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FACTORS INFLUENCING HOUSEHOLD ADOPTION OF SOLAR HOME SYSTEM IN BASO LIBEN DISTRICT, EAST GOJJAM ZONE, ETHIOPIA

BY

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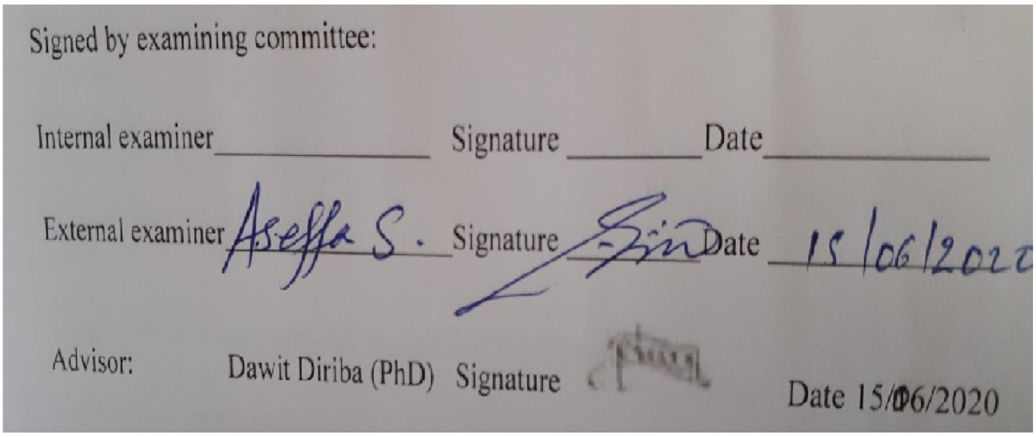
This is to certify that thesis prepare by Asmare Mossie, entitled: *Factors Influencing Household Adoption of Solar Home System in Baso Liben district, East Gojjam Zone, Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Masters of Art (Environment and sustainable Development) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.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Chairs of Department or Graduates Program Coordinator

DECLARATION

I, hereby declare to school of graduate studies of Addis Ababa University, that this thesis entitled "Factors Influencing Household Adoption of Solar Home System in Baso Liben district, East Gojjam Zone, Ethiopia" is my original research work for the master's degree of environment and sustainable development and has not been presented in any university. For the best of my knowledge, all sources of materials pieces of information used in this study are fully acknowledged and referenced based on the standards and regulations of the university.

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Date of submission:________________

Place: Addis Ababa University

Department: Environment and Sustainable Development

Advisor: Dr. Dawit Diriba

DEDICATION

To

Rural mothers of Ethiopia, who have been struggled with poverty and detrimental energy sources, and live to transcend the lives of others, but not yet live for themselves.

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ABREVATIONS

AREI	African Renewable Energy Initiative
CDKN	Climate and Development Knowledge Network
CSA	Central statistical Agency
ERG	Ethio Resource Group
GTP	Growth and Transformation Plan
GTZ	Gesellschaft für Technische Zusammebarbeit
ICF	International Care Facility
IEA	Unternational Energy Agecy
ISEI	International Solar Energy Institute
LED	Light Emitting Diodes
MoWIE	Ministry of water Irigation and Electricity
NGO	Non Governmental Organization
ODI	Overseas Development Institute
PV	Photo Voltaic
REEEP	Renewable Energy and Energy Efficiency Partnership
REN	Renewable Energy Policy Network
SHS	Solar Home System
TERI	The Energy and Resource Institute
UNEP	United Nation Environmnet program
WCED	World Commision on Environmnet and Development
WHO	World health Oorganizaation
NCSEA	The National Council of Structural Engineers Associations

ABSTRACT

Solar energy, which is abundant and accessible with low price and minimum ecological and environmental hazard, is a significant one to bring a desired human's life improvement. Because of limitation of using this opportunity, the majority of f the rural population of Ethiopia is still suffered with lack of electricity access. This study tried to investigate the major factors influencing households' adoption of solar home system in Baso Liben district east Gojjam zone, Ethiopia. Descriptive cross sectional study design was employed with both qualitative and quantitative data collection approaches. 371 sample household respondents were selected randomly, of which 228 and 143 households were from adopted and non adopted sides respectively from four purposively selected kebeles of the district based on infrastructural accessibility, high adoption intensity, time and other physical factors. The quantitative data were collected through structured questionnaires whereas the qualitative data were collected through interview with key informants in addition to questionnaires. Binary logistic regression model was employed to estimate the effects of determinants on households' decision to adopt solar. The result indicated that income found to have a positive effect on solar home system adoption at a statistically significant level (P<0.1). Likewise participation in off farm income activities, house type, educational status, training access, media access, and prior knowledge/awareness positively associated with adoption of solar home system at statistically significant level (P<0.1, P<0.01, P<0.05, P<0.01, P<0.01, and P<0.05 respectively). On the other hand, gender and access to electricity negatively associated with solar home system technology adoption at statistically significant level (P<0.05). Therefore the result of this study suggests that providing awareness creation training about utilization of solar technology; improving economical status of households through creating different off farm income opportunities and improving media availability should be taken in to account either by government or other development programs in order to increase the rural households' propensity to adopt clean and renewable energy. Similarly, strategies targeted to improve educational status of rural households have multidimensional benefits including intensifying their awareness level regarding benefits of using clean and modern energy technologies.

Key words: *Adoption, Energy, Solar energy technology, Solar home system, Renewable energy, Environment, Household, Rural, Determinants*

CHAPTER ONE

INTRODUCTION

This chapter introduces the background of the research in global, regional and local context, statement of the problem, research questions, objectives addressed in the research, significance, the scope that had been covered, organization of the study and limitations during conducting the research.

1.1.Background of the study

Energy access to human being is a precondition requirement for development and welfare as well as successful economic development and job opportunity (UNEP, 2017). Solar energy is among the cleanest energy resources that do not contribute to the rise of global warming. This is often represented as “alternative energy” to those fossil energy sources such as coal and oil. Its accessibility with low price and abundant source of energy with minimum ecological and environmental hazard is a significant one to bring a desired human’s life improvement. The rise of fossil fuel scarcity has created the opportunity to increase global approach towards solar energy (Solangib, 2011).

In the global context, the share of renewable energy in the production of power capacity grew to over 33% in 2018. From which hydropower accounted about 60% of production of renewable electricity. It is followed by wind power, solar PV and bio power, which accounts 21%, 9% and 8% respectively (REN21, 2019). Even though hydropower is still the main source of renewable energy, solar PV has become the largest market for current new investment due to its unsubsidized solar PV generated electricity which leads rapidly declining costs that competes fossil fuels in numerous nations of the world (KPMG International Cooperative, 2015).

In case of Africa, about 48% of the population does not have electricity access still 2017. Of which the largest share is sub Saharan Africa inhabitants, where 57% or about 602 million of people still live in dark (REN21, 2019). Whatever the energy accessibility is like this, the continent’s great resource base is exploited only in case of gas, oil & coal, largely untouched in renewable. Solar energy only accounts about 1% out of the total energy demand (IEA, 2014). The study conducted by GTZ (2010) is also stated that the Africa continent is endowed with a variety of both non-renewable and renewable energy resources diversity which is unequally distributed across the continent. The main energy resources include gas, oil, and coal that account for 7.5 percent, 7.6 percent, and 3.6 percent of the world total respectively. The hydropower potential of the continent also accounts about 12% of the world total. The continent also has huge and abundant source of renewable energy. The capacity of the continent's annual solar radiation ranging from 5 to 7 kWh/m2 (A. Brüderle, 2010). Which indicates a huge potential of the continent with clean solar energy, could be taken as a bright hope for the future to solve the current energy crisis observed in the continent.

Regarding Ethiopia, the electricity need is still huge. As evidences showed, more than half of the total population of the country (56 percent), almost the same to that of sub Saharan Africa (57%), still does not have access to electricity (MoWIE, 2019). Thus, addressing energy poverty and enhancing livelihood of its people through modern energy provision pose the challenges (Abera, 2019).

Solar energy has the capability to serve as the user's capacity in small or large scale, mainly can be utilized in two forms; photovoltaic and thermal energy. Thermal energy is the use of heat to run a heat engine to generate electricity, while photovoltaic involve the direct conversion of sunlight into electricity (Howell, 2011). A similar study by Thomas B. Johansson, etal(1992) stated that Photovoltaic technology is cost-effective in providing electricity to rural areas at the very smallest scales (typically less than 100 watts) in areas with no access to grid electricity and where electricity demand is characterized by low levels and infrequency that could not even be completed by diesel electricity. Solar photovoltaic technology has a great potential to support rural development by providing household lighting, radios, and television sets, and to refrigerate medicines at rural clinics.

Ethiopia has great potential for solar energy as it receives a solar radiation of 5,000-7,000 Wh/ m^2 depending on the locale and the season. The solar radiation averages 5.2 kwh/m2/day. The values vary with the seasons, ranging from 4.55 to 5.55 kWh/m2/day, and over space, ranging from 4.25 kWh/m2/day in the extreme western lowlands to 6.25 kWh/m2/day in Adigrat area

(REEEP, 2014), and has a total solar energy reserve potential of 2.199 million TWh per annum (Deribew, 2013). Instead of taking advantage of this opportunity, as stated by Abera (2019), lack of modern energy such as solar is, in particular immense in rural areas of Ethiopia.

In order to spread electrification access throughout the country, the government has been implementing two strategies, namely extension of the national grid and provision of off-grid modern energy technologies (Abera, 2019). In 2017, the Government of Ethiopia has achieved significant effort in electrification sector. During that year, about 33 percent of the population has been connected with on-grid electrification and 11 percent of the population also connected with off-grid pre-electrification with the combined achievement of 44 percent of electricity access (MoWIE, 2019). The action plan of the National Electrification Program for "achieving universal electricity access nationwide by 2025",is launched in an efficient and transparent manner as well as in a strategic and comprehensive way, for the benefit of all citizens of the country. By 2025, 65 percent of access provision is targeted with grid solutions and 35 percent with off-grid technologies (solar off-grid and mini-grids) (MoWIE, 2019).

Therefore, the main purpose of conducting this paper is to examine factors influencing households solar home system technology adoption specifically used as source of energy for lighting and communication purpose such as radio, TV and mobile charging. Logistic regression model was used to estimate the effects of major determinants on households' decision to adopt solar. The result of this study will help to inform policy makers in the energy sector by providing timely information about the current situation of solar energy technology adoption and its determinants in rural areas particularly the study area.

1.2. Statement of the problem

Even though Ethiopia is dependent on traditional biomass fuels to meet its energy needs, there are plentiful and diverse renewable resources and available electricity generating technologies that can give the opportunity to the country to shift away from the current energy system. These resources and technologies include energy efficient biomass cook stoves, solar thermal and photovoltaic, biogas, large and small-scale hydropower, wind, and geothermal (Howell, 2011). In addition to poor accessibility of electricity, the energy sector of the country is too much dependent on hydropower. This increases its vulnerability due to the increasing risk of draught caused by climate change (Guta, 2017).

The electricity consumption rate in rural Ethiopia is very low compared to that of the urban coverage. As stated by Lighting Africa (2012), there is also a great disparity of power distribution in the country. In Ethiopia, as in most Sub-Saharan Africa countries, the gap between urban access and rural electric access is huge. Which is evidently assured that about 96 percent of urban households of the country are connected to the grid (99.9 percent in Addis Ababa), whereas only 27 percent of households living in rural areas of the country have access to electricity services. Most rural customers gain access through off-grid solutions. The problem is highly experienced in deep-rural areas, where 5 percent of people have been accessed with electricity. As noted by TERI (2014), such problem is mainly emanated due to the difficulty and expensiveness of connecting the rural population living in isolated villages to a centralized electric grid. Due to this reason, Most of the households in the rural villages depend on Kerosene lamps for lighting and wood and charcoal for cooking. This high dependence of rural households on biomass resources causes adverse effect on environment as it emits a lot of carbon and also damages the health of the people using it (Mekuria, 2016).

Adoption of solar energy technology has encountered challenges that make it impossible to utilize the technology in a successful way on any extensive scale. Not only can solar PV be used for lighting and powering low voltage appliances, the cost of installation is extremely expensive especially for low income rural populations in Ethiopia (Howell, 2011).

As noted by TERI (2014), there is High demand in off grid areas for solar systems especially with dual purpose of lighting and mobile charging and there are also markets for solar technologies that support radio and TV; but due to its low quality and nonexistent after sale services, it often builds distrusts in the quality of products when the products breakdown after a short period of usage. The problem is going to be seen as complex that high installation costs and poor installation services came together for large PV systems and solar home systems (SHS).

Many researches have been conducted regarding determinants of solar technology adoption at household level in different countries. Researchers such as Keriri (2013) and Regina (2016) in Kenya and Tahir (2017) in pakistan tried to study many socio ecconomic and demographic factors of solar energy technology. Similarly, many researchers (Guta, 2018; Anteneh, 2019; and Legesse, 2016) have investigated the demographic and socio economic determinants of solar energy technology adoption in rural Ethiopia by applying different models. For instance, (Guta (2018) applied logistic regression model, whereas Legesse (2016) and Anteneh (2019) used probit regression model. Anteneh (2019) and Legesse (1016) revealed the effects of the level of education of the household, land size, number of cattle, level of income, and age of the head of household on solar technology adoption. Whereas Guta (2018) investigated the effects of much more variable in a broad sense such as, trees, and saving including the above mentioned variables using logistic regression. In addition, other determinants such as institutional factors (Guta, 2018; Anteneh, 2019), level of knowledge and awareness (Anteneh, 2019), alternative source of energy (Legesse, 2016) have been investigated. In addition Guta (2018), tried to see the socioeconomic and demographic variation of adopters and non-adopters by applying descriptive statistics.

But there is a research gap in the above mentioned empirical studies in addressing institutional factors such as awareness creation training given to the households either formally or informally. Housing types and size, which are among socio economic factors that could determine households' willingness to adopt solar energy technology is not addressed properly. There is also a little information about how access to communication technologies could affect adoption intensity. Therefore, this paper is mainly focused on filling the observed gap by examining the effects of training and housing conditions on rural households' decision to use solar home system technology, as well as by assessing the effects of communication technologies including cell phone and media. The other reason for selecting the study area is that it is the highland area where the natural resource such as forest resources serving as source of energy is highly degraded and there is no such kinds of research has been conducted still.

1.3. Research questions

- What is the attitude of households towards solar energy technology?
- Which socioeconomic and demographic characters show a significant variation between adopters and non-adopters of solar home system?
- What are the potential factors influencing households' decision to adopt solar home system?

1.4. Objectives of the study

1.4.1. General Objective

The general objective of the study is to examine factors influencing household adoption of solar home system.

1.4.1.1.Specific Objectives

- To assess household's attitude towards solar energy technology.
- To analyze demographic and socioeconomic variation of adopters and non adopters of solar home system
- To examine factors influencing household adoption of solar home system

1.5. Significance of the study

The study tried to fill the information gap by investigating the role of different factors determining household's decision of solar home system adoption in the study area. The result of the study will have development and policy significance by providing current and valuable evidences for policy makers leading them to make better decision in the formulation of effective development programs, and strategies related to addressing rural energy crisis by shifting towards alternative renewable and clean energy. It will also have academic relevance by exploring the existing phenomena and new knowledge which enhances social and economical development. In addition, it will be helpful for different government bodies such as water and energy sectors existing at national, regional, zonal and woreda level and for stakeholders such as private solar product distributors, NGOs who have been engaged on different sustainable development programs by providing timely information.

1.6. Scope of the Study

The study was conducted in Basoliben district, East Gojjam zone of Ethiopia. It is targeted on four purposively selected kebeles of the district, namely Yelemelem, Yegelaw, Michig and Limichim. It is focused on examining factors influencing household adoption of solar home system (specifically used as source of energy for lighting, charging, and other communication purposes). In this study, the researcher also tried to analyze the households' attitude towards solar energy technology and socioeconomic and demographic variation between adopter and non-adopter households of the study area.

1.7. Limitation of the study

The researcher encountered some constraints during investigation of this study. One of the constraints was accessibility of transportation to reach the selected rural kebeles. Financial constraints for different expenses such as transportation and lack of paying satisfactory per diem while collecting the data and lack of time to collect data extensively also were big challenges. Unwillingness of some key informants and interviewees to give sufficient answer to the questionnaires was the other challenge due to their fear to trust by connecting the issue with politics. Absence of some important and recent literatures also limited the researcher while conducting the research.

1.8. Definition of terms or Concepts

Adoption: The choice to acquire and use a new invention or innovation (Hall & Khan, 2002).

Clean energy: Is energy derived from renewable, zero-emissions sources ("renewables"), as well as energy saved through energy efficiency measures (NCSEA).

Energy: A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work (Merriam-Webster).

Household: Those who dwell under the same roof and compose a family. It is also social unit composed of those living together in the same dwelling (Merriam-Webster).

