ACCEPTANCE AND MANAGEMENT CONSTRAINTS OF SOLAR HOME SYSTEMS IN RURAL AREA OF MECHA DISTRICT, AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

M.Sc. THESIS

BY

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APPROVAL SHEET-1

This is to certify that the thesis entitled “acceptance and management constraint of solar home systems in rural area of Mecha District, Amhara national regional state of Ethiopia*”* is submitted in partial fulfillment of the requirement for the degree of Master of Sciences with specialization in Renewable energy utilization and management. It is a record of original research carried out by Berhanu Kassa Yigzaw Id. No. MSC/REUM/R005/09, under my supervision; and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly Acknowledged. Therefore, I recommended it to be accepted as fulfilling the thesis requirements.

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Name of post graduate coordinator	Signature	Date

APPROVAL SHEET-2

We, the undersigned, members of the Board of Examiners of the final open defense by Berhanu Kassa have read and evaluated his thesis entitled "acceptance and management constraint of solar home systems in rural area of Mecha District, Amhara regional state of Ethiopia "and examined the candidate. This is, therefore, to certify that the thesis have been accepted in partial fulfillment of the requirements for the degree of Master of Science.

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Name of the Chairperson Signature Date

Kassahun Yimer (PhD) 14/06/2018 .

Name of Main Advisor Signature Date

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Name of Internal Examiner Signature Date

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DEDICATION

This thesis manuscript is dedicated to my beloved father, Mr. Kassa Yigzaw, and my mother, Mrs. Demeku Mengistie for devoting their time to help me throughout their life.

DECLARATION

I hereby declare and affirm that this thesis entitled “acceptance and management constraint of solar home systems in rural area of Mecha District, Amhara regional state of Ethiopia” is my own work. Any scholarly matter that is included in the thesis has been given recognition through citation.

This thesis is submitted in partial fulfillment of the requirements for Msc. degree in Renewable energy Utilization and management at Hawassa University WondoGenet College of Forestry and Natural Resource. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Berhanu Kassa	______________________	______________
Name of student	Signature	Date

LIST OF ABBREVIATIONS

AC	Alternative current
CSA	Central statically agency
DBE	Development bank of Ethiopia
DC	Direct current
ETB	Ethiopian Birr
EPA	Environmental Protection Authority
FGD	Focus Group Discussion
GHG	Green House Gas
GMW	Giga million watt
GIZ ECO	Deutsche Gesellschaftfür Internationale Zusammenarbeit-Energy Coordination Office
GWEC	Global wind energy council
GW	Giga watt
HA	Hectare
HH	Household
IEA	International energy agency
IRENA	International Renewable Energy National Agency
KII	Key Informants Interview
KWH	Kilo Watt Hour
LED	Light Emitting Diode
M	Meter
MME	Minister Des Mines of Energy

MM	Mill meter
M^2	Meter square
M^3	Meter Cubic
MW	Mega watt
NGO	Non-Governmental Organization
PWP	Peak Watt Peak
REB	Rural Electrification Board
REF	Rural Electrification Fund
REEP	Renewable Energy and Energy Efficiency Partnership
REES	Rural Electrification Executive Secretariat
SHS	Solar Home System
USA	United States of America
TV	Television
TWA	Tara watt hour
WEC	World Energy Council
WB	World Bank
WH	Watt Hour

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GLOSSARY

Adoption: in this study adoption refers to the decision of households to acquire/adopt solar home systems and interest to use.

District/Woreda: District /Woreda / refers to government's administrative unit in Ethiopia which is equivalent to district.

Household: Here household refers to a group of people who eat together regularly and /or who sleep under the same roof together.

Inefficient: here inefficient refers to using cooking devices with high biomass consumption low per –unit energy production and increased emission of smoke and particular test.

Injera: injera is the traditional food in major Ethiopian households, and mostly prepared from "teff".

Kebele: kebele refers to the lowest administrative structure in Ethiopia.

Solar home system: are stand–alone photovoltaic that offer a cost-effective mode of supplying for amenity power for lighting and appliances to remote off-grid households and which consists from a system of 8_{pwt} p_{wt} up to $130_{pwt\ in}$ Ethiopian context.

Solar lantern: is a portable lighting device or mounted fixture used to illuminate areas and which consists a system has less than 8_{pwt} in Ethiopian government context

Management constraint: means as this study there is a constraint of technical ,financial and institutional arrangements towards SHS adopters.

ABSTRACT

It has been reported that about one billion People still do not have access to electricity and three billion people still rely on solid fuels and kerosene for cooking and heating. One of the recommended solutions to address the rural energy demand is to adopt solar home systems .Solar home system provides substantial benefits to rural households mainly in providing lighting energy services. SHS have instrumental impact in improving lights to off-grid, reducing greenhouse gas emission and reduces impacts on health among rural livelihoods. However, most rural households in developing countries rely heavily on traditional biomass for their domestic energy use. This study was conducted to investigate acceptance and management constraint of solar home systems in rural area of Mecha District, Amhara National Regional State of Ethiopia. Multi-stage sampling procedure was followed to select sample households in the area . A total of 114 households (60 adopters and 54 non-adopters) were involved in the household survey. SPSS version 22 and Stata version 13.1 statistical software were used to analyse the data. The result of this study showed that wood, agriculture residuals and kerosene were the most commonly used fuels by adopter and non-adopter households for their domestic energy use. Besides, a considerable number of adopter (100%) and non-adopter (18.5%) households had positive attitude and awareness towards SHS technology. This was due to the fact that it is an alternative domestic and efficient energy source to improve fuel wood scarcity and improving lighting; it reduces women's health problem and it improve children education status. Almost all sampled Adopters has positively accepts the SHS technology. Technical ability of adopters was found to be weak and was found management constraint for the installation of technology were major barriers such as lack of financial, institutional (access to credit), technical support and other institutional arrangements. For better scaling-up and sustainable adoption of SHS technology that leads for improving lighting energy, reducing deforestation and mitigating climate change the governmental energy institution, non-governmental organization, private sector and public sectors should work hand –in-hand within a good set up of strategic framework of collaboration.

Keywords: *acceptance, Adopter, Energy consumption, management constraint, Mecha district, solar home system*

1. INTRODUCTION

1.1. Background for the study

1.06 billion peoples still do not have access to electricity and 3.04 billion people still rely on solid fuels and kerosene for cooking and heating (IEA, 2015; World Bank, 2017). The World Bank (WB) estimates that 65.1% of the rural population in developing countries is without electricity and to address modern energy services worldwide is indeed a major challenge (S.Mandelli et al., 2016). According Adana (2016), demand of electricity in the world will grow by 50% in 2050, mostly in developing and emerging economies. To meet this demand while also to realizing global development and sustainable goals, government must implement policies and strategies that enable modern source of energy such as solar, that it achieves its full potentials .

The electrification rate (the percentage of the population with access to electricity) in sub-Saharan Africa is the lowest of any developing Region (World Bank, 2015a). Electrification rate in sub-Sahara Africa rose from 22.7% in 1990 to 26.1% in 2000, and reached 35% in 2012 (World bank, 2015a). Sub-Saharan African with irregular and extremely low incomes struggle to pay for modern energy service, and they end up paying relatively high prices for poor energy qualities and energy services like candles or kerosene lanterns. However, in recent years Africa economy has shifted middle class and access to low cost lighting imports have caused rapid shifts in the lighting share in some countries, as Africa shifts from kerosene to LED light powered by batteries, solar home systems and solar lanterns (IRENA, 2016, p.25). Through this few corporations and fewer variety of organizations followed and at the instant they have been introduced in much all countries of the world. A number of successful pilot projects received wide-spread attention. After this successful histories solar home system gradually become adopted as viable options to provide electricity service to rural peoples in developing countries (F.D.J *et al*, 2000).

According to F.D.J. et al (2000) in developing country rural households needed very wide modern access of energy however a common finding is that households with larger systems are generally more satisfied with their systems, than households do accept systems of lower quality associated performance in an open market wherever the relation between value and qualities is evident. In Senegal (Sarr, 1998), both household groups of systems without controllers and with higher quality but higher price were satisfied with their PV system, and, frequently asked recurring complaints of SHS households in the absence of functioning maintenance and service schema or the cost of such services.

In 2012, Ethiopia had 86 million people residing in 16 million households with 83% of the population in rural areas (ESEF, 2014). According to recent national statistics, 3.7 million households were using electricity for lighting in 2011 with electrification rate at 23% at the national level, 88% in urban, and 5% in rural area. The rural population of Ethiopia relies heavily on firewood, kerosene, batteries, and candles for lighting, cooking and heating purpose with detrimental effects on the environment, human health and on economy. The settlement pattern of rural population also makes it challenging to connect every rural village to the grid (ESEF, 2014).

Ethiopian has a very positive attitude towards off-grid electrification and the most strategic national policies include access to energy as the main objectives. Off-grid solar applications are instrumental for the development of rural area in Ethiopia. However, the relatively large upfront costs associated with it constitute hurdle hindering progress. Ethiopia has been establishing policy issues, strategies, and recommendation for solar lighting product dissemination and instillation. Therefore, first solar lighting system in Ethiopia, installed in 1986- these systems were installed for rural home lighting and for school lighting. The largest of these was a 10.5Kwp system installed in 1985 in Central Ethiopia which served 300 rural households through a micro grid in the village. This system was later upgrade to 30kwp in 1989 to provide power for the village water pump and grain mill (Freiburg, 2012).

There were other demonstration project by the government and NGOs in the 1990s but not significant initiatives before 2003 when REF was established. The Rural electrification fund itself only began project implementation in 2009 when it installed the first round of solar PV system for institutions such as school and health clinics in rural areas. The REF has since installed more institutional systems and home systems, the most recent the distribution of more than 28000 home systems currently being distributed through energy services cooperatives in the four regional states of Oromiya, Amhara, SNNP and Tigray. However, developing countries are confronted with many challenges until installation of SHS at the rural household level regarding the installation of SHS including public accepts of SHS, lack of income to purchase SHS, lack of frontal orientation of SHS, lack of technical skills needed the time of mechanical difficulties, lack of awareness of SHS and lack of home appliance suitable for SHS (Alem *et al* 2003; Nieuwenhaut et al., 2001; woumukonya, 2007). So far, research activities related to solar home systems in Mecha district were limited to investigating the contribution of solar home systems in providing light and mobile phone charger, radio and television since very few solar home systems were available. Nevertheless, in recent times, solar home systems has been adoption profoundly, hence the number of rural households using the technology has been increasing. That is the reason why this research has been initiated to study the acceptance and management constraint of solar home systems.

1.2. Statement of the problem

In Ethiopia, electricity consumption of rural area per household is very low compared to that of urban coverage. This is mainly due to the difficulties and expensiveness of connecting the 85% of it rural population in isolated villages to centralized electric grid (TERI, 2014). More than 85% of rural household heavily dependent on fossil-based light sources, predominantly kerosene, On average they use kerosene for 3 hours per day and spend ETB 38 (US$2) per month on kerosene. Kerosene and dry cell battery consumption for lighting by rural households not only erodes the household budgets but also has significant negative environmental implications (Lighting Africa program, 2012; Ethiopia market intelligence, 2013). The amount of black carbon and carbon dioxide emitted annually from burning kerosene for lighting by rural households is estimated at about 15,000 tons and 580,000 tons, respectively. Similarly, a significant amount of hazardous heavy metals and chemicals escape into the environment from unsafely disposed of dry cell batteries by rural households. The majority of households expressed a high degree of dissatisfaction over the adequacy, cost, convenience, and quality of lighting received from kerosene lamp (Araya Asfaw, 2010; Ethiopia market intelligence, 2013).

