the water source reliable? 1=Yes, 0=No

E. Biogas Installation Decision

1. Are you aware of what biogas technology is? 1=Yes 0=No
2. If yes to Q. 1 are you aware of its benefits 1=Yes 0=No
3. If No to Q. 1, why are you not using the biogas? 0= lack of awareness 1= lack of initial capital 2=access to loan facilities 3=not enough cattle 4= lack of information 4=other (Specify)
4. Do you have access to credit services? 1=Yes, 0=No

F. GENDER AND BIOGAS

1. Do you think use of biogas saves time? Yes=1 No=0 3=I don't know

2. Division of household tasks and time allocations by gender and age

Activities	In the last 7 days in hours				
	Husband	Wife	Daughters	Sons	Hired labour (M/F)
Cooking					
Baking injera					
Cleaning the house					
Child care					
Washing clothes					
Fetching water					
Collecting dung					
Collecting fire wood					
Collecting crop residue					
Livestock care					

G. HEALTH AND BIOGAS

1. What type of energy source were you using before installation of biogas?
   Open=0 Charcoal=1Kerosene=2 stove=3other… … … … … …
2. Does your current energy source produce smoke .0=More 1=Less **2=**The same **3=** Not sure

3. Do you have a latrine yes =1 no =0

4. What are the major health problems before and after the installation of the biogas technology

Major health problems	Has anyone in your family been affected by these diseases	Victims- 0= Male adults, 1= female adults, 2= Male children, 3= female children 4= infants less than 5 years]	Before installation of biogas	Cost of treatment
Respiratory problems				
Itchy eye				
Burns				
Diarrhoea as a result of water borne diseases				
Injury/violence during collection				
Back pain due to heavy load				

H. **FOOD CONSUMPTION AND BIOGAS**

1. Fueltype and use

Fuel type	Purpose					Expenditure/month
	Baking injera/bread	Cooking	Boilingwater	Lighting	Others, specify	

Electricity						
Fuelwood						
Charcoal						
Animal dung						
Crop residues						
Kerosene						
Dry cells						
Others, specify						

2. Household expenditure

Item lists	Measurement	Quantity	Expenditure/ month
1. Education			
2. Food items			
Teff			
Maize			
Sorghum			
Wheat			
Barley			
Different beans			
3. Salt, sugar, soap oil and other			
4. Grain mill services			
5. Clothing female			
6. Clothing male			
7. Furniture			
8. Communication			
9. Transport			
10. Ider			
11. Donation to religious institutions			
12. Pesticide			
13. Veterinary service			

3. How many times do you eat per day? ___________
4. How many meals do you cook on average per day? _________________________
5. Are your meals diversified? 1=yes 0=no
6. Do you use bio-slurry for fertilizer? 1=yes 0=no
7. If Yes to Q 6 For which crops do you apply bio-slurry? 0 = Cereals 1=Oil crops 2=Pulses 3= vegetables 4=others, specify _______________
    8. Do you think the fertilizer quality of bio-slurry is better than the traditional manure? 1=yes 0=no
9. If yes to Q 6, what better qualities does it have? 0=.Provides more yield 1=Has less weeds 2=Prevent pests 3=More fragile and easier to apply 4=Has less smell 5=Other, specify ______
10. If No to Q 6 specify ____
11. If you don't use bio-slurry for fertilizer, please, state why. __________________________
12. How much money have you saved from the reduction of chemical fertilizer? _________

Thank You