Renewable energy: Renewable energy is defined as energy that is produced by natural resources such as sunlight, wind, rain, waves, tides, and geothermal heat that are naturally replenished within a time span of a few years (Lund, 2014).

Solar home system: Is stand-alone photovoltaic **systems** that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas that are not connected to the grid SHS can be used to meet a household's energy demand fulfilling basic electric needs (Energypedia).

Solar technology: This refers to the energy from the sun that is converted into thermal or electrical energy for a variety of uses including lighting, heating water, pump water and run other household appliances (Solar Energy Industries Association).

1.9. Organization of the thesis

This study has five chapters. The first chapter introduces the background of the study, statement of the problem, objectives, significance, scope and limitation of the study. The second chapter reviews theoretical and empirical literatures related to determinants of household adoption of solar energy technology. The third chapter describes the methodology and tools used in the research. The fourth chapter presents and discusses the major results and findings of the study. The last chapter of the paper presents conclusion and recommendations of the research.

CHAPTER TWO
LITERATURE REVIEW

2.1. Background

2.1.1. Overview of energy sector in Ethiopia

The energy consumption of Ethiopia is heavily dependence on biomass with limited form of modern energy (Guta, 2018). The consumption is estimated to be about 31,050 kilotons of oil equivalent (ktoe) in 2009 with a per capita energy consumption of 0.4 ktoe. The national energy balance of the country is dominated by a heavy dependence on traditional biomass energy (wood fuels, crop residues, and cattle dung), which accounts for 92 percent of total energy consumed. Electricity and Petroleum contribute only one percent and seven percent, respectively (REN21, 2019). Photovoltaic systems are cost effective and reliable means to increase access not only to electricity but also to information and communication through mobile devices, Radio receivers and TV sets. PV is already an important source of power for the mobile network in Ethiopia. It will also be important for providing powers to the social institutions such as schools, clinics and water supply (ERG, 2012). Lighting sources in Ethiopia can be divided between grid connection, kerosene, modern off-grid technologies, and PV battery based systems. Urban zones rely on an existing grid network, while in rural areas most lighting products are powered using kerosene fuel and conventional thermal generation (Lighting Africa, 2012)

2.1.2. Current status of solar energy use in Ethiopia

In view of the fact that the government of Ethiopia, needs to install solar having at least 500 MW of capacity by 2020, it will have to enhance the development of solar projects if it wants to meet its ambitious target. The capacity of solar PV has almost tripled over the past five years in Ethiopia. However, despite the abundant solar resources in the country, as of now, only 14 MW has been installed, it represents only 0.3% of the country's total energy capacity. Still, it was the only growing category of renewable year on year from 2016-2017, when compared to the stagnated growth of wind and hydro energy applications. Solar capacity in Ethiopia is expected to soar in the near future with several large scale projects under development (Solarplaza, 2019).

2.2. Theoretical literature review

2.2.1. Theory of Reasoned Action

The Reasoned Action Theory proposed that rational thought grounds human behavior in it and the model uses the Principle of compatibility, which predicts that attitudes reflect behavior only in the extent of the two going to have the same valued outcome state of being (evaluative disposition) (Ajzen, 1985)

Subjective norms and beliefs shape these attitudes, and situational factors affect these variables' relative importance. Reasoned Action Theory accounts for times when people have good intentions, but translating intentions into behavior is dissatisfied due to the feeling of lack of control over the behavior or lack in confidence (Hanna, 1995)

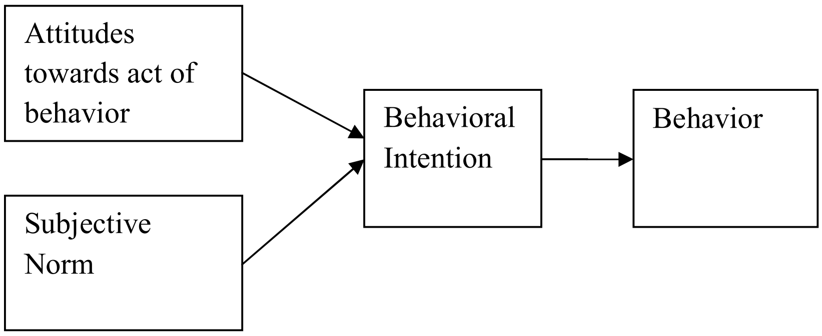

Figure 1: Theory of Reasoned Action (Adopted from Fishbein and Ajzen, 1975)

Theory of reasoned action can also be used in technology adoption as a fundamental theoretical framework. Attitude and subjective norm are important determinants of the intentions of peoples for the purpose of performing an action such adopting and using new technology such solar energy technology. Attitude is having a significant influence on the intention to adopt and continue to the use of technology (Abeka, 2016).

2.2.2. Innovative Diffusion Theory

The theory of innovation diffusion explains, predicts, and accounts for the factors which influence adoption of an innovation. It provides perceptions that individuals have to adopt an innovation such as renewable technology. (Rogers, 1995). According to Sahin (2003), Rogers' innovation decision process starts with the knowledge stage, what?" "How?" and "why?" are the critical questions in the knowledge phase. In this step, an individual learns about the existence of innovation and seeks information about the innovation which can motivate the individual to learn more about the innovation and, eventually, to adopt it. In addition, people can adopt an innovation such as solar energy technology without this knowledge, but this misunderstanding of the innovation may cause its discontinuance. The individual shapes his or her attitude after he or she knows about the innovation, so the persuasion stage follows the knowledge stage in the innovation-decision process. Furthermore, Roger states that while the knowledge stage is more cognitive (knowing) centered, the persuasion stage is more affective (or feeling) centered.

According to Rogers (2003,) technology adoption behavior of individual such as solar technology is determined by his or her perceptions regarding relative advantage, compatibility, complexity and observability of an innovation which influence the rate of innovation adoption. These facts have relation with those variables of the study such as level of knowledge and awareness of the household towards solar energy technology. There is characteristic difference between People who adopt an innovation early and those who adopt an innovation later. First of all, it is important to understand the characteristics of the target population when promoting an innovation to a target population that would help or hinder adoption of the innovation. The stages that a person follows to adopt and whereby diffusion is accomplished are awareness of the need for an innovation, decision to adopt (or reject) the innovation, initial use of the innovation to test it, and continued use of the innovation.

The main purpose of communication is to achieve mutual understanding among the participants by receiving, creating, and sharing information. The two most powerful communication channels are mass media and the interpersonal exchange of information. The interpersonal exchange of information is more powerful in convincing a social system to accept a new innovation the time dimension describes how an individual passes from first exposure to the innovation until its adoption or rejection (Regina, 2016)

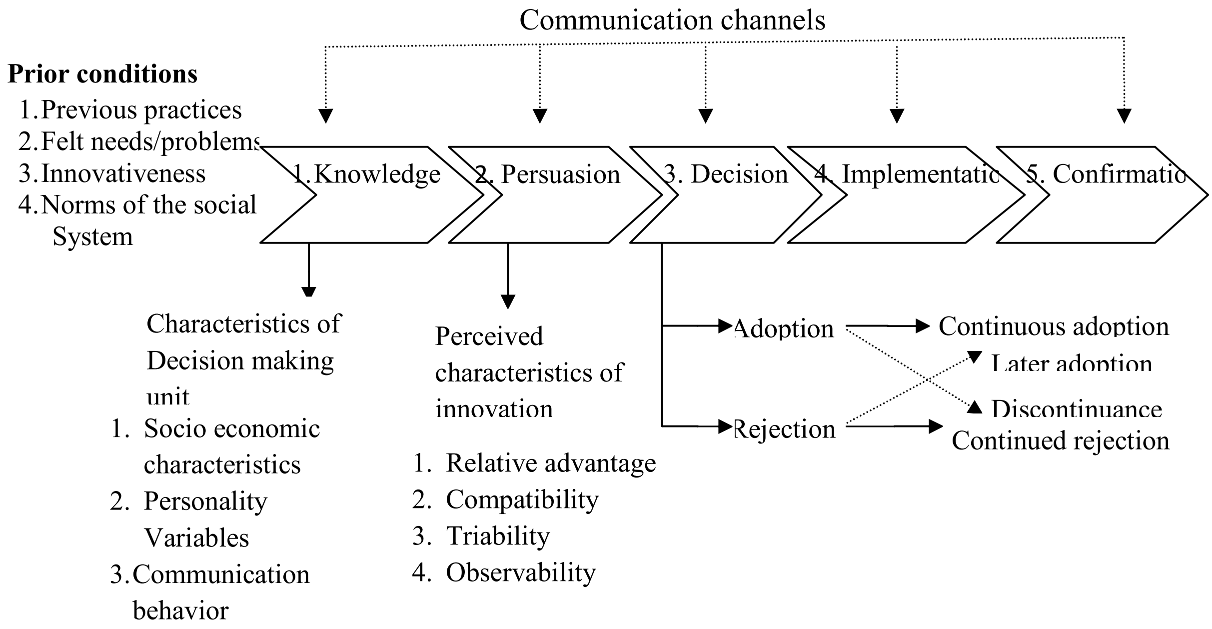

Figure 2: The Innovation Diffusion Theory (Adopted from Rogers, 1960)

2.2.3. The energy ladder and fuel stacking hypothesis

The energy ladder model shows the relationship between an increase in economic well-being of household and the type of fuel they tend to use. Hosier & Dowd (1987) implies that as income raises households consume fuels that occupy higher rungs, ascending the energy ladder. A move up to a new fuel is simultaneously a move away from the fuel used before (Heltberg, 2005).

As the socioeconomic status of families grow, they throw out technologies that are less costly, inefficient and more polluting and shift from universal reliance on biomass fuels to fuels belonging to the second phase, such as kerosene, coal and charcoal. In the last phase of the ladder, households switch to fuels such as LPG and electricity (Heltberg R. , 2004). As shown in the figure below, the fuels on the energy ladder are ordered according to the household's preferences based on physical characteristics, including cleanliness, ease of use, cooking speed, and efficiency.

A variant to the energy ladder hypothesis explains multiple cooking fuel use (fuel stacking) whereby households retain the use of traditional fuel albeit movements up the energy ladder. Fuel stacking explains the case where households simultaneously use a myriad of cooking fuel usually on both upper and lower stages on the energy ladder (Heltberg R. , 2003). This is also analyzed by Hosier & Dowd (1987), who primarily tested the energy ladder hypothesis to analyze household's fuel choice in Zimbabwe, confirmed that income is a major determinant of the choice of fuel type.

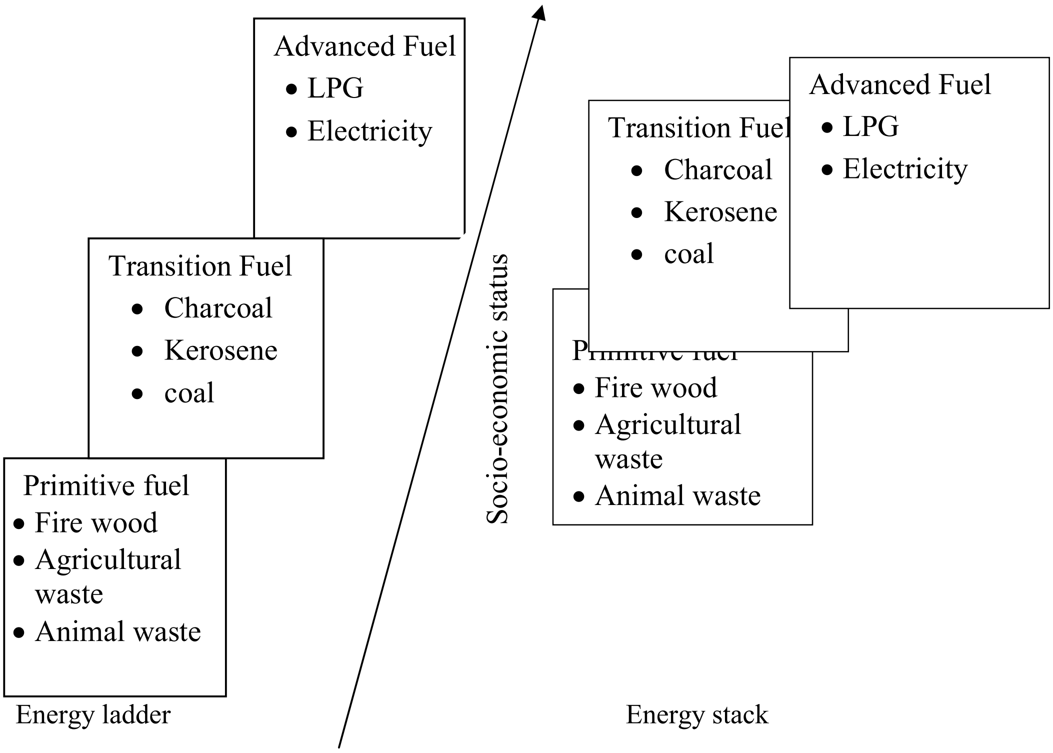

Figure 3: The energy transition process (Adopted from Schlag and Zuzarte, 2008**)**

2.3. Empirical Literature

2.3.1. Factors determining solar technology adoption

2.3.1.1. Attitude of household towards solar technology

.Attitude towards renewable energy is described as the perception of the potential users', their belief about the benefits and drawbacks of the new technology and about their intention to buy the technology. However renewable energy is expensive, its benefits are continuing as well. Hence, adequate level of awareness and correct information should be provided to bring better understanding of both benefits and disadvantages of the renewable technology (Rashid, 2012)

There is enhancement of the positive/favorable attitudes of household heads towards adoption of renewable energy sources (like solar and biogas). the method of introducing renewable energy sources (solar and biogas) in the study area, that includes intensive promotional and awareness campaigns has given the beneficiaries an opportunity to see, feel and experience the benefits of alternative renewable energy sources (solar and biogas) and have belief and trust on the existing and future development of the technology. However, neutral attitude household heads needed to be motivated to change their attitude towards favorable side then it can be scale up expansion of renewable energy sources for rural households in minimizing rely on biomass energy sources ultimately can reduce deforestation (Legesse, 2016).

2.3.1.2. Level of knowledge and awareness

Level of awareness and knowledge highly determines the household adoption towards solar technology. Knowledge and awareness about solar technology can be transferred from one person to another through different information sources such as neighbor and friends /family relatives and local markets through government and non-government campaigns. As revealed by Naomi (2014), there is a direct relationship between the adoption of solar technology and awareness and knowledge about the technology. Lack of adequate information of households on the negative health outcomes associated with inefficient combustion of solid fuels, impedes the growth of market demand for clean energy (Beyene, 2018).

2.3.1.3. Institutional factors

There is lack of coordination among the health and energy sectors, ministerial departments, regional and national agencies, the public and the private sector and national and international agencies. Coordination among ministries could be improved by ensuring better understanding of clean energy to make it a priority; for example, currently, the child and maternal health units in the Ministry of Health do not promote awareness of the health risks of household air pollution. As stated by Getachew E Beyene (2018), institutional arrangements are a barrier, as directorates are shared among three ministries (Ministry of Water, Irrigation and Electricity, Ministry of Environment and Forestry and Climate Change and Ministry of Mines, Petroleum and Natural Gas), and key institutions have overlapping mandates and insufficient technical staff and instrumentation to provide diversified energy sources at different levels. Moreover, involvement of the private sector is limited because of the lack of incentives and working capital.

2.3.1.3.1. Financial accessibility

In Ethiopia due to lack of access to finance, there is poor distribution channels for solar technology products. In addition, access to international capital is very difficult. Even though international investors are needed to engage on investment, but foreign currency is restricted for them and off limits for local companies. During the time of investing those international companies in Ethiopia, investors from abroad need to obtain a special permission in a time consuming process that lacks transparency (Kat Harison et al., 2016). According to information obtained from the Development Bank of Ethiopia, about 80% of the solar products imported into the country using the Bank's finance facility were solar lanterns. In recent market intelligence survey the information obtained from key stakeholders and end users also indicated that the price of a SHS is greater than a solar lantern (Lakew, 2017).

Credit access influences the households propensity to adopt new technologies specially for low income households. it can assist rural households to purchase technological products the they needed. One study stated that an increase in accessibility of credit enhances household adoption of new technologies (Khushbu *et al*, 2015).

2.3.1.3.2. Training

The opportunity or lack of getting training could affect the household adoption of solar energy technology. According to the research conducted in Kenya by Keriri (2013), stated that there is a positive relationship between the individuals who had received informal or formal training on solar systems and use. In order to be more confident about the new innovations, trainings can help people towards the adoption and active usage of the technologies provided (Bizien, 2017). Training about new ideas or technologies such as solar energy technology adds a crucial value in the minds of trainees where they acquire this by performing practically the knowledge or the information they read and heard from different sources. This rationale is justified by Ali (1998), who stated that the effective training must be able to take care of all the theories of learning in order to change the action, belief and knowledge components of a trainee simultaneously (Ali, 1997).