Due to this, Ethiopia has established policy issues, strategies, and recommendation for solar lighting product dissemination and instillation. Ethiopian rural electrification found it comported to provide electricity in rural villages such as SHS technology when is most appropriate to rural electrification, and have social, economic, and environmental benefits. Vastly superior to kerosene lamps, electrical lights change families to increase their days when sunset fruitfully and agreeably, by learning, working, or just change of state and consumption dinner in an exceeding well-lit home. Reducing the requirement to store and burn kerosene improves air quality and safety. The system additionally ease access to data and amusement via radio and TV and facilitate families stick with it income- generating activities (REF,2013).

According to Steven(2000) some factors that raised by adopters have negatively affect the implementation of SHS technologies such as lack of promotion as well as dissemination of solar home systems, lack of information about SHS, lack of capital for SHS businesses and consumer financing programs, lack of trained technicians, managers, and other human infrastructure needed for system delivery and maintenance and Market distortions stemming from import duties on SHS equipment and subsidies for kerosene.

In Amhara Region over 10,000 SHS technology were put in in rural areas. According to Steven (2000) expressed that to Disseminate SHS technology loosely in rural households has moon-faced with adoption/management barriers, and these barriers continues to be surfaced in Amhara Regional state of Ethiopia similarly.

Due to this, the Researcher is studying to investigate acceptance and management constraint of Solar home systems in rural area Mecha district, Amhara National Regional state of Ethiopia. As far as the researcher’s knowledge is concerned, there was no study conducted on the acceptance and management constraint on SHS technology in rural area of Mecha district, Amhara National Regional state of Ethiopia. Therefore, this study is adding an original contribution to the existing fund of knowledge with regard to the acceptance and management constraint of solar home systems decision.

1.3. General Objective of the study

The main purpose of this study is to investigate acceptance and management constraints of solar home systems in rural area of Mecha District, Amhara National Regional state of Ethiopia.

1.3.1. Specific objectives

- To identify rural households' level of awareness on solar home systems.
- To assess management constraints of solar home systems utilizer by rural households.
- To investigate energy consumptions of solar home systems utilizers and non-utilizers in rural households.

1.3.2. Research Questions

The following basic Research questions were addressed in this study:

1. What is the level of awareness on solar home systems by rural households in Mecha District, Amhara National regional state of Ethiopia?
2. What are the management constraints of SHS adopters by rural household in Mecha District?
3. What are the Energy consumptions in SHS adopters and non-adopters among rural households?

1.4. Scope of the study

Geographically, this study is limited to Mecha District in rural areas (kebeles) in Amhara National Regional State of Ethiopia. Conceptually, this research is limited to identifying the acceptance and management constraint of SHS technology at the household level. Theoretically, the research is based on the ideas of public acceptance, financial, technical, institution structures and Diffusion of Innovation theories in identifying acceptance and management constraint of SHS technology or not.

Besides, methodologically the study was employed mixed research methods and in terms of time, this research used cross-sectional data that gathered in identifying the acceptance and management constraint of SHS technology.

1.5. Limitation of the study

This research did not include the urban areas that are found in Mecha district. This study also limited to only ‘SHS’ adopters and non-adopters. The study does not include other PV technology. The research is limited to identifying the acceptance and management constraint of SHS technology at the rural household level; it is not about sustained use.

1.6. Significance of the study

The findings of the study may help project implementers, private companies , NGO, local ‘SHS’ dealers, Regional water, Irrigation and Energy bureau, at all level and District water office, Kebele agents and National rural electrification fund Program of Ethiopia to know about the determinant factors that affect households to acceptance and management constraint of solar home systems . The above mentioned institutions and stakeholders can easily identify potential interventions effectively which can play crucial role for their success and this in turn improves the likelihood of the adoption of the technology by the households. As a result, all the households and the projects would be beneficiaries, and at large this contributes its part for the realization of Ethiopia’s Green Economy Strategy. Other researchers may also use the findings of this study in relation to factors affecting the acceptance and management constraint of SHS technology in rural areas. The study will also serve as an input and spring point for those who have an interest to investigate the issue thoroughly.

LITERATURE REVIEW

2.1. Potential of solar radiation in Ethiopia

Ethiopia is gifted with renewable energy sources. This includes hydro, wind, solar, geothermal and biomass. Due to this fast economic growth demand electricity in urban and rural areas are increasing. Therefore, it is expected to raise energy by rate of 10-14% per year until 2037 (Lighting Africa, 2012). Recently in Ethiopia 26.6% of population have access to electricity grid. It implies more than 73.4% of people do not access modern energy electricity. The share is increased due to an extension of electricity national grid on the hand and an increased the installation, dissemination of number of solar home systems, solar lanterns and mini grids (S.baurzhal, 2016)

Ethiopia has 13^{th} months of sun shine. It has received solar irradiation 5000-7000 Wh/m^2 according to region and season and thus has great potential for great for the use of solar energy. The average solar radiation is uniform around 5.47 kwh/m^2/day. The value fluctuates seasonally from 3.73-5.65 kwh/m^2/day and with allocation from 3.73 kwh/m^2/day in the western lowlands to 5.65 kwh/m^2/day in Northern Ethiopia (Retscreen, 2017)

2.2. Solar home system

Solar energy is the energy from the sun. It is often called 'alternative energy' to fossil fuel and has been used by humans for thousands of year. Photovoltaic system is a power system designed to supply useful solar energy by means of photovoltaic. It can be grouped in to stand- alone system and grid connected systems. In stand-alone system the solar energy yield is matched to the energy demand. Since the solar energy yield often does not coincide in time with the energy demand from the connected loads, additionally storage systems (batteries) are generally used. If the PV system is supported by an additional power source for instance a wind or diesel generator this is known as photovoltaic hybrid system.

Solar home systems (SHS) are stand-alone photovoltaic system that offer cost effective mode of supplying power for lighting and appliances to remote off-grid households. In rural area, those are not connected to the grid. It typically has a capacity of between 10wp up to 130wp. SHS can be used to meet a household's energy demand fulfilling basic electric needs. It consists several components includes solar panels to absorb and convert sunlight into electricity, a solar inverter to change electric current from DC to AC, a battery to store energy from a solar inverter as well as mounting, cabling and other electrical accessories to set up working systems .

Figure 1: Solar home system with components

Solar home system (SHS) they contributes to the improvement of living standards for instance reducing indoor air pollution and improving health as they replace kerosene lamps, providing lighting for home study, giving the possibility of working at night and facilitating the access to information and communication (radio ,TV, mobile phone charging) and to reduced women work load.

Furthermore, SHS avoid greenhouse gas emission by reducing the use of non-renewable energy resources like kerosene, gas or dry cell batteries or replacing diesel generators for electricity generation (EnergyPedia, 2017)

2.3. Overview Energy Resource in Ethiopia

There is a huge energy resource potential in Ethiopia, which, if utilized, could minimize the present energy crisis prevailing in the country especially in rural areas and improve the process of demand of electricity in rural areas. The total exploitable renewable energy that can be derived annually from primary solar radiation, hydropower, wind, forest biomass, hydropower, animal waste, crop residue and human waste is about 654 ktone in the same year (AFREC, 2015). Out of this, the exploitable of primary solar radiation is about <1 %, while the exploitable of biomass resources and agricultural residue is about 50% and 30% respectively.

Table 1: Energy resource potential of Ethiopia

Source	Unit	Exploitable reserve	Exploitable (%)
hydropower	Twh/year	650	2.8
solar/day	Wh/m^2	5-7	1
wind	MW	252	1
power speed	m/s	7-9	
geothermal	GMW	10	1
Wood	million tons	1149	30
agriculture residue	Million tones	15-20	50
Natural gas	Billion tones	25	2.7
Cool	Million tones	00	-

Source: GTZ, WEC, REEP, GWEC and MME, 2018

2.4. Overview Energy consumption in Ethiopia

The energy sector of Ethiopia is one of the least developed in the world despite the presence of an enormous energy resource endowment. This is reflected by the low per capita energy consumption of households. Furthermore, heavy reliance on traditional energy of rural households of Ethiopian has been revealed by a number of studies. For example, Karekezi and Ranja (1997) quoted in Anderson et al 1999:68 stated that Ethiopia is the fourth largest user in the east Africa of traditional fuels for household energy use, with 86% of the population dependent on traditional biomass (e.g., fuel wood and dung) to meet their energy needs. This is in comparison to 90% for Sub-Saharan Africa and approximately 60% for the African continent. The excessive deforestation, which led to the depletion of wood stock, caused what is known as the household energy crisis in Ethiopia. In Ethiopia, presently 95% of national energy consumption is derived from fuel wood, dung, crop residues, and human and animal power. The remaining 5% is from electricity, 90% of which is generated by hydropower (WB, 2006). In Ethiopia the main sources are woody biomass (78%), dung (8%), crop residue (7%) and petroleum (5%) (Eshete *et al*., 2006).

2.5. Diffusion of innovation theory

Rogers' diffusion of innovation theory is the most appropriate for investing the adoption of technology in higher education and educational environment (Medina, 2001; Parisot, 1995). In fact much diffusion research involves technological innovation so Rogers (2003) usually used the word ‘’technology’’ is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome (p.13). It is composed of two parts hardware and software while hardware is ‘’ the tool that embodies the technology in the form of a material or physical object, ’software’’ is the information base for the tool’’ (Rogers, 2003, p. 259). Since software (as a technological innovation) has a low level of observability, its rate of adoption is quite slow.

For Rogers (2003), adoption is a decision of ‘full use of innovation as the best course of action available’’ and rejection is a decision ‘not to adopt an innovation’’ (p.177). Rogers defines diffusion as ‘the process in which an innovation is communicated thorough certain channels over time among the members of a social system’’ (p.5) as expressed in this definition, innovation, communication channels, time, and social system are the four key components of the diffusion of innovation.

2.5.1. Four main elements diffusion of innovation

Innovation: - Rogers offered the following description of an innovation: ‘’an innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption’’ (Rogers, 2003, P.12). An innovation may have been invented a long time ago, but if individual perceive it as new, then it may still be an innovation for them.

Uncertainty is an important obstacle to the adoption of innovation. an innovation‘s consequences may create uncertainty:’ ‘’consequences are the changes that occur in an individual or a social system as result of the adoption or rejection of an innovation’’ (Rogers 2003, p.436). To reduce the uncertainty of adopting the innovation, individuals should be informed about its advantages and disadvantages to make them aware of all its consequences. Moreover, Rogers claimed that consequences can be classified as desirable versus undesirable (functional or dysfunctional), direct versus indirect (immediate result or result of the immediate result), and anticipated versus unanticipated (recognized and intended or not).

Communication channel:-The second element of the diffusion of innovation process is communication channels For Rogers (2003), communication is “ a process in which participants create and share information with one another in order to reach a mutual understanding ” (p.5). This communication occurs through channels between sources. Rogers states that “a source an individual or an institution that originates a message. A channels is the means by which a message gets from the source to the receiver’’ (p.204). Rogers states that diffusion is specific kind of communication and includes these communication elements: an innovation, two individuals or other units of adoption, and a communication channel. Mass media and interpersonal communication are two communication between two or more individual. On the other hand, “ diffusion is a very social process that involves interpersonal communication relationship’’ (Rogers, 2003, p.19)

Time: - according to Rogers (2003), the time aspect is ignored in most behavioral research. He argues that including the time dimension in diffusion research illustrates one of its strengths. The innovation –diffusion process, adopter categorization, and rate of adoption all include time dimensions.

Social system: - the social system is the last elements in the diffusion process. Rogers (2003) defined the social system as “ a set of interrelated units engaged in joint problem solving to accomplish a common goal’’ (p.23). Since diffusion of innovation takes place in the social system, it is influenced by the social structure of the social system. For Rogers (2003), structure is “ the patterned arrangement of the units in a system’’ (p.24)

2.5.2. The innovation decision process

Rogers (2003) described the innovation –decision process as “an information –seeing and information –processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation’’ (p.172). For Rogers (2003), the innovation–decision involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation .these stages typically follow each other in time –ordered manner .this process is shown in figure 2.

Knowledge stage:- the innovation–decision process starts with the knowledge stage in this step, an individual learns about the existence of innovation and seeks information about the innovation " what'', " how'' and " why'' are the critical questions in the knowledge phase .

The persuasion stage: - the persuasion step occurs when the individual has a negative or positive attitude toward the innovation, but " the formation of a favorable or unfavorable attitude toward an innovation does not always lead directly or indirectly to an adoption or rejection '' (Rogers, 2003, p.176).

Decision stage: - at the decision stage in the innovation –decision process, the individual chooses to adopt or reject the innovation. While adoption refers to full use of an innovation as the best course of action available, "rejection means '' not to adopt an innovation (Rogers, 2003, p.177).

Implementation stage: - at the implementation stage, an innovation is put into practice.

Conformation stage: - the innovation–decision already has been made, but at the conformation stage the individual looks for support for his or her decision.

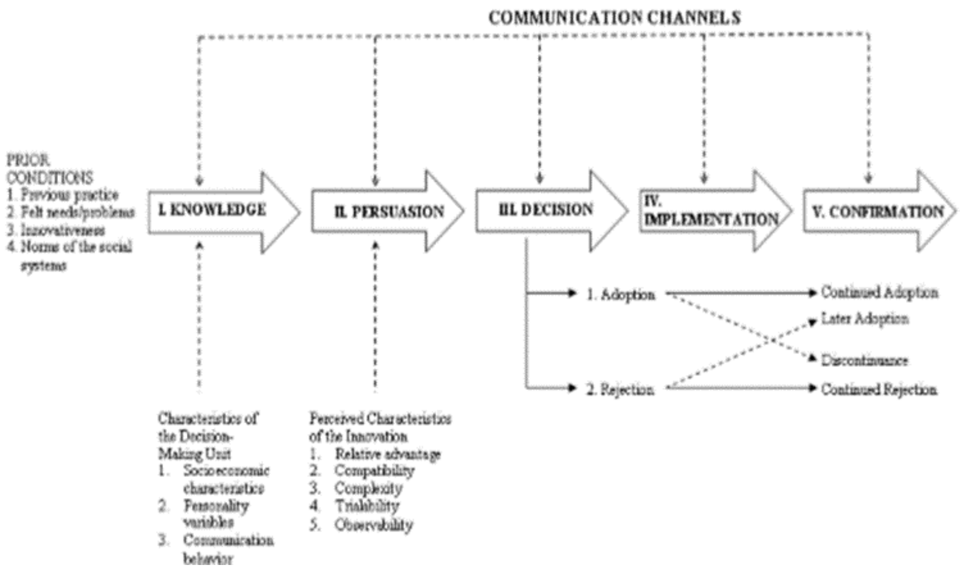


Figure 2: A model of five stages in the innovation –decision

Source: diffusion of innovation fifth edition by Everett M. Roger © 2003

2.5.3. Attribute of innovation and rate of adoption

Rogers (2003) described the innovation – diffusion process as " an uncertainty reduction process '' (p.232), and he proposes attributes of innovation that help to decreases uncertainty about the innovation. Rogers (2003) defined the rate of adoption as " the relative speed with which an innovation is adopted by member of social system (p.221) Attribute of innovation includes five characteristics of innovation,

Relative advantage: - is the degree to which an innovation is perceived as being better than the idea it supersedes.

Compatibility: - is the degree to which an innovation is perceived as consistent with the existing value, past experiences, and needs of potential adopters.

Complexity: - is the degree to which an innovation is perceived as relatively difficult to understand and use.

Observability: - is the degree to which the results of an innovation are visible to others.

2.5.4. Adopter category

Rogers (2003) defined the adopter categories as " the classification of members of a social system on the basis of innovativeness'' (p.22). The classification includes innovators, early adopters, early majority, and laggards. In each adopter category, individuals are similar in terms of their innovativeness.

" Innovativeness is the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system '' (Rogers, 2003, p.22).

Innovators: - Rogers (2003), innovators were willing to experience new idea. Thus, they should be prepared to cope with unprofitable and unsuccessful innovation, and a certain level of uncertainty about the innovation.

Early adopter: - compared to innovators, early adopters are more limited with the boundaries of the social system. Rogers (2003) argued that since early adopters are more likely to hold leadership roles in the social system, other members come to them to get advice or information about the innovation.

Early majority: - Rogers (2003) claimed that although the early majority have a good interaction with other member of the system, they do not have the leadership role that early adopters have However, their interpersonal networks are still important in the innovation diffusion process.

Late majority:-similar to the early majority, the late majority includes one- third of all members of the social system who wait until most of their peers adopt the innovation.

Laggards:-as Rogers (2003) stated, laggards have the traditional view and they are more skeptical about innovation and change agents than the late majority.

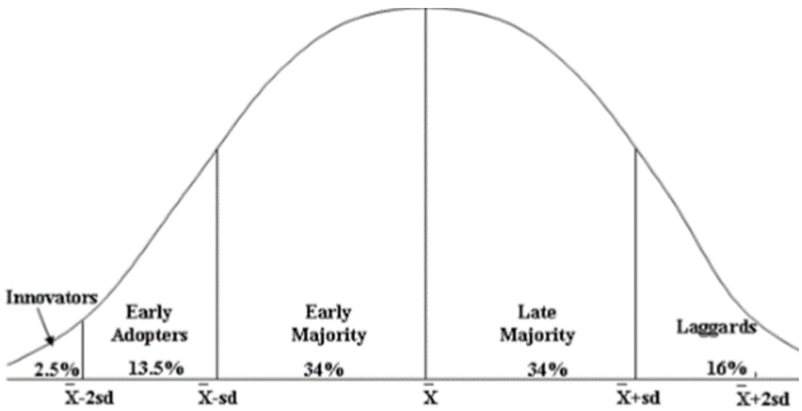


Figure 1: adopter categorization on the basis of innovativeness

(**Source:** Everett M. Roger © 2003)

2.6. Overview of Energy policy, financial, institutional and technical mechanism of implementation SHS in Ethiopia

Recently issued policies on the environment give alternative sources of energy their due place in the future of energy development in the country (EPA, 1997a; EPA 1997b). The need for the use of alternative energy sources (e.g. solar power, wind, biogas, agricultural bio-fuel, liquid bio-fuel or small hydroelectric plants) for towns and villages remote from the national grid has also been well recognized.

The following are some of the policy guidelines set for the development and management of the country's energy resources in general and use of alternative sources of energy in particular (EPA, 1997b:83-85).

- To adopt an inter-sectorial process of planning and development which integrates energy development with energy conservation, environmental protection and sustainable utilisation of renewable resources?
- To promote the development of renewable energy sources and reduce the use of fossil energy sources both for ensuring sustainability and for protecting the environment, as well as their continuation into the future;
- To develop alternative energy sources for towns and villages remote from the national grid
- To place an increasing reliance on energy efficient technologies, sustainable use of renewable resources, and the development of indigenous energy resources;
- To acquire, develop, test and disseminate appropriate and improved energy use technologies (e.g. improved stoves, charcoal kilns, solar powered cookers and heaters);
- To demonstrate and support the use of other energy sources (e.g. geothermal, solar, etc.) in the various economic sectors where it is currently little used such as in transportation, irrigation, crop-drying, food processing, fish drying, and thermal heating
- To promote and assist the private sector to assemble and manufacture energy development facilities and end-use appliances.

According to Ethiopia policy report (2012) several financing mechanisms are already in place and could be replicated or expanded to support the development of the off-grid lighting market in Ethiopia. The REF is the main financial mechanism available in Ethiopia that could be used to disseminate off-grid lighting devices in the country. As mentioned previously, REF's mission is to support all off-grid rural electrification projects through government, NGO, and private sector channels. REF has successfully advocated for duty exemption on PV systems and all other modern off-grid lighting products as well as lobbied the Rural Electrification Board (REB) to reduce the equity contribution of the private sector to only 5% REF is considering making the REF loan interest-free. The REF loan is currently administered by the Development Bank of Ethiopia (DBE), which is the financial intermediary between the REF and project promoters. The DBE disburses funds during project implementation and later recovers loans pursuant to the loan agreement entered into between REES and project promoter.

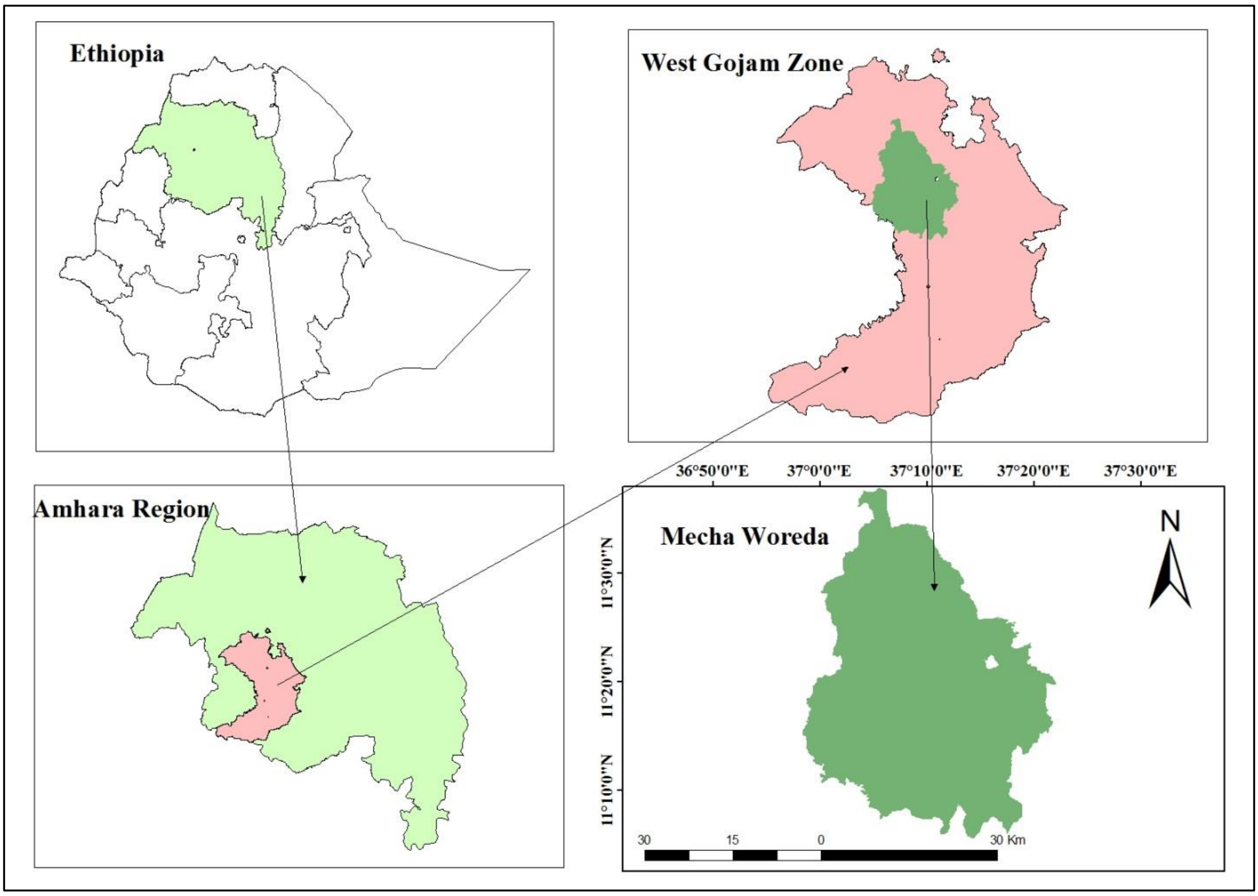
MATERIALS AND METHODS

3.1. Site description

3.1.1. Location and Topography

Mecha District is located in 525 km from north of Addis Ababa, 30km South of Bahir Dar in North West Gojjam zone in Amhara Regional State of Ethiopia. The District is located between at 11^{o}10'N and 11˚25'N latitude and 37^{o}2'E and 37˚17'E longitude in Blue Nile basin (Mezgebu werku, 2014; CSA, 2017)

Figure 4: Map of the study area.