2.3.1.3.3. Accessibility of infrastructure

Solar energy technology adoption can also be affected by the accessibility of agricultural extension centre, the location of household from the market, the main road and electric grid. As Legesse (2016) stated, accessibility of agricultural extension center, health extension center, market and access to the main road have direct and indirect contribution on the adoption of renewable energy such as solar and biogas. There is a mean difference between the distance from households' home of adopters and non adopters to agricultural extension center. Which was statistically significant and he concluded that location of renewable energy adopter households are close to agricultural extension center. Similarly, the average distances from the household's home to the main road for alternative renewable energy source for adopter and non adopters were statistically significant. In addition, as the researcher's suggestion, the distant from household's home to market services had negative effect on the decision of adoption of renewable energy source and also significant, that means when the distance of the household's head from the market is increased , the probability of adoption of renewable energy source will be decreased. But it is opposed by Anteneh (2019), who stated that when the households' house distance from local market increase, the probability of adoption of solar energy increase with a positive sign. However, as the researcher proposed, the local market distance is not a statistically significant variable. This is supported by Keriri (2013), the research conducted in

Kenya, in that there is a positive relationship between the distances from the vendor to the households' home. The households' distance from electricity grid can also influence the decision households to use solar energy technology. According to Keriri (2013), the majority of the community members was far from Electricity Grid and had low chances of electricity connection in the near future. This implies that it might be best alternative for households to adopt solar energy to address their energy shortage.

2.3.1.4. Demographic Factors

2.3.1.4.1. Gender of households' head

The effect of gender type of household head on the adoption of solar energy technology varies from place to place based on different socio economic background of the household. According to Anteneh (2019), female headed households are less likely to adopt solar technology compare to male headed households and it is statistically significant. But the study conducted by Guta (2018) suggested that Male headed households are less likely to adopt solar energy technology compared to female-headed counterparts; where the percentage of males households who adopted solar energy technology were less compared to that of non-adopter male households.

2.3.1.4.2. Marital status

Marital Status of the household head is also another important determinate of household adoption of solar energy technology. According to Anteneh (2019), single and divorced household heads have a negative significant effect on the decision of adoption of solar energy and they are statistically significant. This implies that a single household head has of lower Probability of adopting solar technology compare to married household heads. Similarly, the divorced household head has less likely to the adoption of solar energy compared to the married household head. In addition to this, the widowed household head respondent has a negative sign. It indicated that that widowed household heads less likely to adopt solar energy compared to the married household head (Anteneh, 2019).

2.3.1.4.3. Age of households' head

The age of households has a positive and significant effect on the likelihood of the solar energy technology adoption of the households (Guta, 2018), in that he suggested that the households' head who adopted solar energy technology were relatively older compared to non-adopters. But this view is contested by Legesse (2016), and Anteneh (2019), who suggested that the adoption of solar energy has a negative and significant relation with households' age. Legesse (2016) argued that when the age of household head increase, the probability of adoption of solar energy technology will.

2.3.1.4.4. Family size of household

Household size is one of the key demographic factors that determine households' willingness to adopt clean energy sources. Studies found that household size has a negative effect on the adoption of solar energy and statistically significant (Anteneh 2019; Gitoone, 2014; Abera, 2019). He also suggested that the results indicate when household size increased, the probability of households to adopt solar energy technology will decrease by (Anteneh, 2019). But it is contrary to the study conducted by Guta (2018), where he illustrated that household size was found to have a significant and it has positive influence on the adoption of solar energy technology.

2.3.1.5. Socio Economic factors

2.3.1.5.1. Level of Income

Income level of the household is one of the key socioeconomic determinants of solar technology adoption. Many researchers confirmed that the probability of the household adoption of solar energy has a positive and significant relation with household income (Guta, 2018; Anteneh, 2019; Legesse, 2016). The variable is statistically significant (Anteneh, 2019; Guta, 2018). Other researcher Abera (2019) concluded similarly that households with low income level choose relatively cheap energy sources, but have harmful effect for their health and environment. This means households with relatively high income level prefer to choose relatively expensive but are clean and modern

2.3.1.5.2. Education Level of Household

Adoption of household towards modern and clean energy could be affected by education level of the head of the household and family members. While households with literate heads tend to choose electricity than the illiterate ones, the latter choose more of kerosene and dry cell. Household with family members that attained high school or more prefer electricity and dry cell. To the contrary, households posing family members with less education use more of kerosene and dry cell than electricity or solar energy (Abera, 2019).

The other research conducted by Guta (2018) in Woliso, noted that the average education levels of both the head and spouse in year were high compared to their respective non adopters head and spouse respectively. This view is supported by research conducted by Anteneh (2019) in Gurage, who suggested that The household head who can read and write are more likely to adopt solar technology as compare to household head that doesn‘t have school enrollment, and it is statically significant. He also added that the respondents with primary education have, respondents with secondary education have, more chance of adoption of solar energy than with no education. Therefore, it could be concluded that that the more household head get more education they are likely to be exposed to more information such as the adoption of solar energy (Guta, 2018; Anteneh, 2019).

2.3.1.5.3. Housing condition

Housing characteristics such as type and size could be one factor that could determine the household adoption of solar energy technology. Evidences found that the number of room of house has positive correlation with solar energy technology adoption (De Groote, 2016 and Abera, 2019). According to De Groote etal (2016), important houseing characteristics such as house age, house size, roof insulation and quality of the roof are statistically significant. There is positive correlation between roof quality of the house and PV installations, as extra investment costs are involved at low roof condition, resulting in lower adoption. It also proposed that as larger house sizes typically have a larger roof surface that give more opportunity to avoid disturbances such as shadow from trees or chimneys and window vents from the roof and thus resulting in an increased probability of adoption. As the researchers revealed, the age of house has a negative effect on PV adoption, where the rate of adoption of solar technology decreases with the age of the houses (De Groote, 2016).

2.3.1.5.4. Land size of Households

Ownership of sizable plot of land is an important asset that affects households' decision to adopt new technologies. It provides extra income for each household and hence enables them to afford costs of the technology. In general, households with large plot of land are less likely to prefer lighting sources that could potentially substitute solar energy system. It is expected that large plot of land enables households to prefer grid connected electricity over solar energy (Abera, 2019). Similarly, Legesse (2016) stated that household those have larger farmland has a positive significant effect on the decision of adoption of renewable energy source. The above view is also supported by Guta (2018), who suggested that landholding size has a significant and positive influence on the households' adoption of solar energy technology.

2.3.1.5.5. Number of cattle of household

Household ownership of cattle is one of the factors affecting solar energy technology in rural areas. Cattle resource is one of the key household assets in rural area of Ethiopia, which contributes for draft power, cash, food, etc. According to Anteneh (2019) and Legesse (2016), households' livestock ownership has a positive effect on the decision of adoption of renewable energy at a significant level, where as the number of livestock resource increase, the probability of adoption of renewable energy source will increase.

2.3.2. Socioeconomic differences between adopters and non adopters

The research conducted in USA by revealed that Households who adopted solar energy technology have higher incomes, live in larger homes, more educated, and expect to stay in their homes for longer than their non-adopting peers (Sigrin *et al.*, (2015). The researchers also revealed that the two groups (adopters and non adopters) differs in their expectation regarding impact solar could have on their home resale value and electricity retail rate changes. When we examine differences between early and more recent adopters, those who adopt recently are increasingly installing solar to protect against price increment of future electricity and to lower electricity costs as opposed to adopting strictly for environmental reasons. In case of Ethiopia, according to Guta (2018), there is a significant variation in education level of households between adopters and non adopters like USA. As he sated, households who adopted solar energy technology had more educated household heads and spouses compared to non adopters head and spouse have average education level. In case of asset, there is a significant difference between two groups in land holding size and cattle ownership.

In terms of land holding size, adopters having more land than the non-adopters, and in terms of cattle ownership, adopters of solar energy technology had a significantly higher average number of cattle compared to non-adopter. There is also a significant variation in the age of households between adopters and non adopters in that adopters were relatively older compared to non adopters. But, this opposes Sigrin *et al*. (2015), where there is no difference found between individuals who are retired non retired regarding solar energy technology adoption. However, other paper conducted by De Groote *et al* (2016), viewed the issue exclusively from the above researchers' views, who proposed that there is a fact that older generations have less concern for environmental issues and global warming than younger generations or have a lower knowledge of the technology such as solar which affects the adoption rate.

As Guta (2018) stated, gender of households' head shows a significant variation between adopters and non adopters, where the adopted percentage of male headed households less that compared to noon adopted male headed households. Similarly, there is a significant variation in the household size between adopters having average inhabitants compared to non-adopters inhabitants. It is supported by another study who confirmed that adopters were found to be significantly more likely to have children living in the household (Sigrin *et al*., 2015).

2.4. Conceptual Framework

The figure below shows the relationships between adoption of solar home system and different factors/independent variables /determining households' decision either to adopt or reject the technology.

In this study, adoption stands for full adopter households of solar home system and still using it, and non adopters are those households who are not still used solar energy technology in their home.

The study tried to establish facts about to what extent socio economic factors including income level, participation in off farm income earning activities, level of education, house type, size of land, and number of cattle are expected to limit the adoption extent towards solar home system. Demographic characteristics such as, gender, age, marital status and family size are also other independent variables expected to affect the adoption trend of household towards solar energy technology. The other institutional factors including credit access, training, and access to communication technologies, media access and distance might influence households' decision to adopt solar. Prior information or knowledge that households have about solar energy technology also considered to be one of the factors which can influence the adoption decision of households. the mal function of solar products. The attitude of households towards solar energy technology is considered as moderating variable, which also could affect the adoption intensity. There are also intervening variables such as government policies and procedures that may influence the relation between independent and dependent variables in the study area.

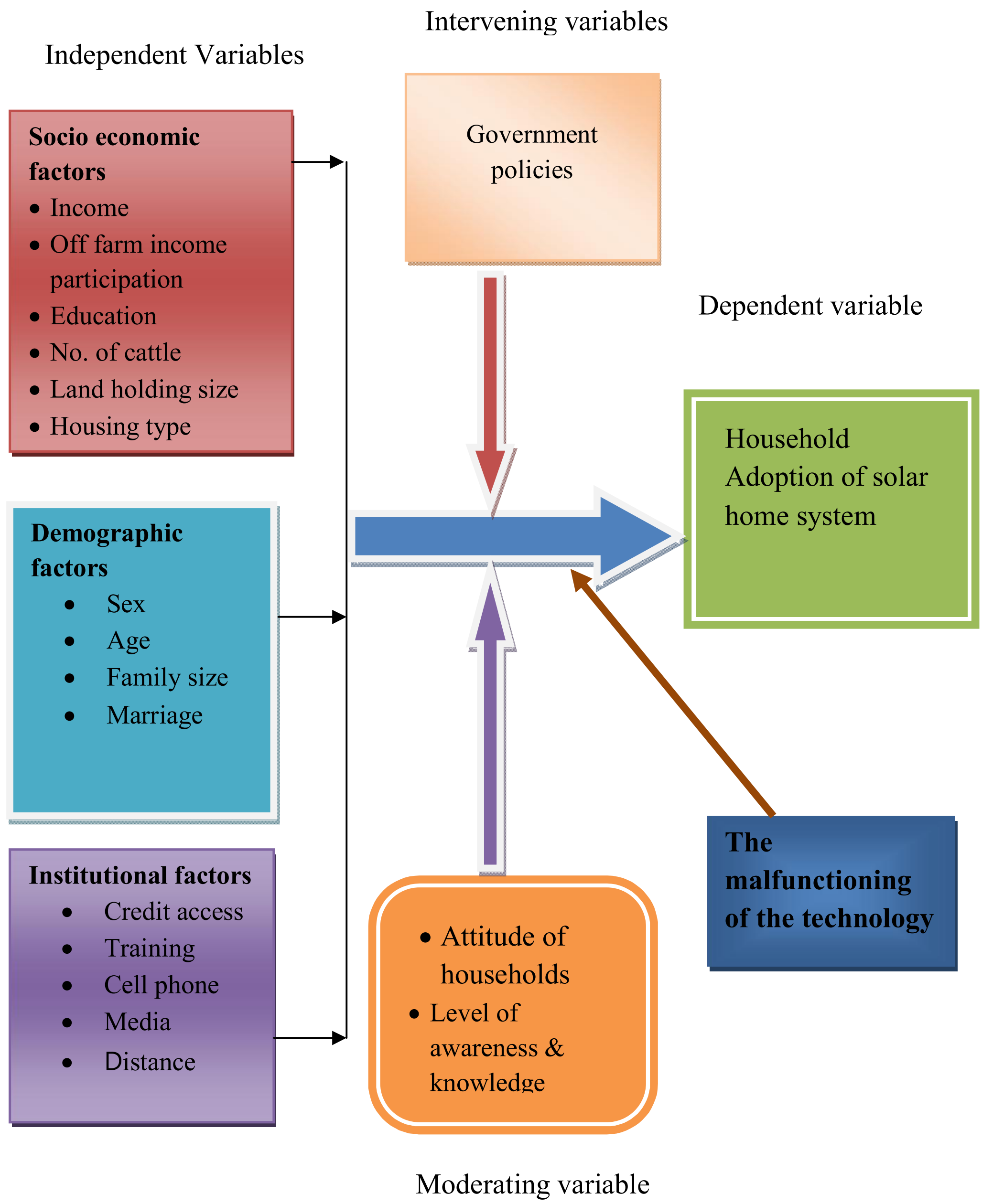

Figure 4: Conceptual framework

Source: Researcher's own construction

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Description of Study Area

The study was conducted in Basoliben district, East Gojjam zone of Amhara national and regional state. It has GPS coordinate of $10^0$09'60.00"N latitude and $37^0$34'59.99" E longitude. It is located 307 km North West of Addis Ababa, the capital city of Ethiopia and 292 km far from the regional capital, Bahir Dar. The district is bordered on the south by a bend of Abay river which separates it from Oromia region, on the north east by Aneded, and on the North West by Gozamin woredas. The total area of the district is about 113,284 hectare with two agro ecological zones of woina dega (46%) and kola (54%). The district is characterized by hilly (35%), flat topography (30), mountain (25%), and valley (10%). The annual rain fall of the district ranges from 900 mm to 1200 mm, and temperature ranges from 15 to 25 C^o. The district has 22 rural and 4 urban and semi urban kebeles with the total population of 170,387. Of which the number of men and women accounts 47.4% and 52.6% respectively. Out of the total population of the district, only 7.9% of the population is urban resident and the majority (92.1%) is rural settler.

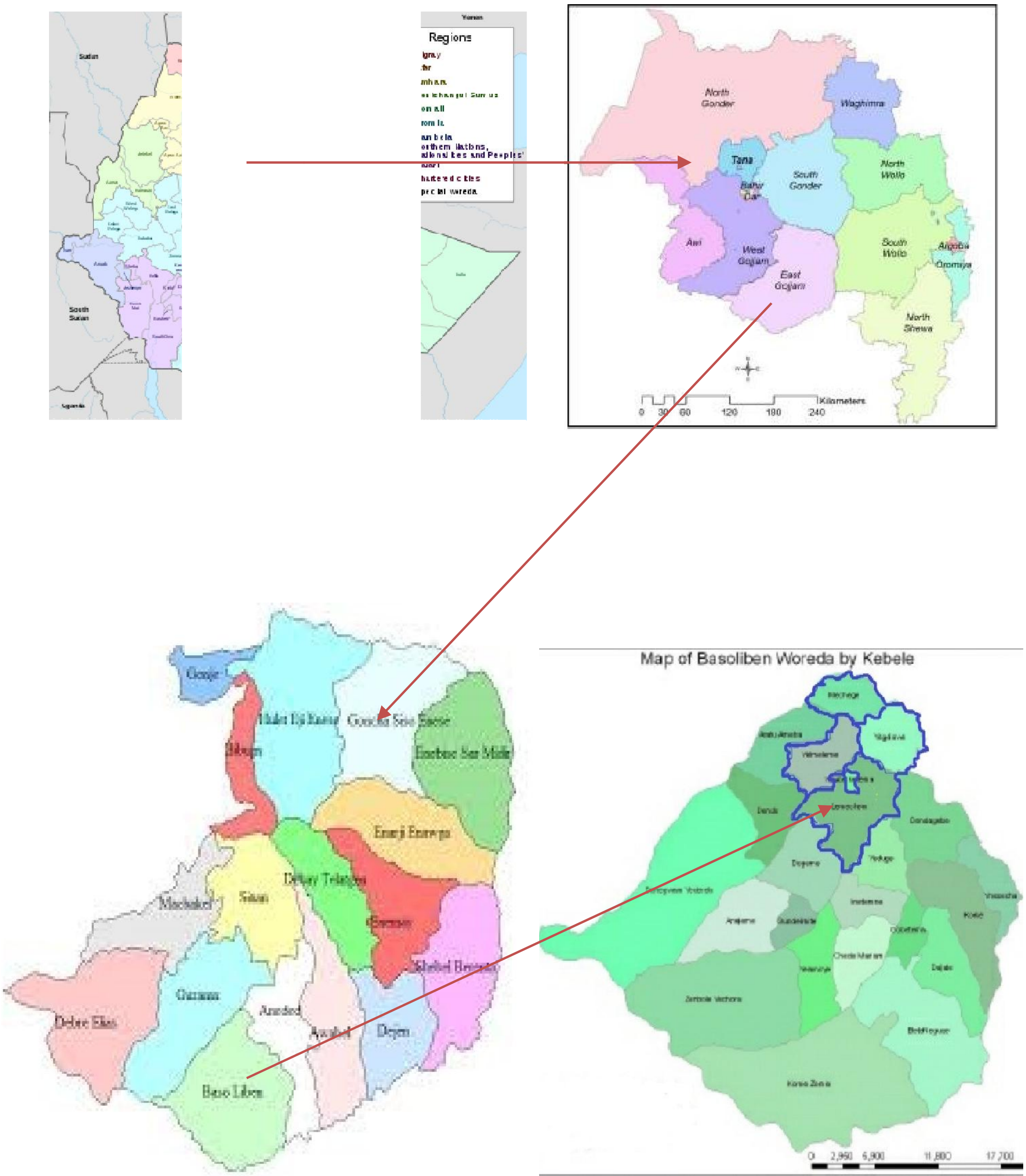

Figure 5: Map of study area (CSA, 1994)

3.2. Research Design

A research design is a procedural plan to be adopted by a researcher that determines the path going to be proposed to take for own research journey (Kumar, 1989). Among several designs, cross sectional research design is selected and employed for this study in order to examine factors influencing household adoption of solar home system based on the rationale that the study had short period of time, where the data collection was carried out with one time survey. According to Kumar (1989), cross sectional study design is best suited to studies aimed at finding out the prevalence of phenomenon, problem, situation, attitude or issue by taking a cross section of the population. It incorporates both quantitative and qualitative approaches and is useful in obtaining an overall picture as it stands at the time of study (Kumar, 1989).