3.1.2. Climate

The mean annual rainfall recorded in the area was 1480 mm and mean monthly temperature of 25.8˚c.The elevation ranges between 1885-3131 meters above sea level, and the slope ranges from nearly flat to vary steep (Fikur, 2009).

3.1.3. Population

Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), this District had a total population of 292,080, an increase of 36.55% over the 1994 census, of whom 147,611 were men and 144,469 women; the majority of the population, which is 269,403 or 92.24% were rural populations. The total area of the district is about 159,899 ha . A total of 66,107 households were counted in this district, resulting in an average of 4.42 persons to a household, and 64,206 housing units. The majority (98.91%) of the populations practiced Ethiopian Orthodox Christianity as their religion. The largest ethnic group reported in Mecha was the Amhara (99.91%). Amharic is spoken as a first language by 99.96%.(Tsegaye, 2012)

3.1.4. Soil, Water and Forest Resources

According to Mezegeb (2014) Mecha has three types of soils such as Nitisols were very extensive soil types in the study areas. It has 19,886ha (78.2% of the entire area), describe upland plain but with slight sheet and gully erosion. They are red clay upland soils, well- drained, acidic soil with relatively good soil permeability. These soils is the best suited for irrigation due to their good workability and relatively flat topography.

Vertiosls were found in the depression plain. which had 2775.62ha (10.9% of the entire area). It describes the flat decondition basin soils, with slope of 0 to 2 %, developed on recent alluvium parent material derived mainly from basalt rocks.

Land cover is short wetland grasses, reeds and sedges. It is mainly used for extensive grazing. The soils is not suitable for irrigated and rain fed agriculture but were marginally suitable for introduction of pasture. The major obstacle to the utilization of these soils is the necessity to install drainage system, either designed to lower the groundwater table or to intercept seepage or surface runoff water. Which had 2,775.62ha (10.9% for the entire area).

Out of which, identified potential resources, relatively irrigation and drinking water are identified as abundant resources. Especial the construction of Koga irrigation increases the availability of water for irrigation purpose. Still the supply of drinking and irrigation water for both livestock and for the rural poor varies from village to village and from season to season.

The total area of the district is about 156,027 ha. Of this, nearly half, 72,178 hectares are used for cultivation. Forestland and the grazing land cover are 18,547ha and 15,591ha respectively. The land covered by water bodies are accounts for about 1,386 ha (Molla Tafere et al., 2014).

3.1.5. Farming system

According to Mekonne (2015) the present land use of the area is dominated by traditional, rain fed, subsistence peasant farming on individual holding and traditional grazing on the flat cultivated land. The overall farming system is strongly oriented towards grain production and dependent on the use of oxen for land preparation. The populations generally keep a number of livestock for production of milk by-products and as transferrable assets. Crop residue and extensive grazing in the depression plains and basis are the major contributors to livestock feed resources. Agriculture is dominated by rain fed production of cereals such as teff in lower elevation and barley in the higher elevation, pulses such as chickpeas, lupin and vetch and oilseed such as Niger seed as well as finger millet. Grazing is predominantly concentrated in the low lying areas (depression basins and flood plains).

3.2. METHODS

3.2.1. Data source and type

For the purpose of this study, data from both primary and secondary data sources were collected and used to achieve the objectives of the study.

3.2.2. Primary data source and type

Primary data were collected from sample households through Questionnaire, Focus Group Discussion, and Key Informants Interview and Field Observation. Primary data were mainly related to respondents' demographic characteristics, peoples' awareness and willingness towards SHS technology, users of fuel wood, agricultural residual for domestic energy consumption and kerosene and SHS technology per households.

3.2.3. Secondary data source and type

Secondary data were collected from Regional and District Water, Irrigation and Energy office, Kebele agricultural natural resource office, and other published and unpublished materials. Secondary data were used to provide information on the issues related to identifying adopter and non-adopter household heads in the target population.

3.2.4. Sampling Techniques and sample size

For this study, multi-stage sampling procedure was applied to select SHS adopter's and non-adopter's in rural households. At first step, out of 40 kebeles found in Mecha district, two rural kebeles were selected purposively. At large, there is homogeneity in households' socio-economic characteristics, institutional set up and livelihood structures in all rural kebeles of Mecha District (Mecha District Water Irrigation and Energy Report, 2009) and their contiguous to kerosene light and fuelwood. The more a homogeneous population, the smaller the sample size was found to be representative (Israel, 1992).

When the response for the attributes being measured is assumed a dichotomous, the use of Yamane's (1967) tables and formulas to determine sample size is more appropriate (Israel, 1992). Since the dependent variable in this study is dichotomous, the researcher used Yamane's formula to determine the sample size for the questionnaire respondents, i.e.;

$$\mathrm{n} = \frac{\mathrm{N}}{1+\mathrm{N}(\mathrm{e})^2} \text{ ---1}$$

Where *n* is the sample size, *N* is the population size, and *e* is the level of precision at 91% significance level

In the two selected rural kebeles, there are a total of 1500 households (Felege hiwot kebele=850) and Gercheche kebele= 650). Therefore, the sample size (n):

$$n = \frac{1500}{1+1500(0.09)^2}$$

n=114

To determine sample size in each kebele, the researcher employed proportional sampling technique, the total samples is (114) from to the selected kebeles proportionally. Each kebele sample size is computed as follow in table form.

Table 2: proportional sample size determination

Kebels	HHS no	How to compute	sample size
Felegehiwot	850	850xtotal sample/ total HH=850*114/1500	65
Gercheche	650	650xtotal sample/ total HH= 650*114/1500	49
Total	1500	650*114/1500+850*114/1500	114

Source: own computation, 2018

Households for the structured questioners were selected by using systematic random sampling technique in each kebele from the households' frame. The reason behind to employ this sampling technique is its simplicity, fast and low costly (Zou, 2006). To overcome some flaws of this technique, the researcher did check-up whether the households were systematically arranged or not, in each kebele frame. In the case of selecting the respondents of the questionnaire, the respondent households were selected. This is in line with Damte and Koch (2011). With regard to the semi-structure interviews and the focus group discussions, the key informants were drawn from the respective kebeles based on their awareness and knowledge of SHS technology by using purposively sampling method. A total of 12 individuals were interviewed in both kebeles and 10 participated in the focus group discussion.

3.2.5. Data collection methods

Both qualitative and quantitative approaches were employed to address objectives of the study. In this study, awareness or knowledge of selected households that assumed to have influence on the adoption of SHS was assessed. Different methods were used to collect both qualitative and quantitative data. These include semi-structured household survey, checklists for key informants interview and focus group discussion and field observations

3.2.6. Household survey

The household survey questionnaire guide had both open and closed ended questions. Open-ended questions were prepared to ask information related to households' most commonly used kerosene for lighting , fuelwood and agricultural residual for domestic energy use, source of fuel wood and socioeconomic characteristic and their association to the adaption of SHS technology. Closed-ended questions were also asked to capture information mainly related to households' awareness and willingness towards the acceptance of SHS technology and dummy variables of independent variables in the model.

3.2.7. Focus group discussion

According to May (1993) the advantage of FGD is that it allows the interaction with a range of key informants and allows the researcher to focus on group norms and dynamics around the issue being investigated. In this study, FGDs were conducted among the people comprising 6 participants in two group at selected two kebeles. The members of focus group were selected from both adopter and non-adopter of SHS technology in each selected kebeles. According to Gill and

Chadwick (2008), a focus group discussion composed of between six and fourteen members is adequate. Some open-ended questions that play a vital role in addressing objectives of the study were prepared for discussions. From focus group discussions, qualitative information which is related to the most commonly used kerosene fuel and fuelwood for cooking and lighting; households' awareness and willingness towards SHS technology and other relevant questions for this study were collected.

3.2.8. Key Informants Interview (KII)

The interview was adopted as a method for data collection partly due to its cost effectiveness and its strength of capturing empirical data in both informal and formal settings (Kothari, 1990). KII was employed in order to support the data, which was collected from household survey. The key informants were those experienced and knowledgeable households on SHS technology. Eight key informants (4 key informants from each kebele) were selected by the help of water Irrigation and energy experts of the District. Informants were interviewed in their homes during weekend time to find them easily and get genuine information. The interviews was conducted in Amharic language.

3.2.9. Field Observation

In this study, besides the KII and FGD, direct field observations were also conducted to evaluate the functional status (functional or not functional) of each SHS technology. Moreover, it was used to identify the parts of SHS technology which had been failed and made the SHS technology not functional. This information was used to counter-check the information provided by household respondents, focus group participants and key informants.

3.3. Methods of Data Analysis

3.3.1. Data collection procedures

Since the study was conducted in two rural kebeles, four enumerators were involved in data collection that were fluent in Amharic, two to each kebele. In order to collect the data from the respondents the enumerators took two hours training about the questions ,when, where, how and to whom the questionnaire to be distributed. The questionnaire was used as the basis of structured interviews, rather than self-completed, since the respondents' literacy level was found low. Only 2 respondents can read and write Amharic from the total of 10 randomly taken respondents for questionnaire pre-test purpose in Felgehiwot rural kebele. The data were collected within four weekends in the morning and afternoon. This was because since the respondents are farmers it was in Sebastian days that enumerators more probably get the respondents free of work at home. Each enumerator spent the full weekend's days in respected kebeles and the researcher had supervised the enumerators. The semi-structured interviews and the focus group discussion with key informants were held by the researcher within four weeks side to side with the questionnaire.

During the time of the interview, the Interviewers were got the written consent from respondents and the orally informed consent was obtained from each respondent with the concerns of SHS cooperation, each respective kebele agricultural office agents had highly cooperated in informed and persuaded farmers to cooperate with the enumerators as in administering and collecting the structured questioners.

3.3.2. Analysis procedures

Descriptive analysis: -. The descriptive statistics of frequency, percentage, mean and standard deviation were used by using the SPSS software version 22 while econometric analysis done by STATA version 13 in analyzing the data collected through questioners. The data collected through semi-structured interviews and focus group discussions were analyzed by the use of intensive textual analysis. Descriptive statistics were employed to determine and assess the following aspects: respondents' Demographic, their awareness and willingness towards SHS technology, and to quantify the proportion of the most commonly used kerosene for lighting and fire wood for domestic energy consumption. Independent sample t-test and chi-square test were also employed to test the existence of a significant difference between adopters and non-adopters.

Econometric Model: - Binary logistic regression model was used since the dependent variable (adoption of SHS technology) was in dichotomous (dummy) form, binary logistic regression was used to predict the effects of the independent variable on the dependent (outcome) variable. Logistic regression was used to model the probability of a positive outcomes for a binary 0 or 1 outcome variable as a function of covariates (Shahidur R, Khandker et al, 2014)

To capture the effects of such factors, the study was estimated solar home system technology demand using the following equation:

$$Sij = a + b\ Xij + gVj + eij \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equ.(2)}$$

Where Sij indicates whether ith household living in jth kebeles had a SHS unit (a binary variable with a value of 1 when a household has a technology and 0 otherwise), Xij represents household-level variables, including measures of household assets and education of household members. Vij represents kebeles-level exogenous variables (e.g., infrastructure and prices, including alternative energy sources). Finally, eij equals an unobserved random error, while b and g are parameters to be determined. Due to this the binary nature of solar home system technology adoption, a logit model was applied to the solar home systems technology adoption equation (Khandker et al, 2014)

3.4. Operational Definitions and Description of variables

This study included variables of SHS technology adoption, demographic characteristics, source of energy consumption, awareness, source of information and technical ability. Here under these variables were defined and described as follows.

3.4.1. Dependent variable

Adoption of SHS technology**:** it was a dummy dependent variable with a value of 1 if the household adopted the technology and a value 0 otherwise that their source of energy could be inefficient traditional type of source of energy (kerosene, dry cell battery, firewood, dung, crop residue and the likes).

3.4.2. Independent variables

Independent variable were selected based on the existing theories and empirical studies (Puzzolo et al, 2013; Damte &Koch, 2011; Rogers, 2003; Masera et al., 2000). The definition of these selected explanatory variable were given below

Household income it was a continuous variable measured in Ethiopian Birr. It was expected that households with higher income could have access and benefit from modern source of energy and improved technology than those with lower income in the study area.

Age of household head: it was a continuous variable measured in years. It was expected that the younger families could participate in modern source of energy and used improved technology than older generation due to their challenging behavior to accept the technology easily.

Educational status of household head: it was a dummy variable with a value of 1 for those who were literate, 0 otherwise for illiterate. It was expected that literate household heads have better chance to participate in modern source of energy and to used improved technology than illiterate headed of household in the study area.

Sex of household head: it was a dummy variable with a value of 1 for male household heads, and 0 for female. It was expected that relatively male-headed households could participate modern source of energy and used improved technology than female- headed of household.

Marital status: in this study marital status was dummy which refers to the respondent's state of being single or married. Value of '1' was given to married and '0' for single

Household size: In this study, it was a continuous variable; the number of family size living in the same household affects household energy consumption patterns due to the availability of active labor force and educations. It was expected that the larger family size could participate in modern source of energy and used improved technology than smaller family size in the study area.

Awareness: Individuals who had access to information could have a better awareness and probability to adopt SHS technology. Hence, the variable awareness was hypothesized to have a positive relationship with SHS adoption.

Technical Ability (TECHABL): access to technical ability had make the individuals to adopt SHS technology. It was expected that households having technical ability have a better probability to adopt SHS technology than those households with no ability to technical in the study area.

Financial availability (FINACAVA): Access to financial availability was a key factor for adoption of SHS technology. Thus, positive relationship was also hypothesize between availability of financial and adoption of SHS technology.

Institutional Factors (INSTITFACT): institutional factors in this study which included provision of services (e.g. awareness creation, quality control and price regulation) and supports (e.g. technical, material and financial). Access to institutional was a key factor for adoption of SHS technology. Thus, a positive relationship was also hypothesized between availability of institutional and adoption of SHS technology.

3.5. Model Specification

To model regression when the dependent variable was dichotomous, taking 0 or 1 values, there was a need of a probability model that had these two features (1) as Xi increases, Pi= E(Y=1 | X) increases but never steps outside the 0-1 interval, and (2) the relationship between Pi and Xi was nonlinear; thus, one can easily use cumulative distribution function (Gujarati, 2004). Both Logistic and Probit regression models satisfy the above two requirements. But, even though there was no basis in statistical theory for preferring one over the other, there were two practical advantages of the logit model over probit model (Fox, 2010). The first one was its simplicity: the equation of the logistic CDF was very simple. The second was its interpretability: the inverse linearizing transformation for the logit model was directly interpretable as log-odds, while the inverse transformation for probit does not had a direct interpretation. By taking in to consideration these advantages, the researcher preferred to use binary logistic regression model to predict the effects of independents variable on the dependent variables. Therefore a household's SHS technology adoption was modelled as a dichotomous variable with values 1 'if a household adopt SHS technology and 0 'otherwise'. Here the dependent variable was dichotomous, i.e. to adopt or not to adopt: thus, the independent variable Yi=1 if the household adopt the SHS technology, and Yi=0 if the household do not adopt. To adopt or not to adopt in relation to independent variables can be depicted in linear probability as follow.

Where X is the independent variable and Y=1 means the household adopt the SHS technology; thus the adoption of SHS technology Can be expressed as follows.

$$Pi = E(Y=1 \div Xi) = \beta 1 + \beta Xi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equ.}(3)$$

Where X is the independent variable and Y=1 means the household adopts the SHS technology; thus, the adoption of SHS technology can be expressed as follow.

$$Pi = E(Y=1 \div Xi) = 1 \div 1 + \exp(\beta 1 + \beta Xi) = 1 \div 1 + \exp(-zi) \ldots\ldots\ldots\ldots\ldots\ldots \text{equ.}(4)$$

Where Zi= β1+β2Xi. It is this equation (1) known as the cumulative logistic distribution function (CDF). here Zi (i.e. Xi); thus, satisfying the two conditions required for a probability model. But, this non-linearity of Pi both in Xi and β's creates a problem in estimating parameter. To overcome this problem, there is a need of another equations. Here, Pi is the probability of adopting and it is given by

$$1 \div 1+\exp(-zi) \text{……………………..equ.(5)}$$

Then (1-Pi), the probability of not adopting, is

$$(1-Pi)= 1 \div 1+\exp(-zi) \text{……………………………….equ.(6)}$$

Therefore, one can write

$$Pi \div (1-Pi)= 1+\exp(Zi) \div 1+\exp(-Zi) \text{……………………………………equ.(7)}$$

Pi÷(1-Pi) is the odds ratio in favor of adopting the SHS technology, i.e.; the ratio of not adopt technology. Taking the natural log of equation (2), one can obtain

$$\ln (Pi \div 1-Pi) = Zi = \beta 1+\beta 2Xi \text{…………………………………………..equ.(8)}$$

This log of odds ratio is linear both in X and in the parameters. Therefore, the logit model of adoption for the sample respondent households was expressed as follows; with intercept term (βo) and Xi independent variables can be equated as

$$\ln (Pi \div 1-Pi) = \beta o+\beta 1X1i + \beta 2X2i+\text{---------}+\beta kXki \text{……………………equ.(9)}$$

here βo, stands for the intercept term, while Xk are the hypothesized determents of SHS technology adoption and βk are the parameters to be estimated .Hence, the logit model for adoption of SHS technology was a function of respondent’s sex, age, marital status, level of education, household income from off farm, household size, awareness, capacity of technology, technical ability, source of information, finance and institutional factor.

3.6. Diagnostic test

Before the start of complete analysis, various diagnostic test were conducted to make the data ready for regression. Any analysis should incorporate a thorough examination of logistic regression diagnostic before reaching a final decision on model adequacy (Hosmer et al, 1997).

MODEL- fit test was one of the most useful tests for truly assessing model fit for binary logistic regression models (Gujarati, 2004). To assess the usefulness of the model in indicating the amount of variation in the dependent variable, the cox & Snell R Square and the Nagelkerke R Square, described as pseudo R2- statistics (from a minimum value of 0 to a maximum of approximately 1) were tested . Since pseudo R2 was found 0.1503, the model was fitted well. In a rule of thumb p- value of 0.05 is taken in assessing the goodness of-fit test. In this study the prob > chi2 was found to be 0.1622 which is greater than 0.05 (see appendix 1). Thus, the model was good Normality test was also checked by using Ladder –of –power quantile- normal plots.

To test the correlation between variables included in the model pair-wise correlation test was run. As general rule, multi-collinearity was a problem when the correlation result is above 0.80 and below -0.80 (stock & Watson, 2007). The coefficient of all variables were found to be above -0.0690 and below 0.0505 (see appendix 2). In addition, variance inflation Factor (VIF) and tolerance level (1/VIF) were two important measures of multi-collinearity problem (Wooldridge, 2003). According to Wooldridge, by rule of thumb, VIF value of 10 or tolerance indexes of 0.10 were used as a critical point to indicate serious multi-collinearity problem. And, the minimum and maximum VIF values for this test were found

1.04 and 1.25, respectively, with mean value of 1.12(see appendix 3). Therefore, there was no severe multi- collinearity problem.

Table 3: summarize diagnostic test

Tests	Test names	prob>chi^2/ F-value
gof	Pearson (chi^2)	0.1622
ovtest	Ramsey RESET	0.5160
Link test	hatsq	0.0000
hettest	Breusch-pagan/cook-Weisberg	0.3871
vif	Minimum =1.04 and Maximum =1.25	mean =1.12

Ramsey RESET test using powers of the fitted values of adoption was, also run to detect model specification bias. And the 'Ho: model has no omitted variables 'was accepted with insignificant p-value of 0.5160(see appendix 3). The link test was run to test the model specification error. And while the hat was found significant with p- value of 0.000, hatsq was found to be insignificant with p-value of 0.1503 (see appendix 3). Therefore, the model was modelled correctly and no important omitted variable(s). Bresch –pagan /cook- Weisberg test was run for checking heteroskedastic problem and 'Ho: constant variance' was accepted with insignificant p-value of 0.3871 (see appendix 3). Therefore, there was no heteroskedastic.

Table 4: Independent variables, their description, type and expected effects

Variable	Type	Expected sign	Description
Sex	Dummy	-ve	Sex of household heads ('1'men ,'2' women
Age	Continues	+ve	Age household heads year
Marital status	Dummy	-ve	Marital status of household head (1 'married and 0 'single'
Education level	Discrete	+ve	Education level of Household head(0'illiterate'and'1'literacy')
Awareness	Discrete	+ve	'1'stands for aware and '0' otherwise
Technical ability	Discrete	-ve	Technical ability SHS adoption by measurement
Source of information	Discrete	+ve	Source of information households about SHS technology
Capacity of SHS technology	Discrete	+ve	Capacity of SHS adoption by p_{wt}

4. RESULTS AND DISCUSSION

4.1. Socio-economic and Demographic Characteristics of Households

4.1.1. Sex, martial and educational status of households

Out of the total number of SHS adopter sample households, about 46.5% were male-headed while 6.1% were female-headed households (Table 5). In addition, about 39.5% of the non-adopter respondents were male-headed households and 7.9% were female-headed households. The proportion of male respondents was higher than female respondents in both adoption categories.

With regard to educational status, 16.7% of the SHS Adopter sample households were literate whereas 35.9% were illiterate. On the other hand, for 24.6% non-SHS adopter households were literate whereas 22.8% were illiterate. The proportion of illiterate was higher than literate respondents in both adoption categories. Therefore, they had relatively lack access to information about SHS technology.