3.3. Types and Source of Data

Both qualitative and quantitative types of data relevant to conduct the research were collected from both primary and secondary sources. The Primary data was collected through questionnaire from sample household respondents, and key informant interview with distributors, kebele experts, saving and credit institutions and woreda's water and energy office. The Secondary data will be obtained from written documents, various reports, books, published researches and other related sources.

3.4. Sampling techniques and sampling size

Both purposive and random sampling techniques were used as needed in this study. According to Kumar (2011), purposive or judgment sampling is used to provide the best information about the objectives of the study and also to describe a phenomenon about something for that only a little information is known. Regarding random or probability sampling, each element has equal chance to be chosen as a sample in the population, which means in sampling, the choice of one element is not dependent on the choice of the other element (Kumar, 1989)

In this study, out of the total of 22 rural kebeles of the woreda, 4 of them were selected purposively to conduct the study based on infrastructural accessibility, high adoption intensity, time, and other physical factors. The respondents were selected randomly by proportionate their number from both adopted and non adopted sides of households living in the purposively selected Kebeles of the woreda. The researcher used simple random sampling in order to remove bias and to get precise information. The purposively selected kebeles were Yelemelem, yegelaw, Michig and Limichim. According to the woreda's administration office data (2019), the total population of yelemelem kebele is 6550 of which 3238 are males and 3312 are females, with the total households of 1336. Yegelaw kebele has a total population of 4010, of which 1900 are males and 2110 are females with 818 of total households. Michig kebele has a total population of 5024, of which 2399 are males and 2625 are females with total households of 1025. The remaining kebele, Limichim has a total population of 9759, of which 4781 are males and 4978 are females with total households of 1991.

The required sample size for the purpose of this study was determined using the formula developed by Yamane (1967) with 95% level of confidence.

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

Where: n = sample size

N = total number of households

e= level of precision

So, the total sample size of the study was:

$$n = \frac{5170}{1+5170(0.05)2} \approx 371$$

Table 1: Distribution of sample respondents by kebeles

No	Name of the kebeles	Total population	Total household number	Total no. of solar adopted HHs	Total no. of non adopted HHs	Sample size		
						Adopted	Non adopted	Total samples
1	Yelemelem	6550	1336	766	571	55	41	96
2	Yegelaw	4010	818	747	71	52	6	58
3	Michig	5024	1025	512	513	37	37	74
4	Limichim	9759	1991	1170	821	84	59	143
Total		**25343**	**5170**	**3195**	**1976**	**228**	**143**	**371**

Source: Baso Liben Woreda administrative office (2020)

3.4. Data collection Methods and instruments

The qualitative and quantitative data collection methods were used to investigate the issue in detail. The main reason behind of using qualitative method of data collection is that it helps to gain an understanding of underlying opinions, reasons, and also provides insights into the problem. Whereas the reason of using quantitative method is that it allows for meaningful comparison of responses across participants and study sites (Gill *et at.*, 2008

3.4.1. Questionnaires

This data collection instrument was employed to collect data from sample house hold respondents. Questionnaires are helpful to respondents, which enable them to stay behind in unnamed or unidentified condition to be honest in their response (Schindler, 2003). Structured and semi structured questions were included in the questionnaire to collect both quantitative and qualitative data concerning all objectives of the research. The questionnaire contains the socio-economic characteristics of the selected household, demographic and institutional factors determining the household adoption of solar home system. The questionnaires were administered in Amharic/local language for local households and key informant interviewees.

3.4.2. Key informant Interview

The main rationale of using this instrument is that it provides flexibility to explore new ideas and issues that had not been anticipated in planning the study but that are relevant to its purpose. A key informant interview is one of the data collection instruments often provide data and insight from knowledgeable people that cannot be obtained with other methods (Kumar, 1989). Using this data collection instrument, issues related to objective one and two of the research such as factors determining the adoption trend and attitude of the household were assessed. As described in the table below, a total of 12 individuals from different sectors including representatives of saving and credit institutions, solar energy product distributors, kebeles' officials and woreda experts of water and energy office who have detail information about solar energy technology was selected purposively and interviewed to know their ideas, and opinions about the overall situation of solar home system adoptions and its determinants for the purpose of qualitative data.

Table 2: key informants interviewed from different sectors

No.	Sector/place	Number of key informants		Total
		Male	Female	
1	Kebele	2	1	3
2	Woreda's energy office	2	-	2
3	Saving & credit association	4	-	4
4	Solar energy technology product distributors /agents	2	1	3
	Total			12

3.6. Methods of Data Analysis

The data analysis in this research was dependent on qualitative and quantitative methods. The qualitative data were analyzed using content analysis and the quantitative data were also analyzed using descriptive and inferential statistics. Logit model was used to analyze the effect of different factors influencing households' decision in adoption process. T-test and chi square test were conducted to compare the socio economic and demographic differences of the two respondent categories of adopters and non adopters of solar home system. Moreover, data collected thorough key informant interview from different bodies were analyzed using textual analysis. Statistical packages such as SPSS version 23 and excel were used to manage and analyze the data. The collected data were presented using different statistical techniques such as percentage and frequency distribution.

3.7. Model specification

The study used binary logistic regression model since the dependent variables are dichotomous. This means that it takes the value of 1 if someone adopts solar energy technology and it has the value of 0 if not (Gujarati, 2004). The reason behind using this model in the study than probit model is that the equations of logit model are and it is directly interpretable as log-odds, while the probit does not have a direct interpretation (Pindyck and Rubinfeld, 1981). This model is also used in previous studies by several researchers for the same issue such Guta (2018) and Yusuf and Adeyemi (2019). According to Park (2013), there are two models of logistic regression, binary logistic regression, and logistic regression models. Binary logistic regression is basically used when the dependent variable is dichotomous (only two categories) and the independent variables are either continuous or categorical (Adepoju, 2019).

The logit regression use maximum likelihood method to estimate parameters in the model after transforming the response variable into logit (Carson, 2008). The product of the probabilities of solar energy adoption success and non adoption specifies the maximum likelihood of the models. The coefficients of the logit model, like the ordinary regression coefficient, define the parameter estimates. According to Gujarati (2004), the equation of the model is written as follows after converting the dependent variable into the natural log of the odds (logit):

$$P_i = E(Y) = {}^{1}\!/_{\mathrm{x}} = \frac{1}{1+e^{-(B_1+B_2X_i)}} \text{...} \textbf{(2)}$$

Where (p_i) is the probability of adopting solar home system, (x_i) stand for the set of explanatory variables (i.e. income, off farm income, level of education, gender of the household head, age of the household head, land size, number of cattle, family size, marriage, housing condition, prior knowledge or awareness, infrastructure/distance, credit accessibility, training access, mobile access, media access, electricity access).

When equation 2 is logistic regression equation, let consider, Z_i=B_1+B_2x_i or replaced by zi in the first equation, then we obtained equation 2.

$$P_i = \frac{1}{1+\mathrm{e}^{-\mathrm{z}_\mathrm{i}}} = \frac{\mathrm{e}^{\mathrm{z}}}{1+\mathrm{e}^{\mathrm{z}}} \text{...} (3)$$

In equation 3, Z_i exist between -∞ and +∞ and P_i is between 0 and 1. Where P_i shows the probability of households who use solar energy technology, and X_i is the explanatory variable, (i) is an individual household observation (where pi equal to one the probability that households use solar energy technology and 1-P_i, is the probability of households who can be categorized under not using. Then, the probability of households who do not use can be explained in equation 4 as follows:

$$1 - P_i = \frac{1}{1+e^{z_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Equation 5 can be obtained by dividing the households who use to those who do not use solar energy technology. Therefore, the equation is;

$$\frac{p_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Using the natural logarithm of both sides of the equation, equation (6) can be obtained

$$\ln\left(\frac{p_i}{1-p_i}\right) = ln = [e^{B_o} + \sum_{i=1}^{M} B_i X_i] = Z_i \ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

When the disturbance term Ui is taken in to account, the logit model becomes:

$$Z(i) = B_o + B_1X_1 + B_2X_2 + B_3X_3 + \cdots . B_mX_m + u_i \ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

Where Bo is the intercept, B_1, B_2, B_3… Are the slope parameters in the model. The slope coefficient indicates the change log-odds in favor of being adopting solar energy technology as independent variable change. X_i stands for the vector relevant characteristics of households whereas U_i is error term.

$$Z_i = B_o + \sum_{i=1}^{M} B_i X_i + U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

Therefore, the above econometric model was used in this study to analyze the factors determining household's adoption of solar energy technology.

3.8. Description of explanatory variables

This study was mainly aimed on examining factors influencing decisions to adopt solar technology used at household level. In this study, socioeconomic, demographic, and institutional variables were expected to be the main factors influencing rural households' decision to adopt solar home system.

Household income is one of socioeconomic factors that could affect adoption of solar energy technology. Many literatures indicated that as households' income get higher, their propensity to adopt solar energy technology also increase compared to their counter parts (Guta, 2018; Anteneh, 2019; Legesse, 2016). Thus, in this research household income is expected to have positive influence on solar home system adoption. Moreover, asset variables (number of cattle and land holding size) positively affect solar energy adoption since they are the main source of households' income in rural areas. Therefore, number of cattle and land holding size are expected to positively influence households' willingness to adopt solar home system. Participating in off farm income earning activity is one of the key socioeconomic factors that could affect solar energy technology adoption. Off farm income is considered as a substitute for borrowed capitals for rural household economies where credit availability is either misplaced or dysfunctional (Obayelu A., 2017). Another study regarding this revealed that households who have additional income (remittance) are more likely to invest on solar energy technology (Anteneh, 2019). Therefore, this is also expected to have positive effect on solar home system adoption.

Empirical studies concerning demographic variable are inconclusive and still debatable. Regarding gender of household head, there are two contrasting groups, which means the first group argued that male headed households are more likely to adopt solar energy technology (for instance Anteneh, 2019) and in the other side, female headed households are more likely to adopt solar energy technology (Guta, 2018; Partick, 2009). Therefore, in this study gender of household head is expected to have either positive or negative influence on solar home system adoption.

Some literatures revealed that older household heads are less likely to adopt solar energy technology compared to younger ones. That means it has a negative influence on households willingness to adopt solar energy technology (Anteneh, 2018 and Legesse, 2016). But other study found that households' age has a positive influence on solar energy technology adoption, because it might be related to the fact that older household heads may be wealthier as they accumulate more productive resources that enable them to invest on solar energy technology (Guta, 2018). In this study age of households' head is hypothesized to affect solar home system adoption either positively or negatively. Likewise family size is expected to have either positive of negative influence on solar home system adoption. Literatures indicated that family size has a negative effect on solar energy technology adoption (Gitone, 2014; Anteneh, 2019 and Abera, 2019). This is because households with large family size spend more resources in upholding of their children rather than investing on solar energy technology. The other study also revealed that household size has a positive effect on solar energy technology adoption (Guta, 2018). But marital status is expected to have a positive influence on solar home system adoption. Previous evidences stated that married household heads are more likely to adopt solar energy technology than either single or divorced household heads (Anteneh, 2019).

Regarding education, studies revealed that education level of household heads have a positive effect on solar energy technology adoption (Abera, 2019; Guta, 2018 and Anteneh, 2019). This is because of the reason that education enhances individuals' health and environmental awareness that helps them to choose clean and modern energy sources. Thus, in this study educational status of household heads is expected to positively influence the adoption of solar home system. Similarly, type and size of house is expected to positively affect solar home system adoption. Some evidences found that the number of room of house has positive correlation with solar energy technology adoption (De Groote, 2016 and Abera, 2019). Prior information or knowledge that households have about solar energy technology is considered as one driving factor of solar energy adoption. A study found that there is a positive relationship between the adoption of solar technology and awareness and knowledge about the technology (Naomi, 2014). Therefore, it is proposed to influence solar home system adoption positively in the model estimation.

Training is one of the institutional factors considered as a key driving factor of solar energy technology adoption at household level. Training given for households about solar energy technology has a positive effect on their decision to adopt (Keriri, 2013). The other study also added that trainings can help people to be more confident about the new innovations for adoption and active usage of the technologies provided (Bizien, 2017). Therefore, in the study, training is controlled in the model and it is hypothesized to positively affect solar home system adoption. Likewise credit accessibility is the other institutional factor to be estimated in the model. One literature stated that an increase in accessibility of credit enhances household adoption of new technologies (Khushbu et al, 2015). This is because it can assist rural households to purchase technological products the they needed. Therefore, access to credit was expected to positively affect solar home system adoption.

Solar energy technology could be influenced by media (either radio or TV) and mobile phone access. Media and phone access create exposure to households to be more aware of new and timely information about new technologies. Regarding this a previous study revealed that accessibility of modern communication technologies including radio and mobile cell phone found to have positive influence on adoption of modern and clean energy technologies (Abera, 2019). Thus, in this study both media and cell phone access are expected to have positive effect on adoption of solar home system.