And with regard to marital status, 48.2% of the SHS adopter sample household were married whereas 4.45% were single. On the other hand, 43.9% of non-SHS adopter households were married whereas 6.5% were single. This implies that most of respondents were married.

Table 5: Distribution of respondents by their Sex, Martial and Education Status

Sex	SHS adopter(60)		Non-SHS adopter(54)			
	Frequency	Percent	Frequency	Percent	χ2	p-value
Female	7	6.1%	9	7.9%	0.58	0.59
Male	53	46.5%	45	39.5%		
Total	60	52.6%	54	47.4%		
Education	level					
Illiterate	41	35.9%	26	22.8%	4.77	0.037**
Literate	19	16.7%	28	24.6%		
Total	60	52.6%	54	47.4%		
Martial						
Single	5	48.2%	4	6.5%	0.26	0.734
Married	55	4.4%	50	43.9%		
Total	60	52.6%	54	47.4%		

** A significant variation at 5 % level of significance along the column

4.1.2. Age, Household size, House type, Household Income and Households off-farm Income per year

The age structure of sample households showed that the average age of SHS adopter and non-adopter were 47.67 and 51.52, respectively, the standard deviations for adopters and non-adopters are 9.77 and 8.140 respectively. This finding reveals that there is mean variation between the SHS adopters and non-adopters' age. The average age of adopters is less than the average age of non- adopters. This implies that the younger the age, the more likely to be SHS adopter and the older the age the more to be SHS technology non-adopter and vice-verse. This may be the older people are found to be more conservative towards accepting new technologies. The mean age difference between the two categories was found to be statistically significant at 5% significant level).

In the study area, the average household size and standard deviation of SHS adopter sample households were 3.80 and 0.877 persons, respectively. On the other hand, the average household size and standard deviation for non-adopter sample households were 3.83 and 0.69, respectively. Though there is a little bit mean difference in family size of both adopters and non-adopters, the t-value shows that there is insignificant relationship between the family size of the adopters and non-adopters decision to adopt SHS technology.

Almost all households in the study area lived in corrugated sheet type of houses and a major income of all sample household comes from agriculture. The t-test result showed that there is no significant difference between adopter and non-adopter of sample households at 5% significance level. And the mean and the standard deviation of adopter income from off- farm per year were 5382.5 and 4107.9 birr respectively and non-adopters were 10132 and 10504 birr respectively. This implies that adopter income from off- farm, the more likely to purchase or installed SHS technology. And the two categories was found to be statistically significant at 5% significance level.

Table 6: Distribution of Respondents by Age, Marital Status, Income, and Size, Household and off-farm per year

Variables	Unit	SHS adopter (60)		Non-SHS adopter (54)		
		Mean	SD	Mean	SD	p-value
Age	year	47.67	9.777	51.5	8.14	0.025**
Household income	type	1.02	0.129	1	0.00	0.345
Household size	number	3.83	0.877	3.80	0.69	0.804
House type	type	2.00	0.000	2.00	0.00	<0.000***
income(off-farm) per year	Birr	5382.5	4107.9	10132	10504	0.002***

***and * * shows significant variation at 5% level of significance

4.2. Type of Fuel and Energy Sources Pattern in Rural Household

Out of the total number of SHS Adoption households, about 52.6% used wood while 47.4% used non- adopters. With regard to dry cell battery, 2.63% of the SHS Adoption household were used dry cell battery while others, non–adopters were not used dry cell battery. The sample adopter household, 18.9% consuming kerosene fuels whereas 81.1% of non-adopter households consuming kerosene fuels.

Additionally most of the adopter households , using solar home systems while others, non-adopter households were not used SHS technology. SHS adopter sampled households, 3.8 % using solar lantern while 96.6% of non-adopter households were used solar lantern from (table 7). From the above analysis it can be understood that for most households, wood is the main source of energy for lighting, cooking and of the cooking activities and baking Injeras. Baking injera is the primary activity in terms of its energy requirement from fuel wood. This may be because since Injera is the staple food in Ethiopia, in each household, Injera is eaten. So as to feed household members, Injera may be made frequently which leads to consume much fuel-wood as compared to other cooks. This heavily dependency of agricultural residuals and leafs as sources of energy in rural areas may have implication to deforestation, farm lands productivity and high risk households health status.

Table 7: Distribution of Respondents by Energy source in rural households

Energy sources	SHS adopter (60)		Non-SHS adopter (54)			
	Frequency	Percent (%)	Frequency	Percent (%)	X^2	p-value
Wood	60	52.6	54	47.4	-	-
Dry cell battery	3	2.63	0	-	2.773	0.098
Kerosene	7	18.9	30	81.1	24.973	0.000***
SHS	60	100	0	0.000	114	0.000***
Solar lantern	1	3.8	25	96.2	32.154	0.000***
Agricultural residual	60	52.6	54	47.4	-	-

*** shows significant variation at 5% level of significance

4.3. Awareness and adoption of SHS technology

All sampled adopter households and 18.5% non-adopter respondent had awareness about solar home systems. As in the study most of the household heads were aware of SHS technology. On the other hand, 81.5% of non-adopter households did not have awareness about the SHS technology (Table 8). This indicate that they were unable to get detail information about the system since they spend most of their time at work and home to carry out their tasks. The chi-square result revealed that there is a significant difference on awareness about the system between the two adoption categories at 5% significance level.

Table 8: Awareness and adoption of solar home system

Do you have awareness about SHS technology	SHS adopter(60)		Non-SHS adopter (54)			
	Frequency	Percent	Frequency	Percent	$\chi2$	P-value
Yes	60	100	10	18.5	79.619	0.000***
No	0	0	44	81.5		

*** shows significant variation at 5 % significance level across the row

4.3.1. Sources of Information about solar home system.

Information sources were basic to facilitate adoption and dissemination of solar home systems. In the study area, a significant proportion of respondents (55%) had got information about solar home system from social day (farmer day) of the kebele for the first time. And also friends, family members and neighbors, Radio and Television and energy expert were additional sources of information, accounting about 26.7%, 13.3% and 5%, respectively (Table 9).

Table 9: source of information about solar home system

Source of information about SHS technology	SHS adopter(60)	
	Frequency	Percent
Friends, family member, or neighbor	16	26.7%
Energy expert	3	5%
Radio / Tv	8	13.3%
Farmer day	33	55%

4.3.2. Capacity or type of solar home systems

Among all sampled household adopter, 26 adopters used $8p_{wt}$, 23 adopter used $10p_{wt}$ whereas the remaining $20p_{wt}$, $60p_{wt}$, $75p_{wt}$ were used each adopter in the study kebeles. The $8p_{wt}$ system has seen the fastest growth, followed by the $10p_{wt}$ system. The price declines have made these capacity system attractive choices; both allow for using a moderate range of appliances (e.g., light and mobile phone charger). However, focus group discussants and key informants revealed that sometimes there is a problem providing maintenance services and availability of equipment on SHS technology(Table 10).

Table 10: Capacity of solar home system

capacity of solar home system	SHS adopter (60)	
	Frequency	Percent
$8p_{wt}$	26	43.3%
$10p_{wt}$	23	38.3%
$20p_{wt}$	2	3.3%
$60p_{wt}$	6	10%
$75p_{wt}$	1	1.7%

4.3.3. Technical ability of households on SHS

Table 11 shows that about 98.3% of sampled adopter households had not technical knowledge or ability to maintain SHS technology. On the other hand, 1.7% of sampled adopter households had technical knowledge or ability which maintained SHS.

Table 11: Technical knowledge of SHS adopter

Do you have Technical knowledge of SHS	SHS adopter (60)	
	frequency	Percent
Weak knowledge	59	98.3%
Average knowledge	1	1.7%
Strong knowledge	0	0

4.4. Acceptance of SHS for earlier adopter and later adopter by using Innovation diffusion process

To examine innovation diffusion and decision process on rural households' acceptance on solar home systems adoption for earlier adopter and later adopter in the study area , it is necessary to check whether solar home systems is clean , reduce carbon emission, reduce pollution, compatible with modern living, generate saving, home improvement, visual statement of beliefs, acts all of the time, an appreciating asset, maintenance free, add value to a property, affordable technology, attractive, short payback and Simple to install in a property were analyzed. Those attributes of innovation diffusion process were examined using five scale Likert response questions .In this study the respondents answered strongly agree and agree which indicated earlier adopters and others undecided, disagree and strongly disagree indicated later adopters (from 5=strongly agree, 3= undecided to 1= strongly disagree). As it can be seen from table 12, majority (52.6 %) of respondents strongly agreed and agreed and the rest (41.1 %) disagree and strongly disagree. It implies that more than half of the earlier adopters accepted the technology. Whereas the remaining do not accept the technology indicating the necessity of more awareness campaign for later adopters.

Table 12: acceptance of SHS earlier adopter and later adopter

Solar home systems attribute or statements	Innovation attribute	Earlier adopter		Later adopter	
		Frequency	Percent	Frequency	Percent
It Solar homes system is a clean technology	ra&c1	60	52.6	-	-
It Solar homes system Reduced carbon emission	ra&c1	60	52.6	-	-
It Solar home system reduced pollution	ra&c1	60	52.6	-	-
It Solar home system compatible with modern living	c1	60	52.6	-	-
It Solar home system Generates savings	ra	60	52.6	-	-

It Solar home system is Home Improvement	Ra	60	52.6	-	-
It Solar home system Provides a visual statement of beliefs	Ra	45	39.5	14	13.2
It Solar home system Acts all of the time	ra&c1	56	49.1	4	3.5
It Solar home system are an appreciating asset	Ra	17	14.8	43	37.8
It Solar home system is Maintenance free	ra,c1,c2	12	10.5	48	41.1

It Solar home system Add value to a property	Ra	18	15.8	42	36.8
It Solar home system is Affordable technology	Ra	55	48.2	5	4.4
It Solar home system is Simple to install in a property	c2	16	14	44	38.6
It Solar home system is Attractive	ra,c1,o	59	50.7	1	0.9
It Solar home system has a short payback	Ra	44	38.6	16	14

NB: ra=relative advantage, c1=compatibility, c2= complexity and o= observability

4.5. Management constraint of SHS adopters

The study examined management constraint on rural households' solar home systems adoption for earlier adopter and later adopter in the study area. It is also necessary to check whether lack of access credit to consumer to use of solar home systems, unviable as the rate of return is low lack, high cost of product, lack of resource and implementation, lack of requesting bodies or institutions or lack of capacity in current organization on SHS, lack of requirement or unfavorable rules and regulations on SHS, luck of institutions and capacity to fix standards on SHS, lack of training facilities and experts and bad quality and work ethics and lack of qualities control were analyzed. Those management constraint were examined five scale Likert response questions, In this study the respondent were answered strongly agree and agree which indicated earlier adopters and others undecided, disagree and strongly disagree indicated later adopters (from 5=strongly, 3= undecided to 1= strongly disagree). As a result, the data were analyzed by using mean, standard deviation and percentage. So that, when the mean response is below 3 it indicates that the variable is either strongly disagreed or dis agreed and when it is above 3 shows that either the variable is strongly agreed and agreed. As it can be seen from the below table(13,14,15) , a lack of training facilities and experts, unviable as the rate of return is low and lack of institutions and capacity to fix standards on SHS the mean of 1.52, 1.63 and 1.78 respectively. The data gained from key informants also support the finding of the descriptive. The key informants also identified lack of training facilities and experts, unviable as the rate of return is low and lack of institutions and capacity to fix standards on SHS technology as the most likely management constraints for the adoption of SHS technology by the rural households. The main reason for rural households' lack of training facility and experts and fix standards on SHS about the relative benefits of SHS technology was attributed to the absence of rural energy experts at kebele level. The key informants revealed that at kebele level there is no a person or an expert assigned by the government concerning SHS technology. The other management constraints identified by these informants was access of credit rate of return is low. The key informants revealed that at kebele level there is no a person or an expert to monitor or regulate cooperatives SHS technology. And rural households had poor customs to return credit to the organizations. As it can be seen from table 13,14 and 15, majority (46 %) of respondents strongly agreed and agreed and the rest (43 %) dis agree and strongly dis agree. It means that those 46 % of respondents perceive there is management constraints. Whereas the reset with approximately proportional percentage perceived that there is management constraint this implies that there is still a need to strengthen the management problem. implies that more than half of the earlier adopters accepted the technology. Whereas the remaining do not accept the technology indicating the necessity of more awareness campaign for later adopters