Distance from home to different infrastructures including main road, market and agriculltural extension center are also considered as key factors expected to affect solar PV technology adoption. Legesse (2016), found that both distances from home to main road and agricultural center have a negative effect on households' willingness to adopt soalr energy technology. This is due to the reason that the average distance of households to agricultural extension center might affect their information accessibility regarding solar and other agricultural extension services that would influence their product. Likewise, distance from home to surrounding market negatively affect solar energy technology adoption (Legesse, 2016). That means since solar products are found in market areas, households who are close market are more adopters. Therefore, distance from home to, main road, agricultural extension center and market are proposed to negatively influence solar home system adoption

Table 3 Description of Explanatory Variables and their expected sign on the adoption of solar energy technology at household level

Variables	Definition	Description while encoded	Expected sign	Sources & their findings /sign/
Income	Total income of household in terms of birr per year	Continuous variable, Birr	+	Guta, 2018 (+); Anteneh, 2019 (+); Legesse, 2016 (+)
land	The size of farm land	Continuous	+	Abera, 2019 (+);

	a household owned in hectare	variable, number		Legesse, 2016 (+), Guta, 2018 (+)
Cattle	The number of cattle a household have, which is measured in TLU	Continuous variable, number	+	Anteneh, 2019 (+); Legesse, 2016 (+)
Off farm income	Income source activities other than agriculture	Dummy, 1= If the household has off farm income, 0= otherwise	+	Obayelu A., 2017 (+) Anteneh, 2019 (+)
Gender	Sex of the household head (either male or female)	Dummy, 1= male, 0= female	±	Guta, 2018 (male= (-), female (+)); Anteneh, 2019 (Male=(+), female= (-)) Partick (2009) (male= (-), female (+))
Age	Age of the household head measured in year	Continuous variable, year	±	Guta, 2018 (+); Anteneh, 2019 (-); Legesse, 2016 (-)
Family size	Number of family members in a household	Continuous variable, number	±	Gitone, 2014 (-), Anteneh, 2019 (-); Guta 2018 (+), Abera, 2019 (-)
Marriage	Marital status of the household head /single, married, widowed or divorced/	Dummy, 1= married, 2= single, 3= divorced, 4= widowed	+	Anteneh, 2019 (+)
Education	Education status is a state of being educated or not	Dummy, 1=Literate, 0= Otherwise	+	Abera, 2019 (+); Guta, 2018 (+); Anteneh, 2019 (+);

House	House condition which is differentiated in terms of size and the material which made from	Dummy, 1=traditional(terraced), 2= one room tin roofed house, 3= two room tin roofed house, 4= three and above room tin roofed house	+	De Groote et al. 2016 (+), Abera, 2019 (+)
Prior information /knowledge	Knowledge or information about something which is obtained informally from different sources	Dummy, 1= if the household has prior information/knowledge about solar energy, 0= otherwise	+	Naomi, 2014 (+)
Training	practically acquired skills about something / solar in this case /	Dummy, 1= If household got training, 0= otherwise	+	Keriri ,2013 (+); Bizien, 2017 (+); Ali, 1998 (+)
Credit	A loan from financial institutions or other bodies.	Dummy, 1= If household got access to credit, 0= otherwise	+	Khushbu et al, 2015 (+)
phone	Electronic device helps to communicate together /in this case cell phone is a dummy variable/.	Dummy, 1= if household has cell phone,0 if not	+	Abera, 2019 (+)
Media	Electronics or other means used to access information /in this case it might be radio	Dummy,1= Yes, 0= otherwise,	+	Abera, 2019 (+)

	or TV/			
Distan mark.	Market distance measured in km.	Continuous, kilo meter	-	Legesse, 2016 (-); Anteneh, 2019 (-); Keriri, 2013 (-)
Distanc agriext.	Distance from agricultural extension service measured in km.	Continuous, kilo meter	-	Legesse, 2016 (-)
Distanr oad.	Distance from the main road measured in km.	Continuous, kilo meter	-	Legesse, 2016 (-)
Kebele-dummy		Kebele dummy (0= Michig, 1= Yelemelem, 2= Limichim, 3= Yegelaw)	±	

3.9. Data validity and reliability

The main reason of performing validity and reliability in research were to determine whether the questionnaires are fit to collect the desired data or not. Validity was used to decide how the inferences carried out for the result of the assessment are meaningful and serve the purpose of assessment. In this study, content validity was employed to affirm whether the data collection tools achieve the measurement or not. In addition, the data collection tools were shown to experts who have better understanding about the issue to get relevant input to improve it.

As Creswell (2014) stated, "Reliability refers to whether scores to items on an instrument are internally consistent (i.e. are the item responses consistent across constructs?), stable over time (test- retest correlations), and whether there was consistency in test administration and scoring." Reliability reflects consistency and replicability over time. During the time of conducting this research, pilot study was carried out prior to undertaking the main investigation to test the reliability of data collection tools by using 10% of the respondents in the selected kebeles. In this study cronbachs' alpha was applied to calculate the reliability of data gathering tools and found to be 0.714. According to George and Malley (2003), the result of reliability from cronbach's alpha coefficient ranges from 0.7 to 0.79 is considered as acceptable. Therefore, since the reliability test for data gathering tools of this research is 0.714, the overall internal consistency was acceptable.

3.10. Ethical considerations

To protect their research participants' security, researchers need to perform certain activities such as promote the integrity of research, develop a trust with them; guard against delinquency and immodesty that might reflect on their organizations or institutions; and cope with new challenging problems (Creswell, 2014). In this study the respondents were well informed about the objective and the purpose of the study. The researcher guaranteed the respondents that their response was only used for the purpose of the research. Furthermore, their property and identity were secured and unidentified for anybody. Since this is a voluntary activity or support, any respondent who refuses to be interviewed was not being forced to get his/ her response.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1. Descriptive analysis

4.1.1. Demographic and socio-economic characteristics of households

The demographic and socio-economic characteristics such as sex, age marital status, family size, education level of households' head, land holding size, livestock number, household's income, participation in off farm income activities and house type were assessed to indicate their effect on the adoption of solar home system.

As shown in the table below, a total of 371 (61.5% adopted and 38.5% non-adopted) household respondents were participated in the study. Of which 90.8% were males and 9.2% were females headed households. From adopted households, 92.5% of them were male headed and 7.5% were female headed, whereas the male and female headed non adopted households were 88.1% and 11.9% respectively. The chi-square (X^2) test indicated that there is no statistical association between sex of respondents and decision to adopt solar home system. The mean ages of adopted and non adopted respondents of solar energy technology were 48.06 and 52.29 years respectively. This indicates that the non adopter households of solar home system were relatively older than adapters. The P value of t test for this result indicated that there is a significant ($P<0.01$) mean difference between the age of solar technology adopters and non adopters. On the contrary, Guta (2018) revealed that household heads of solar energy adopters are relatively older than non adopters.

The average family size of households was 4.91, which is a bit more than the national average rural family size of the country, which was 4.9 (CSA and ICF, 2016). The average family sizes of the adopted and non adopted respondents were 4.78 and 5.15 respectively. This signifies that households who adopted solar energy technology had less family size than non adopter households. The p- value for family sizes also indicates that there is a significant ($P<0.05$) mean difference between adopter and non-adopter households. Regarding the marital status, the majority (87.3%) of the respondents were married, while 1.1%, 4.6%, and 7% were single, divorced and widowed respondents respectively. The X^2 test indicated that there is no statistical association between marital status of household heads and decision to adopt solar home system.

In the same way, concerning educational level, as shown in the table 4, 40.7% of the household heads were illiterate who couldn't read and write. The other 47.71%, 10.24%, 0.8%, 0.3% and 0.3% were those who able to read and write/basic education/, primary education, secondary education /9-10/, preparatory education /11-12/ and TVET and above level of education respectively. The analysis indicated that more number of educated households' heads were solar technology adopters compared to non adopters. The chi square test showed that there is a statistical association between education level of household heads and decision to adopt solar home system.

Regarding the type of house, there is a significant difference between adopters and non adopters. As shown in the table 4, 8.1% of the households had tin roofed house with one room, 47.4% of households had tin roofed house with two rooms and the remaining 44.5% of households had tin roofed house with three and above rooms. The analysis indicated that the majority of adopters were owned relatively better housing condition /tin roofed houses with two rooms and three and above rooms/. But, most of non adopter households were inhabited in houses with two rooms and below. The X^2 test indicated that there is a statistical association between housing type of respondents and solar home system adoption.

Table 4: Demographic and socio economic characteristics of respondents on categorical /dummy variables

Explanatory variables	Category	Adopters		Non adopters		Whole sample		X^2 test
		No.	%	No.	%	No.	%	
Sex of HH head	Male	211	92.5	126	88.1	337	90.8	**0.150**
	Female	17	7.5	17	11.9	34	9.2	
	Total	228	100	143	100	371	100	
Marital status	Single	3	1.3	1	0.7	4	1.1	**0.196**
	Married	204	89.5	120	83.9	324	87.3	
	Divorced	10	4.4	7	4.9	17	4.6	
	Widowed	11	4.8	15	10.5	26	7	

	Total	228	100	143	100	371	100	
Education level	Illiterate	66	28.9	85	59.4	151	40.7	0.000
	Basic education/able to read & write/	129	56.6	48	33.7	177	47.71	
	Primary education	28	12.3	10	6.9	38	10.24	
	Secondary education/9-10/	3	1.3	-	-	3	0.8	
	Preparatory education/11-12/	1	0.4	-	-	1	0.3	
	TVET & above	1	0.4	-	-	1	0.3	
	Total	228	100	143	100	371	100	
Off farm income participation	Yes	30	13.2	7	4.9	37	10	0.012
	No	198	86.8	136	95.1	334	90	
	Total	228	100	143	100	371	100	
House type	One room & tin roofed	4	1.8	26	18.2	30	8.1	0.000
	Two rooms & tin roofed	90	39.5	86	60.1	176	47.4	
	Three and above rooms & tin roofed	134	58.8	31	21.7	165	44.5	
	Total	228	100	143	100	371	100	

Source: own survey data (2020)

Regarding the land holding, the majority (98.7%) of the households had their own land, whereas 1.3% of households had no land. As shown in the table 5, the average land holding size of the two groups indicates that adopters had more land size (1.579 hectares) than non adopters (1.343 hectares). This difference shows a statistically significant at 1%.

The majority of the households (97.3%) owned cattle (in tropical livestock unit).Whereas 2.7% had no their own cattle. As indicated in the table 5, there is a significant difference between the number of cattle of adopters and non adopters, where adopters had higher mean (3.872) than non adopters (2.678).

The analysis showed that the mean of annual income of solar energy adopters (88992.69 birr) was greater than the mean of annual income of non adopters (66107.45 birr). The p value for income indicates that there is a significant (P<0.01) mean difference between adopters and non adopters of solar energy technology. In addition, 10% of the households had additional income sources /off farm income including remittance 5.4 %, hand craft 1.6%, and trade 3%/ in addition to their main income source /agriculture/. But, the majority (90%) of the households had no additional income. The p value of t-test for additional income also shows a significant variation at 5% between the two groups.

Table 5: Descriptive statistics and test of mean differences of demographic and socio-economic characteristics of respondents on continuous /discrete variables

Explanatory variables	Min	Max	Adopters		Non adopters		Total mean	Total SD	P-value for t-test
			Mean	Standard deviation	Mean	Standard deviation			
Age	27	90	48.06	10.201	52.29	10.947	49.69	10.682	0.000
Family size	1	9	4.78	1.519	5.15	1.477	4.91	1.498	0.020
Land holding size	0	4.50	1.579	0.790	1.343	0.632	1.487	0.742	0.002
Household's income	14196	261700	88992.69	37476.82	66107.45	34806.10	80170.7	38092.31	0.000
cattle (TLU)	0	11.2	3.872	2.133	2.678	1.475	3.411	1.991	0.000

Source: own survey data (2020)

4.1.2. Descriptive analysis of institutional factors affecting solar home system adoption

The majority (96.5%) of the households had opportunity of getting credit. The remaining 3.5% of respondents had no access to credit. Most of respondents (84.6%) who had no credit access were non adopters, while 15.4% were adopters. X^2 test for this result shows that there is a statistical association between credit access and solar home system adoption.

The majority (99.16%) of those households who had credit opportunity were from credit institutions and the remaining 0.84% of respondents' credit access were from rich individuals. Even though the majority of the respondents had credit opportunity, most of them were not willing to borrow money either from credit and saving institutes or other body due to different reasons. As shown in the table 6, only 22.4% of total respondents (36.4% of the adopted) borrowed money to buy solar energy technology products. 8.2% of respondents were not willing to borrow due to their fear of inability to pay, 10.2% of respondents refrained themselves from credit due to high interest rate, 42.9% of respondents confirmed that they did not need any credit service, 10.5% of respondents reported that they could not get credit due to credit delay and bureaucracy, and the remaining 5.4% of respondents refrain themselves due to both fear of inability to pay back the credit and high interest rate.

Table 6: Reasons of respondents who had no credit access to buy solar energy technology product

Reasons	Frequency	Percentage
Credited	83	22.4
Fear of inability to pay	32	8.6
High interest rate	38	10.2
No need of credit	159	42.9
because of credit delay and bureaucracy	39	10.5
Fear of inability to pay & high interest rate	20	5.4
Total	371	100.0

About 55.26% of the respondents received informal /awareness creation/ training on how to utilize solar energy technology products in their home. The remaining 47.74% of respondents replayed that they had never received neither formal nor informal training regarding solar energy technology. The training was delivered by the energy office of the woreda and solar energy product distributors /agents/ jointly. As shown in the table 7, the X^2 test indicated that there is a statistical association between training and solar home system adoption.

Respondents who gained training about solar energy technology had different confirmations concerning the training they received. Out of the total respondents who accessed to training, 34.14% of them replayed that the training helped them to use solar in their home in a very good manner. 60.98% of them replayed that the training helped them to use solar in a good manner and the remaining 10% responded that they didn't get any advantage from the training they had.

As shown in the table 7, below, 51.2% of the respondents had their own mobile cell phone, whereas 48.8% had no mobile cell phone. More households (65.4%) who adopted solar energy technology had mobile cell phone compared to non-adopters (28.7%).This indicated that those households who had mobile cell phone had more chance of getting information about solar energy technology than those who had no mobile cell phone. Similarly, regarding media access, 81.9% of the total respondents accessed with media (79.7% radio & 2.2 TV). The remaining 18.1% had no either radio or TV. Most of solar energy technology adopters (995.2%) had media access (91.2% radio & 3.9% TV) compared to non adopters (60.8%) (55.9% radio & 4.9% TV).. The X^2 test for both mobile cell phone and access to media showed that there is a statistical association with households' decision to adopt solar home system.

Table 7: Institutional factors of solar home system adoption on categorical /dummy variables

Variables	Category	The whole sample		Adopted		Non-adopted		X^2 test
		No.	%	No.	%	No.	%	
Credit	No	13	3.5	2	0.88	11	7.69	0.001
	Yes	358	96.5	226	99.12	132	92.31	

accessibility	Total	371	100.0	228	100	143	100	
Training access	Yes	205	55.26	183	80.26	22	15.38	0.000
	No	166	44.74	45	19.74	121	84.62	
	Total	371	100	228	100	143	100	
Own cell phone	Yes	190	51.2	149	65.4	41	28.7	0.000
	No	181	48.8	79	34.6	102	71.3	
	Total	371	100	228	100	143	100	
Media access (either radio or TV)	Yes	217	95.2	87	60.8	304	81.9	0.000
	No	11	4.8	56	39.2	67	18.1	
	Total	228	100	143	100	371	100	
Electricity access	Yes	14	3.8	4	1.75	10	6.99	0.010
	No	357	96.2	224	98.25	133	93.01	
	Total	371	100	228	100	143	100	

Source: own survey data (2020)

Regarding electricity, 96.2% of total household respondents were not accessed. However, only 3.8% were accessed to electricity. Of those households who had been connected to grid, 28.57% were solar energy adopters, whereas 71.43% were non adopter households. The X^2 test reveals that there is a statistical relation between grid connection and solar home system adoption.

As shown in the table 8, the minimum and maximum distances of households' home from the main road were 0.04 and 8 km. respectively. The mean distance of households who adopted solar home system was 2.69 km whereas the mean distance of respondents who didn't adopted was 3.42. Km. The p value for the distance of households' home from main road indicated that there was a significant mean difference (P<0.01) between the mean of the two groups. Regard to the distance of households' home from agricultural extension center, the minimum and maximum distances were 0.2 and 8 km respectively, and the mean of adopters (2.79) was relatively less than from the mean of non adopters (3.36). It indicated that most of non adopters live relatively far from agricultural extension center than adopters. The p value for this also shows a significant mean variation (P<0.01) between the two groups. The analysis also shows that the minimum and maximum distance of households from market area were 0.1 and 12 km respectively. The mean distance of adopters (5.02km) and non adopters (5.88 km) from the market area showed that most of non adopters were relatively far from the market area (town) where they couldn't get information and chances of observing solar energy technology products. The p value of the t-test for this also shows significant mean difference (P<0.01) between the two groups.

Table 8: Descriptive statistics of distance of households from different infrastructures /continuous or discrete variables/

Explanatory variables	Min	Max	Adopters		Non adopters		Total mean	Total SD	P-value for t-test
			Mean	Standard deviation	Mean	Standard deviation			
Distance from home to main road in km.	0.4	8	2.69	2.20	3.42	2.19	2.97	2.23	0.002
Distance from home to agricultural extension center in km	0.2	8	2.79	1.46	3.36	1.79	3.01	1.62	0.001
Distance from home to market	0.1	12	5.02	1.69	5.88	1.74	5.35	1.76	0.000

Source: own survey data (2020)

4.1.3. Types of renewable energy sources and energy efficient technology used by the household

Respondents were asked to know any renewable energy sources and energy efficient technologies to utilize energy. As shown in the table 9, 50.5% of respondents have only used solar energy technology, 0.5% of respondents have used, biogas, 10.2% of respondents have used both solar energy technology and also improved stove, 1.1% of respondents have used both solar and biogas and 6.55% of respondents have used improved stove. The remaining 31.5 % of respondents haven't used any renewable energy sources as well as improved stove. This implies that the majority households of the study area are adopting solar rather than other renewable energy sources and improved stove.

Table 9: Type of renewable energy sources and energy efficient technology used by households

Types of renewable energy sources	Frequency	Percentage
Solar	186	50.1
Biogas	2	.5
Improved stove	24	6.5
solar & improved stove	38	10.2
solar & biogas	4	1.1
I haven't use any renewable energy and improved technology	117	31.5
Total	371	100.0

Source: own survey data (2020)

4.1.4. Solar energy technology adoption

Out of the total household respondents, 61.5% installed solar home system in their home, whereas 38.5% of households had not installed. The result implies that since the majority of households adopted solar energy technology, the woreda has high adoption rate of solar energy technology in the selected four kebeles.

According to the information gained from energy office of the woreda, awareness creation about solar energy and linkage with distributors/agents of solar technology products at office level was started in 2004 E.C./2012 G.C) jointly with credit and saving institutes. As shown in the line graph below, there was an increasing trend of solar energy technology adoption from the starting year of distribution up to 2010 E.C (2018 G.C). But there was a decreasing trend after 2018. During the time of survey, discussion with key informants from solar energy product distributors and energy office revealed the reason why it becomes decreased;

After the year 2018, there was an instable condition due to socio-political problem in most parts of the country. So it was not easy time for distributors/agents to move from place to place freely in order to sell solar energy technology products. In the other side, after those households who have the need and capacity had bought solar energy technology product, the adoption trend has been decreased. Because most of the remaining households who haven't yet solar are so weak economically to afford it and they have to wait until they own financial capacity (key informants from energy office and solar product distributors, 2020).

Furthermore, in this year (2020 G.C), some household respondents (3 respondents) bought solar directly from shop, but according to the information gained, no solar energy technology distribution was undertaken by the facilitation of the office and credit and saving institutes until this data was gathered.

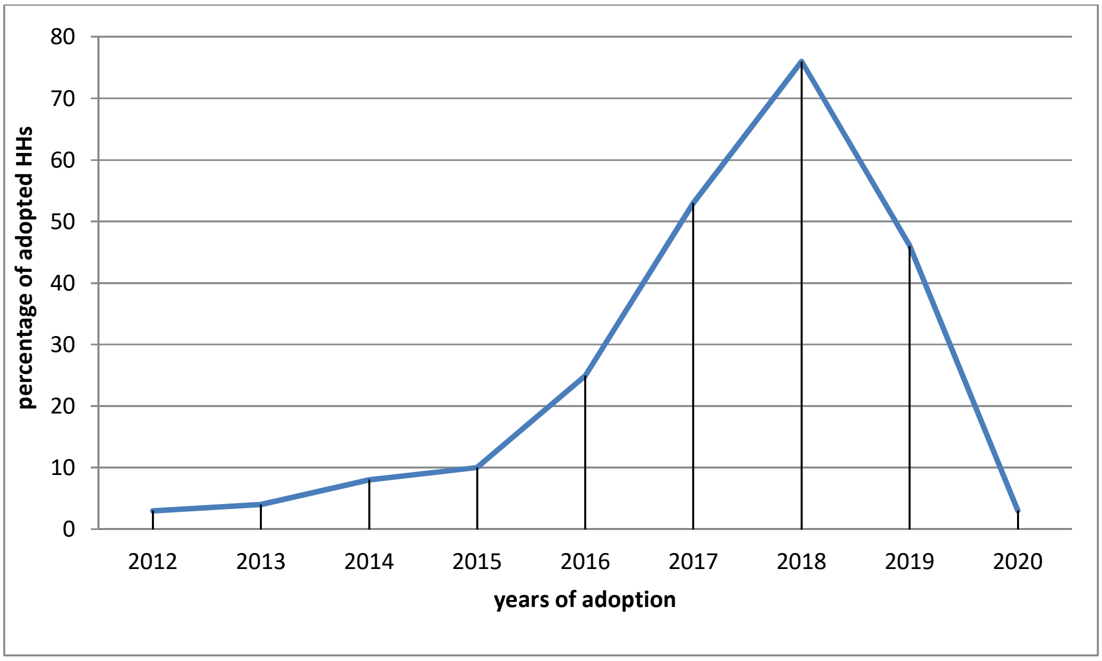

Figure 6: Trends of solar energy technology adoption

4.1.4.1. Types and services of solar energy technology products installed by households

The types of solar energy technology products installed by households are clearly shown in the table 11. Out of the total adopted households 21.9% had installed solar home system products with two lamps, whereas 78.1% of adopted households had installed solar home system product with three and above lamps. This implies that the majority of households who adopted solar energy technology in the study area had installed solar home system products with three and above lamps.

Households who installed solar energy had used solar energy for different purposed in addition to lighting source. As indicated in the table 10, 23.7% of solar energy adopted households had used solar energy only for lighting source, 74.1% of households had used solar energy as source of power for lighting, mobile charging and radio, and 2.2% of households had used solar energy as source of power for lighting, mobile charging, radio and TV. This implies that the majority of rural households who adopted solar energy technology are accessed with information in addition to light. This result corresponds with the research conducted in Bangladesh by Ehsanul et al. (2017), who proposed that solar home system increased the opportunity of information access for rural areas through watching TV and/or listening to radio broadcast information.

Table 10: Services of solar energy products in adopted households

Service type	Frequency	Percent
Lighting only	54	23.7
Lighting, charging and radio	169	74.1
Lighting, charging, radio & TV	5	2.2
Total	228	100.0

Source: own survey data (2020)

Households who adopted solar energy technology got solar energy technology products in different ways. As shown in the table below, 36% of adopted households received solar products from distributors with credit through facilitation of government office and credit and saving institutes. The other 18.4% and 45.2% of adopted respondents also got solar energy products by direct buying from shop themselves and by cash from distributors through facilitation of government office and credit and saving institutes respectively.

Table 11: Ways of getting solar energy technology products

Ways of getting solar energy products	No. of respondents	Percentage
By credit access	83	36.4
Direct buying from shop	42	18.4
By cash from distributors through government office & credit institutes	103	45.2
Total	**228**	**100**

Source: own survey data (2020)

4.1.4.2. Reasons of adopting solar energy

Households who adopted solar home system replayed their reasons about why they had adopted it. As clearly shown in the table 12, 12.7% of the adopted respondents used solar home system in terms of cost effectiveness of the product. 14.5% of adopted respondents confirmed that they adopted solar home system because of its reliable energy source; 11% of respondents adopted the technology in terms of their environmental and health awareness; 2.2% of the adopted respondents replayed that they had adopted solar in terms of both its cost effectiveness and reliable energy source; 25.9% of the adopted households confirmed that they had accepted solar energy technology in terms of both its cost effectiveness and their environmental and health awareness; 12.7% of them adopted in terms of its cost effectiveness, reliable energy source and their environmental and health awareness; and the remaining 21.1 % of the adopted respondents confirmed that they adopted solar energy in terms of reliable energy source and their environmental and health awareness. The result revealed that most of the respondents adopted in terms of cost effectiveness and environmental and health awareness they acquired. Today, the costs of kerosene and battery/dry cell used for sources of lighting in most rural area of Ethiopia are getting higher and become beyond their financial capacity to afford the day to day expense for it. But those adopted households have no more expense regarding their home light after once they invest on solar in addition to its positive environmental and health impact.

Table 12: Reasons of adopting solar home system

Households' reasons	Frequency	Percent
Cost effectiveness	29	12.7
Reliable energy sources	33	14.5
Environmental and health awareness	25	11.0
Cost effectiveness and & reliable energy source	5	2.2
Cost effectiveness and environmental and health awareness	59	25.9
Cost effectiveness, reliable energy source and environmental and health awareness	29	12.7
Reliable energy source and environmental and health awareness	48	21.1
Total	228	100.0

Source: own survey data (2020)

In addition to sample household respondents, Key informant interviewees also explained some reasons that are considered to be driving factors for solar energy technology adoption;

The improvement of community consciousness and a need for change to acquire better living condition is one reason of adopting solar energy technology. In addition most parts of the study area are off grid where no electricity access still. Because of this many households considered solar energy as the only and the best way to solve their problems of energy sources for lighting. Furthermore, its environmental value is high. Because it substitutes other lighting energy sources that could affect health of family members and environment including non rechargeable dry cell that can be used as lighting energy source and its remnant also pollutes the environment while dropped out after usage (key informants from energy office, 2020).

Using solar energy technology is economically feasible than other energy sources. For instance if households use dry cell/battery as source of light for their home, they have to buy dry cells within at least two weeks interval. The cost to be incurred for it in every two weeks is difficult for low income families. But for those households who use solar energy technology, it is not required to cost more money after ones they invest on it (Key informants from distributors).

4.1.4.3. Reasons of non adopters and sources of energy for their home light

Non adopter households of solar home system responded their reason why they didn't adopt still. As clearly shown in the table below, 30.1% of non adopters were because of lack of awareness about solar energy technology, 22.4% were because of their low financial capacity to afford the cost, 10.55 were due to high degree failure of solar energy technology products they observed and heard from other users, 9.8% were due to other alternative energy that substitutes solar, 4.2% were because of both lack of awareness and unable to afford the cost of solar products, 0.7% (one respondent) was due to lack of credit accessibility, 11.9% were due to both failure of the product and lack of attention of solar product distributers to implement the guarantee signed, and the remaining 10.5% were due to lack of solar product supply that the households could afford. Therefore, the result indicated that as compared to other factors, lack of awareness about solar energy technology and unable to afford the cost were the major problem of most of households to adopt solar energy technology This result somewhat corresponds with Anteneh (2019), who revealed that most of the problem of rural Ethiopia are poverty and backwardness to adopt new technologies. The third most important problem was failure of the product and lack of attention to implement guarantee signed between households and solar product distributors when the product fail to function. This situation leads households to reject the adoption or discontinuation with the technology.

Moreover, some important factors that influence households' decision are highlighted by key informants;

Even there was an interest to use solar energy technology within the community, many of the households unable to afford the cost due to their low financial capacity, due to the failure of some types of solar energy products and lack of awareness. Some households also afraid that if the solar energy technology they bought is once failed to function, it couldn't be repaired and used again. The cost of solar products also doesn't reflect the purchasing power of the households. Many households need solar energy products as per their financial capacity to buy, such as solar energy products with one or two lamps. But many distributers supply only solar energy products with three and above lamps which are beyond the capacity of most of households (Key informants from woreda energy office and yelemelem and Michig kebeles, 2020).

Furthermore, discussion with key informants helped to dig additional factors related to government and institution;

There are governmental and institutional factors affecting adoption of solar home system in the study area. One of the factors was lack of quality assurance of solar energy technologies products by government body before they have been allowed to be distributed to the user/customer. Most of the time solar products are scraped and passed without being checked their quality. Therefore due to lack of attention of the government and strong chine from top to bottom in order to control the distribution and quality of solar products, most products fail within a short period of time after distribution (key informants from saving and credit institutes and Limichim and Yegelaw kebeles, 2020). This result corresponds with TERI (2014), revealed that due to low quality and nonexistent of distributors after sale services, it often builds distrusts with in households when the products broken down after a short period of usage.

Regarding the guarantee, the government had a gap to enforce distributors to fulfill their obligation according to the agreement signed. Because, most of the time distributors do not keep their promises of repairing solar energy products according to their agreement. This trend pushed away many households from solar technology (Key informants from Yegelaw, Limichim and Yelemelem kebeles).

Table 13: Reasons of not installing solar home system

Reasons	Frequency	Percentage
Lack of awareness about solar energy technology	43	30.1
Lack of credit accessibility	1	.7
Unable to afford the cost	32	22.4
High degree failure of solar products	15	10.5
because of another alternative	14	9.8
lack of awareness & unable to afford the cost	6	4.2
failure of the product & lack of attention to implement guarantee	17	11.9

Lack of solar product supply that the household need	15	10.5
Total	143	100.0

Source: own survey data (2020)

Most of non adopter households of solar energy technology (82.5%) use battery/dry cell as source of energy for their home light. 7.7% of non adopters use battery and kerosene alternatively as sources of energy for their home light. 7%, 1.4% and other 1.4% of non adopters use electricity, kerosene, and biogas as source of energy for their home light respectively. The result of this study indicated that most of the rural households who didn't adopt solar energy technology are dependent on battery/dry cell for their home light. This finding doesn't correspond to that of Anteneh (2019), the study conducted in Gurage, who proposed that most of none adopted households (97%) use kerosene. As clearly shown in the table below, there were also households who use both battery and kerosene as light source. This corresponds to Abera (2019), who revealed that "unlike cooking energy, households' lighting energy choice involves more diverse and competing alternatives".

Table 14: Lighting energy sources of non adopters of solar home system

Types of energy source for lighting	Frequency	Percent
Battery/dry cell	118	82.5
Battery & kerosene	11	7.7
Electricity	10	7.0
Kerosene	2	1.4
Biogas	2	1.4
Total	143	100.0

Source: own survey data (2020)

4.1.5. Level of knowledge and awareness about solar energy technology

This study tried to see the extent of knowledge and awareness of respondents having about solar energy technology. The respondents asked to know their prior information about solar energy technology. Based on this, 91.4% of them reported that they have prior information about solar energy technology; whereas 8.6% of respondents confirmed that they have no prior information about solar energy technology so far.

The chi-square test showed that there is a statistical association between prior information/knowledge and decision to adopt solar energy. This result matches with Legesse (2016), who proposed that the majority (84.3%) of respondents have information about the benefits of renewable energy sources such as solar and biogas while 15.7% of them have no information in Ambo district.

Respondents got information about solar energy technology in different ways. As clearly shown in the table below, 55.3% of respondents reported that they got information about solar energy technology through government, financial institutes & distributors' promotion, 29.9% of respondents got information from friends/neighbors or relatives, 6.2% of respondents confirmed that they got information from media /radio, TV/, and 8.6% of them reported that they have not heard any information about solar. This implies that the majority of households have information about solar from government, financial institutes & distributors' promotion in the study area.

Table 15: Means of getting information about solar

Means of getting information	Frequency	Percentage
Through government, financial institutes & distributors' promotion	205	55.3
From Friends /Neighbors/relatives	111	29.9
From media /radio, TV.../	23	6.2
Have not heard of it	32	8.6
Total	371	100.0

Source: own survey data (2020)

4.1.6. Households' attitude towards solar energy technology

For the sake of deep understanding about attitudes of respondents about solar energy technology, likert scale with ranges of five scales values was used. These mean score ranges were 1 to 1.80 (strongly disagree), 1.81 to 2.60 (disagree), 2.61 to 3.40 (neutral), 3.41 to 4.20 (agree), and 4.21 to 5 (strongly agree). In this study, as clearly indicated in the table below, regarding cost effectiveness of solar energy technology, 42.5% and 57.5% of respondents strongly agreed and agreed respectively. The mean score of all responses of respondents for this item was 4.43 found between 4.21 and 5, which reveals that respondents believed by cost effectiveness of solar energy technology.

Similarly, regarding social viability of solar energy technology, 25%, 74.6% and 0.4% of respondents confirmed as strongly agree, agree and neutral respectively. The mean score of all responses of respondents for this specific item was 4.22. This implies that most of the respondents have positive attitude towards social and economical viability of solar energy technology.

Regarding easiness of solar technology to use, the survey result indicated that 30.7%, 62.7% and 6.6% of respondents reported as strongly agree, agree and disagree respectively. The mean value of all responses for this item was 4.18, which shows that the majority of households who use solar have no difficulty to use solar energy technology.

According to the survey result, concerning energy freedom gained from solar energy, 34.2%, 63.2%, 1.3% and 1.3% of respondents conformed as strongly agree, agree neutral, and disagree respectively. The mean score of this item for all responses was 4.30, which reveals that the majority of rural households who use solar energy technology are free from other energy source dependency for their home light.

Likewise, with regard to its more advantageousness than other energy sources, 9.6%, 23.2%, 51.8%, and 15.4% of respondents reported as strongly agree, agree, neutral and disagree. The mean score of all responses of this item was 3.27. This indicates that more than half of respondents were neutral to show their attitude towards more advantageousness of solar energy than that of other energy sources.

In the same way, regarding solar energy as environmentally friend technology, the survey result showed that 78.9%, 20.6% and 0.4% of respondents confirmed as strongly agree, agree and neutral respectively. The mean score of all responses of respondents was 4.79, which reveals that the majority of rural respondents have positive attitude for environmental value of solar energy technology.

Table 16: Attitudes of households towards solar energy technology

Attitudes of respondents		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean score	SD
Using solar energy technology is cost effective	%	0	0	0	57.5	42.5	4.43	0.495
	No.	0	0	0	213	158		
Using solar energy technology is socially viable	%	0	0	0.4	74.6	25	4.22	0.441
	No.	0	0	1	277	93		
Solar energy technology is easy to use	%	0	6.6	0	62.7	30.7	4.18	0.736
	No.	0	24	0	233	114		
Using solar energy technology creates energy freedom	%	0	1.3	1.3	63.2	34.2	4.30	0.564
	No	0	5	5	234	127		
It is more advantageous than all energy sources used for lighting	%	0	15.4	51.8	23.2	9.6	3.27	0.837
	No.	0	57	192	86	36		
considered as environmental friend technology	%	0	0	0.4	20.6	78.9	4.79	0.422
	No	0	0	1	77	293		

Source: own survey data (2020)

Discussion with key informants clarified some attitudinal issues that households feel towards solar energy technology;

Since the solar energy technology is new for the local community, most of the households hesitate and become slow to adopt the technology until they see solar in use in the house of their relatives or neighbors. This is due to information gap about solar and further training is required to bring attitudinal change. Some portion of the rural society has been aware of solar energy either in formal or informal way. But it needs still more and more awareness to make them the beneficiary of the technology (key informants from yelemelem kebele).