Table 13: Financial constraint of SHS adoption

Financial		SA	A	U	D	SD	Mean	Sd
There is lack of access to credit to consumer use of SHS	fr	27	20	0	0	13	2.2	1.55
	Pr	45	33.3	0	0	2.1		
There is unviable as the rate of return is low	fr	25	34	0	0	1	1.63	0.663
	Pr	41	56	0	0	1.7		
There is high cost of product ,resource and implementation	fr	25	25	0	0	10	2.08	1.394
	Pr	41	41	0	0	16		

NB: fr= frequency, pr= percent, SA= strongly agree, A= agree, U= undecided, D=disagree SD= strongly disagree and sd= standard devation

Table 14: Institutional constraint of SHS adopters

Financial		SA	A	U	D	SD	Mean	Sd
There is lack of requesting bodies or institutions or lack of capacity in current organization on SHS	fr	23	29	0	0	8	2.02	1.269
	Pr	38	48	0	0	13		
there is lack of requirement or unfavorable rules and regulations on SHS	fr	24	32	0	0	4	1.80	0.998
	Pr	40	53	0	0	67		

NB: fr= frequency, pr= percent, SA= strongly agree, A= agree, U= undecided, D=disagree SD= strongly disagree and sd= standard deviation

Table 15: Technical constraint of SHS adopter

Technical		SA	A	U	D	SD	Mean	Sd
There are luck of institutions and capacity to fix standards on SHS	fr	28	27	0	0	5	1.78	1.09
	Pr	46	45	0	0	8		
There is lack of training facilities and experts	fr	29	31	0	0	3	1.52	0.504
	Pr	48	51	0	0	1.7		
There are bad quality, work ethics and lack of qualities control	fr	26	24	0	0	10	2.07	1.401
	Pr	43	40	0	0	16		

NB: fr= frequency, pr= percent, SA= strongly agree, A= agree, U= undecided, D=disagree ,SD= strongly disagree and sd = standard deviation

4.6. Energy consumption from various sources by rural household (kg/month)

The average monthly fuelwood, non-fuel wood biomass and kerosene consumption per household was found to be 1107.7 kg/month, 980 kg/month, and 0.23 l/month respectively for adopter and 1674.1 kg/month, 1481kg/month and 1.69 l/month respectively for non-adopter. Adopters used fuel wood and non-fuel wood only for baking Injera, cooking wat and made breads. The results obtained from independent sample t-test indicated that there is a significant difference on average monthly fuel wood consumption and per capita fuel wood consumption between adopters and non-adopters in the study area (Table 16). However, it may be noted that ownership of the SHS replaces consumption of fossil fuels such as kerosene among the SHS households. For example, SHS households consumes less than 1 liter of kerosene per month, compared to almost 2 liters per month consumed by the non-adopters (Table 16). This means that SHS adoption had probably reduced average household consumption of kerosene by 1liters per month. The difference in the level of consumption of kerosene is statistically significant 5% significant level.

Table 16: Household energy consumption and use, by SHS adoption and non-adoption

Energy sources	SHS adopter (60)		Non-SHS adopter(54)		
Energy consumption	Mean	SD	Mean	SD	p-value
Fuelwood (kg/month)	1101.7	767.2	1674.1	234	0.000***
Non-fuel wood biomass (kg/month)	980	572	1481	316	0.000***
Kerosene (l/month)	0.23	0.65	1.69	0.47	0.000***

*** shows significant variation at 5 % significance level across the row

Note: Consumption figures are average values for households that use a particular energy source; [ii]

A) Non-fuelwood biomass includes dung, tree leaves, crop residue, charcoal and jute stick[iii]

4.7. Econometric Model Result

According to this econometric result, in the study area households' income from off-farm per year and awareness are significantly influence households SHS technologies adoption decision. The other variables sex, age, marital status, education level, household size, source of information, capacity of technologies and technical ability are no found to be significant in determining the likelihood of SHS technologies adoption decision. The below table 17 shows the odd ratio of SHS technology adoption, the p-value and the marginal effects of explanatory variables included in the binary logistic model.

Income from off-farm per year : Household's income from off-farm per year about SHS technology had positive and significant effect on the adoption of the SHS technology at significance level of 5%. (Table 17). This result showed that households who had better income comes from off-farm per year were more likely to adopt the SHS technology. The marginal effect value was 0.000024. This implies that as adopter income from off- farm per year had good the probability of adoption of SHS technologies will increased by about 0.02%. This finding implies, household income from off-farm per year could purchase SHS technology in household level. The result of the present study is supported by faisal Ahammed et al (2008) and Abdulla (2015) who investigated that solar home system use is affected by household income from off-farm per year.

Awareness : Household's awareness about SHS technology had positive and significant effect on the adoption of the SHS technology at significance level of 5% (Table 17). This result showed that households who had better access to information sources were more likely to adopt the SHS technologies. This might be that promotion on different public media enables them to have a better understanding about the socioeconomic benefits of the SHS technology. The marginal effect value was 0.216412 (Table 17). This result confirms that as household's access to information about SHS technology increased by one unit, the probability of SHS technology adoption will be increased by about 21.6% (Table 17). This shows that household's access to information about SHS technology from social day (farmer day), Energy experts of the district, neighbors and mass media is vital for increasing the adoption of the SHS technology. The result of the present study is supported by

F.D.J. Nieuwenhout et al (2000) who investigated that solar home system use is affected by awareness.

Table 17 : Binary logistic Regression Model Result

Owners	Odds Ratio	Std. Err.	Z	P>z	dy/dx
Sex	0.41236	0.2557398	-1.43	0.153	-0.17949
Age	1.020846	0.0262463	0.8	0.422	0.004181
Martial	0.5244637	0.4218916	-0.8	0.422	-0.13077
Education level	1.716899	0.736493	1.26	0.208	0.109524
Income from off-farm	1.000122	0.0000428	2.85	0.004***	0.000024
Household size	1.101723	0.2996145	0.36	0.722	0.01963
Source of information	1.064262s	0.0922112	0.72	0.472	0.01262
Capacity of solar home system	1.000238	0.0106527	0.02	0.982	4.83E-05
Awareness	2.909659	1.296989	2.4	0.017***	0.216412
Technical ability	0.9272467	0.3885942	-0.18	0.857	-0.01531
_cons	0.1429186	0.2682235	-1.04	0.3	

*** show significant 5% significance level respectively

Number of obs = 114

LR chi2 (10) = 23.62

Prob > chi2 = 0.0087

-Log likelihood = 67.05153

Pseudo R2 = 0.1497

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In the study area concerning fuel type for household energy consumption, wood is the main source for cooking and the cooking activities, baking injera is the primary activity in terms of its energy requirement from fuel wood. Non-fuel wood biomass and kerosene fuels were found to be the other sources of energy. The heavily dependency of wood, agricultural residual and kerosene fuel as source of energy in rural areas may exacerbate, partly drought, deforestation and climate change which in turn lead to environmental degradation and farm land productivity reduction.

The House type and income come from agriculture were not found to be statistically significant to determine households' SHS technology adoption decision. Age, household size and income come from off-farm per year were found to be statistically significant to determine households' SHS technology adoption decision. This implies that the probability of SHS technology adoption, for older age households' decreases than as compared to younger age ones and low mean income from off- farm per year birr decreases as compared to high mean income from off-farm per year ones. One plausible explanation for this may be because of younger households are active and awareness to the new technologies. On the other hand married households were found to be more SHS Technology adopter than single households. This implies that the probability of SHS technology adoption for single households' decreases as compared to married households. One plausible explanation for this may be because of married households' have a children's and the full power to make economic decision as compared to single ones. In addition illiterate households were found to be more SHS technologies adopter than literates. The examination indicates that the probability of SHS technology adoption for literate households decreases as compared to illiterate households. This may be resulted from that illiterate households are got first chance by governmental SHS cooperatives than literate households.

In assessing status of SHS technology adoption in the study area, almost half of households (47.4%) were found to be non-adopter of SHS technology. A perceived benefits of fire wood saving, kerosene fuel savings and safer use and promote off-grid lighting were found to be the main reason to adopt SHS technology. With the concern of awareness almost all adopters were aware about SHS technology and 18.5% non-adopters were aware about SHS technology. In part this may be attributed to low public awareness creation work that has been done by concerned bodies mainly District water Irrigation and Energy offices (through District energy rural experts), District agricultural offices (through kebele natural resource management experts) and SHS technology dealers since a dealer had a permission document through respected bodies were found be more likely accessible source of information for rural households. Social association (farmer day) and media (mainly radio and TV) were also indicated to be the other more accessible sources of information for rural households regarding to SHS technologies. With regard to places, religions places, natural resources management works, meeting places and market places were found to be more accessible places for rural households to get information. Lack of training facilities and experts, low unviable rate of return and capacity fix standard of SHS technology increase the management constraints that affect SHS technology adoptions. In case of SHS technologies is low available and less expanded public awareness about its benefits, the probability of adoption may be low. Adopting the technology has a positive effect on acceptance of SHS technology.

5.2. Recommendations

- ✓ Based on the conclusion of the study, public awareness creation effort should be strengthened and targeted on religious places, natural resources management works, meeting places and market places through, for instance, rural energy experts, natural resources management experts and others.
- ✓ Social association (farmer day) and media (mainly radio and TV) should play a great role in promoting SHS technologies.
- ✓ SHS cooperatives should be work kindly to literate households .
- ✓ Management constraint has also needs to be addressed by the concerned body.