Sometimes it is observed that when households see solar products being deteriorated or broken down their own solar, then they are going to hate the technology because of costing a lot of money for maintenance of damaged product (key informants from energy office).

4.2. Econometric results of determinants of solar home system adoption

In this study logistic regression was employed in order to estimate the effects of the most important explanatory variables on the adoption of solar energy technology. The response variable was either adopting or not adopting solar energy technology. Those households who had solar energy technology were considered as "adopter" and those who had not considered as being "non adopter".

Before running the regression analysis, pair wise correlation was conducted in order to check the existence of multicollinearity among categorical/dummy variables. The result showed that there is no multicollinearity except between marital status and gender, which is 0.828 (Appendix IV). According to Maddala (1992), the correlation value of 0.75 and above indicates a stronger relationship between dummy independent variables. Therefore marital status is excluded from the model to reduce its effect on the regression estimate. The variance inflation factor (VIF) was also computed to test multicollinearity among continuous variables. The VIF results were found to be less than 10 and it indicated that there is no a problem of multicollinearity across continuous independent variables (Appendix IV).

The Hosmer and Lemeshow test is applied to estimate the overall model fit. Since the p- value is greater than statistically significant level (0.05), which is .0.87, the estimated model has adequate fit for the purpose. For this study the correct model predictions for adopters and non adopters were 90.8% and 85.3% respectively, and the overall correct model prediction was up to 88.7%. The pseudo R^2 (Nagelkerke R Square) of the estimated model is 74.2%, which indicates that 74.2% of the total variation in dependent variable/solar energy technology adoption was explained by independent variable.

As shown in the table 17, from the total of 18 explanatory variables included in the model, 9 of them were found to be statistically significant to affect households' decision to adopt solar home system. These variables include; income, off farm income, educational status of households' head, housing type (namely; tin roofed house with two rooms and tin roofed house with three and above rooms), prior information/knowledge, gender, training access, media access and electricity access/connection to grid. Kebele dummies were also included and controlled in the model.

Number of variables including number of cattle, cell phone access and distance from agricultural extension to home, were not statistically significant but found to have positive effect of solar home system adoption. On the contrary, variables such as land holding size, age of household head, family size, credit accessibility, distance from home to main road, and distance from home to market were statistically insignificant and found to have negative effect on households' decision to adopt solar home system.

4.2.1. Income level of household

Income of household is found to be one important factor of households' decision to adopt solar energy technology. The study showed that income of household has a positive effect on solar energy technology adoption at a statistically significant level ($P<0.1$) (Table 17). The odd ratio of binary logistic regression indicated that as income of household increase by one unit, the probability of adopting solar energy technology increase by a factor of 3.018 ($P<0.1$). The Walder statistics (3.071) also indicated the strong association between income and solar energy technology adoption. This implies that as households become economically strong, their propensity to invest on renewable energy technology also increases. This result is consistent with Guta (2018), who revealed that as the households income become higher, their purchasing power increase and as the same time their demand for solar energy technology become higher. It also agrees with (De Groote et al., 2016), who argued that income of household is economically important and has significant effect on solar energy technology installation. Generally the observed positive correlation in the model estimation indicates the fact that when households got richer, they able to adopt new technologies such as solar.

4.2.2. Participation in off farm income earning activities

Participation in off farm income earning activity is among the main socio economic factors that influence households' decision to adopt solar energy technology. As shown in table 17, the result of logistic regression indicate that off farm income has a positive effect on solar energy technology adoption with a statistically significant level ($P<0.1$). The odd ratio showed that households who participate in off farm income earning activities are more likely to adopt solar by a factor of 4.182 as compared to those households who have no off farm incomes. The Wald statistics (3.404) also indicated that there is a strong association between off farm income activities and solar energy technology adoption. This implies that households who participate in additional off farm income earning activities are more economically powerful than those who haven't additional off farm income in order to invest on solar energy technology for domestic purpose.

4.2.3. Housing type of household

Housing types of households were divided in to three categories, namely tin roofed house with one room, tin roofed house with two rooms and tin roofed house with three and above rooms. Households having two rooms and three and above rooms house are positively correlated with solar energy technology adoption at statistically significant level ($P<0.01$). The odd ratio of logistic regression indicated that solar home system adoption of households with two room and three and above rooms house are higher by a factor of 9.799 ($P<0.01$) and 16.899 ($P<0.01$) respectively as compared to households having house with one room. The Wald statistics of both with two rooms (6.730) and three and above rooms (8.327) also indicated that there is highly significant association between house size and solar home system adoption. The result implies that households who have house with more rooms tend to use light energy sources (such as solar) that could be available for all rooms as the same time. On the other hand as the size of home increase, its comfortableness increase to install solar panels up on the roof. This result is consistent with Groote et al (2016), who pointed out that houses having larger size typically have a larger roof surface that gives more comfort and flexibility to avoid disturbances on the roof and thus resulting in an increased probability of households' adoption of solar energy technology. Similarly, another study revealed that compared to other energy sources (dry cell and kerosene), solar energy adoption increase as rooms of house increase (Abera, 2019).

4.2.4. Gender of household head

Gender plays a significant role in determining households' decision to adopt solar energy technology. The result of the study indicated that male household heads are less likely to adopt solar hole system by a factor of 6.172 ($P<0.05$) compared to female headed. This implies that women are more responsible for the fulfillment of household energy sources than men in the household in rural Ethiopia including the study area. This result corresponds with previous study by Partick (2009), who revealed that women are more active in participation of environmentally friend technologies than men. It is also supported by Guta (2018), who found that women are more willing and highly attached with household energy utilization than men in a household, but contrasts with the finding of Anteneh (2018), who revealed that male household heads more likely adopting solar energy technology than married respondents.

4.2.5. Educational status of household heads

Education status of household heads is one important factor of households' willingness to adopt solar energy technology. In this study, households' head educational status was classified in to two groups, namely literate (those who attended formal education) and illiterate (those who didn't attend formal education). According to the model estimation, education status was found to have a positive influence on solar PV technology adoption at statistically significant level ($P<0.05$). The odd ratio indicated that literate household heads are more likely adopt solar home system by the factor of 21.212 (0.05) compared to illiterate household heads. The Wald statistics (5.505) showed that education has a strong association with adoption of solar energy technology.

The result reveals the fact that households who have no formal education are less likely to adopt solar home system compared to their counter parts. Better exposure to education makes households to be more flexible to know, understand and aware of new renewable energy technologies and also their health and environmental benefits. This result is consistent with Guta (2018), who revealed that education increases households' awareness regarding the health, environmental, economic and societal relevance of solar energy technology. This clearly shows that in addition to its role to increase awareness, advancing in education level increases households' earning capacity that endures their capacity to invest on clean energy technologies such as solar. The other study added that as households acquire better education level, they are more likely to be more informed about adoption of other best sources of energy (Gitone, 2014).

4.2.6. Prior information/knowledge

The result of this study shows that prior knowledge or awareness of households has a positive influence on households decision to adopt solar energy technology at a statistically significance level (P<0.05). The odd ratio showed that adoption of respondents who have prior knowledge or information about solar energy technology is higher by a factor of 547.032 (P<0.05) as compared to households who had no prior information about solar. The Wald statistics (5.494) also indicated that there is a strong statistical association between prior knowledge and solar home system adoption. This implies that households who have accumulated prior knowledge or awareness are more likely to adopt solar home system. However, households who have low awareness or knowledge level, tend to use risky and low efficient energy sources such as kerosene. This is also related to that if they didn't have information about the bad and good side of the new technology, they become reluctant whether to accept or reject it. This result corresponds with Naomi, (2014), who found that there is a positive relationship between the adoption of solar technology and awareness and knowledge about the technology.

4.2.7. Training access

Access to training found to have a positive influence on solar energy technology adoption at a statistically significant level (P<0.01). The odd ratio indicated that the adoption of respondents who have been accessed with training is higher by the factor of 17.949 (P<0.01) than those who haven't been accessed. The Wald statistics (49.899) also showed highly significant association. This implies that as households got training about the use of solar energy technology, the probability of their adoption increase. This means training removes their previous doubt about the technology and endures their ability to decide whether to accept or reject it in a reasonable manner. This result confirms the previous study by Keriri (2013), revealed that there was a positive relationship between solar energy technology adoption and either formal or informal training delivered. Therefore, provision of training to rural households increases their awareness level and their inclination to adopt solar energy technology.

4.2.8. Media access

Media accesses found to have a positive influence on solar energy technology adoption at a statistically significant level (P<0.01. The odd ratio indicated that households who accessed with media are more likely to adopt solar by a factor of 6.242 ($P<0.01$) than those who haven't any media access. The walder statistics (7.155) also indicated the strong significant association between media access and solar energy technology adoption. This reveals that most of rural households use radio as source of new information about new technologies and ideas in a timely manner. The result is consistent with Abera (2019), who indicated that access to modern communication technologies such as radio has positive influence on the adoption of modern and clean energy technologies.

4.2.9. Electricity access

Connection of households to grid is also one of the determinants with negative effect on solar energy technology adoption at a statistically significant level ($P<0.05$). The odd ratio of solar home system adoption showed that the adoption of households who have grid connection were decreased by a factor of 0.104 ($P<0.05$) compared to households who had no grid connection. This reveals that rural households going to adopt solar energy technology as an alternative energy source if they haven't electricity access. This result corresponds with a previous literature, which stated that in developing countries, unavailability of grid connection creates an opportunity to solar PV diffusion among potential users more rapidly (Tahir et al., 2017).

Table 17: Results of logistic regression model on determinants of households' adoption of solar home system

Variables	Estimated coefficient (B)	Stand. Error (S.E.)	Wald	Odds ratio Exp(B)
Logincom.	1.105*	.630	3.071	3.018
offarmparticip	1.431*	.775	3.404	4.182
TLU	.066	.155	.182	1.068
land	-.533	.351	2.309	.587
credit	-1.714	1.112	2.378	.180
housetype				
housetype(1)	2.282***	.880	6.730	9.799
housetype(2)	2.827***	.980	8.327	16.899
gender	-1.820**	.754	5.830	6.172
age	-.030	.021	2.143	.970
familysize	-.184	.144	1.635	.832
edustatus	3.055**	1.302	5.505	21.212
priorinfo	6.305**	2.690	5.494	547.032
owncellphone	.402	.433	.861	1.494
mediaaccess	1.831***	.685	7.155	6.242
trainingaccess	2.888***	.409	49.899	17.949
distroad	-.042	.117	.129	.959
distfarmext	.061	.146	.173	1.063
distmarket	-.068	.135	.257	.934
electricityaccess	-2.263**	1.004	5.082	.104
kebeledummy				
Kebeledummy(1)	1.525***	.583	6.847	4.594
Kebeledummy (2)	1.150*	.626	3.374	3.159
Kebeledummy(3)	2.088**	.883	5.597	8.070
Constant	-19.867***	7.159	7.702	.000

Hosmer & Lemeshow test = 0.870, Nagelkerke R^2 = 0.742,

Model prediction = 88.7, -2log likelihood = 201.537[a,] No. of observation = 371

***, ** and * indicates level of significance at 1%, 5% and 10% respectively..

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Using clean and renewable energy sources have paramount importance to reduce adverse health and environmental impacts of using detrimental energy sources as well as keep households from extra cost especially for citizens from low income countries like Ethiopia. This study was conducted to investigate major determinants of solar energy technology adoption of rural households in four kebeles of Baso Liben district, northern Ethiopia. In the study area, almost all of households are not connected with grid electricity. Recently, many of the rural households of the study area have a propensity to adopt solar home system for their home purpose. Because their awareness level regarding economical value of using solar and health and environmental impacts of using detrimental energy sources such as kerosene is rising from time to time. Out of the total sample household respondents, 61.5% adopted solar energy technology. Based on the finding, adopters and non adopter households are varied in many of demographic and socioeconomic variables. There is a significant difference in case of age, family size, educational level, housing type, land holding size, number of cattle, and off farm income between the two groups. The overall analysis of the households' attitude indicated that the majority of them have positive view regarding solar energy technology. On the other hand, lack of awareness and unable to afford the cost of solar products are found to be challenges for most of non adopted household in the study area. Furthermore, key informants also revealed that lack of quality assurance and failure of distributors to implement guarantee are additional challenges in the study area.

In this study, binary logistic regression is employed to estimate the effects of demographic, socio-economic and institutional factors on households' decision to adopt solar home system. Variables including income level, off farm income activity, housing type, household heads' education status, training access, media access and prior knowledge are statistically significant and have positive effect on solar home system adoption. On the contrary variables including gender and electricity access are statistically significant but negatively affect solar home system adoption.

5.2. Recommendation

Based on the findings of the study, the researcher suggests the following recommendations:

- In order to minimize the dishonesty of some households having on solar technology products due to quality deterioration, the government must establish a system that assures solar product qualities before dissemination as well as there must be continuous follow up and control over those solar technology providers to keep their warranty term.
- Since economic variables such as income level of household and participation in off farm income earning activities are strong predictor variables that determine solar home system adoption, appropriate policy options targeted on improving households economic status to reduce poverty is viable to increase their capacity to invest on solar energy technology.
- Diversification of income sources of rural households through creating different opportunities of off farm income generating activities is better to enhance their economic level, indirectly increases their propensity to adopt solar home system technology. If the income level of rural households grows, not only enhance their willingness to adopt solar, but also the overall wellbeing of the family become improved. The availability of basic needs including house type and size could affect the decision to use solar. Mostly, regarding housing condition, the number of rooms and roof quality may influence to install solar. Therefore the improvement of households' economical wellbeing leads them to have better housing condition that also could enhance them positively to adopt solar home system.
- Efforts targeted on improving educational status have multiple benefits for rural community. Education boost up households' consciousness level in social, economical, and cultural spheres; it helps to generate different income opportunities, increases awareness about energy sources which are relatively cheap but have detrimental health and environmental effects and leads them to use clean and modern energy sources including solar.
- Households who were trainer about utilization and importance of solar energy technology are more likely to use solar as source of light for their home. Therefore, rural households should be provided training about solar energy technology and its

importance properly, should be oriented how to use it, which increases the life span of solar product by reducing its deterioration caused due to technical faults during installation or daily operation. Rural households also need to have environmental awareness and the value of renewable energy in order to shift them from using traditional biomass energy source to solar, which is modern and clean energy source. The government and other donors such as NGOs who have been engaged on development programs to improve rural livelihoods should invest to support awareness creation training about solar in different ways.

- Media plays a significant role in accessing accurate and timely information for rural society. It is possible to motivate, aware or educate most of rural households at a point in time. Therefore, rural households should be aware to use information sources including radio and other media alternatives as necessarily. Moreover, appropriate information should be released using different medias including radio, pamphlets, and brochures for rural households in order to aware them about utilization of renewable energy source such as solar as well as their health and environmental values.
- Rural households who are far from grid electricity have a tendency to adopt solar energy technology. But many of them might not have financial capacity to afford it. To address this issue, appropriate policy options that could be implemented cooperatively with donors of development programs to access solar energy to households living in off grid rural areas might be viable to solve energy deficiency of poor households. Furthermore, since almost all of the rural households live in off grid areas, the government should take the issue as cross cutting to give the best and quick response, including accessing with alternative renewable energy sources such as solar.
- This research used cross sectional data to examine factors influencing solar home system adoption. However, investigating the effects of major determinants on solar energy adoption that encompasses wide rural geography and community using longitudinal data is required. Moreover, using appropriate model, further researches may explore the effects of product specific attributes including product quality and price on household adoption of solar energy technology.

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APPENDIX I

Addis Ababa University

College of Development Studies

Research questionnaires

Introduction

The main purpose of this questionnaire is to collect relevant information for investigating the research entitled "Determinants of household adoption of solar energy technology in Baso Liben district, East Gojjam zone, Ethiopia". The researcher is conducting this study for partial fulfillment of the requirements for degree of masters' art in Environment and Sustainable Development. Your response will be of a great importance to the study therefore, you are kindly requested to fill it honestly. I sincerely express my thanks for your unreserved cooperation in advance. The information you provided will be used only for academic purpose and will be strictly confidential.

General information

Kebele………………… Interviewee ID…………. Date and time of interview………….

Name of Enumerator…………………….. . Checked by………………………….

Part I: Households information

1. Gender of household head:

   Male ☐ Female ☐
2. Age of household head
3. Marital status of household head

   Single ☐ Married ☐ Divorced ☐

   Widowed ☐
4. Family size of the household ………………………
5. Household's head religion

   Orthodox ☐ Muslim ☐ Protestant ☐ Catholic ☐

   Other ☐
6. Education level of household head

☐ Illiterate ☐ Secondary education /9-10/

☐ Basic education ☐ preparatory education /11-12/

Religious/abinet education ☐ TVET and above

☐ Primary education

☐ Primary education /7-8/

Part II: source and amount of income of household

7. Annual income of the household

No	**Sources of income**		**Mark in front of your income source**	**Amount of income in birr**
1	Crop farming			
2	Raring and selling animas	Ox		
		Cow		
		Bull		
		Goat and sheep		
		Donkey		
		Horse		
		poultry		
		Others,…..		
3	Trading/shop/			
4	Monthly salary			
5	Selling own products/crop, vegetable..)			
6	Others, specify …………			
	Total income			

8. Do you have additional income from nonfarm activities?
   1. Yes 2. No
9. If yes, the type and amount of exogenous/non farm income you have got in the last twelve months? (please mark)

No	Types of exogenous income	Mark the type/s of exogenous income/s	Annual mount of exogenous

			you have practiced	income the household got
1	Remittance	Domestic		
		Foreign		
2	Safety net			
3	Wage			
4	Hand crafts			
5	Others specify…………..			

Part III. Farm land size

10. Do you have your own land?
    1. Yes 2. No
11. If your answer is yes, how many hectares of land do you have?....................
12. Hectares of land you have been using for crop production
    1. Your own land cultivated by household…………………….
    2. Rented in hectares of land ………………….
    3. Rented out hectares of land for others…………..
    4. Hectares of share cropped land ………………..
    5. Not used hectares of land ……………..
    6. Specify if there is other………………… …...

Part IV. Cattle ownership

13. Do you have your own Animals?
    1. Yes 2. No
14. Which type and how many numbers of animals do you have?
    1. Ox ………………………… 4. Goat and sheep
    2. Cow,……………………….. 5. Donkey
    3. Bull ……………………… 6. Horse
    7. Others specify…………….

Part V. Access to credit:

15. Do you have opportunity of getting credit?
    1. Yes 2. No
16. If yes from where do you get credit?
    1. From bank

2. From credit and saving institutes
3. Fromm rich individuals
4. From others, specify……………………..

17. Did you borrow money for the purpose of buying solar technology products?
    1. Yes 2. No
18. If you get credit, how is the payback period of credit you have got?
    1. Short payback period 2. Long payback period
19. If you didn't get credit, why? /Multiple answers are possible for this/.
    1. Fear of inability to pay
    2. High interest rate
    3. No one is voluntary to give credit
    4. No need of credit
    5. Others, specify …………………

Part VI: housing condition of households

20. Do you have your own house?
    1. Yes 2. No
21. How did you get the house you have been living in?
    1. Self built
    2. Rent
    3. Purchase
    4. Inherited from family
    5. Others, specify ……………………………
22. What is the type and size of home you are living in?
    1. Traditional (terraced house)
    2. One room & tin roofed
    3. Two rooms & tin roofed
    4. Three rooms and above tin roofed …………………….

Part VII: infrastructure access

23. How far is your home from the main road in kilo meter/meter? ……………
24. How far is your home from agricultural extension center in kilo meter/meter? ………

25. How is your transport accessibility when you go to agricultural extension center?
    1. Using own foot 3. Using animal & motorized
    2. Using animal & own foot 4. Using foot & motorized 5. Other means please specify……………
26. How is your transport accessibility when you go to health center?
    1. Using own foot 3. Using animal & motorized
    2. Using animal & own foot 4. 4. Using foot & motorized 5. Other means please specify……………
27. How far is your home from electricity grid in kilometer/meter?...............
28. How far is your home from market in kilometer/meter?...............
29. How is your transport accessibility when you go to market?
    1. Using own foot 3. Using animal & motorized
    2. Using animal & own foot 4. Using foot & motorized 5. Other means please specify……………….
30. Do you have mobile phone access?
    1. Yes 2. No
31. What electronics media have you been accessed with?
    1. have not media access 2.Radio 3. TV 4. TV & radio 5. Other, please specify ………………….

Part VIII: Training

32. Have you got training regarding solar energy technology?
    1. Yes 2. No
33. If yes, what form of training did you get?
    1. Formal 2. Informal/short/
34. Who delivered training for you?
    1. Government office/water and energy office/
    2. Financial institutes
    3. Other, please specify……………………………
35. How much did that training help you?
    1. helped me in a very good manner
    2. helped me in a good manner
    3. Didn't help me

4. Other, specify……………………….

Part IX: household expenditure

36. How much is your average annual household expenditure (please fill only the type of expense you have)

No.	Types of expense	Amount of annual expenditure in Birr
1	Food crops and pulses	
2	Agricultural inputs (fertilizer, improved seed, land rent…)	
3	Vegetables and fruits/onion, tomato, cabbage...	
4	Oils and spices	
5	Meat, milk products and egg	
6	Drinks /water, soft, alcoholic.. /	
7	Clothes & shoes	
8	Medicines	
9	House rent	
10	Transportation	
11	School fee	
12	Energy /cooking, lighting…/	
13	Social affairs	
14	Communication /phone top up, /	
15	Other expenses	
Total expense in Birr		

Part X: solar energy technology adoption

37. Does your home connected with electric grid?

1. Yes 2. No

38. Reasons of choosing sources of energy for lighting

No.	Reasons	Energy sources for lighting						
		Solar	Biogas	Fire wood	Battery	Kerosene	Electricity	Others
1	cost effectiveness							
2	reliable energy							

	source							
3	In terms of environmental awareness							
4	For additional light source							
5	Cost effectiveness & reliable energy source							
6	Cost effectiveness & environmental awareness							
7	cost effectiveness & reliable energy source							
4	Other, specify							

39. Energy sources that the household using together/ mix/

Service type	Types of energy sources					
	Solar	Biogas	Battery/dry cell/	Kerosene	Firewood	Electric/grid
For lighting						
For cooking						
Others, specify						

40. The type of renewable and improved energy technology that the household currently using
    1. Solar 3. Improved stove
    2. Biogas 4. Others, specify ……………………………
41. Did you install solar energy system in your home?
    1. Yes (go to question 44-53) 2. No (go to question 54-56)

42. When did you install solar system for your home? .... E.C

43. What is your reason to choose and install solar rather than other energy sources?

    1. Cost effectiveness
    2. reliable energy source
    3. In terms of environmental awareness
    4. For additional light source
    5. Cost effectiveness & reliable energy source
    6. Cost effectiveness & environmental awareness
    7. cost effectiveness & reliable energy source

44. Who was responsible for buying solar in your home?

    1. Husband 2. Wife 3. Together /husband & wife/ 4. Other, specify…….

45. The type of solar you have installed?

    1. Solar PV with one lamp
    2. Solar PV with two lamps
    3. Solar PV with three & above lamps
    4. Other specify……………………………..

46. What services does solar energy support in your house?

    1. Lighting only
    2. Lighting, charging and radio
    3. Lighting, charging, radio & TV
    4. Others, specify …………………………………..

47. From where did you get/buy solar PV product?

    1. Through water and energy office of the woreda
    2. through financial institutes
    3. Direct buying from shop
    4. From other sources, please specify…………………………..

48. How did you get solar PV product from water and energy office?

    1. On cash payment
    2. On credit accessibility
    3. By aid
    3. By other means, please specify…………………….

49. How did you get solar PV product from financial institutes?

    1. On cash payment
    2. On credit accessibility
    3. By aid
    3. By other means, please specify…………………….

50. Have you done any business using solar energy?

    1. Yes 2. No

51. If yes, what type of business are you doing with solar energy? Please explain

    ……………………………………………………………………………..

52. If you did not install solar energy technology still in your home, what type of energy source are you using for lighting?

    1. Kerosene 3. Fire wood
    2. Dry cell/battery 4. Others, specify ……………………

53. If you did not install solar energy technology still in your home, why? /Choosing more than one is possible/.

    1. Lack of awareness about solar energy technology
    2. Lack of credit availability
    3. Unable to afford the cost
    4. High degree failure of the product
    5. Because of an other alternatives
    6. Others, specify………………………

54. If you didn't install solar still, are you planning to install soon?

    1. Yes 2. No

Part XI: Level of knowledge and awareness about solar /for both adopters & non adopters/

55. Do you have any prior information about solar energy technology?

    1. Yes 2. No

56. H if your answer is yes, how did you get the information about solar for the first time?

    1. From friends/neighbors/ relatives
    2. From media/radio, TV/
    3. through government promotion
    4. through financial institutes' promotion

5. Have not heard of it

6. If there is other means, please specify…………………………….

57. Do you think that solar energy technology has positive contribution?

1. Agree 2. disagree

58. Please mark your appropriate response

Attitudes of respondents	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Using solar energy technology is cost effective					
Using solar energy technology is socially viable					
Solar energy technology is easy to use					
Using solar energy technology creates energy dependency					
It is more advantageous than All energy sources for lighting					
They have seen as environmental friend technology					

APPENDIX II

Questions for key informant interviews

1. What are the major factors that influence solar technology/renewable energy adoption of the household? ………………… ……………… ……………… ………….. ………… ……………………………………………………………………………… …………
2. How is the community view/perception towards solar energy technology? ……………………………………………………………………………… ……………………………………………………………………………… …………………………
3. Is solar energy relevance to the future? How --------------------------------------- --- ---------------------------
4. The reasons why solar energy technology is adopted?...…… ……………… …………………………… ………… ……… ………………………… …………………………………………………
5. What are the best ways to increase awareness on solar energy technology among households?.. ....
6. Is there any governmental and institutional influence affecting you to adopt solar energy technology? What are thy and how ------------------------------------ --- ---

APPENDIX III

Logistic regression result of determinants of solar home system

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	201.537[a]	.546	.742

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	Df	Sig.
1	3.857	8	.870

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Step 1[a]	age	-.030	.021	2.143	1	.143	.970	.932	1.010
	Familysize	-.184	.144	1.635	1	.201	.832	.628	1.103
	edustatus(1)	3.055	1.302	5.505	1	.019	21.212	1.653	272.145
	logincome	1.105	.630	3.071	1	.080	3.018	.877	10.383
	offarmpartic(1)	1.431	.775	3.404	1	.065	4.182	.915	19.119
	land	-.533	.351	2.309	1	.129	.587	.295	1.167
	TLU	.066	.155	.182	1	.669	1.068	.789	1.448
	credit(1)	-1.714	1.112	2.378	1	.123	.180	.020	1.592
	housetype			8.351	2	.015			
	housetype(1)	2.282	.880	6.730	1	.009	9.799	1.747	54.954
	housetype(2)	2.827	.980	8.327	1	.004	16.899	2.477	115.302
	distroad	-.042	.117	.129	1	.719	.959	.763	1.205
	distfarmext	.061	.146	.173	1	.677	1.063	.798	1.415

distmarket	-.068	.135	.257	1	.612	.934	.717	1.216
owncellphone(1)	.402	.433	.861	1	.354	1.494	.640	3.491
mediaaccess(1)	1.831	.685	7.155	1	.007	6.242	1.632	23.882
trainingaccess(1)	2.888	.409	49.899	1	.000	17.949	8.055	39.992
electricityaccess(1)	-2.263	1.004	5.082	1	.024	.104	.015	.744
priorinfo(1)	6.305	2.690	5.494	1	.019	547.032	2.809	106531.924
kebeledumy			9.494	3	.023			
kebeledumy(1)	1.525	.583	6.847	1	.009	4.594	1.466	14.397
kebeledumy(2)	1.150	.626	3.374	1	.066	3.159	.926	10.783
kebeledumy(3)	2.088	.883	5.597	1	.018	8.070	1.431	45.516
gender(1)	-1.820	.754	5.830	1	.016	6.172	1.409	27.041
Constant	-19.867	7.159	7.702	1	.006	.000		

a. Variable(s) entered on step 1: age, Familysize, edustatus, logincome, offarmpartic, land, TLU, credit, housetype, distroad, distfarmext, distmarket, owncellphone, mediaaccess, trainingaccess, electricityaccess, priorinfo, kebeledumy, gender.

```
             Step number: 1

             Observed Groups and Predicted Probabilities

      80 +                                                                                                    +
         I                                                                                                    I
         I                                                                                                    I
F        I                                                                                                    I
R     60 +                                                                                                    +
E        I                                                                                                    I
Q        I                                                                                                    I
U        IN                                                                                                  yI
E     40 +N                                                                                                  y+
N        IN                                                                                                  yI
C        IN                                                                                                  yI
Y        IN                                                                                                  yI
      20 +N                                                                                                yyy+
         IN                                                                                            yyy yyyI
         IN                                                                                           yyyyyyyyI
         INNN NNNN  N      N   y   N     N N    y        y                 y     y   y y y   y  y y yyyyyyyyyyI
Predicted ---------+---------+---------+---------+---------+---------+---------+---------+---------+----------
  Prob:   0       .1        .2        .3        .4        .5        .6        .7        .8        .9         1
  Group:  NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyyy

          Predicted Probability is of Membership for yes
          The Cut Value is .50
          Symbols: N - No
                   y - yes
          Each Symbol Represents 5 Cases.
```

APPENDIX IV

Multicollinearity test of dummy independent variables using pair wise correlation

Correlations

		Gender	marital status	Education status	off farm participation	Credit	House type	mobile phone access	media access	Training access	Electricity access	Prior info.
Gender	Pearson Correlation	1	.828**	-.057	.019	-.143**	-.169**	-.232**	-.264**	-.128*	-.014	-.069
	Sig. (2-tailed)		.000	.277	.715	.006	.001	.000	.000	.014	.790	.186
	N	371	371	371	371	371	371	371	371	371	371	371
marital status	Pearson Correlation	.828**	1	-.069	.008	-.178**	-.168**	-.237**	-.257**	-.136**	.040	-.076
	Sig. (2-tailed)	.000		.185	.872	.001	.001	.000	.000	.009	.448	.143
	N	371	371	371	371	371	371	371	371	371	371	371
Education status	Pearson Correlation	-.057	-.069	1	-.036	.069	.099	.118*	.148**	.190**	-.072	.081
	Sig. (2-tailed)	.277	.185		.487	.185	.057	.024	.004	.000	.168	.118
	N	371	371	371	371	371	371	371	371	371	371	371
off farm participation	Pearson Correlation	.019	.008	-.036	1	.063	.108*	.019	.086	.101	.076	.038
	Sig. (2-tailed)	.715	.872	.487		.223	.037	.716	.098	.053	.146	.464
	N	371	371	371	371	371	371	371	371	371	371	371
Credit	Pearson Correlation	-.143**	-.178**	.069	.063	1	.157**	.195**	.330**	.212**	-.039	.150**
	Sig. (2-tailed)	.006	.001	.185	.223		.002	.000	.000	.000	.452	.004
	N	371	371	371	371	371	371	371	371	371	371	371
House type	Pearson Correlation	-.169**	-.168**	.099	.108*	.157**	1	.386**	.395**	.323**	.088	.194**
	Sig. (2-tailed)	.001	.001	.057	.037	.002		.000	.000	.000	.090	.000
	N	371	371	371	371	371	371	371	371	371	371	371
mobile phone access	Pearson Correlation	-.232**	-.237**	.118*	.019	.195**	.386**	1	.439**	.358**	.023	.142**
	Sig. (2-tailed)	.000	.000	.024	.716	.000	.000		.000	.000	.652	.006
	N	371	371	371	371	371	371	371	371	371	371	371
media access	Pearson Correlation	-.264**	-.257**	.148**	.086	.330**	.395**	.439**	1	.339**	.056	.180**
	Sig. (2-tailed)	.000	.000	.004	.098	.000	.000	.000		.000	.280	.000
	N	371	371	371	371	371	371	371	371	371	371	371
Training access	Pearson Correlation	-.128*	-.136**	.190**	.101	.212**	.323**	.358**	.339**	1	-.135**	.226**
	Sig. (2-tailed)	.014	.009	.000	.053	.000	.000	.000	.000		.009	.000
	N	371	371	371	371	371	371	371	371	371	371	371
Electricity access	Pearson Correlation	-.014	.040	-.072	.076	-.039	.088	.023	.056	-.135**	1	.010
	Sig. (2-tailed)	.790	.448	.168	.146	.452	.090	.652	.280	.009		.841
	N	371	371	371	371	371	371	371	371	371	371	371
prior info	Pearson Correlation	-.069	-.076	.081	.038	.150**	.194**	.142**	.180**	.226**	.010	1
	Sig. (2-tailed)	.186	.143	.118	.464	.004	.000	.006	.000	.000	.841	
	N	371	371	371	371	371	371	371	371	371	371	371

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Multicollinearity test of continuous independent variables using VIF

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Age of respondents	.856	1.168
	Family size of the household	.868	1.152
	log of income	.481	2.079
	Size of Land in hectar	.675	1.482
	Number of cattle	.580	1.724
	Distance of the home from the main road in km	.519	1.926
	Distance of the home from from agricultural extension center in km	.707	1.414
	Distance of the home from market in km	.523	1.914

a. Dependent Variable: Solar installation in the household