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Appendices

Appendix 1: logistic Model (Goodness-of Fit Test)

. estat gof
Logistic model for owners, goodness-of-fit test
Number of observations = 114
Number of covariate patterns = 114
Pearson chi2 (103) =   117.08
Prob > chi2 = 0.1622

Appendix 2: pair wise correlation coefficient and VIF tests

. pwcorr sex age martial edulevel offfarme hhsize sinformation capacity_shs awareness_yesno tech_weak

```
             |      Sex age martial Edu level offfarme   hhsize sinfor~n
-------------+-----------------------------------------------------------
         Sex |   1.0000
         Age |   0.0505   1.0000
     Martial | -0.0690   0.0816   1.0000
   Edu level |   0.0306   0.0533 -0.0470   1.0000
    offfarme |   0.0564  -0.0742   0.0323   0.1951   1.0000
      hhsize |   0.0017   0.1307   0.0693   0.0608   0.0482   1.0000
sinformation |  -0.1345  -0.1053  -0.0680   0.0069  -0.0110   0.0226   1.0000
capacity_shs |   0.0529   0.1794 -0.0664   0.0554 -0.0232 -0.0188 -0.2282
awareness_~o | -0.0573   0.0496   0.0086   0.0647 -0.1600 -0.2497 -0.0091
   tech_weak | -0.0137 -0.1517   0.1842 -0.0182 -0.0180   0.0292   0.2363
```

```
             | capaci~s awaren~o tech_w~k
-------------+---------------------------
capacity_shs |   1.0000
awareness_~o |   0.0335   1.0000
   tech_weak | -0.3432   0.0760   1.0000
```

```
-----------------------------------------------------------------------------------------------

    Variable |         VIF       1/VIF
-------------+---------------------------------------------
```

tech_weak	1.25	0.802087
capacity_shs	1.19	0.839092
awareness_~o	1.13	0.885305
sinformation	1.13	0.886955
hhsize	1.11	0.903441
age	1.10	0.909761
offfarme	1.09	0.920058
martial	1.08	0.925830
edulevel	1.07	0.936678
sex	1.04	0.964002
Mean VIF	1.12	

Appendix 3: link test ovtest, hottest tests scale reliability test

Logistic regression Number of obs = 114
LR chi2 (2) = 23.70
Prob > chi2 = 0.0000
Log likelihood = -67.011006 Pseudo R2 = 0.1503

Adoption	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
_hat	1.028452	.2650216	3.88	0.000	.5090189	1.547884
_hatsq	-.0475138	.1591109	-0.30	0.765	-.3593654	.2643378
_cons	.0339202	.2384373	0.14	0.887	-.4334082	.5012487

.Ovtest

Ramsey RESET test using powers of the fitted values of owners

Ho: model has no omitted variables

F (3, 100) = 0.77

Prob > F = 0.5160

. hettest

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

Variables: fitted values of owners

chi2 (1) = 0.75

Prob > chi2 = 0.3871

Appendix 4: logistic Regression Estimation Result

. Logistic owners sex age martial Edu level offfarme hhsize sinformation capacity_shs awareness_yesno tech_weak

Logistic regression Number of obs = 114
LR chi2 (10) = 23.62

Prob > chi2 = 0.0087

Log likelihood = -67.05153 Pseudo R2 = 0.1497

Adoption	Odds Ratio	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
sex	.4123674	.2557398	-1.43	0.153	.1222899	1.390523
age	1.020846	.0262463	0.80	0.422	.9706789	1.073606
martial	.5244637	.4218916	-0.80	0.422	.1083896	2.537717
edulevel	1.716899	.736493	1.26	0.208	.7406401	3.979991
offfarme	1.000122	.0000428	2.85	0.004	1.000038	1.000206
hhsize	1.101723	.2996145	0.36	0.722	.6465283	1.877403
sinformation	1.064262	.0922112	0.72	0.472	.8980445	1.261245
capacity_shs	1.000238	.0106527	0.02	0.982	.9795761	1.021337
awareness_yesno	2.909659	1.296989	2.40	0.017	1.214553	6.970558
tech_weak	.9272467	.3885942	-0.18	0.857	.4078218	2.108241
_cons	.1429186	.2682235	-1.04	0.300	.0036107	5.657019

. Margins, dy/dx(sex age martial edulevel offfarme hhsize sinformation capacity_shs awareness_yesno tech_weak)

Average marginal effects
Number of obs = 114

Dy/dx w.r.t.: sex age martial Edu level offfarme hhsize sinformation capacity_shs awareness_yesno tech_weak

	Delta-method					
	dy/dx	Std. Err.	z	P>|z|	[95% Conf. Interval]	
sex	-.1794948	.1213121	-1.48	0.139	-.4172621	.0582726
age	.0041806	.0051546	0.81	0.417	-.0059223	.0142834
martial	-.1307709	.1613522	-0.81	0.418	-.4470153	.1854736
edulevel	.1095236	.0846789	1.29	0.196	-.056444	.2754911
offfarme	.0000248	7.59e-06	3.26	0.001	9.88e-06	.0000396
hhsize	.0196295	.055	0.36	0.721	-.0881685	.1274276
sinformation	.01262	.0174217	0.72	0.469	-.0215259	.0467659
capacity_shs	.0000483	.002158	0.02	0.982	-.0041812	.0042779
awareness_yesno	.2164123	.0812114	2.66	0.008	.0572409	.3755837
tech_weak	-.0153055	.084868	-0.18	0.857	-.1816437	.1510327

Appendix 5: Questionnaire, Questions for Interview and focus Groups discussion

Wondo Genet College of forestry and natural resources
Hawassa University,
Hawassa Ethiopia.

Department of renewable energy utilization and management

A. Questionnaire filled by rural households

Objective: Dear respondents, the purpose of this questionnaire is to gather primary data about the acceptance and management constraint of solar home system. The study is for partial fulfilment of the requirements for Master's Degree in Renewable Energy utilization and management study at Wondo Genet University. I confirm you that all data will be used for academic purpose and your responses will be kept confidential.

Instructions:

- ✓ No need of writing name.

Where boxes are available please tick (√) in the box.

- ✓ Where boxes are unavailable write the letter(s) and/or answers on the spaces provided.

Thank you for your cooperation!!!

1. Preliminary detail of respondent

1.1	Please Indicate your gender	Male		Female	
1.2	Please indicate your Age				
1.3	Please indicate your Marital status	Single	Married	Divorced	widowed
1.4	Please indicate your education level (years)				

1.5	Please indicate your household head	Husband	wife				
1.6	What is your household's income (per year/per month)?						
1.7	What other activities do you perform? (off-farm)(year/month)						
1.8	How many families have your household?						
1.9	What is your housing type is made?	thatch	corrugated sheet	cement			
2	**Source of energy in rural households**						
2.1	what are your main sources of energy	Biomass	Dry cell batteries	Kerosene	Solar PV	Candles	electricity
2.2	If you choose biomass, why do you use it?	Cooking	Heating	Lighting	Local industries	Others	

2.3	If you choose dry cell batteries, why do use it?	Lighting	Tape recording	Hunting	Other specify
2.4	If you choose kerosene, why do you use it?	Cooking	Lighting	Local industry	Others
2.5	If you choose solar home system, why do you use it?	Light ing	Ent erta inm ent	Local indust ry	Others
2.6	If you choose electricity, why do you use it?	Cook ing	Lig htin g	Hot water	Enterta inment s

3. Knowledge stage								
3.1	Do you have awareness about SHS?	Yes				No		
3.2	If your answer for Q2.1 is yes, from where did you learn about SHS?	Friend, family member or	Energy expert	Radio/TV	NGO	Private companies	Farmers-field day	Billboard on country road advertising
3.3	When you installed solar home system?							
3.4	What is the capacity of your solar home system	10pw	20pw	30pw	50pw	80pw	130 pw	
2.5	What is your ability to understand and apply technical knowledge of SHS?	Weak	Average	Strong				

4. SHS Adopter categories and attribute innovation						
Solar home systems attribute or statements	**Innovation attribute**	**Strongly agree**	**agree**	**Undecided**	**Dis agree**	**Strongly disagree**
It Solar homes system is a clean technology	RA&C1					
It Solar homes system Reduced carbon emission	RA&C1					
It Solar home system reduced pollution	RA&C1					
It Solar home system Safe form power generation	RA,C1					
It Solar home system Could develop in the future	C2					
It Solar home system compatible with modern living	C1					
It Solar home system Generates savings	RA					
It Solar home system is Home Improvement	RA					
It Solar home system Provides a visual statement of beliefs	RA					
It Solar home system Acts all of the time	RA&C1					
It Solar home system are an appreciating asset	RA					

It The positioning of solar panels does not affect the visual landscape	O					
It Solar home system is Maintenance free	RA, C1, C2					
It Solar home system Add value to a property	RA					
It Solar home system are hidden away	RA, C1, O					
It Solar home system is Affordable technology	RA					
It Solar home system is Simple to install in a property	C2					
It Solar home system is Attractive	R, C1, O					
It Solar home system is high level of grant available	RA					
It Solar home system has a short payback	RA					

Key R: Relative Advantage C1: Compatibility C2: Complexity: Observability

4	**Management constraint on installation of solar home system.**					
4.1	Financial					
4.1.1	There is lack of access to credit to consumer use of SHS	Strongly agree	Agree	undecided	Disagree	Strongly disagree

4.1.2	There is unviable as the rate of return is low	Strongly agree	agree	undecided	Dis agree	Strongly disagree
4.1.3	SHS is high cost of product ,resource and implementation	Strongly agree	agree	Undecided	Dis agree	Strongly disagree

4.2	Institutional					
4.2.1	There are lack of requesting bodies or institutions or lack of capacity in current organization on SHS	Strongly agree	agree	Undecided	disagree	Strongly dis agree
4.2.2	there are lack of requirement or unfavourable rules and regulations on SHS	Strongly agree	agree	undecided	disagree	Strongly disagreed
4.3	Technical					
4.3.1	There are luck of institutions and capacity to fix standards on SHS	Strongly agree	agree	undecided	disagree	Strongly disagree

4.3.2	There is lack of training facilities and experts	Strongly agree	agree	undecided	disagree	Strongly disagree
4.3.3	There are bad quality, work ethics and lack of qualities control	Strongly agree	agree	Undecid ed	disagree	Strongly Disagree

5	**Energy consumption from various sources by rural households (kg/month)**		
5.1	**Energy source**	**SHS HHS**	**Non-SHS** HHS
5.1.1	Fuel wood		
5.1.2	Agricultural residues		
5.1.3	Kerosene		
5.1.4	SHS		
5.1.5	Candle		
5.1.6	Bio gas		

Part 2: Guiding questions for interviews with key informants of kebele rural households agents Checklist for FGD

1. Which energy sources are most commonly used for domestic energy consumption in your locality? Why?
2. What inputs are used for solar lighting in your locality? Why?
3. What are the major challenges you faced for utilized solar home system?
4. What factors do you think are obstacles to the successful use of solar home systems in the house?
5. Have you got any training related to solar home system?
6. If your answer for Q5 is yes, do you think that it is enough?
7. How long the electricity light that comes from solar home system is used?
8. Do you think that you have enough awareness about solar home system?

Part 3: Guiding questions for interviews with key informants of kebele rural households agents Checklist for KII

1. Which energy sources are most commonly used for domestic energy consumption in your locality? Why?
2. What is your view on the current status of energy sources? Why?
3. Is kerosene lighting common in your locality?
4. When was dissemination or installation solar home system started in your locality?
5. What factors do you think are obstacles to the successful use of solar home systems in the house?
6. Which institutions are working and supporting dissemination of solar home system? Are they governmental or non-governmental organizations?
7. How many of solar home system are non-functional?
8. Which part (s) of the solar home system is/are mostly fail?
9. How long the electricity light that comes from solar home system is used?
10. Have you offered any training about solar home system? If no, try to justify the reason why.

BIOGRAPHICAL SKETCH

The author was born on June 9, 1985 G.C in Gonder Woreda, N/Gonder, Ethiopia. He attended his elementary and secondary school Education at Nebaru Primary School and Debark Secondary School respectively. Then, he joined Arba-Minche University, Arba-Minche University Applied science faculty to pursue his BSc. degree in 2006 G.C and certified in Applied physics program after three years. In 2004 G.C, he started his career as energy expert and served for eight years at Bahir-dar Water Irrigation and Energy . Finally, he joined again Hawassa University, Wondo Genet College of Forestry and Natural Resources to pursue his graduate study in Renewable energy utilization and management in 2017 G.C.